Development of a decision support tool for analysing the avian conservation measures in semi-arid region

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Abstract: Conservation of Aves has become a great concern for researchers because of their scientific and environmental significance. However, this is a complex decision-making problem as it includes monitoring the birds, determining the reasons for decline in bird species, and devising conservation strategies. This paper documents the design and development of an intelligent decision support tool, to analyse the avian diversity and then suggests decision measures for effective conservation and management of avian fauna in a semi-arid region. The framework of the system involves measuring and mapping the biodiversity, analysing the avian diversity, identifying and analysing the threats, and formulating conservation and management strategies.

Keywords: avian diversity; decision support system; DSS; intelligent decision-making; conservation; management.

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1 Introduction

Birds are one of the best known species that serve as good indicators of biodiversity and environmental change. These are treated highly valued groups of species which can help in making strategic conservation planning decisions for the wider environment.

Declines in bird population has been observed since last few decades which may be due to habitat loss, habitat fragmentation and modification, loss of wintering habitat, and excessive predation. Several bird conservation planning efforts are underway across the world (Tobias et al., 2013; Buechley et al., 2015; Arbeláez-Cortés et al., 2016; Brochet et al., 2016; Snep et al., 2016; Hudson et al., 2017). In India, Islam and Rahmani (2004) and Islam (2006) identified important bird areas as priority sites for conservation of birds. Acharya and Vijayan (2010) collected information on endemic and threatened birds of Sikkim. Panigrahi and Jins (2018) focused on the status of birds in two wildlife sanctuaries, Neyyar and Peppara, located in Agasthyamalai Biosphere Reserve, Kerala State, India. It is observed that the conservation efforts are usually based on the species distribution models, which lack in providing decision support information to the conservation and management stakeholders.

Conservation decision support system (DSS) is a computerised system that provides a set of decision support tools to organise geographical, physical, and biological data for modelling species distribution and conservation planning (Prato, 1999). Inspite of realising the importance of DSS or decision support tools in conserving the birds (Alexander et al., 2008; Rose et al., 2017; Wszola et al., 2017), DSS and decision support tools are utilised by very few researchers (Downs and Horner, 2008; Poirazidis et al., 2011; Sutti et al., 2017) for conservation of birds and their habitats. Moreover, authors generally focus either on selecting the priority areas, or analysing the bird population only.

This paper documents the design and development of an intelligent DSS, the avian conservation support system (ACDSS), for conservation of birds and management of their habitats (C&M) in semi-arid regions. The main objective of this research study is to integrate statistical tools, and multi-criteria decision-making and management techniques with the DSS to provide:

- assessment of avian diversity
- bio-geographical classification of Aves
- identification of disturbance gradient
- selection of priority area
- identification of dominant and focal bird species
- formulation of conservation and management planning strategies for Aves.

2 Materials and methods

2.1 Component-based development approach

DSSs have emerged as a practical approach for applying computers and information to solve decision problems. Recent studies in DSS (Van Pham et al, 2014; Curiel-Esparza et al., 2015; Mohapatra and Lenka, 2016; Ahmad et al., 2017; Caramihai et al., 2017; Dellermann et al., 2017; Sahebjamnia et al., 2017; Akbar et al, 2018; Singh and Singh, 2018) reveals decline in the use of three-element focused generic DSS for decision-making activities. This is due to the fact that the functionalities of standalone DSS are insufficient to facilitate effective decision support for a problem involving multiple criteria, quantitative and qualitative aspects, spatial data, domain knowledge, and fuzziness in human knowledge representation. These challenges require the DSS to be expanded and integrated with other scientific approaches and tools for effective decision-making.

Development of an integrated DSS is a multidisciplinary process which involves the understanding of application domain, mathematical tools and techniques, and computer science. This multidisciplinary nature of DSS development makes it difficult to use traditional software development approaches such as waterfall model and others.

Thus this study follows a component-based software development approach where independent DSS components are developed and then are combined to form a complete DSS through a common interface. The phases of development process are:

