A Systematic Review and Meta-Analysis of *Fasciola* Infections in Domestic Ruminants from the Mediterranean Region (2015–2025)

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Abstract

This systematic review and meta-analysis, conducted in full accordance with the PRISMA 2020 guidelines, aimed to provide an updated and comprehensive estimate of fasciolosis prevalence in ruminants (cattle, sheep, and goats) across the Mediterranean basin during the period 2015–2025. To ensure maximal coverage, an extensive literature search was performed in four major scientific databases—PubMed, Scopus, Web of Science, and ScienceDirect—without any restriction on language or publication country. The search strategy combined a structured set of keywords related to *Fasciola hepatica*, *Fasciola gigantica*, ruminant hosts, and the broader Mediterranean region. Studies were considered eligible when they reported primary data on animal-level prevalence, provided clear sample sizes, employed validated diagnostic techniques (including coproscopy, serological assays, molecular detection, or post-mortem inspection), and were published in peer-reviewed journals. Following screening and quality assessment, a total of 11 studies originating from eight Mediterranean countries—Algeria, Tunisia, Egypt, Turkey, Spain, France, Italy, and Greece—met the inclusion criteria. Altogether, these studies encompassed 23,020 examined ruminants and revealed a wide range of prevalence estimates, from less than 1% to as high as 57%, reflecting substantial regional and methodological variation. Species-specific prevalence averages were 7.9% in sheep, 5.2% in goats, and 25% in cattle, confirming the generally higher susceptibility and exposure risk in bovine populations. The pooled prevalence obtained through a random-effects DerSimonian–

Laird model was 13.96% (95% CI: 8.95–21.13). The analysis revealed extremely high heterogeneity ($I^2 \approx 99\%$), suggesting that differences in climate, husbandry systems, diagnostic tools, and ecological conditions strongly influence infection levels across the Mediterranean basin. Overall, the highest prevalence values were documented in Spain and France, whereas moderate levels predominated in North African and Eastern Mediterranean countries. These findings underscore the considerable epidemiological variability of fasciolosis in the region and highlight the urgent need for harmonized surveillance methods and standardized diagnostic protocols. Strengthening these aspects would enhance the accuracy of risk assessment, support early detection, and guide the implementation of targeted and cost-effective control strategies.

Keywords: fasciolosis; Mediterranean basin; meta-analysis; prevalence; ruminants

1. Context

Fasciolosis is a hepatobiliary parasitic disease caused by the liver flukes *Fasciola hepatica* and *F. gigantica*. This complex zoonosis, classified by the World Health Organization among the neglected tropical diseases, affects a wide range of domestic animals (cattle, sheep, goats, pigs, etc.) as well as humans, resulting in significant veterinary and public health concerns [1, 2]. Transmission occurs through a life cycle involving an aquatic intermediate host and the ingestion of metacercariae attached to vegetation. The parasite has a worldwide distribution, extending from tropical to temperate regions [1-5]. Fasciolosis causes severe economic and health losses, estimated at USD 3–3.2 billion annually due to reduced productivity, liver condemnation, treatment costs, and mortality [6-8]. In ruminants, chronic infection leads to reduced meat, milk, and wool production, delayed growth, infertility, and weakened immunity, heavily impacting livestock industries [8, 9]. Globally, more than 600 million animals and about 2.4 million people are estimated to be infected, highlighting the One Health dimension of this disease [2]. To reduce transmission risk, experts emphasize the need for integrated multisectoral actions targeting the environment (wetlands, snails), livestock reservoirs, and local populations [2].

In the Mediterranean basin, climatic and ecological conditions are particularly favorable for fasciolosis persistence. Mild, humid winters combined with hot, dry summers create typical Mediterranean climates that sustain *Galba truncatula* habitats and metacercarial survival [10]. For instance, malacological studies in Corsica have identified several snail species, including

G. truncatula, capable of hosting *F. hepatica* [11]. Extensive sheep and goat grazing systems common in the region maintain the transmission cycle, as animals become infected by ingesting contaminated vegetation in wetlands. However, prevalence rates vary widely across Mediterranean countries and farming systems. Recent surveys have reported low prevalence (<2%) in arid Maghreb zones [12, 13], while wetter southern European regions show much higher values (often 15–20%) [14]. For example, a Portuguese study found 19–20% seropositivity in sheep from a mountain plateau [14]. Such differences reflect local influences such as rainfall, altitude, watering and antiparasitic practices, livestock species, and diagnostic methods.

