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Animal Epidemiology
Principles and Applications

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Preface

Infectious diseases in animals remain a major challenge to animal health, public health, and food security worldwide. Understanding how these diseases emerge, spread, and affect animal populations is essential for effective prevention and control. Epidemiology provides the tools to study disease patterns, identify risk factors, and implement evidence-based interventions that safeguard both animal and human health.

This document is designed specifically for veterinary students, offering a clear and practical introduction to the principles of animal infectious disease epidemiology. It covers key concepts, study designs, and analytical methods, with the aim of bridging theoretical knowledge and real application in veterinary practice.

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Introduction

Infectious diseases are a major concern in veterinary medicine, affecting animal health, productivity, and welfare, and posing risks to public health through zoonotic transmission. The study of how diseases emerge, spread, and persist in animal populations—known as animal epidemiology—is essential for understanding disease dynamics and implementing effective prevention and control strategies (Thrusfield, 2018).

Animal epidemiology integrates principles from biology, ecology, and statistics to analyze disease patterns, identify risk factors, and evaluate interventions. It provides tools for both descriptive investigations, which characterize the distribution and frequency of diseases, and analytical studies, which examine the determinants and causal relationships of disease occurrence (Dohoo et al., 2010).

The increasing global movement of animals and animal products, intensification of livestock production, and environmental changes have amplified the risk of emerging and re-emerging infectious diseases (FAO, 2023). Consequently, veterinary professionals must be equipped with a solid understanding of epidemiological methods to monitor disease trends, assess risk, and make evidence-based decisions for animal health management.

This docuent aims to provide veterinary students with a comprehensive foundation in the principles and practices of infectious disease epidemiology, linking theoretical knowledge to practical applications in clinical and field settings. By exploring disease dynamics, surveillance systems, and control measures, students will develop the competencies necessary to contribute effectively to animal health, public health, and food security.

Chapter 1

General Definition of Animal Epidemiology

I. General Definition of Animal Epidemiology

Animal epidemiology is the study of how diseases and other health-related conditions are distributed and spread within animal populations, as well as the factors that influence their occurrence. Its ultimate goal is to control and prevent disease, improve animal health, and protect public health. Unlike clinical medicine, which focuses on individual animals, epidemiology looks at disease patterns at the population level, helping to identify risk factors, sources of infection, and the mechanisms behind disease transmission.

The field combines both observational and experimental methods, such as field studies, disease surveillance, and modeling, to better understand how diseases spread and to design effective, evidence-based interventions. Descriptive epidemiology examines patterns of disease by time, place, and animal characteristics, while analytical epidemiology investigates causal factors and evaluates the effectiveness of control measures. Modern animal epidemiology also uses advanced tools, including molecular and genomic techniques, geographic information systems, and big data analysis, to track emerging diseases, antimicrobial resistance, and zoonotic threats.

Animal epidemiology is essential in veterinary medicine, livestock production, wildlife management, and public health. Its main objectives include early disease detection, outbreak investigation, assessment of disease burden, evaluation of control strategies, and informing policy decisions. By understanding disease patterns and risk factors at the population level, epidemiology supports sustainable animal health management and reduces the risk of diseases spreading from animals to humans.

1. Terminology and Vocabulary in Epidemiology

Epidemiology relies on precise terminology to describe and analyze health events in populations. Understanding and using standard epidemiological terms is essential for clear communication, accurate data interpretation, and effective disease control. Key terms commonly used include :

1. **Population at risk**: The group of animals that could potentially be affected by a disease during a defined period.
2. **Case**: An individual animal or unit that meets specific diagnostic or clinical criteria for a diseas).

3. **Incidence**: The number of new cases of a disease occurring in a population during a defined time period, often expressed as a rate.
4. **Prevalence**: The total number of existing cases (new and pre-existing) of a disease in a population at a particular point in time.
5. **Morbidity and Mortality**: Morbidity refers to the proportion of animals affected by a disease, while mortality refers to deaths due to a disease in a population
6. **Risk Factor**: Any attribute, characteristic, or exposure that increases the likelihood of disease occurrence.
7. **Reservoir and Source of Infection**: The reservoir is the habitat (animal, human, or environment) where a pathogen normally lives and multiplies, while the source of infection is the actual entity from which the infection is transmitted.
8. **Transmission**: The mechanism by which a pathogen moves from a source to a susceptible host, including direct contact, airborne, vector-borne, or environmental routes.
9. **Sensitivity and Specificity**: Sensitivity is the ability of a test to correctly identify infected animals (true positives), and specificity is the ability to correctly identify non-infected animals (true negatives).

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Chapter 2

Epidemiological indicators

I. Epidemiological indicators

1. Definition, Importance, and Classification of Epidemiological Indicators

Epidemiological indicators are quantitative tools used to measure the frequency, distribution, and determinants of health-related events in animal populations. These indicators help veterinarians and researchers to understand and manage animal diseases, zoonoses, and health risks in livestock and wildlife

2. Epidemiological frequency indicators

Prevalence

Prevalence is an epidemiological measure that describes the total number of cases of a disease or condition (both new and pre-existing) in a given population at a specific point or over a specific period of time.

It helps to understand the burden of disease in a population and is useful for planning healthcare services, allocating resources, and monitoring public health trends.

$$\text{Prevalence} = \frac{\text{Number of existing cases}}{\text{Total population at the same time}}$$

Incidence types

Incidence measures quantify the occurrence of new cases and are central to etiologic research and evaluation of change in risk over time. Two commonly contrasted measures are cumulative incidence and incidence rate (person-time based), chosen according to study design and follow-up structure.

- **Cumulative incidence** Definition: probability or proportion of initially disease-free individuals who develop the disease during a specified time interval; best when a well-defined cohort is followed and losses are small.
- **Formula** CI = (number of new cases during period) / (number of individuals at risk at start of period).
- **Incidence rate (instantaneous incidence)** Definition: rate at which new events occur per unit of person-time at risk; appropriate when follow-up time varies among individuals and censoring occurs.
- **Formula** IR = (number of new cases) / (total person-time at risk.

3. Epidemiological Measures: Proportion, Percentage, Ratio, and Rate

Epidemiology uses different quantitative tools to describe and compare the frequency of health events in populations. These tools are essential for surveillance, risk assessment, and public health planning.

1. Proportion

A proportion is a type of ratio where the numerator is part of the denominator. It tells us how common a condition or event is in a population.

$$\text{Proportion} = \frac{\text{Number of cases or events}}{\text{Total population (or group)}}$$

Example:

If 50 out of 200 animals have mastitis:

$$\text{Proportion} = \frac{50}{200} = 0.25$$

This means 25% of the animals have mastitis

2. Percentage

A percentage is simply a proportion multiplied by 100. It expresses the same concept but in a format easier to interpret.

Formula:

$$\text{Percentage} = \text{Proportion} \times 100$$

Example:

$$0.25 \times 100 = 25\%$$

3. Ratio

A **ratio** compares **two independent quantities**. The numerator is **not part of** the denominator.

$$\text{Ratio} = \frac{\text{Quantity A}}{\text{Quantity B}}$$

Examples:

- **Sex ratio**: If there are 120 women and 80 men in a group:

$$\text{Sex ratio (female:male)} = \frac{120}{80} = 1.5$$

There are 1.5 women for every man.

Ratios are useful for comparing risks or outcomes between groups.

4. Rate

A rate is a special type of ratio that includes time in the denominator. It measures how quickly new events (like disease, death) occur in a population over time.

$$\text{Rate} = \frac{\text{Number of events during a time period}}{\text{Population at risk during the same period}} \times \text{Constant (exp, per 1,000)}$$

Types of Rates:

1. **Incidence Rate** (new cases):

$$\text{Incidence Rate} = \frac{\text{New cases}}{\text{Total person-time at risk}}$$

2. **Mortality Rate**:

$$\text{Mortality Rate} = \frac{\text{Deaths in a period}}{\text{Population at mid-period}} \times 1{,}000$$

3. **Attack Rate** (for outbreaks):

$$\text{Attack Rate} = \frac{\text{New cases during outbreak}}{\text{Population at risk}} \times 100$$

Rates allow comparison over time and are dynamic, unlike proportions which are static.

4. **Epidemiological rate**

   1. **Infection Rate**

The infection rate refers to the proportion of animals in a population that become infected with a particular pathogen during a specified time period. It measures how quickly a disease spreads.