a identification of system components

b designing system architecture

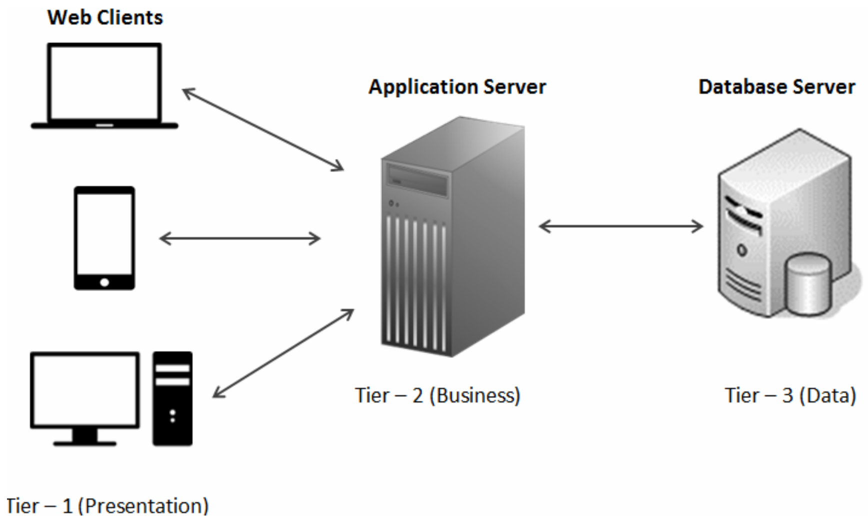
c development of independent (identified) components and their integration

d system implementation.

2.2 The three-tier architecture

Nowadays, web is playing a huge role in application development mainly because of advantages such as platform independency, reduction in distribution costs, ease of use, and widespread access. These advantages motivated to adopt three-tier server-side architecture for the development of the DSS where most of the processing task takes place on server side and requires the user (decision maker) to use a web browser for requesting decision information from the web server. The three-tier architecture of the system comprises of *presentation tier* (user interface tier), business tier (logic tire), and data tier, as shown in Figure 1. The business tier accesses the data tier for data retrieval and manipulation, and sends the results to presentation tier.

Figure 1 Three-tier architecture



3 Development of ACDSS

The developed ACDSS is an intelligent system that will help in:

1 Developing the comprehensive baseline inventory of the birds in a semi-arid region.

2 Computing the species richness and diversity.

3 Estimating the species level parameters of occurrence probability and density for the most commonly encountered species in the study area.

4 Providing the authorities and local community with a better understanding of and appreciation for the diversity and fragility of the birds of the study area.

The detailed description of various activities carried out in developing the ACDSS are described below.

3.1 Identification of system components

Following five components were identified for developing ACDSS:

1 database management sub-system (DBM-SS)

2 model-base management sub-system (MBM-SS)

3 knowledge-base management sub-system (KBM-SS)

4 dialog management sub-system (DiM-SS)

5 central vision exhibit board (CVE-board).

3.2 Designing system architecture

The architecture of the ACDSS is as shown in Figure 2. The DiM-SS and CVE-board components of the ACDSS implement the presentation tier. The DiM-SS communicates with the decision-makers through C&M user desk in order to view the decision support information in graphical environment. MBM-SS and KBM-SS implement the business tier as a means for providing business logic related to decision-making process. The DBM-SS and KBM-SS components of ACDSS implement the data tier. These provide the business layer with required data and knowledge when needed; and store data and knowledge when requested. The three-tier organisation of ACDSS results in improved security, availability, data integrity, and effective usability.

Figure 2 Architecture of ACDSS (see online version for colours)

