

Economic Zoology: A Quantitative Review of Animal-Based Enterprises, Livelihoods, Resource Recovery and Sustainable Bioeconomy

Dr. M. Stephen

Assistant Professor,

PG & Research Department of Zoology,

St. John's College, Palayamkottai-627 002,

Tirunelveli. Affiliated to Manonmaniam Sundaranar University,

Abishekapatti, Tirunelveli, 627012, Tamil Nadu, India

Abstract- Economic zoology deals with the utilization of animals and animal-derived products for food, fibre, medicine, agriculture, industry and livelihood development. Traditionally, economically important zoological enterprises have included sericulture, apiculture, lac culture, fisheries, aquaculture, vermiculture and animal husbandry. In recent years, the field has expanded toward insect-based industries, biological control, pollination services, insect-derived biomaterials and circular bioeconomy applications. This review examines the economic, nutritional, agricultural and environmental significance of major animal-based enterprises using quantitative evidence. Global fisheries and aquaculture production reached approximately 235 million tonnes in 2024, including 195 million tonnes of aquatic animals, while aquaculture exceeded 100 million tonnes for the first time. The sector supports more than 600 million livelihoods worldwide. In India, insect-based enterprises such as apiculture, sericulture and lac culture remain important rural livelihood activities, while emerging applications include insect protein, pollination, waste decomposition and pharmaceutical products. Economic zoology therefore represents an important interface between biodiversity, food production, rural employment, industrial raw materials and sustainable resource utilization. The review highlights opportunities for integrating traditional zoological enterprises with emerging technologies to strengthen the circular bioeconomy.

Keywords— Economic zoology; sericulture; apiculture; aquaculture; lac culture; vermiculture; insect farming; rural livelihood; circular bioeconomy

I. INTRODUCTION

Animals provide a wide range of products and ecosystem services that contribute directly and indirectly to human welfare. Silk, honey, beeswax, lac, fish, shellfish, poultry products, livestock products and vermicompost are examples of commercially important products derived from animals. In addition to direct products, animals provide economically valuable services including pollination, biological pest control, decomposition, nutrient recycling and ecosystem maintenance.

The importance of economic zoology has increased with the growth of the global population, demand for protein and increasing pressure on agricultural resources. Modern economic zoology is no longer restricted to traditional animal production. It

increasingly incorporates insect biotechnology, edible insects, insect-derived pharmaceuticals, biological control agents, waste-converting organisms and high-value biomaterials.

Insect-based industries are particularly important because insects can be reared using comparatively small amounts of land and can generate multiple products. A review of insect industrialization identified silk, honey, lac, insect wax, pollination, biological control, insect protein and pharmaceutical compounds among the major commercial applications.

India has particular significance in this field because apiculture, sericulture and lac culture are established rural enterprises. Ghosh and Jung reported that India's semi-organized insect industry primarily

includes these three sectors and highlighted additional opportunities in insect-derived food, feed, waste decomposition and pollination.

II. MAJOR ENTERPRISES OF ECONOMIC ZOOLOGY

Sericulture and Apiculture

Sericulture involves the rearing of silkworms for commercial silk production. *Bombyx mori* is the major domesticated mulberry silkworm, while non-mulberry silks include tasar, eri and muga. The industry generates income through several stages including mulberry cultivation, silkworm rearing, cocoon production, reeling, weaving and marketing. The economic significance of sericulture extends beyond silk because it generates employment across both farm and post-harvest activities. India's raw silk production reached approximately 38,913 tonnes in 2023–24, with mulberry silk contributing the largest proportion. This makes sericulture particularly relevant to rural employment and smallholder livelihoods.

Apiculture, or beekeeping, is another major component of economic zoology. Honey bees provide commercial products including honey, beeswax, propolis, royal jelly and bee venom. However, pollination is an equally important economic service. Managed bees can increase fruit,

vegetable, oilseed and seed production by improving pollination efficiency.

The economic value of apiculture therefore consists of both marketed hive products and agricultural productivity generated through pollination.

Lac culture, fisheries and aquaculture

Lac culture involves the cultivation of lac insects, particularly *Kerria lacca*, on suitable host plants. Lac is processed into resin, shellac, dye and wax. These products have applications in food coatings, pharmaceuticals, cosmetics, adhesives, electrical products, printing and furniture finishing.