Formula : Number of new infections / Number of animals at risk during a given period.

2. Morbidity Rate

Morbidity rate indicates the proportion of animals in a population that develop clinical signs of a disease during a specified period.

Formula : Number of diseased animals / Total population at risk during a given time.

3. Mortality Rate

Mortality rate refers to the proportion of animals in a population that die due to a particular disease or any cause during a specified time period.

Formula : Number of deaths / Total population at risk during a given time.

4. Case Fatality Rate (Lethality Rate)

Also called lethality rate, it is the proportion of animals diagnosed with a disease that die from it within a certain period.

Formula : Number of deaths due to the disease / Number of diagnosed cases.

5. Attack Rate

Attack rate is a measure of the proportion of animals that become ill during an outbreak in a specified period, usually expressed as a percentage.

Formula : Number of new cases during an outbreak / Number of animals at risk at the start of the outbreak.

6. Rate of Disease Occurrence (Atteinte Rate)

This term often refers to the proportion of animals affected (either clinically or subclinically) by a disease, including those infected but not showing clinical signs.

Formula : Number of affected animals (infected + diseased) / Total population at risk.

5. Epidemiological forms of diseases

1. Epidemic

An epidemic in animal populations refers to a rapid increase in the number of disease cases above the expected baseline level within a specific population or geographic region over a defined period. The key characteristics of an epidemic include:

- **Temporal clustering**: Cases occur within a relatively short time frame
- **Geographic concentration**: Initially confined to a specific area or population
- **Excess incidence**: Number of cases significantly exceeds normal expectations
- **Rapid spread**: Disease transmission occurs at an accelerated rate

In veterinary medicine, epidemics typically trigger immediate response measures including movement restrictions, quarantine procedures, enhanced surveillance, and targeted interventions such as vaccination or culling programs.

2. Endemic

Endemic diseases in animal populations are those that persist at a predictable, steady-state level within a specific population or geographic area over extended periods. Endemic diseases are characterized by:

- **Stable transmission**: Consistent level of disease occurrence
- **Geographic stability**: Disease remains within defined boundaries
- **Predictable patterns**: Seasonal or cyclical variations may occur but within expected ranges
- **Sustained presence**: Disease persists in the population over years or decades

Endemic animal diseases require long-term management strategies including routine surveillance, vaccination programs, and ongoing control measures to maintain disease levels below economically damaging thresholds.

3. Pandemic

A pandemic represents an epidemic that has spread across multiple countries or continents, affecting animal populations on a global scale. Pandemics in animal health are distinguished by:

- **Global distribution**: Disease spreads across international boundaries
- **Multiple species or populations**: May affect various animal species or livestock sectors
- **Sustained transmission**: Maintains spread across diverse geographic and climatic conditions

- **International coordination**: Requires coordinated global response efforts.

Animal pandemics have significant implications for international trade, food security, and global economic stability, necessitating coordinated international response efforts and harmonized control measures.

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Chapter 3

Different Types of Epidemiological Studies

I. Different Types of Epidemiological Studies

I.1 Descriptive Epidemiology

Descriptive epidemiology involves the characterization of the distribution of disease in animal populations and the identification of patterns or trends that may suggest possible causes, guides hypotheses, and directs preventive actions before analytical or experimental studies are conducted.

In animals is the branch of veterinary epidemiology that focuses on describing the occurrence and distribution of diseases within animal populations according to time, place, and animal (host) characteristics. It answers the questions "what," "who: Examines disease occurrence by species, age, sex, breed, production stage, or immune status", "where: Focuses on the spatial distribution of disease" and "when: Analyzes how disease frequency changes over time" before moving to analytical studies that answer "why" and "how."

I.1.1 Objectives

- To quantify the frequency of disease (prevalence, incidence, mortality).
- To identify patterns of disease occurrence by time, place, and animal.
- To generate hypotheses for analytical or experimental studies.
- To support decision-making in surveillance, control, and prevention programs.
- To detect emerging or re-emerging diseases early.

I.1.2 Types of Data and Indicators

Descriptive epidemiology relies on **quantitative measures** such as:

- **Prevalence (P):** proportion of animals affected at a specific time.
- **Incidence rate (I):** number of new cases over a defined period.
- **Mortality rate (M):** number of deaths per population per time unit.
- **Case fatality rate (CFR):** proportion of cases resulting in death.

The following table shows the different sectors and applications of descriptive epidemiology in veterinary public health**.**

Sector	Application of Descriptive Epidemiology	Example
Animal Health Surveillance	Routine collection and analysis of disease data	National Brucellosis surveillance
Zoonotic Disease Control	Describes animal–human interface	Rabies, Anthrax
Wildlife Epidemiology	Monitors reservoir and vector species	Avian influenza in wild birds
Food Safety Epidemiology	Tracks foodborne pathogens in production chain	*Salmonella*, *Campylobacter*
Production & Herd Health	Detects production losses and endemic diseases	Mastitis monitoring in dairy farms

Table 1. Sectors and applications of descriptive epidemiology in veterinary public health

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I.1.3. Cross-Sectional (Prevalence) and Longitudinal (Incidence) studies in descriptive animal epidemiology

Epidemiological investigations in animal health often aim to quantify disease frequency and identify risk factors. Two fundamental observational designs used for this purpose are:

- Cross-sectional studies, which estimate prevalence (existing cases at a point in time).
- Longitudinal studies, which estimate incidence (new cases over a period of time).

Both designs are essential in disease surveillance, risk assessment, and program evaluation.

I.1.3.1. Cross-Sectional (Prevalence) Studies

1. Definition

A cross-sectional study (also called a prevalence study or transversal survey) is an observational design in which exposure and disease status are measured simultaneously in each subject (animal or herd) at a single point in time.

It provides a snapshot of the health status of a population and is widely used in animal health monitoring and surveillance systems.

2. Purpose

- To estimate disease prevalence or frequency of infection in a defined population.
- To identify potential associations between exposures (e.g., management, environment) and health outcomes.
- To generate hypotheses for analytical or experimental studies.

3. Methodology

1. Define the target population and sampling frame (exp, farms, herds, flocks).
2. Select a representative sample using random or stratified sampling.
3. Collect exposure and disease data simultaneously (exp, through clinical exams, serological tests, questionnaires).
4. Calculate prevalence:

$$\text{Prevalence} = \frac{\text{Number of existing cases}}{\text{Total number of animals examined}}$$

I.1.3.2 Longitudinal (Incidence) Studies

1. Definition

A longitudinal study (also known as a follow-up or cohort study) involves repeated observation of the same individuals or herds over time to detect new (incident) cases of disease.

It measures incidence, which reflects the rate at which new infections or health events occur in a population at risk during a specific time period.

2. Purpose

- To estimate incidence rates of disease.
- To evaluate temporal relationships between exposure and disease.
- To assess risk factors or vaccine effectiveness over time.

3. Methodology

1. Define a cohort of disease-free animals/herds at baseline.
2. Classify them according to exposure status (e.g., management practice, vaccination).
3. Monitor the population over a defined period to record new disease events.
4. Calculate incidence rate:

$$\text{Incidence rate} = \frac{\text{Number of new cases}}{\text{Animal-time at risk}}$$

The following table summarizes the main points of difference between Cross-Sectional Study and Longitudinal Study

Feature	Cross-Sectional Study	Longitudinal Study
Main Measure	**Prevalence**	**Incidence**
Time Frame	Single point in time	Over a defined period
Temporal Relationship	Exposure and outcome measured simultaneously	Exposure precedes outcome
Cost and Duration	Low cost, short duration	High cost, long duration
Best Use	Descriptive, hypothesis generation	Analytical, causal inference
Example	Serosurvey of brucellosis	Cohort follow-up of FMD vaccination effect

Table 2. Comparison between Cross-Sectional Study and Longitudinal Study

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I.1.4. Case Studies and Case Series

1. Definition

A case study in animal epidemiology is a detailed description of a single animal or herd that presents with a particular disease or health condition.
A case series involves a group of similar cases, describing their clinical, epidemiological, and management characteristics without including a comparison (control) group.

2. Purpose

To provide early descriptions of new diseases, syndromes, or unusual outbreaks and to generate hypotheses about potential causes, transmission routes, or risk factors.