Small ruminants (sheep and goats) play a major role in fasciolosis transmission but remain less studied than cattle. Across the Mediterranean, *F. hepatica* mainly infects sheep, goats, and cattle [1], yet epidemiological data focusing specifically on small ruminant flocks remain scarce. This lack of information increases uncertainty about the true impact of fasciolosis in Mediterranean small-ruminant farming.

Epidemiological data in the region are fragmented: numerous local studies (in Tunisia, Algeria, Morocco, Italy, Spain, Greece, Turkey, etc.) have used heterogeneous protocols and diagnostic techniques (coproscopy, ELISA, abattoir inspection, etc.), hindering direct comparison. However, for an effective One Health approach and for guiding control strategies (snail control, livestock treatment, health education, etc.), a comprehensive overview of the true prevalence and underlying risk factors is essential. Therefore, a systematic meta-analysis is required to estimate the weighted prevalence of fasciolosis in Mediterranean small ruminants and to identify sources of heterogeneity (country, species, study period, diagnostic method, farming practices, etc.). This synthesis aims to fill existing knowledge gaps, define the actual burden of fasciolosis in Mediterranean livestock, and support optimized control measures within an integrated One Health framework.

2. Data Acquisition

2.1 Literature Search Strategy

This systematic review was conducted in accordance with the **PRISMA 2020** guidelines [15]. A comprehensive search was performed in **PubMed**, **Scopus**, **Web of Science**, and **ScienceDirect** for studies published between **January 1, 2015, and June 30, 2025**. No language restrictions were applied.

Search strings combined terms related to the pathogen, host, and geographic area, connected by Boolean operators (AND, OR) to maximize search sensitivity. The main keywords and their synonyms were as follows:

- **Pathogen:** "*Fasciola hepatica*" OR "*Fasciola gigantica*" OR "fasciolosis"
- **Host:** "sheep" OR "goat" OR "cattle" OR "ruminant"
- **Geographic area:** "Mediterranean" OR "North Africa" OR "Southern Europe" OR "Middle East"
- **Study parameter:** "prevalence" OR "epidemiology"

Each group of terms was combined with the others (e.g., *pathogen AND host AND geographic area AND parameter*) to capture all prevalence studies of fasciolosis in small and large ruminants across Mediterranean regions.

2.2 Inclusion and Exclusion Criteria

Studies were selected according to the following criteria:

- **Inclusion:** studies published between 2015 and 2025; involving cattle, sheep, and/or goats; conducted in a Mediterranean country; reporting prevalence data for fasciolosis with a known total sample size; using direct or indirect diagnostic methods (coproscopy, serology, ELISA, PCR, necropsy, etc.); and published in peer-reviewed scientific journals.
- **Exclusion:** experimental studies, single case reports, or studies not reporting prevalence (e.g., clinical trials); secondary data sources (reviews, meta-analyses, non-indexed reports, unpublished theses); studies that did not specify animal species or sample size.

These criteria ensured the inclusion of original cross-sectional or observational studies focused on the animal prevalence of fasciolosis in Mediterranean contexts.

2.3 Data Extraction

For each eligible study, the following data were extracted: country, study year, animal species (cattle, sheep, goat), sample size examined, number of positive animals, observed prevalence, diagnostic method used, and full bibliographic reference.

Data extraction was performed independently by two reviewers to minimize errors; discrepancies were resolved by discussion and consensus within the research team. All data were recorded in a standardized spreadsheet to facilitate subsequent analysis.

2.4 Statistical Analysis

The pooled prevalence of fasciolosis was estimated through a **random-effects meta-analysis** following the method of **DerSimonian and Laird [16]**, which accounts for inter-study variability. This model is appropriate for prevalence data as it incorporates heterogeneity among independent samples.