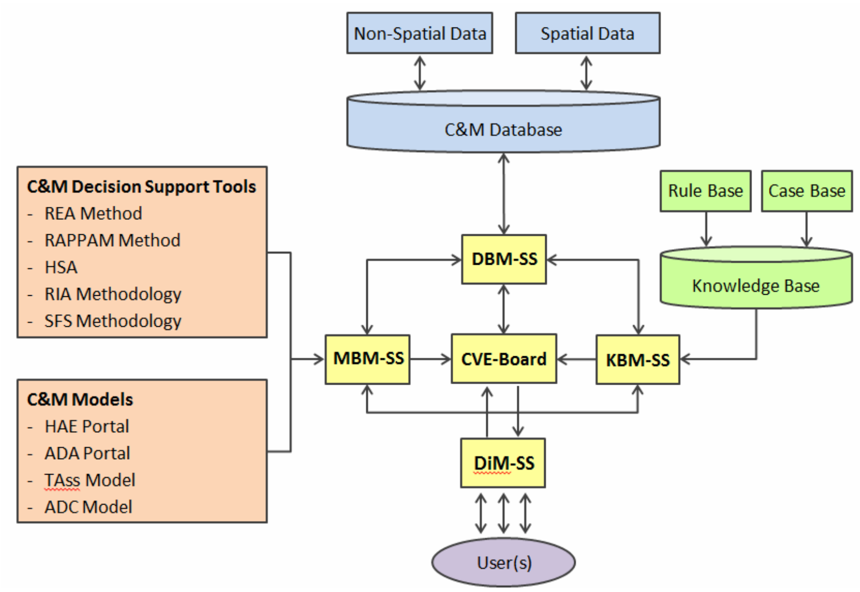
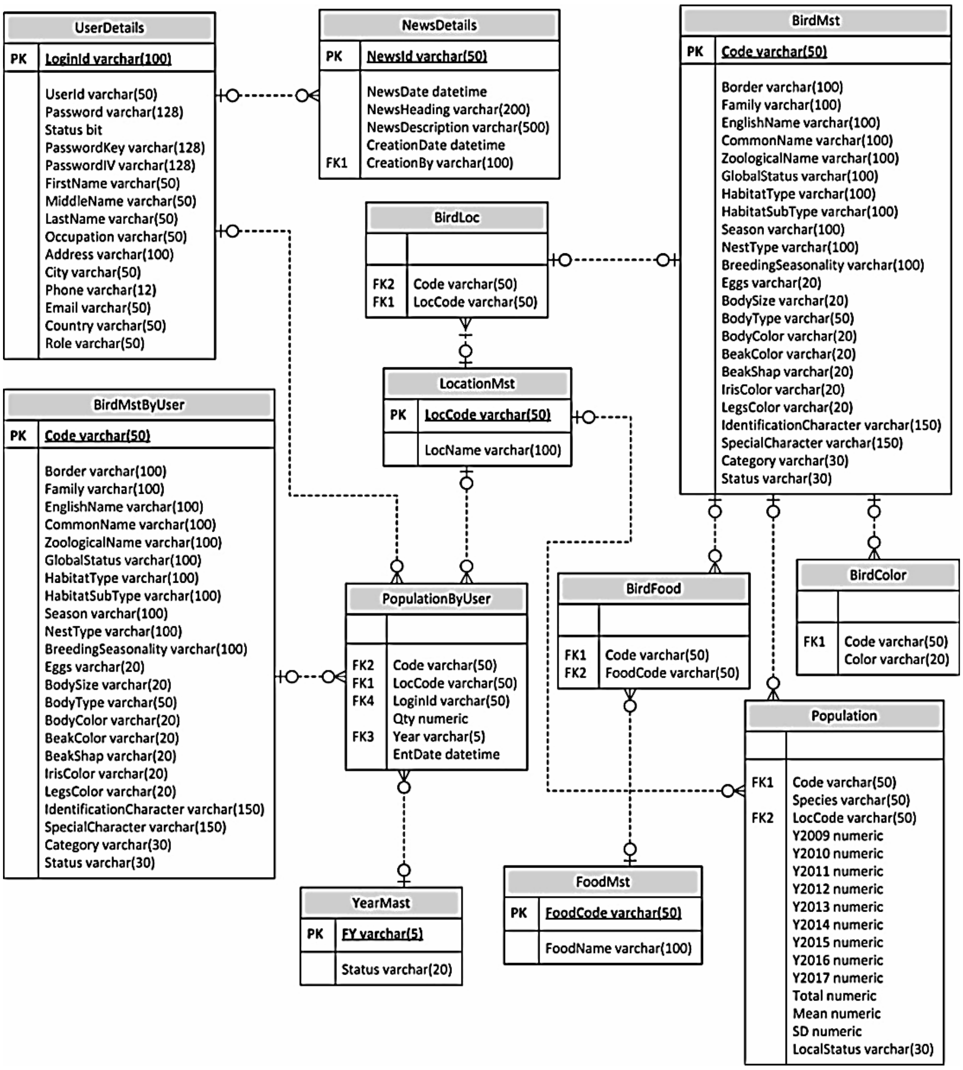