The FAO identifies lac, natural honey, beeswax and silk among commercially important insect-derived products.

Fisheries and aquaculture constitute another major branch of economic zoology. The scale of this sector is considerably larger than many terrestrial animal enterprises. According to the FAO's 2026 fisheries assessment, global fisheries and aquaculture production reached 235 million tonnes in 2024, including approximately 195 million tonnes of aquatic animals. Aquaculture aquatic-animal production exceeded 100 million tonnes for the first time and was valued at approximately US\$371 billion at farm gate. The sector supports more than 600 million livelihoods globally.

Table 1. Major sectors of economic zoology

Sector	Major organism/product	Principal economic output	Major additional benefit
Sericulture	<i>Bombyx mori</i> and other silkworms	Silk	Rural employment
Apiculture	<i>Apis</i> spp.	Honey, wax, propolis	Pollination
Lac culture	<i>Kerria lacca</i>	Lac resin, shellac, dye	Rural income
Fisheries	Fish and aquatic organisms	Fish and seafood	Food security
Aquaculture	Fish, shrimp, molluscs	Farmed aquatic foods	Employment and trade
Vermiculture	Earthworms	Vermicompost	Organic-waste recycling
Insect farming	Edible/industrial insects	Protein, feed, biomaterials	Circular bioeconomy
Biological control	Predatory/parasitoid insects	Biocontrol services	Reduced pesticide dependence

III. QUANTITATIVE ECONOMIC IMPORTANCE

The economic contribution of economic zoology can be evaluated through production, employment, market value, trade, nutritional contribution and ecosystem services.

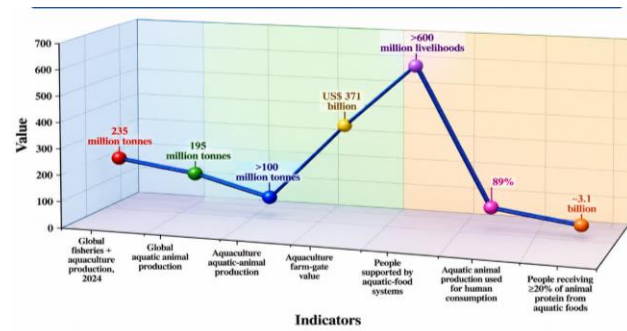
The global aquatic-food sector provides one of the clearest quantitative examples. FAO reported that in 2024, aquatic animal production reached approximately 195 million tonnes, with aquaculture exceeding 100 million tonnes. Approximately 89% of aquatic animal production was used for human consumption, demonstrating its importance to global food systems.

The same assessment reported that aquatic animal foods provide at least one-fifth of animal protein consumption for approximately 3.1 billion people. Thus, fisheries and aquaculture have significance not only as commercial industries but also as contributors to global nutrition.

Table 2. Quantitative indicators illustrating the economic importance of zoological enterprises

Indicator	Reported value
Global fisheries + aquaculture production, 2024	235 million tonnes
Global aquatic animal production	195 million tonnes
Aquaculture aquatic-animal production	>100 million tonnes
Aquaculture farm-gate value	US\$371 billion
People supported by aquatic-food systems	>600 million livelihoods
Aquatic animal production used for human consumption	89%
People receiving $\geq 20\%$ of animal protein from aquatic foods	~3.1 billion

These values demonstrate that economic zoology encompasses industries operating at local household, rural, national and global scales.



IV. EMERGING ECONOMIC OPPORTUNITIES

The scope of economic zoology is expanding rapidly because of advances in biotechnology and circular-economy approaches. Insects are increasingly investigated as sources of protein, lipids, chitin, antimicrobial compounds, enzymes and other bioactive molecules. Insect-derived materials can potentially be used in food, animal feed, pharmaceuticals, cosmetics and biomaterials.

Insect farming may also connect economic zoology with organic-waste management. Certain insects can convert agricultural and food-processing residues into insect biomass while producing frass that may be used as an agricultural amendment. This creates a potential pathway of:

Organic waste → insect bioconversion → protein/lipid recovery → feed/food products → frass → soil amendment.

Recent reviews describe insect industrialization as extending beyond silk and honey to insect protein, biological control, pollination, pharmaceutical compounds and ornamental applications.