Statistical heterogeneity was assessed using **Cochran's Q test** and the **I^2 statistic**. Subgroup analyses were conducted to explore potential sources of heterogeneity, with results stratified by country (e.g., North African vs. Southern European countries), animal species (cattle, sheep, goats), and diagnostic technique (coproscopy vs. serology/ELISA vs. PCR, etc.). All analyses were performed using **R software**, employing the *meta* and *metafor* packages, which provide specialized functions for meta-analysis and related statistics.

3. Results

Marked geographical disparities in the prevalence of *Fasciola hepatica* were observed among Mediterranean ruminants, largely explained by ecological, climatic, and agro-economic factors. A total of 11 studies published between 2015 and 2025 were included in this meta-analysis (Figure 1), covering eight Mediterranean countries: Algeria, Tunisia, Egypt, Turkey, Spain, France, Italy, and Greece. These studies investigated *Fasciola* infections in cattle, sheep, and goats.

The diagnostic methods used included: Coproscopy and sedimentation (Tunisia, Algeria); Post-mortem liver examination (Algeria, Turkey); Bile examination (Tunisia); and ELISA serology (Egypt, Spain, Portugal, Turkey).

The prevalence of fasciolosis varied widely among countries, animal species, and diagnostic techniques (Table 1, Figure2).

In North Africa, studies from Tunisia reported prevalence rates ranging from 9.1 % to 16.5 % in sheep, whereas in Algeria, rates reached 6.5 % in sheep, 2.5 % in goats, and 26.7 % in cattle. In Egypt, prevalence ranged from 3.5 % to 23 %, depending on species and diagnostic method.

In Southern Europe, infection prevalence showed marked geographic variability. Rates ranged from 7.5% in sheep and 14.1% in goats in Turkey to over 50% in goats in Spain, while cattle in Corsica (France) exhibited prevalences between 19% and 46%. In contrast, substantially lower levels were reported in Italy (3–7.9%) and Greece, where prevalence remained below 1% in sheep flocks (Table 1). High infection rates were predominantly observed in humid Mediterranean regions, including Corsica and parts of Spain, where mild winters, regular rainfall, and extensive wet pastures create favorable conditions for transmission, leading to seroprevalence levels of up to 46% in cattle in Corsica [10] and exceeding 50% in goats in Spain [13].

By contrast, arid and semi-arid areas, including inland Algeria and Greece, generally show much lower prevalence. In Greece, only 0.6% of sheep flocks were found to be infected in a nationwide survey [22], reflecting climatic constraints and limited availability of permanent water bodies.

In North Africa and the Middle East, prevalence patterns are more heterogeneous and largely depend on irrigation and local environmental conditions. In northern Tunisia, reported prevalence varied depending on the diagnostic method used [17], while an Algerian meta-analysis estimated an overall prevalence of 1.57%, with markedly higher levels in northeastern coastal regions [23].

Recent evidence from the Pyrenees indicates that *F. hepatica* can persist even at high altitudes (~2000 m), likely due to moist microhabitats, transhumant grazing, and climate-driven extensions of suitable ecological niches [5].

Analysis of 23,020 ruminants across Mediterranean countries revealed an overall crude prevalence of 10.8 % for *Fasciola hepatica* infection. By species, mean prevalence was 7.9 % in sheep (95 % CI: 7.4–8.5), 5.2 % in goats (95 % CI: 4.8–5.7), and markedly higher in cattle (25.0 %; 95 % CI: 23.7–26.3) ($p < 0.001$) (Table 2).

The overall crude prevalence was distinguished from the pooled prevalence, which accounts for inter-study variance under the DerSimonian–Laird random-effects model. The pooled prevalence of *Fasciola* infection in Mediterranean ruminants (2015–2025) was estimated at 13.96 % (95 % CI: 8.95–21.13).

A high degree of heterogeneity was observed across studies ($I^2 \approx 99$ %), indicating substantial variability related to host species, geographical settings, and diagnostic approaches.