In animal health research, case studies and case series are often used to:

- Identify emerging or re-emerging animal diseases (e.g., novel viral infections in livestock or wildlife).
- Describe clinical features, pathological findings, and epidemiological context of an outbreak.
- Highlight biosecurity breaches or management practices associated with disease occurrence.
- Serve as preliminary evidence leading to analytical or experimental studies.

3. Structure of a Case Study / Case Series Report

According to the OIE (World Organisation for Animal Health) and veterinary epidemiological standards, a case or case series report typically includes:

1. Case definition (clinical and laboratory criteria)
2. Description of the animal(s) (species, breed, age, sex, production system)
3. History and clinical findings
4. Diagnostic workup (laboratory confirmation, imaging, necropsy, etc.)
5. Epidemiological investigation (possible sources, contacts, environment)
6. Treatment and outcome
7. Discussion of potential causes, risk factors, and implications for control.

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I.1.5. Ecological (Correlational) Studies in Animal Epidemiology

1. Definition

An ecological study (also known as a correlational study) is an observational epidemiological design in which the unit of analysis is not the individual animal but a group or population — such as a herd, region, or country.

In these studies, both exposures (risk factors) and outcomes (disease frequencies) are measured at the group level and their correlation is assessed.

2. Purpose

The main purpose of ecological studies is to:

- Explore population-level associations between exposures and outcomes.
- Generate hypotheses about possible causal relationships.
- Evaluate environmental, climatic, or socio-economic factors affecting disease distribution.
- Support public health and veterinary policy decisions when individual-level data are not available.

In veterinary epidemiology, ecological studies are often used for:

- Spatial analysis of transboundary or vector-borne diseases (e.g., Rift Valley fever, bluetongue).
- Evaluation of environmental determinants (e.g., temperature, rainfall, livestock density).
- Assessment of regional intervention programs or vaccination coverage.

Ecological or correlational designs are particularly appropriate when:

- The exposure varies between populations rather than individuals.
- The outcome is rare but aggregated data are available.
- You aim to generate hypotheses for future analytical or experimental studies.

3. Example in Animal Health Research

- A study assessing the relationship between average annual temperature and incidence of bluetongue in European cattle herds.
- An ecological correlation between livestock density and risk of African swine fever outbreaks across regions.
- An analysis of pesticide use and bee colony collapse rates across different agricultural zones

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I.1.6. Spatio-Temporal Clusters (Aggregates)

Spatio-temporal clustering analysis is a powerful epidemiological tool used to identify, quantify, and visualize disease aggregation in space and time.

It helps uncover hidden transmission patterns, supports surveillance programs, and informs targeted disease control in animal populations.

However, careful interpretation is required to avoid over-estimating the significance of clusters caused by data quality or demographic variation.

1. Definition

A spatio-temporal cluster (also called a spatio-temporal aggregate) refers to a group of disease cases that occur closer together in space and time than would be expected by chance.

In animal epidemiology, detecting such clusters is crucial for identifying outbreaks, understanding disease spread dynamics, and targeting surveillance or control measures.

In simple terms: A spatio-temporal cluster is an unusual concentration of cases within a defined area and period, suggesting a common source, transmission route, or environmental exposure.

2. Purpose

Spatio-temporal cluster analysis allows researchers to:

- Detect and visualize outbreaks or high-risk zones.
- Quantify the extent and duration of epidemic waves.
- Identify potential risk factors (e.g., geography, herd density, climate).
- Guide surveillance programs and optimize resource allocation.
- Support early warning systems for transboundary and emerging diseases.

3. Applications in Animal Epidemiology

Spatio-temporal cluster analysis is frequently used to study:

- Foot-and-mouth disease (FMD) outbreaks across livestock regions.
- Bluetongue virus (BTV) and its vector distribution.
- Highly pathogenic avian influenza (HPAI) spread among poultry farms.
- African swine fever (ASF) spatio-temporal diffusion across countries.
- Bovine tuberculosis (bTB) persistence in wildlife–livestock interfaces.

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I.2.Analytical (Etiologic) Epidemiology

1. Definition

Analytical epidemiology (also called etiologic epidemiology) is the branch of epidemiology that aims to identify and quantify the causal relationships between exposures (risk factors) and disease outcomes.

While descriptive epidemiology answers *"what, who, where, and when"*, analytical epidemiology answers *"why and how"* diseases occur.
Analytical epidemiology involves the **systematic comparison** of groups of animals — those **exposed** to a suspected risk factor and those **not exposed** — to determine whether the exposure is **associated with disease occurrence** (Dohoo, Martin, & Stryhn, 2014).

Analytical epidemiology is based on **comparison between groups**:

- Animals or herds with the disease (cases) versus those without the disease (controls).
- Animals or herds exposed to a suspected factor versus those unexposed.

This comparison allows estimation of measures of association such as:

- Relative risk (RR) in cohort studies.
- Odds ratio (OR) in case–control studies.
- Attributable risk (AR) or population attributable fraction (PAF) for public health interpretation.

2. Objectives

Analytical (etiologic) epidemiology is a core discipline in veterinary public health that investigates the determinants of disease occurrence through systematic comparison of exposed and unexposed populations.
It provides quantitative evidence for identifying risk factors, understanding causal mechanisms, and designing effective control strategies in animal populations.

The main objectives of analytical epidemiology are to:

- Test hypotheses generated by descriptive studies.

- Measure the strength of association between risk factors and disease (e.g., odds ratio, relative risk).
- Identify causal relationships underlying disease occurrence.
- Provide evidence for disease prevention, control, and policy decisions

3. Main Study Designs in Analytical Epidemiology

Analytical studies can be observational or experimental:

A. Observational Analytical Studies

1. **Cohort Studies**
    - Animals are classified based on exposure status and followed over time to observe disease occurrence.
    - Used to calculate incidence and relative risk.
    - Example: Following vaccinated and unvaccinated cattle herds to compare brucellosis incidence.
2. **Case–Control Studies**
    - Animals are selected based on disease status (cases vs. controls) and compared retrospectively for exposure history.
    - Used for rare diseases and estimation of odds ratios.
    - Example: Identifying factors associated with *Salmonella Dublin* infection in dairy herds.
3. **Cross-Sectional Analytical Studies**
    - Measure exposure and disease simultaneously to estimate prevalence ratios or odds ratios.
    - Example: Investigating the association between herd management practices and mastitis prevalence.

B. Experimental Analytical Studies

- The investigator assigns exposure (e.g., treatment, vaccine, feed supplement). Includes randomized controlled trials (RCTs), field trials, and challenge experiments.

4. Steps in Conducting Analytical Studies

1. Formulate a clear hypothesis (e.g., exposure → outcome).
2. Define the population at risk and sample.
3. Identify exposure and outcome variables.
4. Use appropriate study design (cohort, case–control, etc.).
5. Perform statistical analysis to test associations.
6. Interpret results in terms of causation.

5. Measures of Association and Significance

- Relative Risk (RR) → indicates how many times more likely disease occurs in the exposed group.
- Odds Ratio (OR) → commonly used in retrospective or case–control studies.
- Confidence intervals (CI) and p-values → assess precision and statistical significance.
- Multivariable regression models adjust for confounding factors.

6. Applications in Animal Epidemiology

Analytical epidemiology is used to:

- Identify risk factors for infectious and production diseases.
- Evaluate preventive interventions (biosecurity, vaccination, nutrition).
- Support evidence-based decision-making in veterinary public health.
- Understand transmission dynamics between livestock and wildlife.

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I.2.1. Cross-sectional Analytical Studies

1. Definition

A cross-sectional analytical study (also called a *prevalence study* with risk factor analysis) is a type of observational epidemiological design where both exposure and outcome (disease status) are measured at the same time in a defined population.

- It allows estimation of disease prevalence and assessment of associations between potential risk factors and disease occurrence.
- In veterinary epidemiology, it is often used for:
  - Estimating the prevalence of infectious or production-limiting diseases in livestock populations.
  - Identifying risk factors (e.g., management practices, biosecurity, housing, nutrition) associated with infection or health outcomes.

Table 3 shows the characteristics of this study.

Feature	Description
Timeframe	Single point in time (snapshot).
Population	Defined group of animals or herds.
Sampling	Representative random or stratified sample (individuals or herds).
Measurements	Simultaneous measurement of disease status and potential exposures.
Analysis	Estimation of prevalence and identification of associations (odds ratios).

Table 3. Cross-sectional Analytical Studies Characteristics

2. Sampling Strategy

To ensure validity, the study must use appropriate sampling:

- **Sampling frame**: The complete list of the population under study (exp, all dairy farms in a region).

