International Journal of Life Science Research Archive

ISSN: 0799-6640 (Online)

Journal homepage: https://sciresjournals.com/ijlsra/

(Research Article)

Birds as potential bioindicators for terrestrial ecosystems

Karen Aghababyan *

BirdLinks Armenia NGO, 87b Dimitrov, apt 14, Yerevan 0020 Armenia. Scientific Center of Zoology and Hydroecology, 7 P. Sevak, Yerevan 0014 Armenia.

International Journal of Life Science Research Archive, 2024, 06(01), 001–022

Publication history: Received on 22 November 2023; revised on 14 January 2024; accepted on 16 January 2024

Article DOI: https://doi.org/10.53771/ijlsra.2024.6.1.0112

Abstract

Considering the lack of ecosystems' monitoring in Armenia and the urgent necessity of setting up such a system for decision making in nature conservation and natural resource management, the current paper aims at identification of indicator bird species for the key types of ecosystems in the country and crosscutting influence of climate change. In the forests, the study identified the bird species composition, total number of all birds, and 11 species as indicators of degradation, fragmentation, and aridization. In grasslands, the total number of all birds and seven species indicate degradation of the mountain steppes and meadows due to overgrazing and uncontrolled mowing. In arid lands, the change of bird species composition and total number of all birds indicate degradation of semi-deserts, scrublands, and juniper woodlands due to their transformation into orchards, while six species indicate degradation of these habitats due to overgrazing. In rivers and streams, four species indicate fragmentation of the rivers. In wetlands, at least seven species indicate drainage of the wetlands, and at least one indicates wetlands' pollution. Also, the study identified seven species, which indicate the influence of climate change on birds' distribution at the Eurasian scale. There is still a need for additional study of the indicators of wetlands and lakes, and influence of climate change. A need for improvement of the policy and institutional framework is important as well.

Keywords: Ecosystems; Climate Change; Habitat Degradation; Biodiversity; Monitoring.

1. Introduction

Armenia is a landlocked mountainous country with an elevation range of between 375 and 4090 meters above sea level (a.s.l.), a rigorous terrain, contrasting climatic conditions and a wide variety of habitats, such as semi-deserts, scrublands, juniper woodlands, deciduous forests, mountain steppes and meadows, alpine carpets, various wetlands, canyons, rocks, and screes, which host huge diversity of plants, animals, and fungi.

After breaking up of Soviet Union in 1991, Armenia went into energy and economy crisis. Such a situation caused a decade of over-exploitation of natural resources, supported by lack of regulation and control. Later, in the period from 2000 to 2010 the economy of the country started recovering in three major directions: metal mining, agriculture, and tourism, and from the 2010s it was supplemented also by IT sphere [1]. However, the environmental regulatory framework was underdeveloped and was not supporting those sectors appropriately, which could potentially create various threats to the natural habitats and wildlife.

The industrial activities result in a number of threats to natural ecosystems and biological diversity, with the most significant impacts falling within four main categories: biological resource use, pollution, agriculture and aquaculture, energy production and mining [2].

* Corresponding author: Karen Aghababyan

The mentioned diversity of habitats, as well as geographical position of Armenia at the junction of the European and Iran-Anatolian zoogeographical provinces, results in a relatively rich biological diversity in general and the fauna of the breeding birds in particular. Among 374 bird species [3], which have been recorded in Armenia, 242 are breeding in the country. Among birds, there are several generalist species, which can adapt to many different conditions, however, most of the species are specialized to the specific ecosystems, as such specialization allows them to avoid interspecific competition. Such specialists are usually very sensitive towards environmental changes and response by increase or decrease of their number or breeding productivity. Birds, being highly mobile, usually rapidly react to environmental changes. Beside sensitivity, there are some other features, which allow efficient use of birds as bioindicators. For example, most of the birds are easily detectable and identifiable, which means that it is easy to count them. Many bird species are widespread across countries and continents, which makes their robust use possible, opening opportunities for tracking such global transformations like climate change. Eventually, birds are charismatic objects of wildlife tourism, which makes it possible to involve a wide range of qualified volunteers in the bird surveys, thus decreasing the monitoring costs.

It is therefore natural that birds have been used as bioindicators of ecosystems [4 – 7], climate change [8, 9], and state of biodiversity [10, 11] in many countries. Considering the birds' potential to be used as bioindicators from one side and the obvious gap in monitoring of the state of ecosystems and biodiversity in the country from another, the current paper aims at identification of the bird species and communities, which can serve as indicators of the state of ecosystems and influence of the climate change in Armenia.

2. Methods

2.1. Study area

As it was mentioned, Armenia has large elevation span (Figure 1) and wide range of habitats.

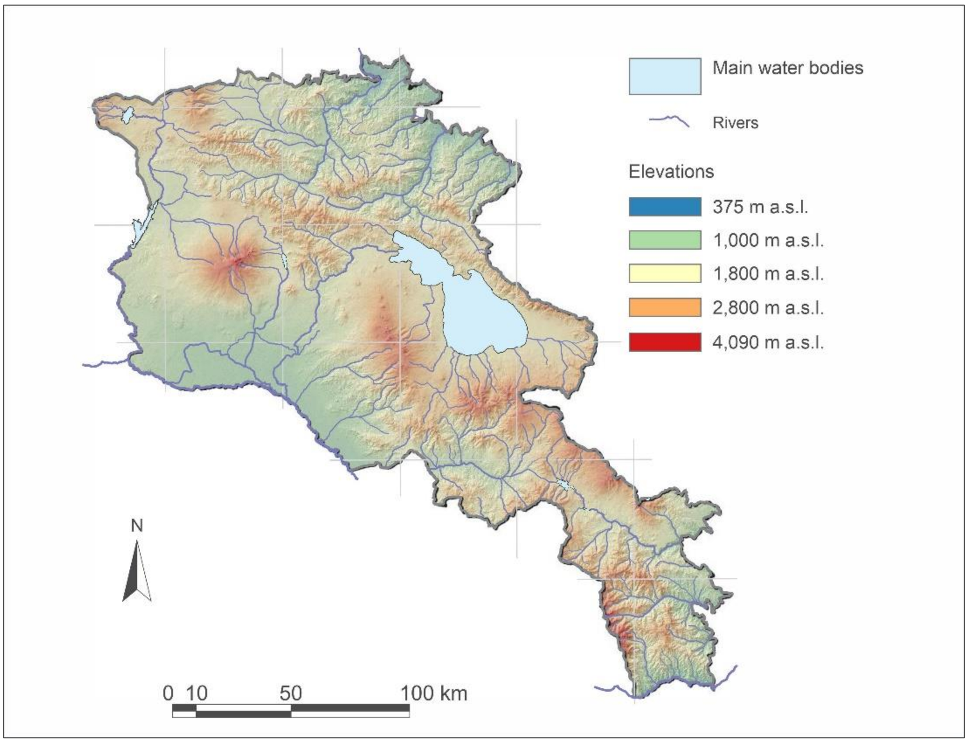

Figure 1 Terrain of Armenia

Armenian grasslands, historically, covered 83.3% of the country, however more recently they have been managed rather intensively [12]. About half of the grasslands have been transformed into arable land for the cultivation of different crops; the other half is used for ubiquitous and often poorly controlled grazing of cattle, sheep, and goats [12]. These activities are leading to a large-scale change in the vegetation, change of animal communities, and often to erosion.

Forests in Armenia occupy about 11.2% of the country. Almost 40% of forests are classified as industrial, and therefore are subject to regular logging [13]. Since the logging practice was developed mostly during the Soviet period, when the dominating concept was timber production, the current exploitation of the forests leads to thinning of forests, reduced shaded areas, fragmentation of forest areas, and aridization.

In Armenia there are several types of water bodies, according to IUCN habitat classification scheme [14], which cover around 4.7% of the area of the country [15]. There are 18 lakes and 16 water reservoirs in the country, including the second largest high mountain Lake Sevan, 41 rivers and 10 canals [16], as well as 3,000 ha of grassy marshes, also called peatlands [15] and 2,000 ha of brackish marshes (own unpublished data). The coastal areas of the lakes are mainly covered by tall grasses of *Phragmites* and *Typha*. The brackish marshes are located mainly in the lowland of Ararat Plain and are mainly covered by *Phragmites*, while the shore is covered by *Salsola* bushes. The grassy marshes are covered by *Phragmites*, *Typha*, and *Carex*. The banks of the rivers are covered by *Phragmites* and various bushes, among which the *Rubus* and *Hippophae* spp. dominate. Marshes in Armenia have been subject to draining (due to traditional underestimation of their importance) for peat production, for control of mosquitos, and for horticulture. Recent aquaculture developments increased wetland pollution [17] by organic matter, residuals of chemical disinfectants, and antibiotics. Another recent development is related to the construction of numerous small Hydro Power Plants (HPPs) on the mountain rivers, which results in river fragmentation.

Open-pit mining of minerals and metals causes habitat destruction, while the processing of the ore often results in land and water pollution. Pollution is also caused by agriculture and affects the habitats and their wildlife mainly through three groups of substances: persistent pesticides, which are widely used for pest control in agriculture and forestry; heavy metals, which enter the food chain due to poor waste management, mining activity, and the use of lead shot in hunting; organic substances, which pollute freshwater habitats due to improper sewage cleaning and disposal, overuse of chemical fertilizers, and improper management of municipal waste [18].

Hunting also presents problems through the unsustainable management of game species and illegal hunting or poaching [18].

Another economic activity continuously developing in the country is tourism [19]. Most of the tourism is related to historic-cultural and skiing activities; however recent developments are aimed at discovering new opportunities. While mostly, tourism development results in the expansion of infrastructure and the associated reduction of natural habitats, it also has a positive effect in terms of ecotourism (birdwatching, mammal-watching, flower-watching, etc.).

2.2. Data collection

The data used for the analyses have been collected in Armenia, covering the period from 1912 to 2019. Most of the data collected in the period between 1912 till 1995 are rather descriptive than quantitative and have been collated in the most comprehensive for that time Handbook of the Birds of Armenia [20]. Starting from 1996, a piloting of the bird quantitative surveys was started in the south-eastern regions of Armenia [21], which was later developed into National Bird Monitoring scheme, systematically conducted since 2003. To secure uniform coverage of the country, the standard European Monitoring Grid with a 10x10-km mesh was applied to Armenia, dividing the territory of the republic into 374 squares. The counted squares were of two kinds: “systematic” ones that, once counting started on them, were systematically counted every subsequent year, and “opportunistic” ones, where counts were carried out when the opportunity arose. In total, in the period of 2003-2019 325 squares were visited at least once during that period, including 147 squares with systematic data collection (Figure 2). The remaining 49 squares were not visited, due to their geographical pattern. Four of those squares are located at the water area of Lake Sevan, and the other 45 squares are in the military sensitive border areas with a restricted access, covering Armenian land area equal to 161.63 km2 (0.54% of the total area of Armenia).