In the forest plot (Figure 2), the red line represents the pooled prevalence (13.9 %) estimated under the random-effects model. Marked heterogeneity among studies reflects variation in species, countries, and diagnostic techniques.

The funnel plot (Figure 4) illustrates the distribution of prevalence estimates by precision (1/SE). The approximate symmetry around the mean suggests moderate publication bias, though a few small studies with high prevalence (e.g., from Spain and France) deviate from the central zone.

By species, cattle exhibited the highest pooled prevalence (~20 %), while sheep and goats showed lower values (11–12 %). Heterogeneity remained high in all subgroups (high Q, $\tau^2 > 0$), reflecting differences in sampling contexts (Table 3). This can be explained by several factors: cattle have a longer lifespan, graze for extended periods (often in wetter areas where snails are abundant), and can harbor heavy infections without showing overt clinical signs, allowing accumulation of parasites. Moreover, cattle often graze on floodplains or irrigated meadows, increasing exposure.

The highest pooled prevalence rates were observed in Spain and France, whereas Maghreb (Tunisia, Algeria) and Middle Eastern (Egypt, Turkey) countries displayed moderate to low values (8–12 %). Inter-country heterogeneity was particularly marked in Algeria and Egypt ($\tau^2 > 1$) (Table 4; Figure 5).

In sheep and goats, mean prevalence was generally lower, but localized outbreaks can reach high levels—sometimes comparable to those in cattle—especially when small ruminants graze near stagnant water. For example, Hammami *et al.* [17] showed that in Tunisian sheep, bile examination revealed higher prevalence than coproscopy, suggesting that many infections go undetected by less sensitive classical methods. In the same region, 37.1% of slaughtered sheep and 25.4% of goats had hepatic fasciolosis [24], indicating strong exposure among animals grazing near ponds.

Recent Algerian data [23] reported prevalence rates of 3.91% in cattle (CI 3.84–3.98), 0.42% in sheep, and 0.12% in goats ($p < 0.001$), underscoring the wide interspecies gap.

In Galicia (Spain), earlier studies also found high caprine prevalence (22.7% seropositive), influenced by breed, with crossbreds being more susceptible [13]. In Egypt, ewes from the Nile Delta showed 22.2% seropositivity [20], a level comparable to local cattle.

Recent studies show that age of animals has a clear influence on the prevalence of fasciolosis. For example, Hammami et al. [17] found that lambs under one year of age had a significantly higher prevalence (8.1%) than older sheep. Conversely, other studies observed that older animals were more frequently infected: among Egyptian cattle in the New Valley [18], prevalence was higher in cattle over 3 years old (30.4%) compared to young animals under 1 year (12.7%). Similarly, age affected caprine fasciolosis in Spain, with a higher prevalence in older goats [13].

Gender may also play a role. For instance, in Egyptian cattle, prevalence was higher in males (24.9%) than in females (20.0%) [18]. Khalafalla [19] also reported a sex effect in Egyptian cattle, while Selim et al. [20] found a slightly higher rate in ewes (♀), though the difference was not statistically significant.

Breed is another identified factor. Pérez-Creo et al. [13] showed that crossbred goats had a higher seropositivity rate (22.7%) than the local breed "Cabra Galega." Similarly, Hammami et al. [17] found a higher prevalence in crossbred sheep compared to local breeds.

Farming practices and management also have an impact. Khalafalla [19] showed that the type of farming significantly affected bovine fasciolosis in Egypt. Likewise, Alba et al. [10] highlighted that risky farming practices (poor pasture management, inappropriate use of flukicides) promoted transmission on the island of Corsica. Flooded or poorly drained pastures where intermediate host snails thrive are especially problematic. In fact, the presence of snail species such as Galba truncatula has been correlated with a higher risk of bovine fasciolosis in Corsica [10]. In Tunisia, infection was more prevalent in summer when sheep graze on wetland areas [17].

