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COLEOPTERA AS BIOINDICATORS AND PEST COMPLEXES IN ARID AGROECOSYSTEMS OF KARAKALPAKSTAN: A LITERATURE-BASED SYNTHESIS FOR SUSTAINABLE AGRICULTURE

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ABSTRACT

Coleoptera are among the most diverse insect orders and include taxa that are simultaneously useful bioindicators, natural enemies, decomposers and harmful phytophages. In Karakalpakstan and the wider Southern Aral Sea region, aridification, salinization, irrigation transformation and expansion of shelterbelts increase the need for systematic monitoring of beetle assemblages. This paper synthesizes published data on ground beetles, darkling beetles, blister beetles, longhorn beetles and host-plant pest complexes from Karakalpakstan and adjacent Northwestern Uzbekistan. Published records indicate 104 species and subspecies of Carabidae in northwestern landscapes, 79 Tenebrionidae in western Uzbekistan, and 27 Meloidae in the Southern Aral Sea region. The most species-rich Carabidae landscape was the Kyzylkum desert, while agrocenoses also retained high recorded richness. The synthesis proposes a practical monitoring framework combining pitfall traps, light traps, host-plant inspection and seasonal

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surveys to support integrated pest management and biodiversity conservation in arid agroecosystems.

Keywords: Coleoptera; Karakalpakstan; Southern Aral Sea; Carabidae; Tenebrionidae; Cerambycidae; agroecosystems; biodiversity monitoring; integrated pest management.

INTRODUCTION

Beetles (Coleoptera) are a central component of terrestrial biodiversity and agricultural ecosystem functioning. Globally, beetles account for roughly a quarter of described animal species, and current estimates of the order continue to emphasize its exceptional richness [1]. This diversity is not only taxonomic: Coleoptera include predators, seed consumers, wood-borers, decomposers, pollinators, root feeders and defoliators. For that reason, beetle assemblages can simultaneously signal habitat quality, contribute to natural pest regulation and reveal emerging phytosanitary risks in changing agricultural landscapes.

The Republic of Karakalpakstan is an especially important region for Coleoptera studies because its agroecosystems are located within the ecological influence of the Southern Aral Sea crisis. Large areas are shaped by desertification, soil salinity, wind erosion, irrigation networks, shelterbelt plantations and the mosaic of natural deserts, tugai fragments and agricultural fields. The regional desert complex includes the Ustyurt Plateau, the Kyzylkum Desert and the Aralkum landscapes formed after the retreat of the Aral Sea. These conditions create strong environmental filters for insects and make the region suitable for studying drought-adapted, xylophagous, phytophagous and predatory beetle groups.

Recent regional publications show that the Coleoptera fauna of Northwestern Uzbekistan is still insufficiently synthesized for applied agricultural use. Ground beetles (Carabidae) are particularly relevant because they are widely used as indicators of habitat alteration and agroecosystem sustainability [2,3]. Darkling

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beetles (Tenebrionidae) are characteristic of arid landscapes and include many desert-adapted species. Blister beetles (Meloidae) are important both ecologically and agriculturally because some larvae parasitize locust egg pods, while adults may affect flowering plants. Longhorn beetles (Cerambycidae) include xylophagous pests of shelterbelts, urban trees and desert woody vegetation [9, 10]. Leaf beetles and Tamarix-associated pest complexes add another layer of relevance for riparian, desert and shelterbelt management [12,14].

The aim of this article is to prepare an EJASB-style literature-based synthesis of Coleoptera in Karakalpakstan with emphasis on agricultural relevance, bioindicator value and pest-management priorities. The objectives were: (1) to summarize recent and classical data on major Coleoptera groups in Karakalpakstan and adjacent Northwestern Uzbekistan; (2) to compare published patterns of species richness across landscapes; (3) to identify taxa and habitats that should be prioritized in monitoring; and (4) to propose an applied monitoring scheme for arid agroecosystems and forest-protective plantations.

MATERIALS AND METHODS

This paper is based on a qualitative synthesis of published sources rather than on newly collected field material. Sources were selected to cover the main Coleoptera families and habitats relevant to Karakalpakstan and the Southern Aral Sea region: Carabidae, Tenebrionidae, Meloidae, Cerambycidae and plant-associated pest complexes. Priority was given to publications that reported quantitative values, study landscapes, sampling periods or species lists from Karakalpakstan, Khorezm and the wider Northwestern Uzbekistan region.