- **Sampling method**:
  - Simple random sampling
  - Stratified sampling (e.g., by region or herd size)
  - Cluster sampling (e.g., farms → animals)
- **Sample size**: Determined using expected prevalence, confidence level, and desired precision.

Reference formulas:

$$n = \frac{Z^2 \times P(1 - P)}{d^2}$$

Where:

- *n*: sample size
- *P*: expected prevalence
- *d*: desired precision
- *Z*: z-score for confidence level (e.g., 1.96 for 95%)

3. Data Collection

Collected variables include:

- **Outcome variable:** Disease presence or absence (binary or categorical).
- **Exposure variables:** Age, breed, production system, vaccination status, hygiene, etc.

Diagnostic methods must be reliable and valid:

- Laboratory testing (e.g., ELISA, PCR)
- Clinical examination
- Farm management questionnaires

4. Data Analysis

- Descriptive statistics: Prevalence, frequency distributions.
- Analytical statistics:
  - Univariable analysis: Chi-square test or unadjusted odds ratio (OR) for each factor.

- Multivariable analysis: Logistic regression to adjust for confounders.

$$\text{Odds Ratio (OR)} = \frac{a/c}{b/d} = \frac{ad}{bc}$$

- **Interpretation**:
  - OR > 1 → exposure associated with higher odds of disease
  - OR < 1 → exposure possibly protective
  - OR = 1 → no association

References

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I.2.2. Cohort Study

1. Definition and Purpose

A cohort study is an observational analytical design in which a group of animals (the *cohort*) that is initially free of the outcome (disease) is followed over time to determine how exposure to one or more risk factors influences the incidence of that disease.

It is particularly useful in veterinary epidemiology for:

- Determining incidence (new cases over time).
- Establishing temporal relationships between exposure and disease.
- Estimating relative risks (RR) and attributable risks.
- Evaluating vaccine efficacy, management interventions, or biosecurity practices under field conditions.

Table 4 shows the characteristics of this study.

Characteristic	Description
Study type	Observational, analytical, longitudinal
Population	Disease-free at baseline
Grouping	Based on exposure status (exposed vs. unexposed)
Follow-up	Over time to detect new cases
Outcome	Incidence of disease or health event
Measure of association	Relative risk (RR) or risk ratio

Table 4. Characteristics of Cohort Study

2. Types of Cohort Studies

1. **Prospective (concurrent) cohort study**
   - Exposure is identified **before** disease occurs.
   - Animals are followed into the future to record new disease cases.
   - Example: Follow dairy cows vaccinated vs. unvaccinated against *Brucella* for 12 months.

2. **Retrospective (historical) cohort study**
   - Both exposure and outcome have already occurred at the time of study.
   - Data are collected from existing records (farm logs, lab results).
   - Example: Using past farm records to examine whether deworming frequency influenced parasitic disease incidence.
3. **Ambidirectional cohort study**
   - Combines prospective and retrospective elements (less common in veterinary settings).

3. Steps in Conducting a Cohort Study

(1) Define the Study Population

- Target population (e.g., all dairy herds in a region).
- Select a **cohort** of animals/herds initially **free from the disease**.
- Ensure representativeness to minimize selection bias.

(2) Define and Measure Exposure

- Identify exposure variables (e.g., management system, vaccination status, feed type).
- Record exposure before disease onset.

(3) Follow-up Period

- Long enough to observe new disease cases.
- Maintain data on **loss to follow-up**, **withdrawals**, or **culling**.

(4) Measure Outcome (Disease Incidence)

- Use accurate diagnostic tests and case definitions.
- Calculate:

$$\text{Incidence Risk (IR)} = \frac{\text{Number of new cases during follow-up}}{\text{Number at risk at start of period}}$$

(5) Data Analysis

- Compare incidence between exposed and unexposed groups using:

$$\text{Relative Risk (RR)} = \frac{\text{Incidence in exposed}}{\text{Incidence in unexposed}}$$

- Adjust for confounders using **multivariable models** (e.g., Cox regression, Poisson regression).

(6) Interpret Results

- RR > 1 → exposure increases risk
- RR < 1 → exposure may be protective
- RR = 1 → no association

Measure	Formula	Interpretation
Incidence risk (IR)	New cases / population at risk	Probability of disease
Incidence rate	New cases / animal-time units	Rate over time
Relative risk (RR)	IR(exposed) / IR(unexposed)	Strength of association
Attributable risk (AR)	IR(exposed) − IR(unexposed)	Excess risk due to exposure

Table 5. Interpretation of Measures in Conducting a Cohort Study

References

1. Dohoo, I., Martin, W., & Stryhn, H. (2010). *Veterinary Epidemiologic Research* (2nd ed.). VER Inc., Charlottetown, Canada. Comprehensive explanation of cohort designs, confounding control, and modeling.
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I.2.3 Exposed–Non-Exposed Study

1. Definition and General Concept

An exposed–non-exposed study (or cohort study) is an analytical observational study in which groups of animals (or herds) are selected based on their exposure status to a specific risk factor. These groups are then followed (prospectively or retrospectively) to determine and compare the incidence of a particular disease or outcome.

- Exposed group: Animals or herds that have been subjected to a potential risk factor (e.g., contact with infected herds, specific feeding practices, housing conditions).
- Non-exposed group: Animals or herds that have *not* been subjected to that risk factor.

The objective is to estimate the association between the exposure and the disease, typically using measures such as the Relative Risk (RR) or Incidence Rate Ratio (IRR).

In animal epidemiology, these studies are essential for identifying causal links between management practices, environmental exposures, or biosecurity breaches and disease occurrence.

Exposed–non-exposed (cohort) studies are powerful tools in veterinary epidemiology to assess causal relationships and disease dynamics in animal populations. When properly designed, they provide high-quality evidence for risk assessment, biosecurity evaluation, and disease control policies.

Type	Description	Example
Prospective Cohort	Animals are enrolled before disease occurrence and followed over time.	Monitoring dairy cows exposed to contaminated feed for mastitis incidence.
Retrospective Cohort	Historical data are used to identify exposure and outcome status.	Reviewing farm records to compare abortion rates in brucellosis-exposed vs. non-exposed herds.

Table 6. Types of Exposed–Non-Exposed Studies

Both designs allow calculation of **incidence**, which is a key advantage over cross-sectional or case-control studies.

2. Steps in Conducting an Exposed–Non-Exposed Study

1. Define the population at risk (herds, species, region).
2. Identify and measure exposure (biological, environmental, management-related).
3. Define outcome variables (disease presence, mortality, reproductive failure, etc.).
4. Follow up (prospectively or retrospectively) to record new cases.
5. Analyze data using appropriate statistical models (e.g., Cox regression, Poisson models, mixed-effects models to account for clustering at herd level).

3. Measures of Association

- **Risk Ratio (RR):**

$$RR = \frac{Incidence_{exposed}}{Incidence_{non-exposed}}$$

- **Attributable Risk (AR):**

$$AR = Incidence_{exposed} - Incidence_{non-exposed}$$

- **Population Attributable Fraction (PAF):**
  Useful to estimate the proportion of disease cases that could be prevented by removing the exposure.

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I.2.4. Case–Control Study

1. Definition

A case–control study is an analytical observational study that compares animals (or herds) with a disease or outcome of interest (*cases*) to animals without the disease (*controls*), to determine whether certain risk factors (exposures) are more frequent among the cases.

Case–control studies are fundamental in animal epidemiology for identifying risk factors and developing preventive strategies.

They are cost-effective, time-efficient, and ideal for retrospective analyses, particularly when diseases are rare or emerging.

However, careful selection of controls, exposure measurement, and bias control are essential for reliable results.

This design works *backwards* from disease to exposure, making it particularly useful for:

- Rare diseases,
- Diseases with long incubation periods, or
- Outbreak investigations where data are collected after disease occurrence.

The following table summarizes the description of this study.

Step	Description
1. Define cases	Animals or herds with the disease or outcome (exp, mastitis-positive cows, herds infected with *Brucella abortus*).
2. Select controls	Animals or herds from the same population but without the disease. Controls should represent the *exposure distribution* in the source population.
3. Assess exposure	Determine whether each animal/herd was exposed to specific risk factors (exp, contact with wildlife, feeding type, management system).
4. Analyze data	Estimate the **odds ratio (OR)** to measure the strength of association between exposure and disease.