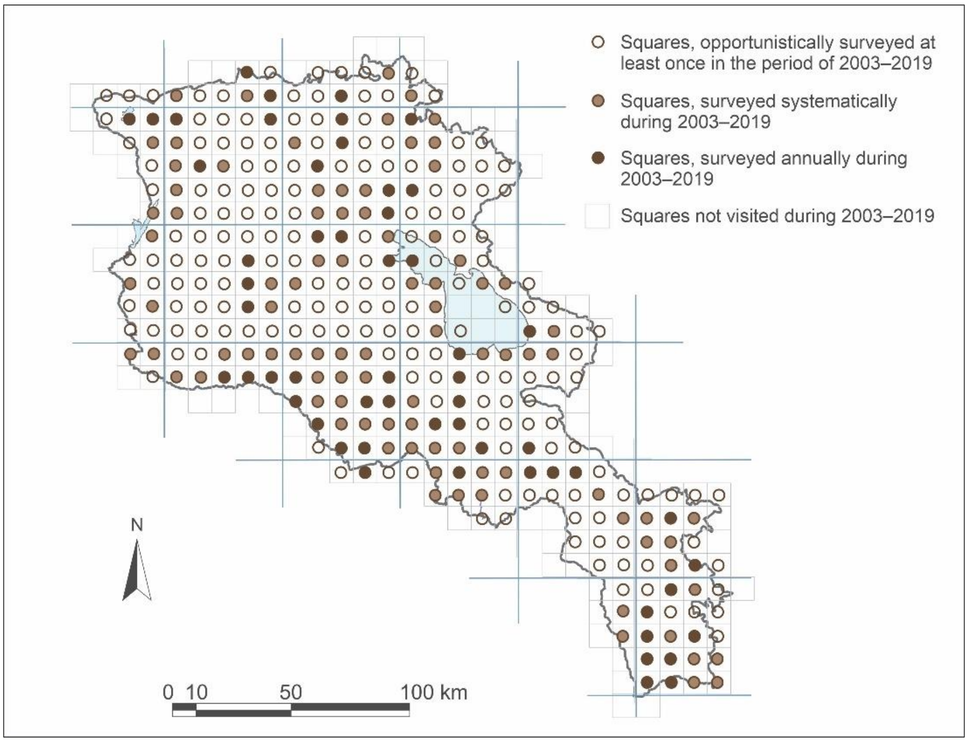

Figure 2 Map of the National Bird Monitoring

2.3. Data analysis

All the data on birds of Armenia, collected since 1996 is currently stored in the database of National Bird Monitoring, owned by BirdLinks Armenia NGO. Analysis of the collected quantitative data is based on determination of possible correlations between the characteristics of bird fauna as a response variable and the characteristics of habitats as an explanatory variable. As the response variables we have selected and tested the total number of bird species, total number of observed bird individuals, and numbers of certain species. The habitats for testing included forest, grassland, arid land, and wetland ecosystems. As the explanatory variables we selected various categories of degradation of these habitats, which were categorized by numbers from 1 to 6. For determination of the possible correlations between the variables, the linear regression model was applied. For description of the models the R^2, *df*, *F* and *P* of *F* have been used. The correlations were considered significant at $P < 0.05$ level [22].

The study of forest birds was implemented from the North-eastern to South-eastern regions of the country and was aimed at identification of characteristics of bird fauna, which can show a level of forest degradation. The forests were categorized from 1 to 6, where 1 was considered as completely degraded forest and 6 was considered as a pristine forest [23].

The study of grassland birds was implemented in several types of grasslands. More arid ones are located at the lower elevation, at steeper areas, and are dominated by tragacanth astragals (*Astracantha* sp.) or the thorny sainfoin (*Onobrychis cornuta*), while others are located at the flatter areas of higher elevation and are dominated by grasses (Poaceae) and other herbal vegetation. The areas above the timberline and some flatter areas above 1,500 m a.s.l. are occupied by wet meadows, while the areas above the 2,500 m a.s.l. are covered by alpine carpets, alternated with rocky outcrops and screes. The study initially included all four types of grasslands and was aimed at identification of characteristics of bird fauna, which can show a level of grassland degradation. For this purpose, we have designated numerical values to the various stages of grassland degradation to be able to use those as the dependent variables. The grasslands were categorized from 1 to 6, where 6 means an area with restricted livestock access (typical for alpine carpets); 5 means the area, where grazing just started changing the composition of the plants, so the proportion of poisonous plants, like chamomile, or thorny species like thistle, is increasing; 4 means the area, where the proportion of poisonous or thorny plants is about or above 50%; 3 means the area where the overgrazing begins causing development of permanent terrasses at paths of livestock moving; 2 means the area, where terrasses make a network that covers at least 20% of the slopes; 1 means the areas, where the cases of erosion have been observed.

Then we analyzed the grassland categories vs. bird data using linear regression model, like in previous case [22]. After the first round, we excluded alpine carpets from the analyses, because they made a certain confusion. Being areas with low level of livestock grazing, they belong to category 6, but they have very specialized bird fauna with natively low number of the species and bird individuals, which breaks the possible correlation, when high category "6" has low number of species, e.g., 20 species (comparable to categories "1-3"), or low number of bird individuals, e.g., 65 (comparable to categories "1-2"). Therefore, for subsequent analyses the alpine carpets have been excluded.

In addition, the population trend of Corn Crake (*Crex crex*) was taken from the published study [24] and linked to the mowing in the meadows. Calculation of population trend in the mentioned study was implemented using TRIM 3.0 software [25, 26]. A Collated Index of abundance is being calculated, then the deviations from the Index are computed and analyzed over time using log-linear Poisson regression and graphed as a linear function to reveal the population changes in the given period. The TRIM output identifies six possible population trends: strong increase, moderate increase, stable, moderate decline, steep decline, or uncertain [25, 26].

The study of birds of arid lands was covering all types in the Central and Southern regions of Armenia: wormwood semidesert, dominated by several wormwood (*Artemisia* sp.), saltwort semi-desert, dominated by variety of saltwort species (*Salsola* sp.), scrubby semi-desert or shiblyak, dominated by Jerusalem thorn (*Paliurus spina-christi*), and juniper woodland dominated by Juniper (*Juniperus polycarpos*). Unlike the previous cases with the forests and grasslands, the transformation of the arid lands under influence of horticulture is less gradual, as usually the arid lands become destroyed, and the orchards or vineyards become established instead of them very fast. In addition to the complete destruction, the surrounding areas are under risk of pollution by pesticides. Also, nomadic grazing takes place in the springtime in arid lands, causing overgrazing.

For determination of the links between bird fauna and exploitation of the arid lands, we first compared diversity of birds in the areas transformed by horticulture and in non-transformed areas using Paired Sample T-Test [22]. Then we analyzed the abundance of several species versus intensity of nomadic grazing. Fort the purpose, we have selected total number of bird species, total number of bird individuals, as well as some typical species of arid lands and analyzed their abundance (dependent variable) vs. the livestock number that is regularly grazing in the area (independent variable) using linear regression model. In addition, the population trend of Woodchat Shrike (*Lanius senator*) was taken from the published study [27], linked to the use of pesticides in surrounding areas. Calculation of population trend was also implemented via TRIM 3.0 software using the same guidelines [25, 26].

The study of water ecosystems covered all the major types: the study of birds of the lakes was mainly conducted at the Lake Sevan, the study of birds of grassy marshes was implemented in Lori, Shirak, and Sisian plateaus, the study of birds of brackish marshes was conducted in Ararat Plain, and eventually the study of birds of riparian zone was made on the several major rivers of the country.

The main human activities, which result in transformation of the lakes and marshes are related to water use. Thus, regular acquisition of the water from Lake Sevan for irrigation needs causes instability of water level, which in turn eliminates the macrophytes (the emergent vegetation of the shoreline zone). Water acquisition from the mountain streams causes drainage of grassy marshes, while development of special drainage system in Ararat Plain resulted in critical shrinking of the brackish marshes. Eventually, development of the small HPPs on the mountain rivers resulted in fragmentation of the rivers.

For the study of the influence of the small HPPs on riparian birds the density of the small HPPs per one kilometer of the rivers was taken as independent variable and the characteristics of birds (total number of species, total number of bird individuals, and numbers of certain species) as dependent variables. The linear regression models tested the relations between the variables.

The main issue of studying the brackish and grassy marshes is the lack of a gradient of their degradation. These areas have been mainly exposed to drainage, either intentional, like the brackish marshes of Ararat Plain [15] or due to water acquisition [15], like most of the grassy marshes in Shirak, Lori, and Aparan plateaus. Therefore, for several species the study has rather descriptive nature than quantitative and describes presence and absence of the species in wetlands. From another side we used population trends of the well-studied Northern Lapwing (*Vanellus vanellus*) [28] linked to the decline of the grassy marshes.

The link between brackish marshes and the bird fauna was demonstrated by the recent study of the wetland restoration in Khor Virap State Sanctuary [29], where for comparison of the bird fauna of the wetlands before and after the restoration, the chi-square test was used [22].

For indication of wetlands pollution, we used rather detailed studies of White Stork (*Ciconia ciconia*) [30 – 32].

For study of the influence of climate change, only qualitative data was possible to collect, which have been interpreted.

3. Results and discussion

3.1. Birds as bioindicators of forest ecosystems

The linear regression analysis of the forest categories vs. total number of bird species recorded at the sampling area (Figure 3a) and the total number of bird individuals recorded there (Figure 3b) have shown a strong correlation between forest category and the number of bird species (R^2 = 0.852, *df* = 18, *F* = 103.850, *P* < 0.001), as well as the total number of bird individuals (R^2 = 0.727, *df* = 18, *F* = 48.037, *P* < 0.001).

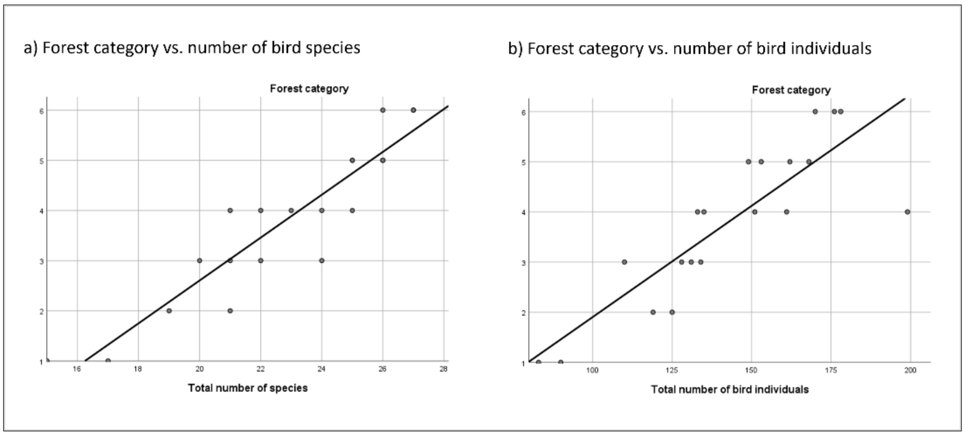

Figure 3 Number of bird species vs. forest category (a) and Quantity of bird species vs. forest category (b). Both figures show a strong positive correlation between the variables

The correlation is biologically justified, which means that overall quality of forest habitat supports more inherent bird species and higher number of individual birds.

Then we moved to identification of forest bird species, which are more sensitive towards forest degradation than the others, analyzing abundance of several species towards the same forest categories. Some of them, listed below, show strong positive correlation with the forest categories (the higher the forest category – the more abundant is the species).

There are three species of tits, which inhabit different types of forest and are a typical cavity-nesting birds. Those are Great Tit (*Parus major*), Blue Tit (*Cyanister caeruleus*), and Coal Tit (*Periparus ater*).

The linear regression applied to these species shows high level of correlation between Coal Tit (Figure 4a) and the forest categories (R^2 = 0.850, *df* = 18; *F* = 101.857, *P* < 0.001) and insignificant correlation for the Blue and Great Tits.

It appears that Coal Tit is much more specialized and therefore is more sensitive towards forest conditions, unlike the other two tit species. In addition, the Coal Tit is rather easy identifiable by voice and appearance, and so, is a good object for monitoring.

Another species is Eurasian Nuthatch (*Sitta europaea*), the only representative of Nuthatches in the forests. It is also cavity nester, that builds on the natural tree-holes with mud. The linear regression applied to this species (Figure 4b) also shows strong correlation (R^2 = 0.744, *df* = 18, *F* = 52.321, *P* < 0,001).