The evidence base included regional faunistic papers on Carabidae in Northwestern Uzbekistan [7], Tenebrionidae of western Uzbekistan [8], Meloidae of the Southern Aral Sea region [9], Cerambycidae in natural and anthropogenically transformed landscapes [10, 11], and Tamarix pest complexes in Northwestern Uzbekistan [12]. General interpretive references on Coleoptera

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diversity, carabid bioindication, agroecosystem sustainability and invasive phytophagous leaf beetles were used to frame regional results in a broader agricultural and ecological context [16, 17].

For tabular and graphic presentation, only numerical data explicitly reported in published sources were used. Regional Carabidae values by landscape were taken from the northwestern Uzbekistan ground beetle study: 36 species and subspecies in Ustyurt, 59 in the Kyzylkum desert landscape, 30 in the Lower Amu Darya Biosphere Reserve and 52 in agrocenoses [19]. Family-level evidence was summarized from published totals: 104 Carabidae species and subspecies, 79 Tenebrionidae species [8] and 27 Meloidae species [9]. For Cerambycidae, the figure refers to priority dominant or repeatedly cited pest taxa from published regional studies, not to a complete family checklist [10, 11].

The proposed monitoring framework was developed from the collection approaches reported in regional publications and from standard entomological practice. The framework emphasizes pitfall traps for epigeic Carabidae and Tenebrionidae, light traps for nocturnal and crepuscular taxa, host-plant inspection for Cerambycidae and Chrysomelidae, and repeated seasonal surveys from late April to October, which corresponds to the activity windows described for ground beetles in northwestern Uzbekistan [7].

RESULTS AND DISCUSSION

The available literature demonstrates that Karakalpakstan is not a peripheral zone for Coleoptera diversity. Instead, it represents a contact region where desert specialists, irrigated-field assemblages, shelterbelt pests, tugai-related species and anthropogenically adapted taxa meet. The best quantitative data currently available are for Carabidae, Tenebrionidae and Meloidae. Together, these sources show a strong need to integrate faunistic knowledge with agricultural monitoring. Ground beetles are the best documented applied indicator group. In the northwestern Uzbekistan survey, 104 species and subspecies belonging to 39

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genera and seven subfamilies were recorded [7]. The same study reported substantial landscape differences, with the highest number of species and subspecies in the Kyzylkum desert landscape and a high value also in agrocenoses. This is important because agrocenoses in arid regions are often viewed only as disturbed habitats; however, the recorded richness suggests that irrigated fields, field margins, canals and shelterbelts may also support active ground-dwelling predator communities if pesticide pressure and habitat simplification are controlled.

Darkling beetles strengthen the desert-biodiversity signal. Expeditions conducted during 2021–2023 in western Uzbekistan, including the Republic of Karakalpakstan, summarized 79 Tenebrionidae species and reported four taxa new for science, as well as several new records for Middle Asia, Uzbekistan, western Uzbekistan and the Ustyurt Plateau [8]. This demonstrates that even recent collecting can substantially change the known fauna of the region. The taxonomic novelty of this group also means that biodiversity monitoring in Karakalpakstan should not be limited to common crop pests, because rare and poorly known desert species may be lost before their ecological roles are understood.

Meloidae data show a direct agricultural connection. The Southern Aral Sea blister beetle checklist included 27 species from two subfamilies, six tribes and nine genera; five species were recorded for the first time in the Southern Aral Sea basin [9]. Larvae of some species, especially within *Mylabris* and *Epicauta*, parasitize locust egg pods. Reported infestation values were 29.2% for *Locusta migratoria migratoria* egg pods and 32.8% for *Calliptamus italicus italicus* egg pods. Therefore, Meloidae should be considered not only as floricolous beetles or potential plant-feeders, but also as a natural regulatory component in locust-prone landscapes.

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Table 1. Selected published evidence base for Coleoptera in Karakalpakstan and adjacent Northwestern Uzbekistan.