Table 7. Description of Case–Control Study

2. Measure of Association: Odds Ratio (OR)

$$OR = \frac{(a/c)}{(b/d)} = \frac{a \times d}{b \times c}$$

Where:

- **a:** exposed cases
- **b:** exposed controls
- **c:** non-exposed cases
- **d:** non-exposed controls

An **OR > 1** suggests a positive association between exposure and disease, while **OR < 1** indicates a protective effect.

A detailed comparison of the analytical epidemiological studies mentioned is presented in Table 8.

Feature	Case–Control Study	Cohort (Exposed–Non-Exposed) Study	Cross-Sectional Study
Main Objective	Identify and quantify **risk factors** associated with a disease by comparing exposure between diseased and non-diseased animals.	Assess the **incidence** of disease in **exposed** vs. **non-exposed** groups to estimate the **risk** or **causal relationship**.	Measure the **prevalence** of a disease and its **associations** with potential risk factors at a **single point in time**.
Study Direction	Retrospective (starts from **disease** → looks back to **exposure**).	Prospective or retrospective (starts from **exposure** → follows to **disease occurrence**).	Neither retrospective nor prospective; **snapshot** in time.
Population Selection	Based on **disease status** (cases = diseased, controls = healthy).	Based on **exposure status** (exposed vs. non-exposed).	Based on **current population**, regardless of exposure or disease.
Main Measure of Association	**Odds Ratio (OR)**	**Risk Ratio (RR)** or **Incidence Rate Ratio (IRR)**	**Prevalence Ratio (PR)** or **Odds Ratio (OR)**
Data Collection Timing	After disease occurrence.	Before (prospective) or after (retrospective) disease occurrence.	At one point in time (no follow-up).

Feature	Case–Control Study	Cohort (Exposed–Non-Exposed) Study	Cross-Sectional Study
Ability to Estimate Incidence	No (only relative odds).	Yes (can calculate incidence).	No (only prevalence).
Time and Cost	Relatively **quick and inexpensive**.	**Time-consuming and expensive**, especially if prospective.	**Fast and low-cost**.
Number of Diseases/Exposures Studied	One disease, **multiple exposures** possible.	One exposure, **multiple outcomes** possible.	Can assess **multiple exposures and outcomes**, but only at one time.
Usefulness	Ideal for **rare diseases** or **outbreak investigations**.	Ideal for studying **causal relationships** and **disease dynamics**.	Useful for **descriptive epidemiology** and **hypothesis generation**.
Bias Susceptibility	High: recall bias, selection bias.	Moderate: loss to follow-up, misclassification of exposure.	High: cannot determine temporal sequence (cause vs. effect).
Main Analysis Tools	Logistic regression (unmatched/matched), conditional logistic models.	Cox regression, Poisson models, mixed-effects models.	Logistic or log-binomial regression.
Example (Animal Health)	Identifying risk factors for **brucellosis**: compare infected vs. non-infected herds and past exposure to wildlife.	Monitoring **mastitis incidence** in cows exposed vs. non-exposed to contaminated bedding.	Estimating **prevalence of tick infestation** in cattle and its association with grazing type.
Interpretation Focus	"Are diseased animals more likely to have been exposed?"	"Does exposure increase the risk of developing disease?"	"What proportion of the population is affected, and what factors correlate with it?"
Typical Output	OR > 1 → exposure associated with disease.	RR > 1 → exposure increases risk.	PR > 1 → exposure associated with higher prevalence.

Table 8. Comparison of Case–Control Study, Cohort (Exposed–Non-Exposed) Study and Cross-Sectional Study

References

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I.3. Evaluative (Experimental or Intervention) Epidemiology

1. Definition

Evaluative epidemiology—also called experimental or intervention epidemiology—is the branch of epidemiology that involves actively testing the effect of an intervention or exposure on a defined animal population.

It differs from observational studies (such as cohort or case–control) because the researcher controls the allocation of the exposure (e.g., vaccination, treatment, or management practice).

It provides the strongest evidence for causality because the researcher manipulates one variable (the intervention) and observes its impact on health outcomes while controlling confounding factors.

2. Main Objectives

- To evaluate the effectiveness of preventive or therapeutic interventions (e.g., vaccines, antibiotics, management practices).
- To assess the impact of disease control programs at herd, regional, or national level.
- To quantify changes in incidence, prevalence, or productivity due to a specific intervention.
- To provide evidence-based recommendations for animal health policies and veterinary practices.

3. Steps in an Experimental Epidemiological Study

1. Define the study population (species, herd, location).
2. Specify the intervention (vaccine, treatment, management change).
3. Randomly assign groups (experimental vs. control).
4. Ensure blinding if possible (to reduce observer bias).
5. Monitor outcomes (disease incidence, mortality, productivity).
6. Analyze data (calculate relative risk reduction, efficacy, or effect size).
7. Interpret and generalize findings considering external validity.

Evaluative (experimental/intervention) epidemiology represents the highest level of evidence in animal health research.
By applying randomized controlled trials, field experiments, and program evaluations, veterinarians and researchers can directly assess the efficacy, effectiveness, and impact of interventions on animal populations.
This approach supports evidence-based decision-making in veterinary public health, biosecurity, and disease control.

References

1. Dohoo, I., Martin, W., & Stryhn, H. (2022).
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I.3.1 Diagnostic Studies

1. Definition and Purpose

A diagnostic study (or diagnostic test evaluation) is a type of evaluative or methodological study designed to assess the accuracy, validity, and usefulness of a diagnostic test used to detect disease in animals or herds.

Diagnostic studies in animal epidemiology are essential for validating and improving tools used to detect, monitor, and control animal diseases.

By integrating statistical and epidemiological evaluation, researchers ensure diagnostic tools are fit for purpose, both in the laboratory and under real-world conditions.

The goal is to determine how well a test identifies diseased and non-diseased animals, compared to a gold standard (reference test).

Diagnostic studies are essential in **veterinary epidemiology** because reliable diagnostic tests are the foundation of :

- Disease surveillance programs,
- Control and eradication campaigns,
- Trade and animal movement regulations, and
- One Health zoonotic disease management.

2. Main Objectives

1. To estimate diagnostic performance (sensitivity, specificity, predictive values).
2. To compare diagnostic methods (e.g., ELISA vs. PCR vs. culture).
3. To validate new diagnostic tools under laboratory or field conditions.
4. To assess repeatability, reproducibility, and cost-effectiveness of tests.
5. To determine cut-off values optimizing sensitivity/specificity (e.g., using ROC curves).

In this study, frequency indicators are examined, and the following table summarizes the general concepts.

Term	Definition	Formula / Explanation
True Positive (TP)	Diseased animals correctly identified as positive.	
False Positive (FP)	Healthy animals incorrectly identified as positive.	
True Negative (TN)	Healthy animals correctly identified as negative.	
False Negative (FN)	Diseased animals incorrectly identified as negative.	
Sensitivity (Se)	Ability of test to detect diseased animals.	$Se = \frac{TP}{TP + FN}$
Specificity (Sp)	Ability of test to correctly identify non-diseased animals.	$Sp = \frac{TN}{TN + FP}$
Positive Predictive Value (PPV)	Probability that an animal testing positive is truly diseased.	$PPV = \frac{TP}{TP + FP}$
Negative Predictive Value (NPV)	Probability that an animal testing negative is truly healthy.	$NPV = \frac{TN}{TN + FN}$

Table 9. General concepts of frequency indicators

The different types of diagnostic studies are illustrated in Table 10.

Type	Description	Example in Veterinary Epidemiology
Test validation against a gold standard	Compare a new test to an established reference (culture, PCR, etc.).	Evaluating an ELISA for *Brucella abortus* against bacterial culture.
Field evaluation study	Assess performance under real farm conditions.	Field performance of a rapid test for mastitis (California Mastitis Test).
Comparative diagnostic study	Compare two or more diagnostic tests for the same disease.	Comparing PCR and antigen ELISA for *Foot-and-Mouth Disease*.
Latent class analysis study	Used when no perfect gold standard exists (uses statistical modeling).	Estimating Se and Sp of multiple tests for *Johne's disease* in cattle.