Figure 3 Normalised E-R model of the database



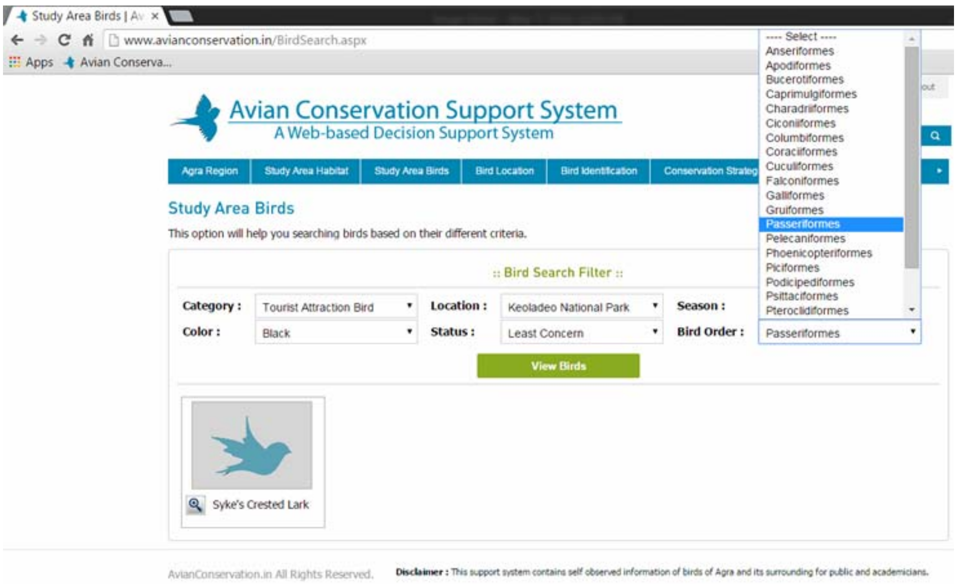
3.3 Development of independent components and their integration

The development process of each component is described below. These components are implemented with free and open-source software packages: Microsoft Visual Web Developer (2008) express edition (lightweight version of .NET development environment provided for free by Microsoft), PostgreSQL (an object-relational database management system on open-source platform), PostGIS (an open-source spatial database extender for PostgreSQL), and quantum GIS (a free and open source geographic information system for editing geospatial data).

3.3.1 Database management sub-system

This fundamental component of the ACDSS refers to the C&M database which follows the relational database approach. DBM-SS component is implemented with PostgreSQL/PostGIS which manages spatial (geometric location of sites) and non-spatial data (bird's data and habitat data). An E-R model for the C&M database is established in Figure 3.

Figure 4 The ADA model (see online version for colours)



3.3.2 Model-base management sub-system

This sub-system includes C&M decision tools and models to provide analytical capabilities to the system. The sub-system comprises of following 4 models that are powered with five decision-support tools (a detailed description of developed/utilised decision-support tools is provided in Appendix A).

1 *Habitat analysis and evaluation (HAE) portal*: this portal utilises rapid eco-regional assessment (REA) Methodology, RAPPAM and the developed habitat suitability analysis (HSA) process (steps given in Section A.3 of Appendix A) to present the optimal relationship between species distribution and the influential variables explaining presence/absence, abundance and breeding success of birds. The inputs to the portal are geometric locations, habitat patch scores and pairwise comparison of each habitat type and sub-types. The output is the thematic map of the site and the habitat suitability value which can be used to predict the presence of the Aves.

   HAE portal also helps in identifying the environmental variables that restrict the distribution of the birds. The environmental variables considered in this study are: measures of climate, landscape structure (for example, connectivity indices), landscape heterogeneity (such as eco-tone cover), resources (such as food availability) and biotic information (like co-occurring competitors). These variables are chosen to reflect the following main influences on the bird species:

- Limiting factors: these are the factors that control the eco-physiology of the bird species (such as minimum winter temperature), or appearance (such as competition) and facilitation.
- Disturbances: these are the types of perturbations affecting the environment systems.
- Resources: these are the materials that can be assimilated by organisms (e.g., availability of insects, or seeds).

2 *Avian diversity analysis (ADA) model*: this model is a species distribution model for answering C&M questions like: ‘Which bird is the most diverse at the study site?’, or ‘Which site should be visited to see a peacock?’, and so on, by providing online access to the textual and tabular data.

On the basis of the sample-wise population (individual and species) count as input, the ADA model:

- analyses the avian abundance
- classifies the species of the habitat bio-geographically
- displays the community composition and species composition of Aves
- determines the population trend and helps in identifying the dominant species
- calculates the diversity indices, as outputs.

In addition, taking foraging, nesting and breeding seasonality behaviors as input, relative abundance is calculated as output.