Coleoptera group	Published quantitative record	Main landscapes/habitats	Agricultural/ecological relevance
Carabidae	104 species and subspecies; 39 genera; 7 subfamilies	Ustyurt, Kyzylkum, Lower Amu Darya reserve, agrocenoses	Predators, seed consumers and bioindicators of soil/field management
Tenebrionidae	79 species; four taxa new for science in western Uzbekistan study	Deserts of western Uzbekistan, including Karakalpakstan	Desert biodiversity, arid-land adaptation, faunistic novelty
Meloidae	27 species; 2 subfamilies; 6 tribes; 9 genera	Kyzylkum, Lower Amu Darya reserve, Southern Ustyurt, agrocenoses	Locust egg-pod parasitoids and floricolous components
Cerambycidae	Five priority dominant/pest taxa repeatedly cited	Forest farms, urban trees, desert woody plants, shelterbelts	Xylophagous pests of Populus, Salix, Elaeagnus and desert shrubs
Tamarix pest complex including Coleoptera	175 pest species from 7 orders on Tamarix spp.	Ustyurt and Kyzylkum desert zones	Host-plant-based monitoring in desert and shelterbelt vegetation

Selected Coleoptera evidence base for Karakalpakstan and adjacent NW Uzbekistan

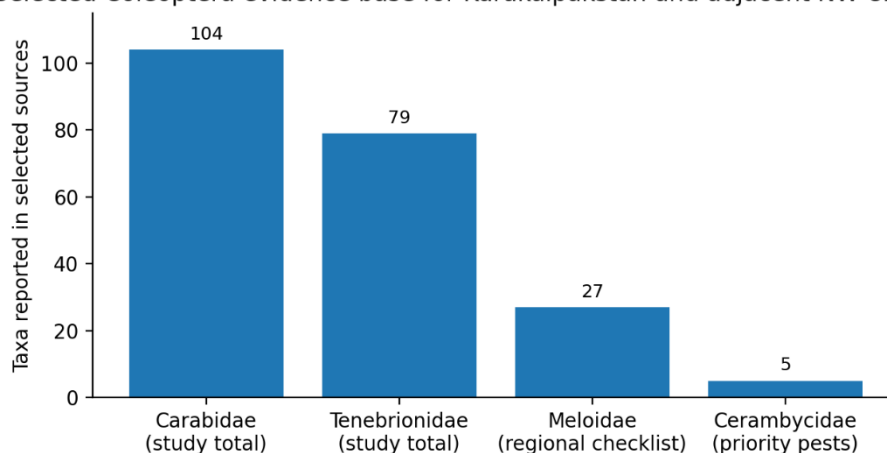


Figure 1. Published Coleoptera evidence base used in this synthesis. Note: the Cerambycidae value denotes priority taxa cited in regional pest studies, not a complete checklist.

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Landscape pattern of ground beetles

The most suitable quantitative landscape comparison is available for Carabidae. The highest recorded richness was in the Kyzylkum desert landscape (59 species and subspecies), followed by agrocenoses (52), Ustyurt (36) and the Lower Amu Darya Biosphere Reserve (30) [7]. These values should not be interpreted as final regional richness because sampling intensity, seasonal timing and method combinations can affect the number of recorded species. Nevertheless, the pattern is useful for setting monitoring priorities.

The high value for the Kyzylkum desert indicates that natural desert habitats remain reservoirs of ground beetle diversity. The high value for agrocenoses shows that agricultural landscapes are not biologically empty; instead, they can maintain diverse ground-dwelling assemblages if field edges, irrigation margins, shelterbelts and low-disturbance refugia are preserved. The lower number reported from the Lower Amu Darya Biosphere Reserve may reflect habitat specificity and sampling coverage rather than lower conservation value. Protected tugai and floodplain habitats are essential because they contain microhabitats that are not available in dry open deserts or intensively cultivated fields.

Within the Carabidae taxonomic structure, Harpalinae was reported as the dominant subfamily with 32 species and 19 genera, whereas Scaritinae included 20 species and Cicindelinae included 12 species [7]. Such dominance is agriculturally relevant: many harpalines combine predation with granivory and may contribute to regulation of weed seeds and small arthropod prey, while cicindelinae are often associated with open sandy or saline substrates. Therefore, a monitoring program should not record only total beetle abundance; it should also separate functional groups by diet, dispersal ability and habitat preference.

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Ground beetles (Carabidae) recorded by landscape in Northwestern Uzbekistan