Next bunch represents flycatchers, presented by three species: Spotted Flycatcher (*Muscicapa striata*), Red-breasted Flycatcher (*Ficedula parva*), and Semi-collared Flycatcher (*Ficedula semitorquata*). All these species are specialized insectivore birds which catch insects on flight. Again, all these species are cavity-nesters. The linear regression applied to these species (Figure 5) shows the following: both Red-breasted and Semi-collared Flycatchers demonstrated strong correlation with the forest categories (R^2 = 0.712, *df* = 18, *F* = 44.393, *P* < 0.001 and R^2 = 0.757, *df* = 18, *F* = 55.964, *P* < 0.001 respectively), while the Spotted Flycatcher doesn't show significant correlation with the forest categories. The Red-breasted and Semi-collared Flycatchers are much more specialized towards the forest conditions than the Spotted one. Besides that, the Spotted Flycatcher is much more secretive and has lower determination rate, so it is hard to conclude whether there is a strong link of the species with forest conditions of not. But certainly, we can say that the Spotted Flycatcher can hardly be used as bioindicator, as its monitoring promises to be quite complicated.

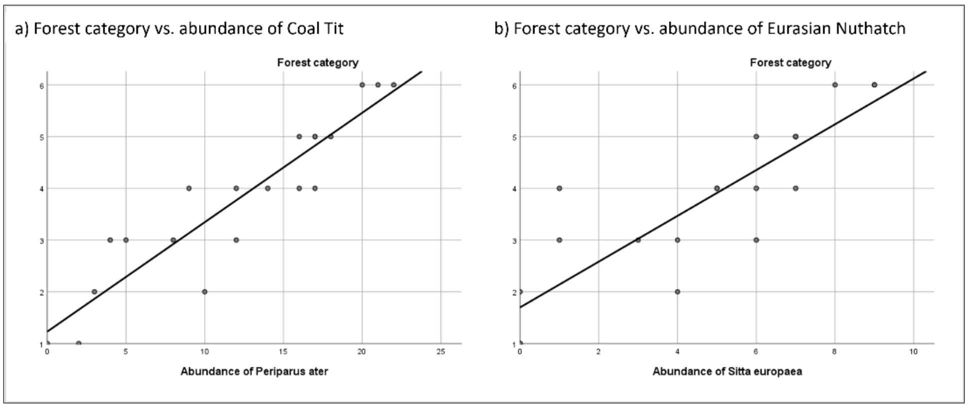

Figure 4 Abundance of Coal Tit (*Periparus ater*) vs. forest category (a) and Abundance of Eurasian Nuthatch (*Sitta europaea*) vs. forest category (b). Both figures show a strong positive correlation between the variables.

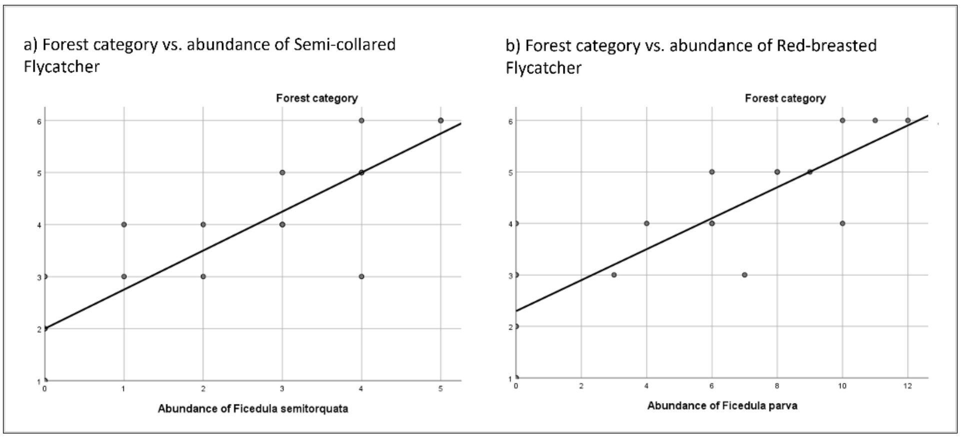

Figure 5 Abundance of Semi-collared Flycatcher (*Ficedula semitorquata*) vs. forest category (a) and Abundance of Red-breasted Flycatcher (*Ficedula parva*) vs. forest category (b). Both figures show a strong positive correlation between the variables.

Another species group represents thrushes. In forest of Armenia there are three such species: Blackbird (*Turdus merula*), Mistle Thrush (*Turdus viscivorus*), and Song Thrush (*Turdus phylomelos*). Application of linear regression to these species identifies strong correlation of Song Thrush abundance (Figure 6a) with the forest categories (R^2 = 0.764, *df* = 18, *F* = 58.332, *P* < 0.001), while the other two demonstrated insignificant relation to the forests' conditions. The Song Thrush appears to be a more sensitive species that loves canopy, shade, and tall trees, while the other two species easily occupy the fragmented woodlands and woodland edges. In addition, the Song Thrushes are easily detectable and identifiable by the vocalization.

Eventually, the last group of species that provides us with an indicator is the leaf warblers. In forests of Armenia, they are represented by three species: Green Warbler (*Phylloscopus nitidus*), Chiffchaff (*Phylloscopus collybita*), and Mountain Chiffchaff (*Phylloscopus sindianus*). The linear regression applied to these species determines a strong correlation of Green Warbler (Figure 6b) with the forest conditions (R^2 = 0.750, *df* = 18, *F* = 54.027, *P* < 0.001), while for the other two species, the link was insignificant. It appears that Green Warbler is more specialized towards the forest, than the other two leaf warblers, especially the Mountain Chiffchaff, which often occupies high mountain gorges with just several trees present.

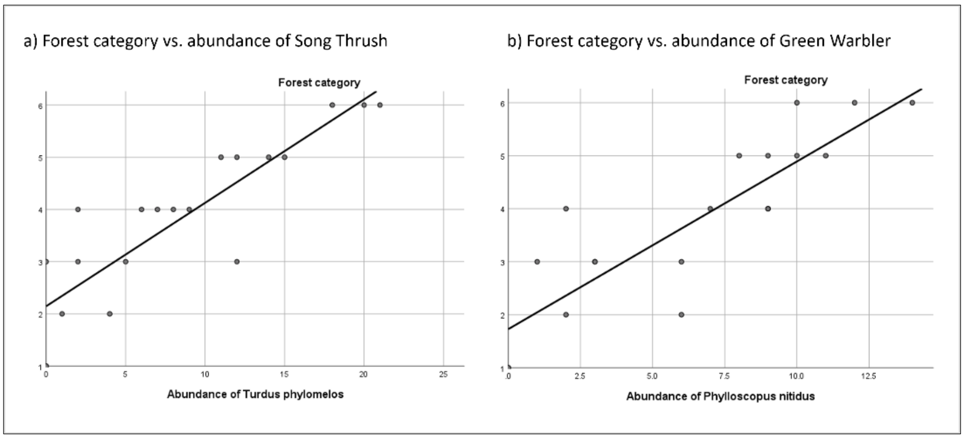

Figure 6 Abundance of Song Thrush (*Turdus phylomelos*) vs. forest category (a) and Abundance of Green Warbler (*Phylloscopus nitidus*) vs. forest category (b). Both figures show a strong positive correlation between the variables.

In the meantime, there are other species, which occupy forest clearings and edges. Among them, we can identify Tree Pipit (*Anthus trivialis*), Red-backed Shrike (*Lanius collurio*), and Common Cuckoo (*Cucculus canorus*), which are first occupy the forest edges and new clearings (e.g., after cutting). In addition, there are some species of arid habitats, which penetrate the forests and indicate the beginning of aridization and desertification of this ecosystem. The most typical ones are Lesser Whitethroat (*Curruca curruca*) and Rock Bunting (*Emberiza cia*).

Concluding the described above, we can state that the study provides us with two tools for indication of the state of the forest. First includes number of bird species and number of bird individuals, while the second includes abundance (or sometimes even presence) of 11 species, which indicate the state of the forest, level of its fragmentation, and possible processes of its aridization.

For the first tool, the surveys should be conducted by counters with very good identification skills of all the forest birds, while for the second, the well trained rangers, students, and other volunteers, who can identify about 30 species by voice and appearance, can be used.

3.2. Birds as bioindicators of grasslands

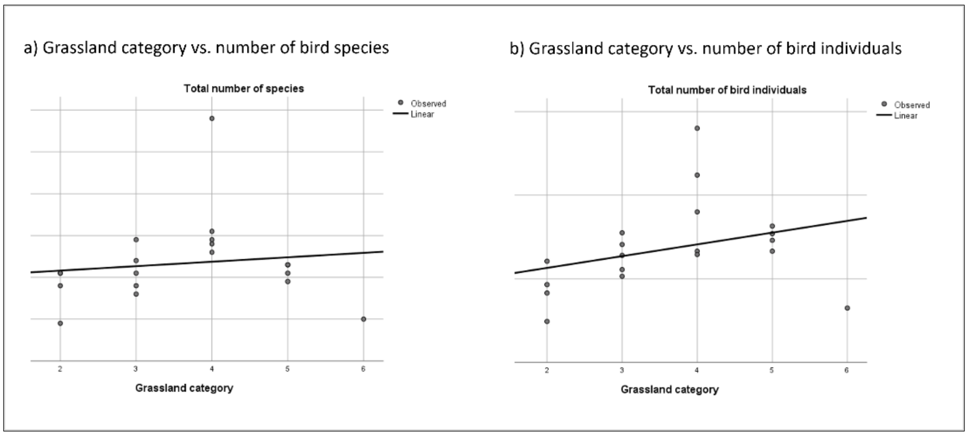

Figure 7 Number of bird species vs. grassland category (a) and Quantity of bird species vs. grassland category (b). Figure *a* doesn't show significant correlation but figure *b* shows strong positive correlation between the variables.

The first set of analyses is aimed at identification of possible correlations between number of bird species and number of bird individuals vs. grassland category (Figure 7).

Interestingly, the analyses didn't reveal significant correlation between grassland category and the number of bird species (R^2 = 0.107, df = 17, F = 2.032, P = 0.172), while the correlation between the total number of recorded bird individuals and grassland category is statistically significant (R^2 = 0.327, df = 17, F = 8.275, P = 0.010).

The correlation is biologically justified, as the overall quality of grassland habitat supports a higher number of individual birds. The lack of correlation in the first case can be justified by non-uniform distribution of several bird species throughout grasslands. Thus, for example, a very sensitive species Grasshopper Warbler (*Locustella naevia*) occurs only in northern and central regions of the country and another sensitive species Crimson-winged Finch (*Rhodopechys sanguineus*) has mosaic distribution and can be absent in the grassland of high category.

As in the previous case we move further to identify the bird species, which are more sensitive towards grassland degradation. Some of the species show strong positive correlation with the grassland categories (the higher the grassland category – the more abundant is the species).

Among the family of Pheasants and Grouses, there are three species, which inhabit grasslands. Those are Common Quail (*Coturnix coturnix*), Grey Partridge (*Perdix perdix*), and Caucasian Grouse (*Lyrurus mlokosiewiczi*).

The linear regression applied to these species shows a high level of correlation between Common Quail (Figure 8a) and the grassland categories (R^2 = 0.493, df = 16; F = 15.550, P = 0.001) and insignificant correlation for the other two species.

It appears that the Common Quail is sensitive enough to be used as indicator, but also it is an easy species for detection by voice, while the other two species are more secretive and do not have calls. Thus, their detection is hard to be standardized into a guideline. Most probably the observed lack of correlations for the Grey Partridge and Caucasian Grouse is a result of lack of uniform data, due to their secretive behavior.

Next set of species includes larks, which are basically represented by four species, the Skylark (*Alauda arvensis*), Wood Lark (*Lullula arborea*), Calandra Lark (*Melanocorypha calandra*), and Horned Lark (*Eremophila alpestris*).

The linear regression applied to these species shows high level of correlation between Skylark (Figure 8b) and the grassland categories (R^2 = 0.618, df = 17; F = 27.499, P < 0.001) and insignificant correlation for the other three species.

It appears that Skylark is sensitive enough towards grazing to be used as an indicator, especially due to its easy detection and identification by the song. For the other species the justification of lack of correlation varies. Thus, Wood Lark is adaptable enough and easily occupies degraded pastures, where the thorny tragacanth bushes start occupation of the empty spots. The Calandra Lark has very patchy distribution, which results in lack of data. The Horned Lark is more typical to alpine carpets, and just occasionally occupies some meadows, which results in insufficient data.