Feeding and environment are associated factors. Simply grazing can expose animals to metacercariae on contaminated aquatic vegetation. Selim et al. [20] identified the presence of snails and the lack of preventive treatment as significantly increasing the risk (Odds ratio ≈6.6

in winter and 3.0 for snail presence). Climate change (increased temperature and rainfall) has even been linked to acute outbreaks in sheep in Italy [21].

Seasonal variation is also critical. Many studies show infection peaks during wet seasons: Ouchene-Khelifi et al. [12] reported summer and winter peaks in Algerian cattle and goats; Selim et al. [20] noted a higher risk in winter (OR ≈ 6.6) for Egyptian sheep. The availability of lymnaeid snails depends on temperature and rainfall. Likewise, Bosco et al. [21] linked an acute outbreak in Italy to a recent increase in precipitation and temperatures.

The diagnostic method used has a major influence on reported prevalence. Immunological techniques (ELISA, antigen detection) are far more sensitive than coproscopy or macroscopic inspection. They can detect early or subclinical infections before egg shedding occurs. For example, a recent Algerian study reported 16.4% prevalence by ELISA, compared with only 1–2% detected at slaughter or by fecal examination—an 8–10-fold difference [23]. In Turkey, Çelik and Çelik [25] found prevalences of 7.5% and 14.1% in sheep (ELISA) and goats (liver inspection), respectively. Similarly, Alba *et al.* [10] observed 46% seropositive cattle in Corsica, while only 19% had eggs detected in bile. This indicates that studies relying solely on coproscopy systematically underestimate the true infection burden, while serological and ELISA-based approaches reveal latent or subclinical infections. The methodological heterogeneity (direct vs serological tests, bile vs feces) contributes substantially to local variability.

Bile examination and liver dissection can detect adult flukes or eggs in the biliary ducts but generally only identify advanced infections. In Hammami *et al.* [17] study, bile examination detected 16.78% prevalence in sheep, compared to 9.12% by coproscopy (p = 0.015), demonstrating a significant diagnostic effect.

Coproscopy is less sensitive, especially in light or prepatent infections, as it depends on egg shedding, which varies with time of day, season, and animal age. For instance, comparative work using Mini-FLOTAC, Flukefinder®, and sedimentation showed that detection sensitivity varies with egg-per-gram load, with Mini-FLOTAC being more reliable at moderate-to-high infection levels (>90% sensitivity above 20 EPG) but less so at lower intensities [21].

4. Conclusion

This meta-analysis highlights a **high degree of heterogeneity** in fasciolosis among Mediterranean ruminants, reflecting a complex interplay of ecological, zootechnical, and methodological factors. Humid temperate regions of southern Europe (France, Spain, northern Italy) show the **highest prevalence**, whereas more arid zones (Greece, inland Algeria and Tunisia) remain **lightly affected**. Cattle are the **most exposed species** due to longevity and preference for wet pastures, while sheep and goats may reach **high local prevalence** depending on grazing systems. Diagnostic methods strongly influence estimates: **serological and ELISA tests** are far more sensitive than coproscopy or liver inspection, for instance 16.4% versus 1–2% in Algerian cattle. These discrepancies emphasize the need for **standardized diagnostic approaches** and the incorporation of **local ecological factors** in surveillance and control programs.

Finally, recent findings suggest that **climate change** and **alterations in water ecosystems** could expand the parasite’s range, underscoring the necessity for **integrated and adaptive monitoring systems** to prevent fasciolosis resurgence in Mediterranean livestock production.

Author Contributions

FA, NAKT, NO designed the study, developed the questionnaire, collected and analyzed the data, interpreted the results, and drafted the manuscript. NAKT, MA performed statistical analyses and provided methodological and bibliographic support. All authors read and approved the submitted version.

Conflict of Interest

The authors declare no competing interests.

Ethics Approval

The study complied with current ethical standards and national veterinary research guidelines, with prior Electronic informed consent were obtained from all participants prior to accessing the questionnaire.

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Data availability

Data are available from the corresponding author upon reasonable request but are not publicly deposited for ethical and confidentiality reasons.

AI use

No AI tools were used in preparing this manuscript.

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