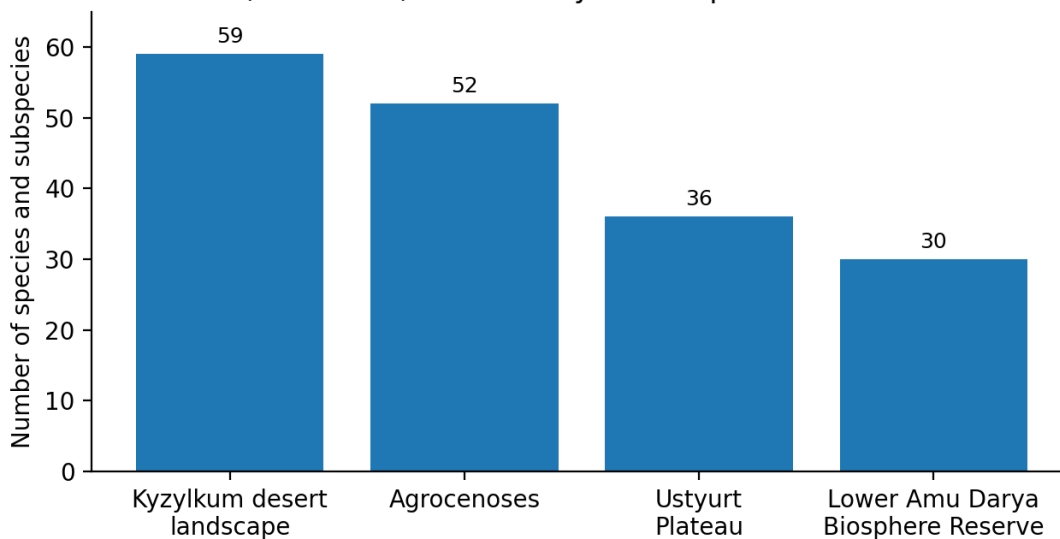


Figure 2. Carabidae species and subspecies recorded by landscape in northwestern Uzbekistan based on published data.

Table 2. Landscape distribution of Carabidae records and applied monitoring interpretation

Landscape	Species and subspecies	Share of total Carabidae list (%)	Interpretive priority for monitoring
Kyzylkum desert landscape	59	56.7	Reference desert assemblage; drought-adapted predators and open-ground taxa
Agrocnoses	52	50.0	Key for sustainable agriculture, field-margin management and pesticide impact assessment
Ustyurt Plateau	36	34.6	Priority arid-land transects and plateau escarpment habitats
Lower Amu Darya Biosphere Reserve	30	28.8	Protected floodplain/tugai reference and conservation comparison

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Pest complexes and agricultural risk

Not all Coleoptera in Karakalpakstan should be treated as pests. A modern agricultural interpretation must distinguish beneficial predators, neutral biodiversity components and harmful phytophages. Carabidae and some Meloidae support ecological regulation, whereas Cerambycidae and several Chrysomelidae-related plant-feeding complexes can become economically important. This distinction is necessary for integrated pest management because broad-spectrum insecticide use can reduce natural enemies together with pest species.

Cerambycidae are especially important for shelterbelts, urban greenery and woody desert vegetation. Regional studies identify *Aeolesthes sarta* Solsky as a dominant or major pest in natural and anthropogenically transformed areas [18, 19]. Other cited longhorn beetles include *Trichotetus turkestanicus*, *Anaglyptus bicallosus* and *Oberea ruficeps* [10]. These taxa are linked with woody plants such as *Populus*, *Salix*, *Elaeagnus* and other shelterbelt or desert plants. Because afforestation and shelterbelt establishment are widely used to reduce wind erosion and improve microclimate, xylophagous beetles directly affect the success of land-rehabilitation measures.

The Tamarix pest checklist adds host-plant-level evidence. Research conducted during 1999–2023 reported 175 pest species associated with Tamarix in Northwestern Uzbekistan, including Coleoptera among seven orders [12]. Of the total Tamarix pest complex, 41 species were reported from stems, 28 from leaves, 4 from roots, 2 from flowers and 100 from mixed plant parts [12]. Even though this dataset is not restricted to Coleoptera, it is valuable for designing inspections of desert shrubs and shelterbelt vegetation because it shows that stem and mixed-part damage dominate host-plant pest structure.

International experience with Chrysomelidae invasions shows why regional surveillance should be proactive. Leaf beetles can have major economic consequences when they become established outside native ranges or when host-

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plant availability increases [13]. In arid Northwestern Uzbekistan, irrigation, shelterbelt planting, trade in seedlings and climate stress may create new opportunities for phytophagous beetles to expand. Therefore, routine monitoring should include pest-risk taxa, beneficial ground beetles and unusual new records, rather than focusing only on visible defoliation.