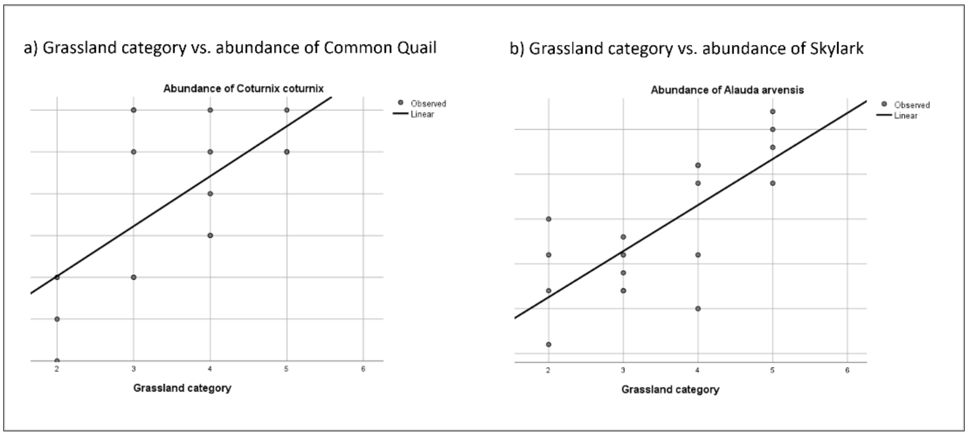

Figure 8 Abundance of Common Quail (*Coturnix coturnix*) vs. grassland category (a) and Abundance of Skylark (*Alauda arvensis*) vs. grassland category (b). Both figures show a strong positive correlation between the variables.

Other several species belong to Old-world Flycatchers, representing chats, redstarts, wheatears, and allies. Among those, the chats are the most suitable ones for analysis, as the rest of the species are linked to the rocky outcrops, and do not depend that much on the grasslands' conditions. The three species of chats include Whinchat, European Stonechat (*Saxicola rubicola*), and Siberian Stonechat (*Saxicola maurus*).

The linear regression applied to these species shows high level of correlation between Whinchat (Figure 9a) and the grassland categories (R^2 = 0.712, *df* = 17; *F* = 41.955, *P* < 0.001) and insignificant correlation for the other chats.

It appears that Whinchat is very specialized to grasslands and therefore is more sensitive towards those conditions. This species is easily detectable and identifiable, which makes it a good indicator of grasslands. The European Stonechat typically inhabits grassy steppes and probably could be linked to those conditions, however, its patchy distribution causes lack of data for sufficient analysis. The third species, Siberian Stonechat, appears to prefer drier habitats, and is probably being more adaptable, moves at higher elevation following the grasslands' degradation and aridization.

Another representative of the Old-world Flycatchers in grasslands is the Bluethroat (*Luscinia svecica*). The linear regression (Figure 9b) applied to the species also shows a high level of correlation between Bluethroat and the grassland categories (R^2 = 0.341, *df* = 17; *F* = 8.778, *P* = 0.009). The species appears to be quite specialized towards grasslands and rather sensitive towards their conditions, however its detection is not always easy, and thus its use as an indicator is somewhat questionable.

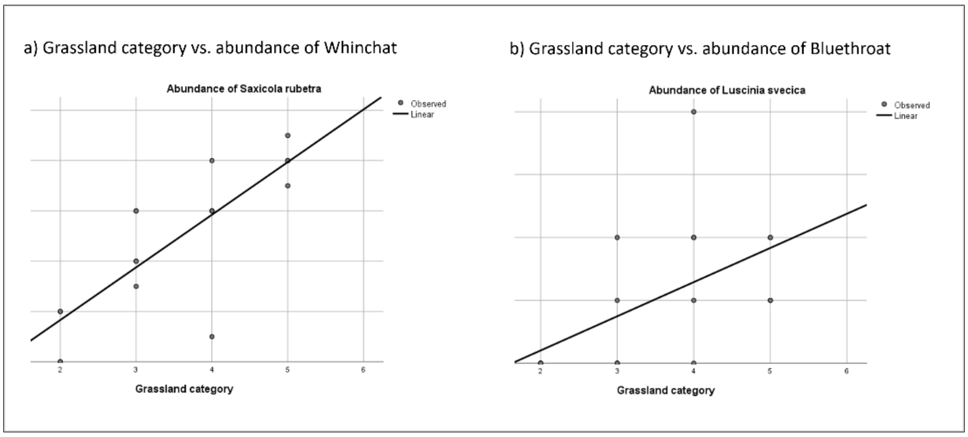

Figure 9 Abundance of Whinchat (*Saxicola rubetra*) vs. forest category (a) and Abundance of Bluethroat (*Luscinia svecica*) vs. grassland category (b). Both figures show a strong positive correlation between the variables.

The last set includes finches and buntings, represented by such species as Linnet (*Linaria cannabina*), Twite (*Linaria flavirostris*), Common Rosefinch (*Carpodacus erythrinus*), Rock Bunting, Ortolan Bunting, Black-headed Bunting (*Emberiza melanocephala*), and Corn Bunting (*Emberiza calandra*).

The linear regression applied to these species shows high level of correlation between Common Rosefinch and Ortolan Bunting (Figure 10a, b) with the grassland categories (R^2 = 0.701, *df* = 17; *F* = 39.871, *P* < 0.001 and R^2 = 0.535, *df* = 17; *F* = 19.567, *P* < 0.001 respectively) and insignificant correlation for the rest of the species.

It appears that Common Rosefinch and Ortolan Bunting are rather specialized towards grasslands and are more sensitive towards changes of the conditions than the other finches and buntings. Moreover, they are easy species for detection and identification by voice and appearance, which make them a good object for monitoring. Among other species, the Linnet, Rock Bunting, Black-headed Bunting, and Corn Bunting seem to be quite adaptable and easily occupy degraded grasslands following the growing of thorny tragacanth bushes. At the meantime, Twite is an inhabitant of alpine carpets that just occasionally occurs in the wet meadows, and thus cannot be a good representative of the steppes and meadows.

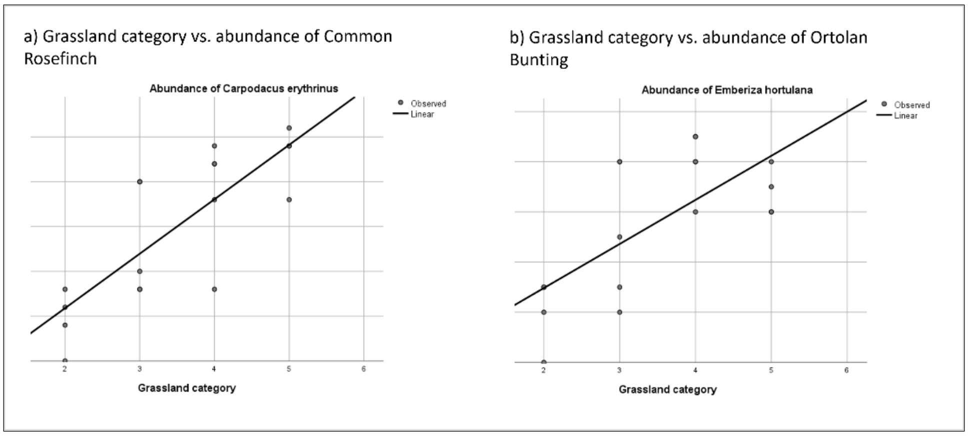

Figure 10 Abundance of Common Rosefinch (*Carpodacus erythrinus*) vs. grassland category (a) and Abundance of Ortolan Bunting (*Emberiza hortulana*) vs. grassland category (b). Both figures show a strong positive correlation between the variables.

Unfortunately, there is not much study on influence of mowing on the birds of Armenia, except the study implemented on the Corn Crake [24] that shows a moderate decline of the species throughout 2003-2019 (Figure 11). This ground-nester, which keeps its brood among the tall grass, suffers from the machinery mowing. The common way of mowing in Armenia, from edge of the area to the center, certainly plays a negative role in brood survival, and therefore also affects the species' population.

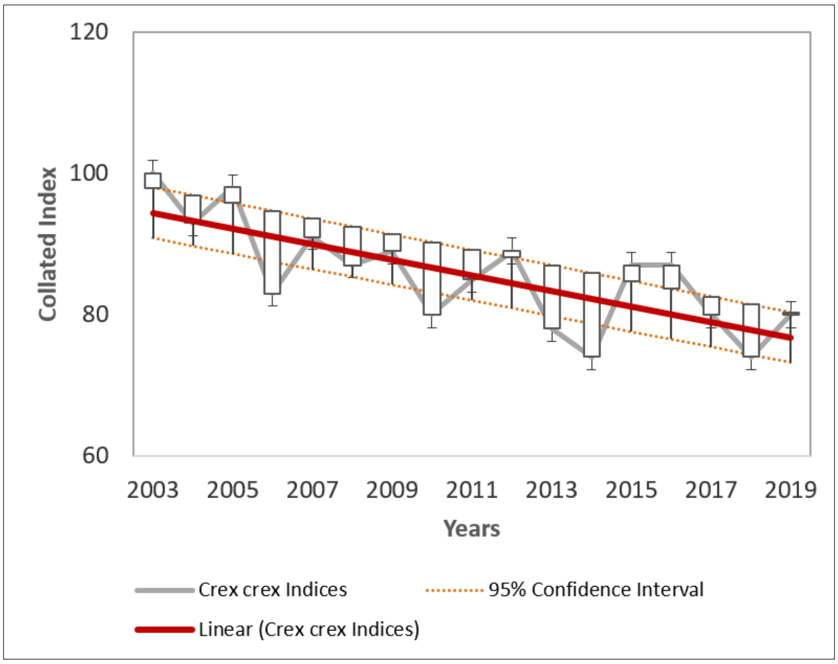

Figure 11 Population trend of Corn Crake (*Crex crex*) in Armenia during 2003-2019 [24]. The figure shows a declining trend of the species in the country.

Concluding the described above, we can state that the selected species can be a definite tool for indication of the state of the grasslands, while the number of bird individuals is rather a supplementary tool, as it is not supported by the number of species, and thus doesn't reflect the true diversity. For the selected tool, the counts can be conducted by well-trained rangers, students, and other volunteers, who can identify about 20 species by voice and appearance.

3.3. Birds as bioindicators of arid lands

Comparison of bird diversity in areas transformed by horticulture and non-transformed areas demonstrated significant difference in terms of the number of species (t = -11.717, df = 15, P < 0.001) and total number of bird individuals (t = -6.018, df = 15, P < 0.001). Such a difference can be justified by the fact that many of the arid species are specialized to seeds and insects of the semi-deserts, scrublands, and juniper woodlands, while the orchards and vineyards replace the native trees and bushes by fruit trees and grapes. At the same time the herbal layer also becomes transformed, as it either exposed to an intensive irrigation, being replaced by the herbal vegetation of the nearby riparian woodlands and scrubs, or just becomes eliminated by use of herbicides.

The analysis of bird characteristics vs. the livestock number shows the following.

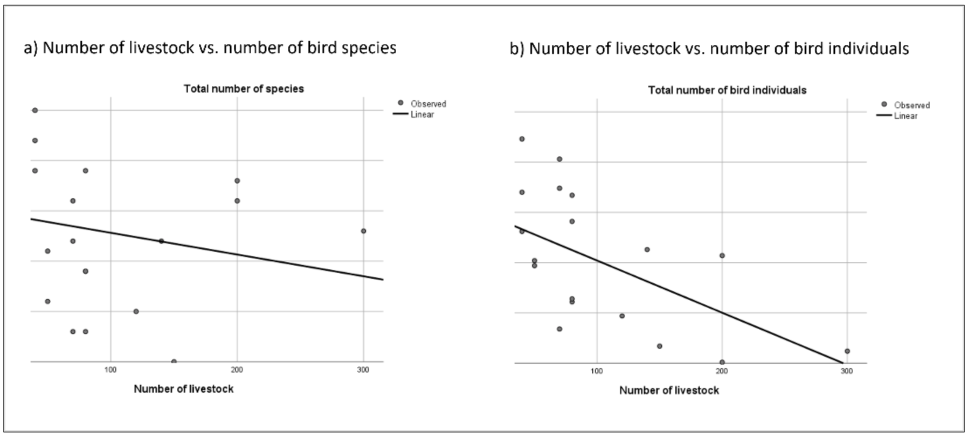

Figure 12 Number of bird species (a) and Quantity of bird vs. number of livestock that regularly grazes the same area. Figure *a* doesn't show significant correlation but figure *b* shows strong positive correlation between the variables.