Similarly, lac insects provide a model of multi-product utilization. Lac resin, dye and wax can enter different industrial value chains, including food, pharmaceutical, cosmetic, adhesive and coating industries.

V. ENVIRONMENTAL SUSTAINABILITY AND CIRCULAR BIOECONOMY

Economic zoology can contribute to sustainability when animal production systems are designed around efficient resource utilization. Aquaculture, for example, can provide large quantities of aquatic food but requires careful management of feed resources, water quality, disease and environmental impacts. FAO's current assessment emphasizes that future growth needs to address sustainability and equitable distribution of benefits.

Vermiculture provides another important example. Earthworms convert biodegradable organic residues into vermicompost, allowing nutrients contained in agricultural and household waste to return to soil. Thus, vermiculture links zoology with waste management, soil fertility and circular nutrient cycling.

Insects also provide ecosystem services that are difficult to replace through conventional technologies. Pollinating insects support crop production, while predatory and parasitoid insects can suppress agricultural pests. These services have economic value even when the organisms themselves are not directly marketed.

Consequently, the future of economic zoology lies increasingly in multi-functional systems, where one organism provides several products and ecological services simultaneously.

Challenges and Future Perspectives

Despite its economic importance, economic zoology faces several challenges. Climate change, habitat loss, diseases, feed costs, water scarcity, market fluctuations and changing consumer preferences can affect animal-based enterprises. Small-scale producers may also experience difficulties in accessing technology, finance, processing facilities and organized markets.

Another challenge is the need to quantify ecosystem services alongside direct market income. For example, the economic value of honey can be directly calculated from market prices, whereas the

value of bee-mediated crop pollination requires a different economic assessment.

Future research should therefore integrate:

- production efficiency;
- employment generation;
- household income;
- value-chain analysis;
- ecosystem-service valuation;
- life-cycle assessment;
- nutritional contribution;
- climate resilience; and
- circular-economy potential.

Emerging fields such as edible insect production, insect biotechnology, precision aquaculture, silk biomaterials, bee-derived bioactive compounds and insect-based waste conversion could substantially broaden the traditional definition of economic zoology.

VI. CONCLUSION

Economic zoology has evolved from the conventional study of commercially useful animals into a multidisciplinary field connecting animal biology, agriculture, food security, rural livelihoods, biotechnology, industrial production and environmental sustainability. Sericulture, apiculture, lac culture, fisheries, aquaculture and vermiculture continue to provide important economic products and employment, while insect farming and animal-derived biomaterials are creating new opportunities. The scale of the aquatic sector illustrates the magnitude of this contribution: global fisheries and aquaculture production reached 235 million tonnes in 2024, while aquaculture alone exceeded 100 million tonnes of aquatic animals and generated approximately US\$371 billion in farm-gate value.

For a Scopus-oriented review, I would make this paper more quantitative by adding 5 figures: (1) global economic sectors of economic zoology, (2) aquaculture production trend, (3) comparison of silk/honey/lac/fish value chains, (4) employment generation, and (5) a circular-bioeconomy pathway connecting animal products with waste utilization.

REFERENCES

1. Ghosh, S., & Jung, C. (2021). Future prospects of insects as a biological resource in India: Potential biological products utilizing insects with reference to the frontier countries. *Entomological Research*, 51, 209–229. (Wiley Online Library)
2. Chen, X., et al. (2022). Insect industrialization and prospect in commerce: A case of China. *Entomological Research*, 52, 178–194. (Wiley Online Library)
3. FAO. (2026). *The State of World Fisheries and Aquaculture 2026*. Food and Agriculture Organization of the United Nations. (FAOHome)
4. FAO. (2024). *The State of World Fisheries and Aquaculture 2024*. Food and Agriculture Organization of the United Nations. (FAOHome)
5. Leather, S. R. (2015). Influential entomology: A short review of the scientific, societal, economic and educational services provided by entomology. *Ecological Entomology*. (resjournals.onlinelibrary.wiley.com)
6. Kolobe, S. D., Manyelo, T. G., Sebola, N. A., et al. (2024). Prospects of rearing selected southern African swarming insects for animal feed: A review on insect farming and the economic value of edible insects. *Agriculture & Food Security*, 13, 6. (link.springer.com)