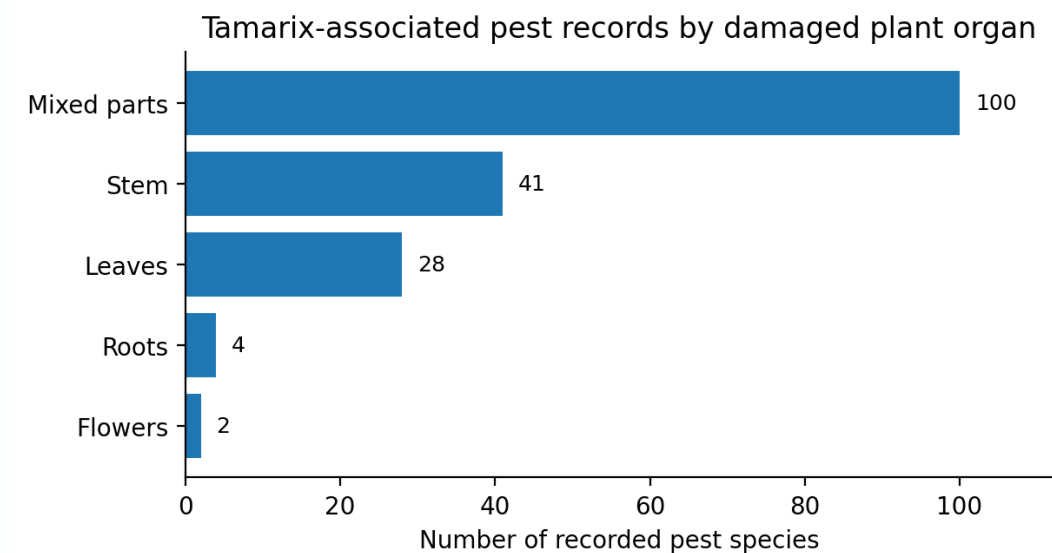


Figure 3. Tamarix-associated pest distribution by plant organ in Northwestern Uzbekistan, based on the complete pest complex reported by Bekbergenova et al.

Applied monitoring framework

A practical Coleoptera monitoring program for Karakalpakstan should be simple enough for repeated use by university laboratories, forest farms and plant-protection services, but detailed enough to produce scientifically comparable data. The minimum design should include four habitat blocks: natural desert, agrocenosis, shelterbelt/urban woody vegetation and protected tugai or riparian habitat. Within each block, the same sampling methods should be repeated seasonally to separate true ecological patterns from short-term activity peaks. Pitfall traps should be the core method for Carabidae and many Tenebrionidae because these groups are active on the soil surface. Regional studies used buried

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bottles, jars or plastic cups filled with preservative liquids, and also reported that seasonal aspects from late April to October are important for adult activity [7]. Light traps should be added for nocturnal Cerambycidae and other flying beetles. Host-plant inspection is essential for Cerambycidae, Chrysomelidae and Tamarix-associated pest complexes; this includes checking stems, bark crevices, leaves, roots and flowers depending on the suspected pest group.

For agricultural decision-making, collected beetles should be classified into at least four functional groups: predators/omnivores, phytophages/defoliators, xylophages/stem borers and desert detritivores. This functional classification is more useful for farm management than a simple species list. For example, a decrease in large predatory Carabidae after pesticide treatment may signal reduced natural pest-control potential, whereas an increase in xylophagous Cerambycidae in stressed shelterbelts may indicate risk to tree survival. Such functional interpretation is consistent with global carabid-indicator research showing that richness, abundance and functional diversity can reflect agroecosystem sustainability [3, 14].

Table 3. Proposed Coleoptera monitoring framework for arid agroecosystems and shelterbelt landscapes of Karakalpakstan.

Target group	Main method	Seasonal focus	Field indicator	Management use
Carabidae	Pitfall traps; hand search	Late April–October	Abundance, species richness, functional guilds	Bioindicator of field disturbance and natural enemy potential
Tenebrionidae	Pitfall traps; visual search	Spring–summer desert activity	Desert specialists and new records	Arid-land biodiversity monitoring and conservation
Meloidae	Sweep net; flower inspection; locust egg-pod survey	Flowering period; locust breeding sites	Adult species and larval parasitism	Locust biological regulation assessment
Cerambycidae	Light traps; stem/bark inspection	April–May and early summer	Boring holes, galleries, adult emergence	Shelterbelt and urban-tree pest management
Tamarix and leaf beetle complexes	Host-plant inspection; sweep net	Vegetation period	Defoliation, stem injury, new phytophagous records	Early warning for shrub and shelterbelt damage

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Seasonal and habitat-based survey design

A field-ready monitoring calendar should begin with early spring reconnaissance of overwintered adults and continue until late autumn, when ground activity declines. In April and May, priority should be given to pitfall traps in field margins, old irrigation channels, sandy ridges and shelterbelt edges because many Carabidae and Tenebrionidae become active after the first stable warming period. During May and June, host-plant inspection becomes more important because adult Cerambycidae, Chrysomelidae and flower-visiting Meloidae are easier to detect on woody plants, shrubs and flowering vegetation. In July and August, high temperature and drought may reduce daytime activity, so evening light trapping and early morning inspections are recommended. September and October surveys are useful for identifying late-season assemblages and for evaluating the effect of pesticide applications after harvest.