A significant correlation between number of livestock that regularly grazes the same area, and the number of bird species (Figure 12a) wasn't found (R^2 = 0.047, df = 18, F = 0.886, P = 0.359), but was determined between the total number of recorded bird individuals (Figure 12b) and number of livestock that regularly grazes the same area (R^2 = 0.345, df = 18, F = 9.467, P = 0.007).

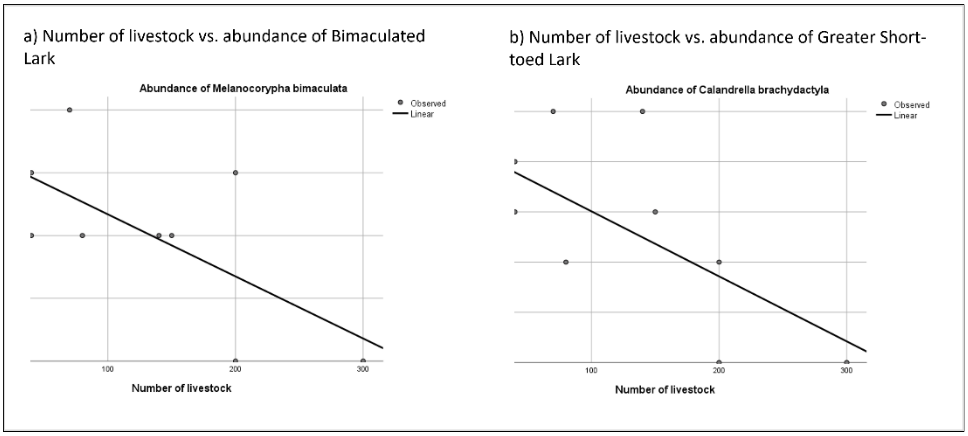

Figure 13 Abundance of (a) Bimaculated Lark (*Melanocorypha bimaculata*) and (b) Greater Short-toed Lark (*Calandrella brachydactyla*) vs. number of livestock that regularly grazes the same area. Both figures show significant negative correlation between the variables.

The correlation is biologically justified, as the less is the number of the grazing livestock, the more biomass of the grasses, legumes, and other important plants stay in the habitat, supporting higher number of insects, and accordingly a higher number of individual birds. The lack of correlation in the first case can be justified by not uniform distribution of several bird species throughout arid lands. Thus, for example, a very sensitive species Sombre Tit (*Poecile lugubris*) occurs only in the southern juniper woodlands, while other sensitive species: Persian Wheatear (*Oenanthe chrysopygia*), Trumpeter Finch (*Bucanetes githagineus*), and Desert Finch (*Rhodospiza obsoleta*) have very patchy distribution and can be absent in most of the observed spots, which results in the insufficient data.

As in the previous case we move further to identify the bird species, which are more sensitive towards intensity of the livestock grazing in the arid lands. Some of the species show strong negative correlation with the livestock number (the more livestock is regularly grazing in the area regularly – the less abundant is the species).

Among the family of Larks, there are five species, which inhabit arid lands. Those are Bimaculated Lark (*Melanocorypha bimaculata*), Greater Short-toed Lark (*Calandrella brachydactyla*), Turkestan Short-toed Lark (*Alaudala heinei*), Crested Lark (*Galerida cristata*), and Wood Lark (*Lullula arborea*).

The linear regression applied to these species shows a high level of correlation between Bimaculated Lark and Greater Short-toed Lark (Figure 13a, b) and the number of livestock (R^2 = 0.480, *df* = 8; *F* = 7.394, *P* = 0.026 and R^2 = 0.437, *df* = 8; *F* = 6.201, *P* = 0.038 respectively) and insignificant correlation for the other three species.

It appears that the Bimaculated Lark and Greater Short-toed Lark are sensitive enough towards grazing to be used as indicators. Among those, the Bimaculated Lark is quite an easy species for detection by voice, while the count of Greater Short-toed Lark requires involvement of counters with advanced identification skills.

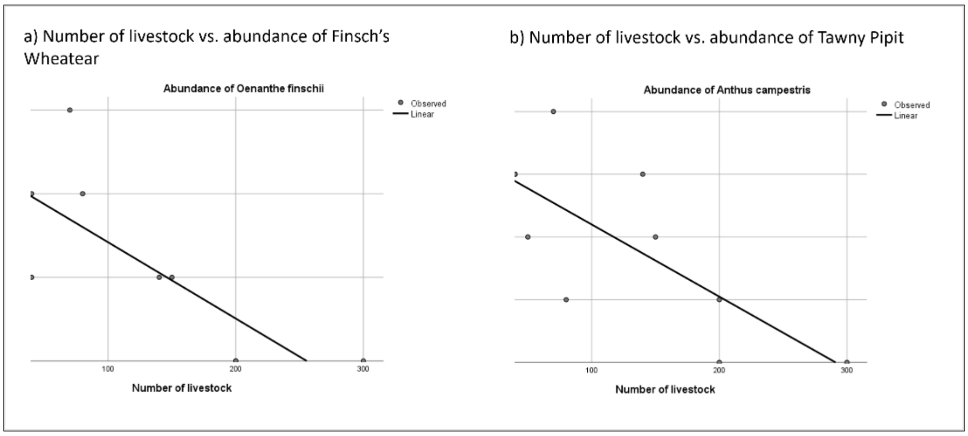

Figure 14 Abundance of (a) Finsch's Wheatear (*Oenanthe finschii*) and Abundance of (b) Tawny Pipit (*Anthus campestris*) vs. number of livestock that regularly grazes the same area. Both figures show significant negative correlation between the variables. Both figures show a significant negative correlation between the variables.

Next set of species includes Old-world Flycatchers, totally represented by ten species and *Silvia* warblers, represented by four species.

The linear regression applied to these species shows a high level of correlation between Finsch's Wheatear (Figure 14a) and the number of livestock (R^2 = 0.635, *df* = 8; *F* = 13.897, *P* = 0.006) and insignificant correlation for the other three species.

It appears that among wheatears, the Finsch's Wheatear (*Oenanthe finschii*) is sensitive towards grazing and can be used as an indicator. The determination of the species is rather easy, as it usually uses the prominent song posts. Its identification can be quite difficult for the beginners though, as it can be confused with the Eastern Bleck-eared Wheatear (*Oenanthe melanoleuca*), and the counters should pass certain training in species identification. Among other species, the Isabelline (*Oenanthe isabellina*) and Eastern Black-eared Wheatear seem to be adaptable enough. The Persian Wheatear is rather sensitive towards habitat transformation [33], however, its restricted distribution doesn't allow a proposition of the species as a widespread indicator. The rest of the species seem to be less dependent on grazing, except the Eastern Orphean Warbler (*Curruca crassirostris*). However, the latest species has uneven abundance across the country, being rather abundant in the south and quite rare in the central regions of the country and it doesn't make Eastern Orphean Warbler a widespread indicator.

The family of the pipits and wagtails is represented by a single species Tawny Pipit (*Anthus campestris*). The linear regression (Figure 14b) applied to this species shows a high level of correlation between abundance of Tawny Pipit and the livestock number (R^2 = 0.575, *df* = 9; *F* = 12.192, *P* = 0.007). The Tawny Pipit seems to be rather sensitive towards grazing and can serve as an indicator. During breeding period, the species is easily detectable and identifiable by song and appearance, which also makes it quite useful.

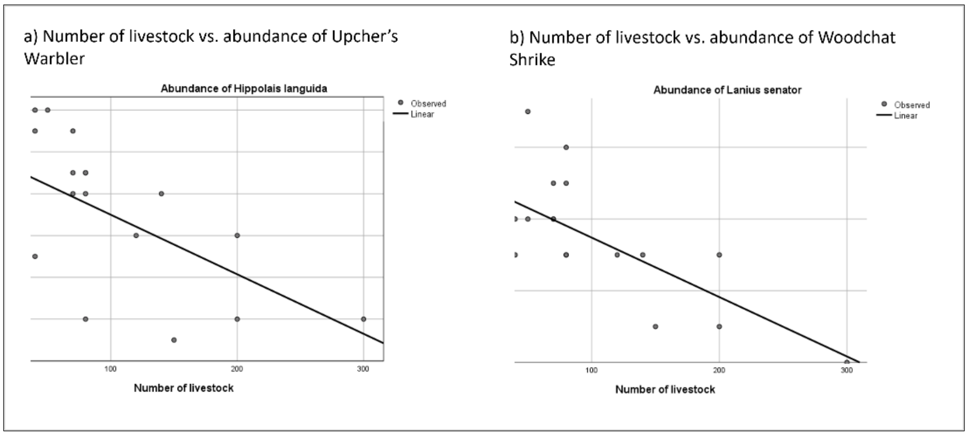

Figure 15 Abundance of (a) Upcher's Warbler (*Hippolais languida*) and Abundance of (b) Woodchat Shrike (*Lanius senator*) vs. number of livestock that regularly grazes the same area. Both figures show significant negative correlation between the variables.

Another family includes reed warblers and allies, which are represented by only two species that inhabit semideserts: Eastern Olivaceous Warbler (*Iduna pallida*) and Upcher's Warbler (*Hippolais languida*). The linear regression applied to these species shows a high level of correlation between the abundance of Upcher's Warbler (Figure 15a) and the number of livestock (R^2 = 0.322, *df* = 16; *F* = 7.585, *P* = 0.014), while the Eastern Olivaceous Warbler doesn't demonstrate any correlation. The Upcher's Warbler appears to be quite specialized towards arid lands and rather sensitive towards grazing, and although its identification by appearance is quite difficult, as it can be confused with the Eastern Olivaceous Warbler, its detection is always easy, especially in the breeding season.

The next family includes shrikes, represented Red-backed Shrike (*Lanius collurio*), Lesser Grey Shrike (*Lanius minor*), and Woodchat Shrike. The linear regression applied to these species shows a high level of negative correlation between Woodchat Shrike (Figure 15b) and the number of livestock (R^2 = 0.476, *df* = 16; *F* = 14.529, *P* = 0.002) and an insignificant correlation for the other two species.

It appears that the Woodchat Shrike is more sensitive towards changes of the conditions of the arid lands than the other two species. Moreover, it is an easy species for detection and identification by appearance, which makes it a good object for monitoring. The other two species appear to be more adaptable towards arid land conditions and grazing intensity.

The last set includes finches and buntings, represented by such species as Linnet (*Linaria cannabina*), Trumpeter Finch, Desert Finch, Rock Bunting, Grey-necked Bunting (*Emberiza buchanani*), Black-headed Bunting, and Corn Bunting.

The linear regression applied to these species identifies insignificant correlation for all of them.

It should be mentioned that some of these species, such as Trumpeter Finch, Desert Finch, and Grey-necked Bunting, are highly specialized, but have a very narrow and patchy distribution. Therefore, the fact of lack of significant correlation is most probably resulted by the lack of data.

Eventually, we have analyzed the population trend of one of the indicator species, the Woodchat Shrike [27] that demonstrates a moderate decline in 2003-2019 ($P < 0.01$), being reduced for 32% during that period. The research demonstrated that the species declined in the lands transformed by horticulture and also in vicinities of orchards and open-pit metal mines.