Table 10. Types of Diagnostic Studies

3. Study Design

1. Select a representative population (animals with and without disease).
2. Apply the test(s) under evaluation to all animals.
3. Determine disease status using a *reference standard* (e.g., culture, necropsy).
4. Construct a 2×2 contingency table (Test result vs. True disease status).
5. Calculate diagnostic indices (Se, Sp, PPV, NPV).
6. Interpret results considering epidemiological context (prevalence, herd-level vs. individual-level testing).

4. Example

Evaluation of a new ELISA for *Brucella melitensis* in sheep:

	Gold standard positive	**Gold standard negative**	**Total**
ELISA positive	85 (TP)	15 (FP)	100
ELISA negative	5 (FN)	95 (TN)	100
Total	90	110	200

→ Sensitivity = 85/90 = 94.4%
→ Specificity = 95/110 = 86.4%
The ELISA shows high sensitivity and moderate specificity — suitable for screening, followed by confirmatory testing.

5. Applications in Animal Epidemiology

- Validation of serological tests (ELISA, complement fixation) for brucellosis, leptospirosis, bovine tuberculosis.
- PCR and molecular assays validation for emerging diseases (e.g., African Swine Fever, avian influenza).
- Rapid field diagnostic test evaluation for mastitis, parasitic infections, or zoonotic surveillance.
- Herd-level testing performance studies (bulk milk ELISA, pooled fecal PCR).

References

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I.3.2. Therapeutic Trial (or Clinical Trial)

1. Definition

A therapeutic trial (also called a clinical trial or intervention study) is a controlled experimental study designed to evaluate the efficacy, safety, or side effects of a treatment, vaccine, or preventive intervention in animals.

It represents one of the most rigorous forms of evaluative epidemiology, because the investigator actively intervenes to apply a treatment or preventive measure and observes its effects on health outcomes.

Example: Testing the efficacy of a new antibiotic, vaccine, feed additive, or antiparasitic treatment in livestock.

2. Objectives

The main goals of therapeutic (clinical) trials in animal epidemiology are:

1. To assess efficacy — whether a treatment truly produces the expected biological or clinical effect.
2. To evaluate safety — identifying possible side effects or adverse reactions.
3. To compare two or more therapeutic strategies (new vs. standard treatment).
4. To determine optimal dosage, duration, or administration route.
5. To assess the impact of an intervention on animal health, production, or transmission of pathogens.

The different Types of Therapeutic (Clinical) Trials are presented in Table 11.

Type	Description	Example in Veterinary Field
Randomized Controlled Trial (RCT)	Animals are randomly assigned to treatment or control groups. Considered the *gold standard* for evaluating efficacy.	Randomized trial evaluating a new vaccine against bovine respiratory disease.
Non-randomized Controlled Trial	Allocation is not random (e.g., based on farm or management conditions).	Testing antiparasitic treatment in selected herds only.
Crossover Trial	Animals receive both treatments in	Comparing two feed

Type	Description	Example in Veterinary Field
	sequence, with a washout period in between.	supplements in dairy cows.
Field Trial	Conducted under natural farm conditions (real-life use).	Evaluating footbath disinfectants in dairy herds.
Challenge Trial	Conducted under controlled laboratory conditions, with deliberate pathogen exposure.	Testing a new vaccine by experimental infection with *Salmonella*.

Table 11. Types of Therapeutic (Clinical) Trials

3. Study method

A well-designed therapeutic trial in veterinary epidemiology includes:

1. **Selection of subjects**
   - Animals (or herds) meeting inclusion criteria.
   - Often stratified by age, breed, or infection status.
2. **Randomization**
   - Random assignment to treatment and control/placebo groups.
   - Prevents selection bias.
3. **Blinding**
   - **Single-blind:** animal owners or evaluators unaware of treatment.
   - **Double-blind:** both evaluators and caretakers blinded to treatment identity.
4. **Control group**
   - Receives placebo, no treatment, or standard therapy.
   - Provides comparison for assessing efficacy.
5. **Outcome measurement**
   - Clinical cure rate, pathogen clearance, milk yield, weight gain, morbidity/mortality rate.
   - Follow-up over appropriate time.
6. **Statistical analysis**
   - Use of relative risk (RR), odds ratio (OR), confidence intervals, survival analysis (Kaplan-Meier), and multilevel models when clustering occurs (e.g., herds).

The statistical indicators of the therapeutic study are presented in Table 12.

Indicator	Purpose
Efficacy (%)	(Incidence in control − Incidence in treated) / Incidence in control × 100
Relative Risk (RR)	Probability of disease in treated vs. control group
Odds Ratio (OR)	Odds of recovery in treated vs. control group
Confidence Interval (95% CI)	Precision of effect estimate
P-value	Statistical significance of observed difference

Table 12. Statistical indicators of therapeutic study

References

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I.3.3. Here–Elsewhere Survey (Comparative Field Survey Between Sites or Populations)

1. Definition

A Here–Elsewhere Survey (*Enquête ici-ailleurs*) is a comparative epidemiological study conducted to evaluate the differences in disease occurrence, management practices, or exposure factors between two or more distinct locations, populations, or ecological settings — typically defined as "here" (the affected or exposed area) and "elsewhere" (the unaffected or reference area). In animal epidemiology, this design helps identify environmental, management, or biological factors associated with the presence or absence of a disease or condition.

The Here–Elsewhere Survey is a valuable comparative tool in animal epidemiology, enabling researchers to identify environmental and management factors influencing disease occurrence. Although causal interpretation must be cautious, this approach provides critical insight into spatial patterns and context-dependent risks, especially in regions with diverse ecological or production systems.

It bridges descriptive and analytical epidemiology, offering practical evidence to guide disease surveillance, prevention, and control programs under varied field conditions.

2. Purpose and Objectives

The Here–Elsewhere Survey aims to:

1. Compare disease frequencies (prevalence, incidence) between different geographic areas or populations.
2. Identify potential risk factors or protective factors linked to differences in disease distribution.
3. Assess the impact of environmental or management conditions on animal health outcomes.
4. Guide disease control programs by pinpointing context-specific risk determinants.
5. Generate hypotheses for future analytical or experimental studies.

3. Concept

This type of study is based on the comparative method; observing differences in disease occurrence between two (or more) populations that are similar in most respects except for one or a few key exposures.

Example:
Comparing *brucellosis prevalence* in two provinces; one with a vaccination program ("here") and one without ("elsewhere").

This approach can reveal causal or contributing factors (exp, climate, biosecurity level, husbandry practices) and contextual variability in disease dynamics.

4. Methodology

A Here–Elsewhere Survey generally follows these steps:

1. Define the study areas or populations
    - "Here": affected, exposed, or intervention area.
    - "Elsewhere": unaffected, unexposed, or control area.
2. Select representative samples from each area
    - Animals, herds, or farms are chosen based on standardized sampling criteria.
3. Collect comparable data
    - Clinical data, serological results, environmental conditions, management factors, etc.
4. Ensure standardization of diagnostic methods
    - The same diagnostic tests and criteria must be applied across areas to ensure valid comparison.
5. Measure disease frequency
    - Prevalence, incidence, morbidity, or mortality rates.
6. Compare using appropriate statistical analyses
    - Chi-square tests, odds ratios, relative risks, or logistic regression models adjusted for confounders.
7. Interpret the observed differences
    - Determine whether differences are due to true epidemiological variation or sampling/measurement bias.

5. Example in Animal Epidemiology

Study Title:

Comparative survey of bovine tuberculosis in two contrasting ecosystems in Algeria ("Here–Elsewhere" study)

- **Objective:** To compare prevalence and risk factors of bovine tuberculosis in two regions with different climates and management systems.
- **methodology:** Cross-sectional survey conducted in both areas using the same diagnostic protocol (tuberculin skin test).
- **Findings:**
    - Prevalence was 12% in humid coastal area vs. 3% in arid inland area.
    - Higher infection rate associated with intensive husbandry and shared water points.
- **Conclusion:** Environmental and management factors likely explain the difference in disease prevalence.

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I.3.4 Before–After Study (Pre–Post Intervention Study)

1. Definition

A Before–After Study, also known as a Pre–Post Intervention Study, is a longitudinal evaluative study that measures specific outcomes before and after the implementation of an intervention, treatment, or control measure in the same population of animals or farms, to determine whether a change in health status, disease frequency, or production parameter can be attributed to the applied intervention.

This design is commonly used in veterinary public health, animal production systems, and field epidemiology to evaluate the effectiveness of disease control programs, vaccination campaigns, biosecurity improvements, or management changes.