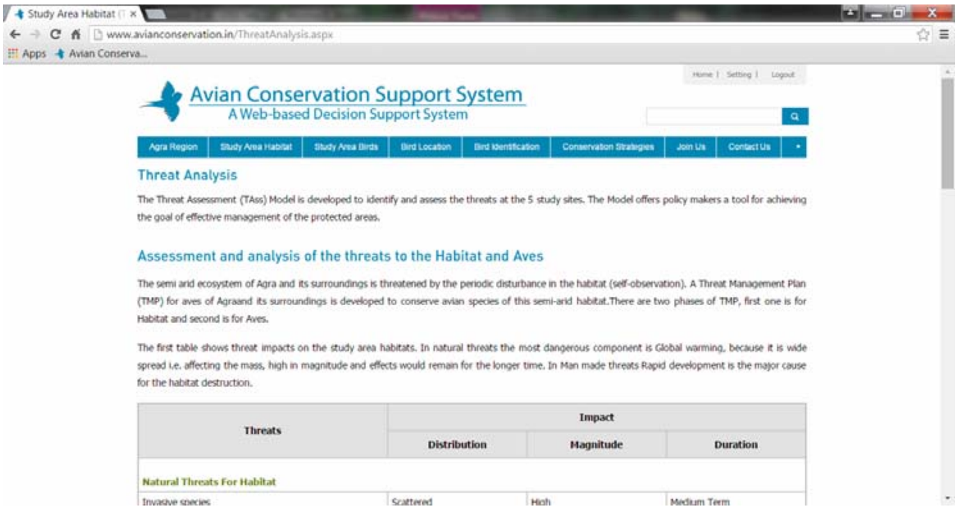
3 *Threat assessment (TAss) model*: it utilises risk impact assessment (RIA) methodology (Section A.4, Appendix A) for analysing the risk impacts. It takes threat impact scores of threat classes, *timing score*, *range score*, and *severity score* for the site and its habitats, and birds; and *fuzzy pairwise comparisons* of the threat classes as input, and determines *risk impact to bird*, *habitat*, and *bird guilds* as the output.

The model also helps in answering the questions like:

- What are the main threats affecting the formal/informal protected areas, and how serious these are?
- What are the important management gaps in the Protected Area system?
- What are the most strategic interventions to improve the entire system?

It provides the policy makers and wildlife authorities with a relatively quick and easy tool to compute the risk impact based on the identified threats that need to be addressed for improving management effectiveness in a protected area (formal/informal).

Figure 5 The TAss model (see online version for colours)



4 *Avian diversity conservation (ADC) model*: on the basis of the scientific analysis, the ADC model is used to formulate the conservation and management strategies for the birds. The inputs to the model are pairwise comparison of SWOT groups together with their parameters, and linguistic ranking of strategies on the basis of SWOT parameters. The outcome of the model is prioritised strategies which are generated by utilising SFS (SWOT-FAHP-SAW) methodology (Section A.5, Appendix A). This model facilitates the policy framework for C&M decisionmaking and helps in adjusting environmental policies and practices to maximise the sustainability.

3.3.3 Knowledge-base management sub-system

The KBM-SS includes a knowledge-base and an inference engine to provide intelligence to the system. This component is responsible for manipulating case-base and rule-base (sub components of KBM-SS), and provides knowledge and experience to MBM-SS to make decision-making process intelligent.

- *Rule-base*: a rule-base contains a collection of IF (conditions) – THEN (conclusions) logic statements (or rules), where statements contained within the IF clause are conditions, while statements within the THEN clause are conclusions or hypotheses.

  Following are the examples of C&M rules:

  Rule 1 IF (BodyColor=‘LB’) AND IF (BodySize=‘SM’) AND IF (BeakShap = ‘SB’)

  THEN EnglishName = ‘Common Kingfisher’ OR EnglishName = ‘Blue Throat’

  Rule 2 IF (EnglishName = ‘Peacock’) AND IF (Season = ‘Winter’) AND IF (HabitatType = ‘Forest’)

  THEN LocName = “SBS”

Rule 3 IF (HabitatType= 'Forest') AND IF (Season = 'Summer') AND IF (LocName = 'KNP')
THEN Total = 12

- *Case-base*: a case refers to the record of previous experience or knowledge tied to a specific problem. The collection of previous cases in memory forms a case-base. In case-based reasoning framework, the solution of a new problem involves four-step cyclic process (a detailed description is provided in Appendix B).

KBM-SS component is developed as an object-relational database, developed using PostgreSQL.

3.3.4 Dialog management sub-system

This component manages the interface between the decision maker(s) and rest of the components of the system. It is the most important component, as it heavily influences how the users perceive and use the system.

DiM-SS capabilities are broadly classified into two categories: query solver and decision crux due to the variety of C&M users with different decision-making tasks. While query solver allows ad hoc retrieval of C&M information, decision crux supports the decision-making tasks using the C&M tools to allow the system's users to generate a number of displays from the data available in the system, in a pre-defined format.

3.3.5 Central vision exhibit board

The CVE-board (Figure 6) is basically communication medium that enables information to be shared among the users in multimedia format (text, table, chart or image format).