While the case of the influence of habitat transformation was discussed above, the proximity of Woodchat Shrikes' range to the copper and molybdenum open pit mine still requires further deeper investigations. The pairs which breed next to the orchards can also suffer from the use of persistent pesticides, which can be accumulated through the food chains, and this is another subject of further deep investigations.

Concluding the section above we can state that lack of grading of degradation in arid land during transformation of the habitat into orchards, makes certain difficulties in the selection of indicator species. Nevertheless, it is obvious that the habitat transformation affects the bird community, and that the indicators can be selected for demonstrating the level of influence of grazing on the arid lands. The monitoring of the birds in arid lands can be conducted by well-trained rangers, students, and other volunteers, who can identify about 30 species by voice and appearance.

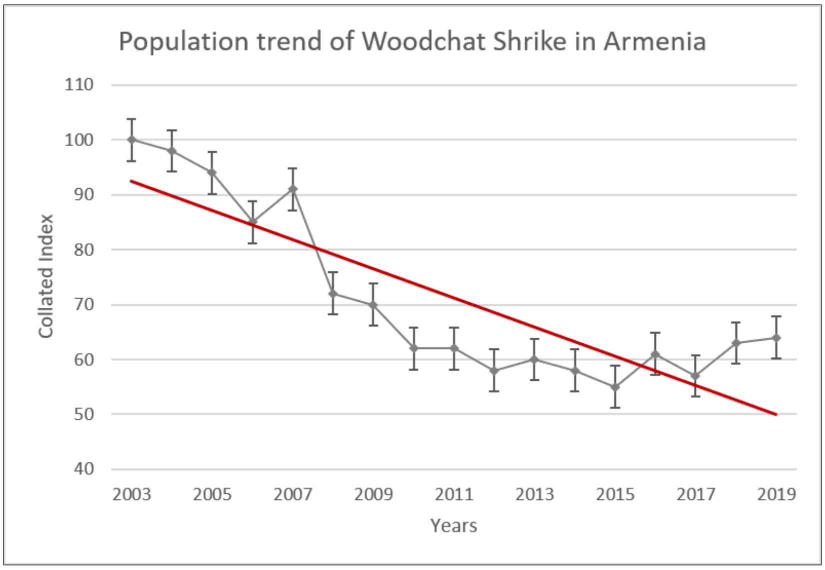

Figure 16 Population trend of Woodchat Shrike (*Lanius senator*) in Armenia in 2003-2019 [27].

3.4. Birds as bioindicators of water bodies: rivers, streams, and wetlands

3.4.1. Rivers and streams

The total number of species and total number of bird individuals didn't show significant correlation with the density of small HPPs (R^2 = 0.001, df = 8; F = 0.007, P = 0.935 and R^2 = 0.043, df = 8; F = 0.363, P = 0.564 respectively), as most probably the number of bird species and the number of birds on the rivers depend on various other factors, which can understate the possible role of river fragmentation by small HPPs.

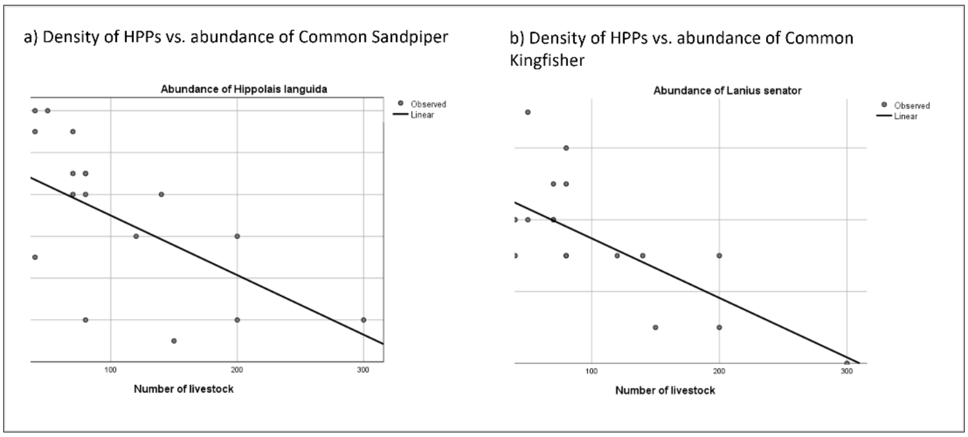

Figure 17 Abundance of (a) Common Sandpiper (*Actitis hypoleucos*) and (b) Common Kingfisher (*Alcedo atthis*) vs. density of small Hydro Power Plants (HPPs) per one km of rivers. Both figures show significant negative correlation between the variables.

The determination of the bird species, which are more sensitive towards fragmentation of the rivers shows that some species demonstrate strong negative correlation with the density of small HPPs (the higher the density – the less abundant is the species).

Among the waders, there are two species, which breed along the rivers and streams. Those are Common Sandpiper (*Actitis hypoleucos*) and Little Ringed Plover (*Charadrius dubius*). The third species, Green Sandpiper (*Tringa ochropus*) is present here year-round as well, but there is no breeding evidence yet.

The linear regression applied to these species shows a high level of negative correlation between Common Sandpiper (Figure 17a) and the density of HPPs (R^2 = 0.414, *df* = 9; *F* = 5.655, *P* = 0.045) and insignificant correlation for the Little Ringed Plover (R^2 = 0.243, *df* = 8; *F* = 2.250, *P* = 0.177), although the negative trend for the later one is traced.

It appears that the Common Sandpiper is sensitive enough towards river fragmentation to be used as an indicator. It is quite a distinct species to be detected during the display and to be identified by morphology, therefore, the species can be included into the monitoring schemes after a short training of the counters. The lack of correlation for the Little Ringed Plover could be a result of the lack of data.

Another typical representative of the riparian bird fauna is the Common Kingfisher, a specialized fish-eater. The linear regression (Figure 17b) applied to this species shows a significant negative correlation between Kingfisher's abundance and the density of HPPs (R^2 = 0.473, *df* = 9; *F* = 7.185, *P* = 0.028).

It appears that the Common Kingfisher is also sensitive towards river fragmentation and can be used as an indicator. The species is unmistakable by morphology, although some training might be needed for its detection, when it flies rapidly along the rivers.

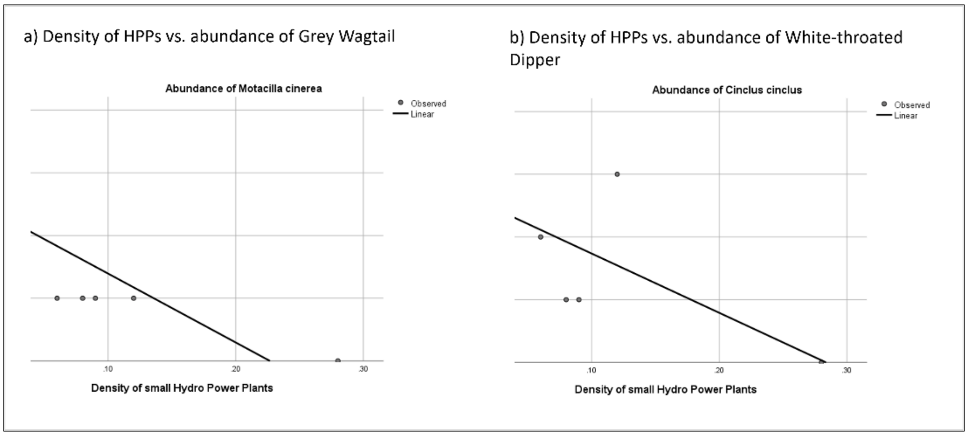

Figure 18 Abundance of (a) Grey wagtail (*Motacilla cinerea*) and (b) White-throated Dipper (*Cinclus cinclus*) vs. density of small Hydro Power Plants (HPPs) per one km of rivers. Both figures show significant negative correlation between the variables.

Among the wagtails, there are two species, which breed along the rivers and streams. Those are Grey Wagtail (*Motacilla cinerea*) and White Wagtail (*Motacilla alba*).

The linear regression applied to these species shows a significant negative correlation between Grey Wagtail (Figure 18a) and the density of HPPs (R^2 = 0.612, *df* = 9; *F* = 12.611, *P* = 0.007) and a lack of correlation for the White Wagtail. The Grey Wagtail is a specialized inhabitant of the rivers and streams and therefore its sensitivity towards river fragmentation was expected, while the White Wagtail is rather a generalist and it appears to be able to adapt to a wide variety of conditions, including river fragmentation. Use of the Grey Wagtail as an indicator is justified also by its easy determination and identification.

The last species that is specialized inhabitant of the rivers and streams is the White-throated Dipper (*Cinclus cinclus*). The linear regression (Figure 18b) applied to these species shows a significant negative correlation between abundance of the Dipper and the density of HPPs (R^2 = 0.457, *df* = 9; *F* = 6.729, *P* = 0.032). The observed sensitivity of the Dipper towards river fragmentation, along with its distinct behavior and unmistakable field-marks, make it another good indicator of the rivers and streams.

Concluding the section on rivers and streams, we can state that the four selected species can be a definite tool for indication of the influence of the HPPs on the state of rivers and streams, while the number of species and the number of bird individuals cannot be used for the purpose.

For the selected tool, the counts can be conducted by well-trained rangers, students, and other volunteers, who can identify about six species by voice and appearance.

3.4.2. Wetlands

Some species, which inhabit grassy marshes, have shown a critical decline due to a practice of excessive water acquisition that leads to draining of the marshes. Thus, the Common Crane (*Grus grus*) disappeared from Lori marshes in late 1990s – early 2000s that coincided with the draining of the grassy marshes in this area. Later, the same species experienced another wave of decline in Lake Arpi National Park, and again it coincided with the increased water acquisition by the local farmers that resulted in significant decrease of the grassy marshes.

Another species, which was well studied during the last decades [28] is the Northern Lapwing. This species shows a significant declining trend (Figure 19) that is linked to the drainage of the grassy marshes. In some spots, like Aparan Plateau it became extinct, due to the same reason.

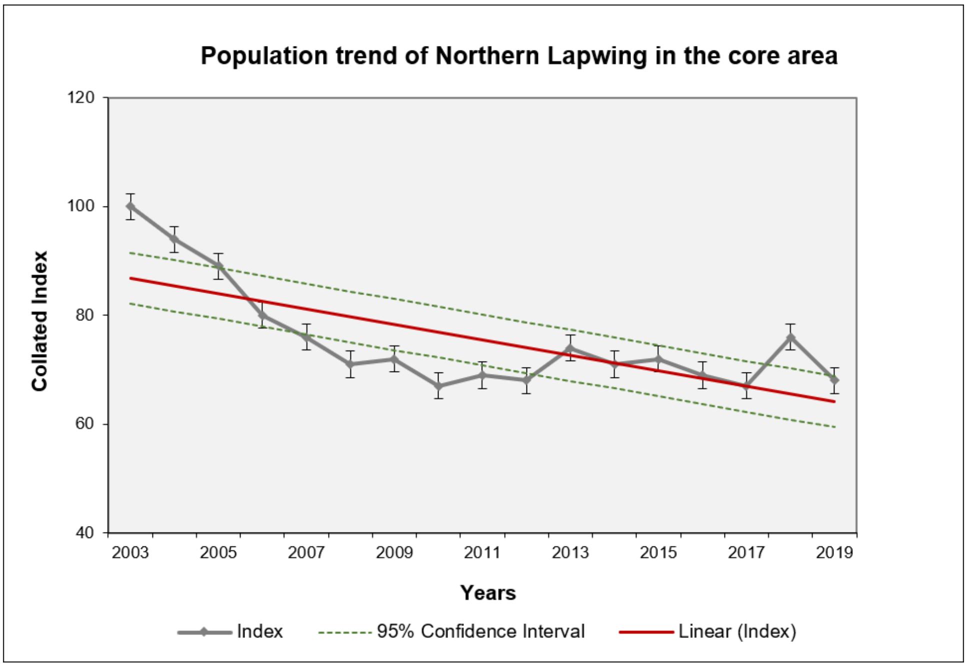

Figure 19 Population trend of Northern Lapwing (*Vanellus vanellus*) in Armenia in 2003-2019 [28].