Habitat stratification is equally important. Natural desert sites should include sandy, clayey and saline microhabitats; agrocenoses should include crop interiors, field borders, irrigation ditches and untreated refuges; shelterbelts should be inspected tree by tree for stem holes, galleries, frass and crown weakening; and tugai or riparian fragments should be treated as reference habitats for moisture-dependent species. Each sample unit should be linked to GPS coordinates, soil condition, dominant vegetation and visible disturbance level. Such standardized metadata will make it possible to compare beetle communities across years, districts and management regimes instead of producing isolated species lists.

The monitoring output should be practical for agriculture. For each site, the final field sheet can include total Coleoptera abundance, number of beneficial predatory Carabidae, number of xylophagous Cerambycidae signs, presence of locust-regulating Meloidae, dominant phytophagous taxa and management notes. When this information is combined with soil salinity, vegetation condition and pesticide-use records, beetles can become a low-cost biological indicator system for Karakalpakstan. This approach is especially suitable for the Southern Aral Sea

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region, where ecological stress is high and where sustainable agriculture requires both pest control and conservation of biodiversity functions.

Data gaps and research priorities for Karakalpakstan

The synthesis also reveals several gaps that should be addressed before a complete Coleoptera-based assessment of Karakalpakstan can be prepared. First, many published records are family-specific and do not use identical sampling designs; therefore, richness values among families should not be compared as if they were collected with equal effort. Second, some important agricultural families such as Curculionidae, Scarabaeidae, Buprestidae, Elateridae and many Chrysomelidae remain insufficiently integrated into one regional database, although they may include both pests and useful decomposers. Third, the dried Aral Sea bottom is developing rapidly as a new anthropogenic-natural landscape, but its beetle fauna is still poorly represented in accessible publications.

Future field work should prioritize repeated transects from the Ustyurt Plateau through the Kyzylkum and Aralkum landscapes to irrigated zones of the Lower Amu Darya. This would allow researchers to test how salinity, soil texture, vegetation cover and land-use intensity affect beetle assemblages. Special attention should be paid to shelterbelts and urban green plantations because these habitats are important for wind protection and human well-being but can also accumulate xylophagous pests. Integrating beetle monitoring with remote sensing and vegetation mapping would make the results more useful for ecological restoration and agricultural planning.

Another priority is the development of a regional specimen and photo archive. Each collected specimen should be labeled with locality, coordinates, date, collector, method, host plant and habitat description. High-quality photographs of adults, larval damage, galleries and plant symptoms can help plant-protection specialists recognize pests earlier. A shared university database would also reduce

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duplication of records and support future publication of a verified checklist for Karakalpakstan.

CONCLUSION

The reviewed evidence confirms that Coleoptera in Karakalpakstan have high scientific and applied value. Published sources report 104 Carabidae species and subspecies in northwestern Uzbekistan, 79 Tenebrionidae species in western Uzbekistan, and 27 Meloidae species in the Southern Aral Sea region. These records show that desert, agroecosystem, shelterbelt and protected-area habitats all contribute to regional beetle diversity. The Kyzylkum desert landscape and agroecosystems are especially important for Carabidae richness, while Ustyurt and Lower Amu Darya habitats provide distinct conservation and comparison value. From an agricultural perspective, the most important conclusion is that Coleoptera should not be managed as a single pest category. Carabidae can serve as indicators and natural enemies; Meloidae may contribute to locust regulation; Tenebrionidae represent arid-land biodiversity; and Cerambycidae include serious pests of woody plants and shelterbelts. Sustainable pest management in Karakalpakstan should therefore combine biodiversity monitoring with targeted control of harmful species. Future work should develop a standardized regional checklist, digitize specimen records, link beetle records to soil salinity and vegetation data, and conduct repeated field surveys across the Ustyurt Plateau, Kyzylkum, Aralkum, Lower Amu Darya reserve and agroecosystems.

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