The developed components are integrated within a common graphical user interface (GUI) to achieve the system's full functionalities. GUI is made up of '.aspx' files populated with appropriate controls using Visual Web Developer 2008 as the .NET development environment.

3.4 System implementation

The decision-making capabilities of ACDSS are evaluated by implementing it for analysing the avian diversity and generating strategies for effective C&M in a semi-arid region, Agra.

4 Case study: implementation of ACDSS in Agra (a semi-arid region)

Agra, a city in Uttar Pradesh (India), is considered to implement ACDSS for assessing the conservation and management of Aves. The study site is a highly biota-sensitive zone and has very rich wildlife which is preserved at many formal and informal sites in and around Agra. This study considers a formal protected area of Agra, the Soor Sarovar Bird Sanctuary (SBS), as a case study. The reason for considering this site is that in spite of the increasing urban pressure all around the area, SBS is able to sustain the Aves up to some extent due to a mix of aquatic habitat, forests, semi-arid zone, river and cultivations.

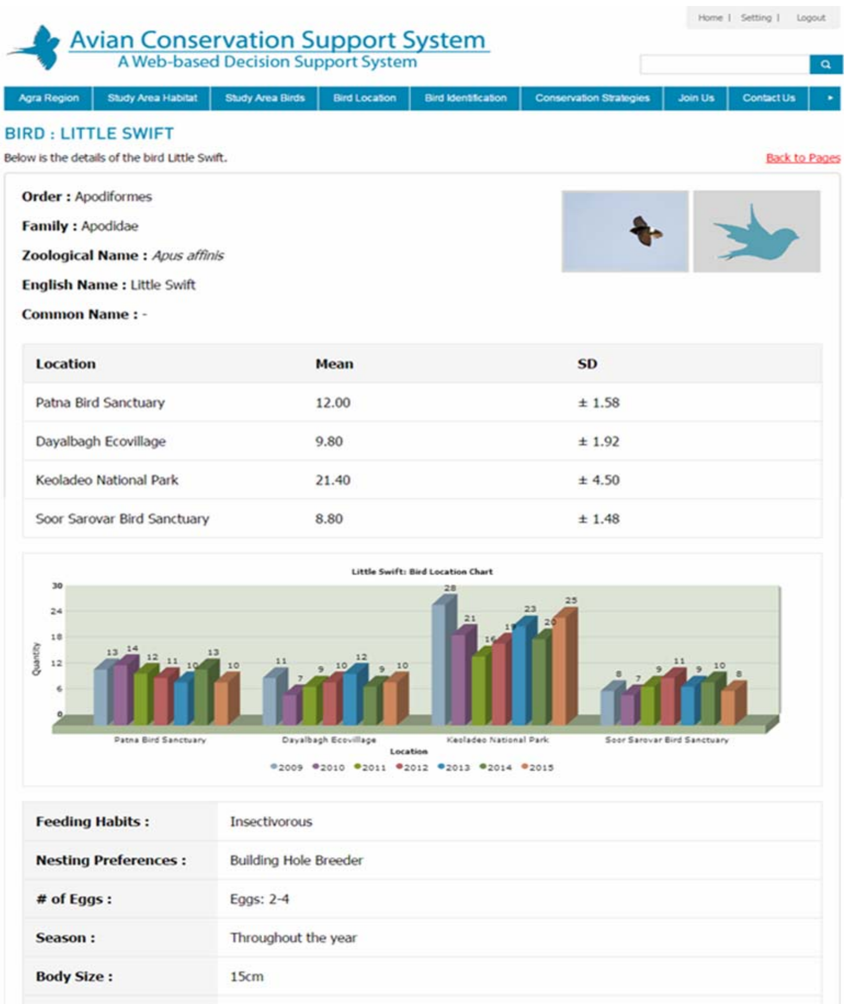
4.1 Survey design

The survey was designed to visit SBS for analysing (analysis was performed using the developed models and tools of ACDSS) the habitats and the birds.

4.1.1 Habitat

Immense field work was conducted by visiting the habitats of SBS multiple times. The study site was divided into quadrates to calculate the ecological data of the habitat. A total of 8 quadrates of one square kilometre were analysed in the habitat. The quadrates were compared to analyse different environmental variables (landscape structure, landscape heterogeneity, resources, and biotic information) in the habitat. The areas within the quadrates were then divided into strata, which were first individually counted and later were summed for the entire area.