The Before–After Study is a valuable evaluative tool in animal epidemiology for measuring the effectiveness of interventions over time in real-world settings. Although it lacks randomization and may be affected by temporal confounding, it remains a practical and informative design for monitoring and assessing disease control programs, particularly when resources or ethical constraints limit experimental trials.

When combined with proper statistical controls or a comparison group, this design provides strong evidence for the impact and sustainability of veterinary interventions.

2. Objectives

The main objectives of a Before–After study are to:

1. Measure changes in disease frequency or animal health indicators following an intervention.
2. Assess the effectiveness of control or preventive measures (e.g., vaccination, treatment, management practice).
3. Evaluate the impact of new veterinary programs or sanitary regulations.
4. Identify residual or unintended effects after an intervention.
5. Provide evidence for adjusting or scaling up animal health programs.

3. Methodology

A **Before–After Study** follows this general structure:

1. **initial (Pre-intervention) Phase**
   - Collect data on disease status, performance, or exposure variables before introducing the intervention.
   - Establish a reference (baseline) level.
2. **Intervention Phase**
   - Apply the specific treatment, vaccination, or management change.
   - Ensure standardization and documentation of the intervention.
3. **Follow-up (Post-intervention) Phase**
   - Collect data on the same variables after the intervention, using identical methods.
   - Compare with baseline to determine changes.
4. **Data Analysis**
   - The difference between "before" and "after" measurements is used to estimate the effect size.
   - Paired statistical methods (paired t-test, McNemar test, or repeated-measures ANOVA) are often applied.
   - Confounding factors (season, management, environmental change) must be controlled.

4. Example in Animal Epidemiology

Study Title:
Before–after evaluation of a vaccination campaign against Newcastle Disease in backyard poultry in Senegal.

- **Objective:** Assess the impact of community vaccination on disease occurrence and mortality.
- **methodology:** 800 chickens monitored before and 6 months after vaccination.
- **Results:**
  - Newcastle Disease morbidity decreased from **35% to 5%**.
  - Mortality dropped from **25% to 4%**.

    - Farmer-reported egg production increased by 20%.
- **Conclusion:** The vaccination program significantly reduced disease burden and improved productivity.

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I.3.5 Health Impact Assessment (Evaluation of a Screening Program or Intervention)

1. Definition

A Health Impact Assessment (HIA) in animal epidemiology is a systematic process used to evaluate the effects of a screening program, disease control intervention, or public health policy on animal health, production, and sometimes public health outcomes.

In essence, HIA aims to determine "Did the intervention improve animal health, reduce disease, or achieve its expected impact?

Unlike a simple before–after measurement, HIA involves a broader evaluation framework that assesses:

- Effectiveness (Did it work?)
- Efficiency (Was it cost-effective?)
- Equity (Who benefited?)
- Sustainability (Are effects lasting?)

A Health Impact Assessment (HIA) is a powerful evaluative approach that goes beyond simple outcome measurement.
It assesses whether veterinary interventions; such as screening, vaccination, or biosecurity programs; have truly improved animal and public health, and whether the benefits justify the costs. By combining epidemiological, economic, and behavioral data, HIA provides decision-makers with robust evidence to design more effective, sustainable, and equitable animal health programs.

2. Objectives

The main goals of a Health Impact Assessment are to:

1. Measure changes in health indicators following a screening or intervention.
2. Assess the effectiveness and cost-effectiveness of veterinary programs.
3. Identify direct and indirect outcomes (e.g., improved productivity, reduced antimicrobial use).

4. Support decision-making for scaling up, modifying, or discontinuing a program.
5. Provide accountability for resource allocation and policy implementation.

3. Methodology

A Health Impact Assessment can be observational or experimental, depending on the context and available data.
It generally includes five key stages resumed in table 13. (adapted from WHO and OIE guidelines):

Step	Description	Example in Animal Epidemiology
1. Screening	Determine whether the intervention requires an HIA.	Evaluation of national brucellosis vaccination program.
2. Scoping	Define objectives, population, and expected outcomes.	Identify affected species, regions, and indicators (prevalence, mortality).
3. Assessment	Collect and analyze data before, during, and after intervention.	Compare infection rates and productivity.
4. Recommendations	Suggest improvements based on evidence.	Adjust vaccination frequency or coverage.
5. Monitoring & Evaluation	Track long-term effects and sustainability.	Periodic post-vaccination surveillance.

Table 13. The five HIA key stages

4. Examples in Animal Epidemiology

Example: Evaluation of Brucellosis Control Program

- **Context:** A national vaccination campaign against *Brucella abortus* in cattle.
- **Design:** Longitudinal monitoring of 50,000 cows over 5 years.
- **Results:**
    - Seroprevalence decreased from 12% to 2.3%.
    - Abortions reduced by 60%.
    - Estimated benefit–cost ratio = 4.5:1.
- **Conclusion:** The HIA demonstrated the high effectiveness and economic justification of the program.

Here, are some applications areas of the study presented in Table 14

Application	Example
Screening program evaluation	Assessing the effectiveness of bovine tuberculosis screening by skin test.
Vaccination campaigns	Measuring reduction in Peste des Petits Ruminants (PPR) or FMD incidence.
Biosecurity programs	Evaluating the impact of hygiene training on disease reduction in poultry farms.
Zoonotic disease control	Assessing rabies vaccination campaigns' public health benefit.
Policy evaluation	Analyzing animal welfare or antibiotic use regulations' effects.

Table 14. Applications in Animal Health and Veterinary Public Health

References

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I.3.6 Molecular Epidemiology

1. Definition

Molecular Epidemiology is a specialized branch of epidemiology that integrates molecular biology, genetics, and epidemiological methods to understand the distribution, determinants, and dynamics of diseases in animal populations.

It focuses on identifying pathogen strains, transmission pathways, genetic relationships, and evolutionary patterns using molecular tools such as PCR, sequencing, genotyping, and phylogenetic analysis. Molecular epidemiology bridges the micro-level (molecular data) with the macro-level (population data).

In veterinary medicine, molecular epidemiology provides crucial insights into disease source tracing, outbreak investigation, pathogen evolution, and the emergence of antimicrobial resistance.

2. Objectives

The main objectives of molecular epidemiology in animal health are:

1. Identify and characterize pathogens at the molecular level (species, strain, or lineage).
2. Trace the sources and transmission routes of infectious agents during outbreaks.
3. Monitor genetic evolution and mutations influencing virulence, resistance, or host adaptation.
4. Understand interspecies transmission between domestic animals, wildlife, and humans (One Health approach).
5. Support surveillance, control, and eradication programs with precise molecular data.

3. Applications in Animal Epidemiology

a) Outbreak Investigation

- Determine whether cases are caused by the same strain or multiple sources.
- Example: Genetic typing of *Bacillus anthracis* isolates during anthrax outbreaks to confirm local vs imported sources.

b) Surveillance and Control Programs

- Monitor genetic evolution of viruses like *Foot-and-Mouth Disease Virus (FMDV)* or *Peste des Petits Ruminants Virus (PPRV)*.
- Supports vaccine strain selection and regional disease control strategies.

c) Antimicrobial Resistance (AMR)

- Detect and track genes responsible for antibiotic resistance.
- Identify transmission between animals, humans, and the environment.

d) One Health and Zoonoses

- Compare genetic data from animal and human isolates to assess cross-species transmission (exp., *Salmonella*, *Campylobacter*, *Brucella*).
- Strengthens integrated zoonotic surveillance.

e) Wildlife and Emerging Diseases

- Study genetic links between wildlife reservoirs and domestic outbreaks (e.g., avian influenza, rabies).
- Understand pathogen adaptation and spillover mechanisms.

Molecular Epidemiology represents a transformative tool in modern animal health research. By linking genomic data with epidemiological information, it provides deep insights into pathogen transmission, evolution, and control.