There are several other species of grassy marshes, which appear to be good indicators as they are present in the areas with existing grassy marshes and do not occur in the areas, where grassy marshes have been degraded. Those are Spotted Crake (*Porzana porzana*), Common Redshank (*Tringa totanus*), Yellow Wagtail (*Motacilla flava*) and Grasshopper Warbler (*Locustella naevia*), however their application as indicators still requires additional study.

Similar pattern appears in the brackish marshes of Ararat Plain. Thus, Black-winged Stilt (*Himantopus himantopus*) disappeared in some areas of Ararat Plain, where the marshes have been drained.

The comparison of the bird fauna of restored brackish marshes in Khor Virap State Sanctuary [29] demonstrated increase of the fauna of breeding birds from 38 to 55 species ($\chi^2 = 32.9$, $p < 0.001$). Among 17 species which inhabited the area after restoration, the Little Grebe (*Tachybaptus ruficollis*), Little Bittern (*Ixobrychus minutus*), Water Rail (*Rallus aquaticus*), Common Kingfisher, Savi's Warbler (*Locustella luscinioides*), and Moustached Warbler (*Acrocephalus* *melanopogon*) should be mentioned as potential indicators. Most of these species are rather easy to detect and identify, either by appearance (like Little Bittern) or by voice (like the cryptic Water Rail and Savi's Warbler), so training in identification is required for the potential counters.

Many other waterbirds, specifically some ducks and waders, also demonstrate a similar pattern of presence / absence, depending on the wetlands' conditions, however, they hardly can be used as indicators of the state of marshes, being also threatened by the factor of hunting, which can cause a confusion in the interpretation of the results.

Another species that demonstrates a good relation to the conditions of the wetlands is the White Stork. Its monitoring is slightly different from all the previous cases, as the monitoring parameters include absolute count of breeding pairs and the breeding success (number of fledglings per occupied nest). The monitoring is implemented in Armenia since 2006 and helped in identification of pollution of the wetlands by Persistent Organic Pesticides and by the waste products of fish-farms and producers of canned food [30 – 32].

Concluding the section on wetlands, we can state that the Northern Lapwing for the grassy marshes and six species for the brackish marshes can most probably be used as the indicators, however the indicators of the wetland ecosystems still require further study. For the selected tool, the counts can be conducted by well-trained rangers, students, and other volunteers.

3.5. Birds as bioindicators of climate change

Armenia is located at the crossroad of three global migration flyways: Black Sea – Mediterranean, East Asian – East African, and Central Asian. Majority of the migrants, which fly through Armenia, belong to raptors, water birds, and passerines, most of which have stopover points in the country, where the birds get rest and sometimes food.

Thus, raptors stop in the grasslands and scrublands, waterbirds stop at the shorelines and wetlands, passerines stop in scrublands and wetlands. Regular observations, conducted since 1995, allowed documenting the changes in occurrence status and migratory patterns for several species. Thus, Shikra (*Accipiter badius*) expanded its distribution to the north-west and begun breeding in Armenia since 2009 [34]. See-see Partridge (*Ammoperdix griseogularis*) expanded its distribution to the north and started breeding in Armenia since 2003 [35]. Spur-winged Lapwing (*Vanellus spinosus*) expanded its distribution to the north, becoming frequently recorded in Armenia since 2016, year-round visitor since 2019 [36], and a breeding bird since 2022. White-tailed Lapwing (*Vanellus leucurus*) was full migrant but starting from 2021 it was recorded staying in the country year-round, thus changing its migration status [37]. The subspecies of Siberian Stonechat *Saxicola maurus variegatus* (by some authors considered as *S.m. hemprichii*), was migrating through the country, but since at least 2010s it stays in the country overwinter, thus shrinking its migration distance. Masked Shrike (*Lanius nubicus*) expanded its distribution to north-east, becoming a regular visitor since 2007, with possible breeding [38]. Desert Finch expanded its distribution to the north and started breeding in the country in 2013 [39]. The current examples show that many birds are entering Armenia, expanding their distribution range from the south, which is most-probably conditioned by the climate change, as it is documented for Europe and North America [40 – 43].

The climate change is also supposed to cause an altitudinal shift for many mountainous birds, however that study has not been finalized for Armenia yet.

3.6. Institutional framework and perspectives for monitoring of birds as bioindicators

The provision on the monitoring of biological diversity is stated in the Law on Fauna [44] and in the Law on Protected Areas [45]. The authority that is supposed to realize the monitoring of biological diversity is Hydrometeorology and Monitoring Center SNCO. However, now, as it was discussed several times in frames of the several recent workshops, none of the state organizations have a relevant capacity of implementation, neither data collection, nor data analysis and interpretation. The National Bird Monitoring Scheme is currently run by BirdLinks Armenia NGO, resulting in regular publications [24, 27 – 33, 37, 46 – 61].

Therefore, the cooperative model between state organizations and CSOs is one of the possible solutions. The CSOs, which are more flexible in terms of using the volunteer force, can develop the data collection scheme (which is the most expensive part of any monitoring), at the same time cooperating with the protected areas and forestry enterprises, to improve their capacity in data collection (at least on the indicator species). The database should be owned by the state, while further analysis and interpretation of the collected data can be done by various organizations which have the relevant capacity. The use of the database for other research projects would require development of the relevant policy and a system of permissions and agreements.

4. Conclusion

The current study for Armenia shows that the birds can serve as good indicators of ecosystems and influence of the climate change on biodiversity. The bird monitoring scheme can help in regular reporting on the state~~s~~ of ecosystems, thus informing the relevant governmental bodies about possible issues, which are ~~is~~ important at the national level and in frames of international agreements. While some parameters of monitoring require involvement of highly qualified data collectors, the separate species can be counted by the sufficient staff of protected areas and forestry enterprises, as well as by volunteers, after short training in species identification and data collection.

Compliance with ethical standards

Acknowledgments

Administrative and information support during this work was provided by the Ministry of Environment of the Republic of Armenia, specifically by Specially Protected Areas of Nature and Biodiversity Policy Department, Department of Bioresource Management, Forest Policy Department, and Surface and Underground Water Resources Management Department. Special thanks to the Khosrov Forest State Reserve, Lake Sevan National Park, Lake Arpi National Park, Dilijan National Park, Zangezur Biosphere Complex, and Armash fish-farm, which allowed intensive work on their land. Significant help in data collection was provided by the members of Armenian Ornithological Society. During 2007–2019, the data collection was supported by the Whitley Fund for Nature through a series of grants on Sustainable Wetland Management in the South Caucasus (the grant agreements have not been provided with numbers), and during 2015–2017 the surveys were also supported by the European Bird Census Council through a grant from the MAVA Foundation for the European Breeding Bird Atlas - EBBA2 (the grant agreements have not been provided with numbers). The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH supported Environmental Programme contributed to the data analysis (grant number 83318294).

Disclosure of Conflict of Interest

The authors declare no conflict of interest.

References

[1] World Economic Outlook Database. Groups and Aggregates. Washington, D.C.: International Monetary Fund. 5 October 2023. [Archived from the original on 2023 Oct 23; Cited 2023 Dec 15]. Available from: https://www.imf.org.

[2] IUCN. Threat Classification Scheme (Version 3.2). 2016 [Cited 2023 Dec 21]. Available from: http://www.iucnredlist.org/technical-documents/classification-schemes/threats-classification-scheme.

[3] Aghababyan K, Khanamirian G, Ter-Voskanyan H, Khachatryan A, Wikström M, Adriaens P. Annotated Checklist to Birds of Armenia. March 2020. BirdLinks Armenia NGO. Technical Report № BLA-2020-001. 2020. DOI: 10.13140/RG.2.2.31616.17920/2.

[4] Venier LA, Pearce JL. Birds as indicators of sustainable forest management. The Forestry Chronicle. 2004; 80(1).

[5] Canterbury GE, Martin TE, Petit DR, Petit LJ, Bradford DF. Bird Communities and Habitat as Ecological Indicators of Forest Condition in Regional Monitoring. Conservation Biology. 2000; 14(2): 544-558.

[6] Martin TG, Possingham HP. Predicting the impact of livestock grazing on birds using foraging height data: Bird foraging height predicts impact of grazing. Journal of Applied Ecology. 2005; 42(2): 400-408.

[7] Dale BC, Martin PA, Taylor PS. Effects of Hay Management on Grassland Songbirds in Saskatchewan. Wildlife Society Bulletin. 1997; 25(3): 616-626.

[8] Soultan A, Pavón-Jordán D, Bradter U, Sandercock B, Hochachka W, Johnston A, Brommer JE, Gaget E, Keller V, Knaus P, Aghababyan K, Maxhuni Q, Vintchevski A, Nagy K, Raudonikis L, Balmer D, Noble D, Leitão D, Øien I, Shimmings P, Sultanov E, Caffrey B, Boyla K, Radišić D, Lindström Å, Velevski M, Pladevall C, Brotons L, Stastny K, Rajković D, Chodkiewicz T, Szep T, Wilk T, van Turnhout Ch, Burfield I, Vikstrøm T, Mazal V, Eaton M, Vorisek P, Lehikoinen A, Herrando S, Kuzmenko T, Bauer H-G, Kalyakin M, Voltzit O, Pärt T. The future distribution of wetland birds breeding in Europe validated against observed changes in distribution. Environmental Research Letters. 2022; 17(024025): 1-13. https://doi.org/10.1088/1748-9326/ac4ebe.

[9] Marjakangas EL, Bosco L, Versluijs M, Xu Y, Santangeli A, Holopainen S, Mäkeläinen S., Herrando S, Keller V, Voříšek P, Brotons L, Johnston A, Princé K, Willis SG, Aghababyan K, Ajder V, Balmer D, Bino T, Boyla KA, Chodkiewicz T, del Moral JC, Dumbović MV, Ferrarini A, Godinho C, Gustin M, Kalyakin M, Knaus P, Kuzmenko T, Lindström Å, Maxhuni Q, Molina B, Nagy K, Radišić D, Rajkov S, Rajković DZ, Raudonikis L, Sjeničić J, Stoychev S, Szép T, Teufelbauer N, Ursul S, van Turnhout CAM, Velevski M, Vikstrøm T, Wilk T, Voltzit O, Øien IJ, Lehikoinen A. Ecological barriers mediate spatiotemporal shifts of bird communities. Proceedings of the National Academy of Sciences. 2023; 120(23). https://doi.org/10.1073/pnas.2213330120

[10] Gregory RD, Noble D, Field R, Marchant J, Raven M, Gibbons DW. Using birds as indicators of biodiversity. Ornis Hungarica. 2003; 12-13: 11-24.

[11] Burns F, Eaton MA, Burfield IJ, Klvaňová A, Šilarová E, Staneva A, Gregory RD. Abundance decline in the avifauna of the European Union reveals global similarities in biodiversity change. Ecology and Evolution. 2021; 11: 16647–16660. https://doi.org/10.1002/ece3.8282

[12] Tumanian R. Country Pasture/Forage Resource Profiles. Yerevan , Armenia: FAO; 2006.

[13] Junge N, Fripp E. Understanding the forestry sector of Armenia: current conditions and choices. Main Report. Yerevan, Armenia: ENPIFLEG; 2011.

[14] IUCN. Habitats Classification Scheme (Version 3.1). 2012 [Cited on 2023 Jan 21]. Available from: https://www.iucnredlist.org/resources/habitat-classification-scheme.

[15] Jenderedjian K. Armenia Keynote Wetlands in Armenia — their values and threats and their contribution to sustainable development and poverty alleviation. Proceedings of 5th European Regional Meeting on the implementation and effectiveness of the Ramsar Convention. Yerevan, Armenia; 2004 Dec 4–8.

[16] FAO. Review of fisheries and aquaculture development potentials in Armenia. FAO Fisheries and Aquaculture, Circular No. 1055/2. Yerevan, Armenia: FAO; 2011.