Figure 6 The CVE-board (see online version for colours)



4.1.2 Birds

The birds were surveyed using direct count, focal and 1–0 scan sampling methods. The habitats of the study site were stratified into 1 × 1 km grids using standard point count method. The birds were recorded in four grids, each grid of 50 m. A total of eight sampling sites were laid down randomly within the grids of the site. Samplings were also made on seasonal basis and the field characteristics were noted down on ornithological sampling data sheet which included species, number of individuals, activities, micro-habitat, threats to birds and other details.

Sampling points were selected either at the edges of core zones or in buffer zones of SBS based on its importance level. The observations were also made according to the generic and species level. In case of line transect method; observation was performed through a straight line (50 m breadth and 500 m length). Random and direct counting was performed for several times.

In addition to birds' data, the spatial data of the study site was collected using a global positioning system (GPS) device. The collected data was organised in a shape file which helped in generating the maps of the study areas.

A number of discussions with experts were also considered as important source of information. An expert assessment (EA) team was formed for this purpose. The team included nine experts from different fields (academicians, policy makers, ornithologists, and field experts). Their responsibilities were:

- rating and ranking the questionnaires
- giving their valuable opinions to ensure the reliability of the data.

4.2 Observations

The survey process revealed:

1 The habitat types and sub-types

   Habitats of the study site were categorised into second and third-levels (Table 1). The REA Methodology was used to evaluate the semi-arid landscapes (comprising of tropical dry deciduous vegetation and humid subtropical climate) and their various environmental aspects (water quality, habitat fragmentation by barriers, presence of buffers zones, and habitats and biota of special concern). The overarching environmental changes within the habitats was also assessed which includes climate change, invasive species, and urban growth. The habitats were also assessed to understand their ecological condition, floral trends, and prospects for green reserves conservation and restoration.

   Suitability of above habitats was analysed on the basis of the criteria presented in Table 2.

2 Data of the Aves population

   A total of 305 bird species belonging to 22 orders and 59 families were observed at the study area. The sample site of SBS was divided in three complex habitat units: terrestrial (n = 188 birds), aquatic-terrestrial (n = 85 birds), and aquatic (n = 32 birds), where n is the number of counted birds.

The dominant order is Passeriformes. The living status includes native, migratory, local migratory and trespasser birds.

On the basis of the food habits, the birds were divided in six guilds: carnivores, carnivores-herbivores, carnivores-scavenger, herbivores, omnivores, and scavenger.

Table 1 Hierarchy of habitat at SBS

Level 1	*Level 2*	*Level 3*
Grassland	Dry savanna, moist savanna	
Scrubland	Xeric shrubs	Dense foliage cover, mid-dense foliage cover, sparse foliage cover
Forest	Tropical dry forest	Saplings, mature tree, old-growth
	Tropical seasonal forest	Saplings, mature tree
	Tropical thorn forests	Saplings, mature tree
Bare ground	Sand dunes, semi-arid plains	
Urban landscape	Farms, gardens	
Wetlands	River	Upstream, low stream, river bank
	Lake/pond	Perennial, annual, seasonal
	Marshes	Seasonal marshes, permanent marshes
	Canal	Perennial, annual, seasonal

Table 2 Description of the selected criteria

S. no.	*Criteria*	*Description*
1	Demographic conditions of the habitat	The present absent data of the species and frequency of rare species.
2	Temporal geography	It concerns the periodic geography of the pre and post habitat fragmentation.
3	Habitat quality	Considers habitat types that are suitable for a species.
4	Seasonal habitat change	
5	Food availability	Considers availability of food for the species considered in the patch.
6	Nesting availability	Considers availability of food for the species considered in the patch.
7	Proximity to water	Considers stagnant or running freshwater sources, e.g., ponds, lakes, rivers in the patch or within the travel distances of an organism.
8	Arbitrary threats to the habitat	Pressure and threats due to land use change and development activities, and all other unwanted activities impacting wildlife (in RAPPAM).

3 Identifying the threats

A list of possible disturbance gradients to the study site was compiled and presented to the EA team for analysing the applicability of each disturbance gradient to the birds at the study site. The disturbance gradients were grouped into threat classes. The resulting list displayed in Table 3, as agreed by the team, formed the basis for the risk assessment.