It strengthens disease surveillance, enhances traceability, and supports the One Health approach by connecting animal, human, and environmental health.
As sequencing technologies become more affordable and data integration tools advance, molecular epidemiology study Notably mentioned in Table 15 ; will play an increasingly central role in preventing, detecting, and controlling transboundary and emerging animal diseases

Pathogen / Disease	Objective	Findings
Brucella melitensis	Identify genetic diversity in Algeria	Found multiple genotypes linked to animal movement
FMD virus	Trace virus lineages across North Africa	Revealed cross-border transmission between countries
E. coli (AMR)	Characterize resistance genes in poultry	Detected plasmid-mediated *mcr-1* gene
PPR virus	Evaluate molecular evolution under control programs	Identified lineage IV dominance and vaccine-like strains
SARS-CoV-2 in animals	Understand interspecies transmission	Found mink-to-human and human-to-cat transmission

Table 15. Examples of Molecular Epidemiological Studies

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Chapter 4

Notion of Bias and Causality

I. Notion of Bias and Causality

1. Introduction

In animal epidemiology, the ultimate goal of research is to identify real causal relationships between exposures (risk factors) and health outcomes (diseases).
However, during the collection, analysis, or interpretation of data, various errors or distortions can occur; these are known as biases.

Bias threatens the validity of a study, while causality defines the truthfulness of the relationship observed.

A sound understanding of both concepts is essential to design, interpret, and evaluate epidemiological studies in veterinary medicine.

2. Definition of Bias

Bias is a systematic error in the design, conduct, or analysis of a study that leads to an incorrect estimation of the association between exposure and disease.
It differs from random error, which occurs by chance.

In other words :
Bias = "Systematic deviation from the truth."

Bias can cause the association between exposure and disease to appear stronger, weaker, or even reversed compared to reality.

3. Main Types of Bias

Biases are generally divided into three major categories:

3.1. Selection Bias

Occurs when the way animals or farms are selected into the study is not representative of the target population or depends on both exposure and disease status.

Examples in animal epidemiology :

- Studying only large commercial farms when small farms have different exposure levels.
- Including only animals brought to clinics (which may be sicker than those on farms).
- Loss to follow-up that differs between exposed and unexposed groups in a cohort.

Impact :
Can distort disease frequency estimates and lead to **false associations**.

3.2. Measurement Bias

Occurs when there is a systematic difference in the accuracy of information collected about exposure or disease status.

Examples:

- Misclassification of infected animals as healthy due to low diagnostic test sensitivity.
- Farmers overreporting vaccination status.
- Laboratory tests with different detection limits used for different groups.

Impact:
Leads to misclassification; either differential (biasing effect toward or away from the null) or non-differential (usually dilutes the true association).

3.3. Confounding Bias

Occurs when the observed association between an exposure and disease is distorted by another variable related to both.

Example:

- Older animals appear more likely to have mastitis because they are older (confounder), not necessarily due to a specific feed type (exposure).
- Farm size may confound the relationship between vaccination and disease prevalence.

4. Definition of Causality

Causality refers to the relationship between a cause (exposure) and an effect (disease or health outcome); that is, whether a factor truly produces or influences the occurrence of disease in an animal population.

In epidemiology:
A causal relationship means changing or removing the exposure would alter the disease frequency.

For example:

- If removing *Brucella* exposure reduces abortion rates → causal link is likely.
- If changing diet improves production independently of other factors → causality is supported.

5. Causal Inference

To decide if an observed association is **causal**, epidemiologists use structured criteria; the most famous being **Bradford Hill's criteria (1965)**, adapted for veterinary contexts.

Criterion	Explanation	Example in Animal Epidemiology
1. Strength of association	Strong associations are more likely causal	Odds ratio of 10 between exposure and disease
2. Consistency	Reproducible across studies, species, and settings	Repeated link between poor hygiene and mastitis
3. Specificity	Exposure leads to one disease (rare in multifactorial diseases)	Specific virus causing a defined syndrome
4. Temporality	Exposure precedes the disease (essential)	Vaccination status recorded before outbreak
5. Biological gradient	Dose–response relationship	More ticks → higher babesiosis incidence
6. Plausibility	Fits known biological mechanisms	Pathogen known to cause inflammation and lesions
7. Coherence	Compatible with existing knowledge	Matches laboratory and field observations

Criterion	Explanation	Example in Animal Epidemiology
8. Experiment	Removal of exposure reduces disease	Deworming reduces parasite burden
9. Analogy	Similar factors cause similar diseases	Similar viral mechanisms across species

Table 16. Bradford Hill's criteria (1965) of Causal Inference

6. Epidemiological Models of Causation

a) One Cause–One Effect (Classical)

Used in simple infectious diseases (exp., *Bacillus anthracis* → Anthrax).

b) Multifactorial Model

Most animal diseases (exp, mastitis, lameness, reproductive failure) result from **a combination of factors**:

- Host (species, age, immunity)
- Agent (pathogen type, virulence)
- Environment (hygiene, nutrition, climate)
- Management (housing, milking procedures)

The concepts of bias and causality are fundamental in interpreting animal epidemiological studies.
While bias threatens the validity and reliability of research findings, causality represents the ultimate goal; identifying true factors responsible for disease.

A well-designed study minimizes bias, controls for confounding, and applies causal inference frameworks to ensure that observed associations reflect real biological mechanisms rather than chance or systematic error. Together, these concepts form the scientific foundation of evidence-based veterinary epidemiology.

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Chapter 5

Epidemiology of Infectious Diseases

Epidemiology of Infectious Diseases

I. Principles of Pathogen Transmission in Animal Populations

1. Introduction

Infectious disease epidemiology studies how pathogenic agents (viruses, bacteria, fungi, parasites, prions) are maintained, transmitted, and spread among animal populations and sometimes to humans (zoonoses).

Understanding the principles of transmission is essential for disease prevention, control, and eradication programs in veterinary medicine.

Transmission of infectious diseases depends on the interaction between three components:

Agent (Biological entity capable of causing disease), **Host (**Susceptible animal that can harbor or transmit the pathogen) and **Environment (**External conditions that affect transmission).

Disease transmission occurs when a pathogen leaves one host, survives in the environment, and infects another susceptible host under favorable conditions.

2. Basic Terms and Concepts

Reservoir: The habitat (host species or environment) where a pathogen normally lives, grows, and multiplies.

Source of infection: The specific entity (animal, person, object) from which the pathogen is transmitted to a new host.

Vector: A living organism (usually arthropod) that transmits the pathogen between hosts.

Vehicle: Inanimate material (water, feed, equipment) that transmits the pathogen.

Portals of entry and exit: Anatomical sites through which pathogens enter or leave the host (respiratory tract, skin, mucosa, etc.).

3. Types of Transmission

Pathogens can be transmitted through direct or indirect mechanisms.

3.1. Direct Transmission

Occurs when the pathogen is transferred immediately from an infected to a susceptible host without an intermediate object or vector.

- **Contact transmission:** licking, biting, sexual contact (exp, *Brucella abortus*, *Tritrichomonas foetus*).
- **Droplet spread:** short-range respiratory droplets (exp, *Bovine respiratory syncytial virus*).
- **Vertical transmission:** from dam to offspring (in utero, during birth, or via milk).

Example:
Transmission of *Mycobacterium bovis* between cattle through aerosols in confined barns.

3.2. Indirect Transmission

Involves a vehicle, vector, or environmental medium.

a) Vehicle-borne transmission

Pathogens are transmitted via contaminated materials:

- Feed, water, bedding, soil, fomites (e.g., instruments, boots).
- Example: *Salmonella* spread via contaminated feed.

b) Vector-borne transmission

Pathogens are carried by arthropods (ticks, mosquitoes, flies).

- Mechanical transmission: pathogen carried externally (exp, *E. coli* by flies).
- Biological transmission: pathogen multiplies/develops inside vector (exp, *Anaplasma marginale* in ticks).

c) Airborne transmission

Tiny infectious aerosols remain suspended and travel over distances (e.g., *Foot-and-mouth disease virus*).

d) Environmental (fomite) transmission

Long-term persistence in contaminated environments (exp, spores of *Bacillus anthracis*).

3.3. Vertical and Horizontal Transmission

Horizontal; Between individuals of the same generation

Vertical; From mother to offspring (transplacental, via colostrum, or egg)

Vertical transmission is especially important for pathogen persistence in herds even after control of horizontal spread.

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Conclusion

Animal Epidemiology: Principles and Applications **provide a comprehensive overview of the key concepts, methods, and practical tools used to understand and manage diseases in animal populations. By examining disease patterns, identifying risk factors, and applying appropriate control strategies, animal epidemiology plays a crucial role in improving animal health, ensuring food safety, and protecting public health. Mastery of these principles enables veterinarians, researchers, and policymakers to make evidence-based decisions and implement effective disease prevention and control programs. As animal health challenges continue to evolve, the application of sound epidemiological practices remains essential in safeguarding both animal and human populations.**