[17] Aghababyan K, Khanamirian G. Pollution of freshwater ecosystems by products of water disinfection and disease prevention chemicals. Electronic Journal of Natural Sciences, National Academy of Sciences of RA. 2015; 1(24): 72–75.

[18] Aghababyan KE, Ter-Voskanyan H, Tumanyan S, Khachatryan A. First National Atlas of the Birds of Armenia. Bird Census News. 2015; 28(2): 52–58.

[19] World Travel and Tourism Council. Travel and Tourism: economic impact 2015, Armenia. Geneva: World Travel and Tourism Council; 2015.

[20] Adamian M., Klem D. Handbook of the Birds of Armenia. California, USA: American University of Armenia; 1999.

[21] Aghababyan K. Vertical-landscape distribution of birds in Meghri region of Armenia. [Ph.D. dissertation]. Yerevan, Armenia: Institute of Zoology of NAS RA; 2001

[22] Daniel WW, Cross CL. Biostatistics: A Foundation for Analysis in the Health Sciences, 10th Edition. Hoboken, NJ, USA: John Wiley & Sons, Inc.; 2013.

[23] Aghababyan K, Ananyan V, Kalashyan M, Khanamiryan G. Analysis of forest pests and pestholes exacerbated by climate change and climate variability in Syunik Marz of Armenia and to identification of the most applicable prevention measures. Report under the “Adaptation to Climate Change Impacts in Mountain Forest Ecosystems of Armenia” UNDP/GEF/00051202 Project. 2010 [Cited 2023 Dec 9]. Available from: http://www.nature-ic.am/en/PR_FA_Reports

[24] Aghababyan K, Khachatryan A, Ghazaryan A, Gevorgyan V. About the state of Corn Crake *Crex crex* Bechstein 1803 in Armenia. Bird Census News. 2021; 34(1): 9-17.

[25] Pannekoek J, van Strien A. TRIM 3 Manual (TRends & Indices for Monitoring data). Statistics Netherlands. 2005 [Cited 2023 Sep 7]. Available from https://www.ebcc.info/art-13/.

[26] van Strien A, Pannekoek J, Hagelmeijer ., Verstrael T. A loglinear Poisson regression method to analyse bird monitoring data. In: Anselin, A. (ed.) Bird Numbers 1995, Proceedings of the International Conference and 13th Meeting of the European Bird Census Council, Pärnu, Estonia. Bird Census News. 2004; 13(2000): 33-39.

[27] Aghababyan K, Khachatryan A. The conservation status of Woodchat Shrike *Lanius senator* in Armenia. Jordan Journal of Natural History. 2021; 8(1): 17-22.

[28] Aghababyan K, Khanamirian G, Ghazaryan A, Gevorgyan V. About Conservation Status of Northern Lapwing *Vanellus vanellus* in Armenia. Journal of Ecology and Natural Resources. 2021; 5(3): 1-9. doi:10.23880/jenr-16000257.

[29] Aghababyan K, Grigoryan V. First attempt of restoration of brackish marshes in Armenia and its influence on the fauna of waterbirds, PREPRINT (Version 1) available at Research Square. 29 September 2023. [https://doi.org/10.21203/rs.3.rs-3377808/v1]

[30] Aghababyan K. White Storks (*Ciconia ciconia* L.): Population tendencies in Armenia. Proceedings of the International Conference "Biological Diversity and Conservation Problems of the Fauna of the Caucasus". 2011 Sep 26-29, Yerevan, Asoghik: 9-13.

[31] Aghababyan K, Khanamirian G, Manukyan M, Ghazaryan H, Pahutyan N, Khechoyan A, Hambardzumyan K, Sharimanyan M, Avetisyan K, Tsaturyan A, Arabyan A, Sahakyan K, Sayadyan A, Khachatryan A, Martirosyan B, Gevorgyan V, Ghazaryan A, Sundar G. White Storks *Ciconia ciconia* L. became victims of environmental pollution of Ararat Plain of Armenia. Journal of Ecology and Natural Resources. 2022; 6(1): 1-10. DOI:10.23880/jenr-16000269

[32] Aghababyan K, Khanamirian G, Ter-Voskanyan H, Khachatryan A, Gevorgyan V. White Storks (*Ciconia ciconia* L.) in Armenia: over ten years of research for conservation. Bird Census News. 2020; 32(1–2): 3–10.

[33] Aghababyan K. The State of Persian Wheatear *Oenanthe chrysopygia* De Filippi, 1863 in Armenia. Journal of Life Sciences – David Publishing. 2020; 14(2020) 9-13. doi:10.17265/1934-7391/2020.01.002.

[34] Ananian V, Aghababyan K, Tumanyan S, Janoyan G, Bildstein K. Shikra *Accipiter badius* breeding in Armenia. Sandgrouse. 2010; 32: 151–155.

[35] Ananian V. The first See-see Partridge *Ammoperdix griseogularis* in Armenia. Sandgrouse. 2004; 26(2): 137–139.

[36] Aghababyan K. Summer observations of Lesser White-fronted Goose *Anser erythropus* and Spur-winged Lapwing *Vanellus spinosus* in Armenia. Sandgrouse. 2019; 41: 2-4.

[37] Aghababyan K. Status and conservation of White-tailed Lapwing *Vanellus leucurus* in Armenia. Wader Study. 2021; 128(1): 87-92. doi:10.18194/ws.00224

[38] Ter-Voskanyan H, Aghababyan K. Masked shrike (*Lanius nubicus*) in Armenia. 2014. Sprawozdanie XII International Confrence on Electric Machines and Drive Systems 17-19.08.2014r. ICEMDS 2014, Barcelona, Hiszpania Sprawozdanie opracowano w ramach promocji projektu: Wibroakustyczna metoda diagnostyczna silników trakcyjnych i generatorów z magnesami trwałymi na podstawie sygnałów własnych"Sprawozdanie nr: TL/045/Op/14Sosnowiec, dnia 29.08.2014 r. Oral Presentation.

[39] Ananian VYu, Drovetski SV, Koblik EA, Fadeev IV, Agayan SA. The desert finch *Rhodospiza obsolete* — a new species for the fauna of Armenia. Russian J. Ornithol., 2013; 22(895): 1799–1803.

[40] Gillings S, Balmer DE, Fuller RJ. Directionality of recent bird distribution shifts and climate change in Great Britain. Glob Change Biol. 2015; 21: 2155-2168. https://doi.org/10.1111/gcb.12823

[41] Hitch AT, Leberg PL. Breeding Distributions of North American Bird Species Moving North as a Result of Climate Change. Conservation Biology. 2007; 21: 534-539. https://doi.org/10.1111/j.1523-1739.2006.00609.x

[42] Lehikoinen A, Virkkala R. North by north-west: climate change and directions of density shifts in birds. Glob Change Biol. 2016; 22: 1121-1129. https://doi.org/10.1111/gcb.13150

[43] Stewart PS, Voskamp A, Santini L, Biber MF, Devenish AJM, Hof C, Willis SG, Tobias JA. Global impacts of climate change on avian functional diversity. Ecology Letters. 2022; 25: 673–685.

[44] Parliament of RA. RA Law on Fauna № HO-52. 2000 [Amended on 23.03.2022, version № HO-74-N; cited 2023 Dec 15]. Available from https://www.arlis.am/.

[45] Parliament of RA. RA Law on Specially Protected Nature Areas № HO-211-N. 2007 [Cited 2023 Dec 15]. Available from https://www.arlis.am/.

[46] Aghababian K, Tumanyan S. On the breeding Peregrines *Falco peregrinus brookei* in some regions of Armenia. In: Sielicki J, Mizera T, eds. Peregrine Falcon Populations – status and perspectives in the 21st Century. Warsaw: Turul; 2009. p. 99-108.

[47] Aghababyan K. Recent counts of White-headed Ducks *Oxyura leucocephala* in Armash wetlands, Armenia. Sandgrouse. 2019; 41: 5-6.

[48] Aghababyan K. Assessment of the state of European Turtle-dove *Streptopelia turtur* Linnaeus, 1758 in Armenia. Polish Journal of Science. 2020; 23(2): 6-10.

[49] Aghababyan K. Caspian Snowcock *Tetraogallus caspius* in Armenia: results of 16 years of monitoring. Alauda. 2020; 88 (4): 311-316.

[50] Aghababyan K. The Yellow-billed Chough *Pyrrhocorax graculus* Linnaeus, 1766 in Armenia: update on conservation status. Polish Journal of Natural Science. 2020; 35(3): 267–273.

[51] Aghababyan K, Aebischer N, Baloyan S. The modern state of Chukar *Alectoris chukar* J. E. Gray, 1830 in Armenia. Ornis Hungarica. 2022; 30(1): 80–96. doi:10.2478/orhu-2022-0006

[52] Aghababyan K, Bauer H-G. Accounts for 21 bird species (Black Francolin, White-tailed Lapwing, Armenian Gull, Bimaculated Lapwing, Radde's Accentor, White-throated Robin, Persian Wheatear, Upcher's Warbler, Green Warbler, Mountain Chiffchaff, Menetries's Warbler, Western Rock-nuthatch, Eastern Rock-nuthatch, Pale Sparrow, Red-fronted Serin, Trumpeter Finch, Mongolian Finch, Rosy Starling, Gray-necked Bunting, Ortolan Bunting, Black-headed Bunting). In: Keller V, Herrando S, Voříšek P, Franch M, Kipson M, Milanesi P, Martí D, Anton M, Klvaňová A, Kalyakin MV, Bauer H-G, Foppen, RPB. European Breeding Bird Atlas 2: Distribution, Abundance and Change. European Bird Census Council Barcelona: Lynx Edicions; 2020.

[53] Aghababyan K, Gevorgyan V, Khanamirian G. The State of Semi-collared Flycatcher (*Ficedula semitroquata* Homeyer, 1885) in Armenia. Proceedings of III International Scientific Conference "Biological diversity and conservation problems of the fauna - 3", 2017 Sep 27-29, Yerevan, Armenia.

[54] Aghababyan K, Khachatryan A, Baloyan S, Ghazaryan A, Gevorgyan V. Assessing the current status of the Common Pochard *Aythya ferina* in Armenia. Wildfowl. 2021; 71: 147–166.

[55] Aghababyan K, Khanamirian G. Baseline study of the Birds at Lake Sevan for further monitoring – 2016-2017. Technical Report № TSE-2017-001. 2017. DOI: 10.13140/RG.2.2.10179.09766.

[56] Aghababyan K, Khanamirian G. The State of Common Wood Pigeon (*Columba palumbus* Linnaeus, 1758) in Armenia. Italian Journal of Woodpigeon Research. Club Italiano del Colombaccio. 2019; 2.

[57] Aghababyan K, Khanamirian G. The State of Bearded Vulture, *Gypaetus barbatus* (Linnaeus, 1758) in Armenia. Bird Census News. 2020; 32(1–2): 11-16.

[58] Aghababyan K, Khanamirian G, Gevorgyan V. An update of current situation of Griffon Vultures *Gyps fulvus* (Hablitz, 1783) in Armenia. Tichodroma – Journal of Slovak Ornithological Society. 2019; 31: 3-10.

[59] Aghababyan K, Khanamirian G, Ter-Voskanyan H, Khachatryan A.. Baseline study of the Birds at Lake Sevan for further monitoring. Technical Report № TSE-2016-001. 2016. DOI: 10.13140/RG.2.2.16575.41124.

[60] Aghababyan K, Klem DJr. Assessment of the state of Black Francolin *Francolinus francolinus* Linnaeus, 1766 in Armenia. Revista Catalana d'Ornitologia – Catalan Journal of Ornithology. 2020; 36: 56-61.

[61] Aghababyan K, Stepanyan H. Booted Eagle *Hieraaetus pennatus* J. F. Gmelin, 1788 in Armenia: update on conservation status. Journal of Life Sciences – David Publishing. 2020; 14 (2020): 14-21. doi:10.17265/1934-7391/2020.01.003.