Table 3 Threat classes (few classes are shown)

Threat class	*Disturbance gradient*	*Type*	*Population component affected*
Wildlife crime	Poaching	Direct	Eggs, juveniles, adults
	Trading		Eggs, juveniles
	Hunting		Adults
Pollution	Vehicular pollution	Indirect	Juveniles
	Chemical run off		Eggs, juveniles
	Sewage and drain water		Eggs, juveniles

The threat classes were divided into two categories (a list of categories is presented in Table 4):

1 Threats direct to the birds (c_1): these are the threats that are directly affecting the birds.

2 Threats to the habitats (c_2): these are the threats affecting the habitats and thus are affecting the birds also.

Table 4 Threat categories

Bird threats	*Habitat threats*
Wildlife crime (WC)	Pollution (Pol)
Collision (C)	Habitat fragmentation (HF)
Emerging infectious disease (EID)	Human intervention (HI)
Human intervention (HI)	Tourism (T)
Tourism (T)	Over exploitation (OE)
Natural threats (NT)	Natural threats (NT)

The data obtained with survey design were utilised as input to five models as discussed in Sub-section 2 of Section 3.3.

4.3 Results

HSA was performed to compute the habitat suitability values (HSV). Suitability of habitats (given in Table 1) was analysed on the basis of the criteria presented in Table 2 (calculations are given in Appendix C).

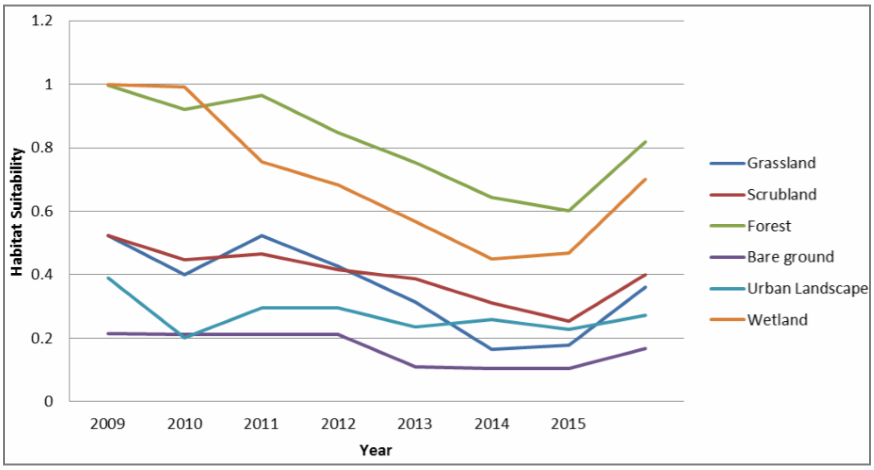
The HSV for study sites were calculated (presented in Table 5) based on the steps given in Appendix A.

Table 5 HSV for the study site

Grassland	*Scrubland*	*Forest*	*Bare ground*	*Urban landscape*	*Wetland*	HSV^{z_i}
0.3858	0.4084	0.7252	0.2778	0.3188	0.7976	0.4444

Figure 7 illustrates the suitability index for all the habitat types of the study site from 2009 to 2015. As can be seen from the Figure, the habitats of the study site were initially deteriorating, but gradually are improving.

Figure 7 Habitat suitability index (see online version for colours)



After analysing the habitats, the ADA model was used to assess the avian diversity of SBS which results in following:

a *Bio-geographical classification of birds*

The bio-geographical classification of birds was examined according to their spatial presence in the study area. The study of bio-geography was performed in two phases. First, the unbiased samples were taken and birds range was marked. In second phase, the ideal locations were studied where the chances of bird occurrence was better. Bird dispersion throughout the habitat was observed to understand changes in their habitat preferences and their living styles due to the complexity of different climates, food availability, and presence of other species and predators.

b *Diversity indices*

The diversity indices were calculated for the sample sites, the habitats, and the birds using *Shannon index* and *Pielou's* measure. The calculated diversity indices showed that the SBS is quite diverse. The diversity index H' for sample sites show that terrestrial is the most diverse habitat type at SBS. The water bodies are not able to sustain a large number of birds. Similarly H' for habitats shows that forest of the study site and wetland are the most diverse habitat types. In general the forests have high diversity because of tree species composition and the wetland have high diversity because of varieties of food sources and varied sources of foraging.

c *Population trend*

Decreasing trend was determined in 51% birds of Agra and increasing trend was observed in 42%, whereas 5% birds were observed stable, and 2% were considered as data deficient. Further, gradual decreasing trend was found only in about 40% birds.

d *Dominating birds*

Dominant birds were identified on the basis of their relative abundance which was used to check their population trend. It was found that out of 16 dominant birds, only one (house crow) is either increasing or is stable.

e *Focal species*

On the basis of computed focal score, 35 birds were identified focal in Agra. This listing helped in making specific strategies for the birds that need immediate protection.

Next, the TAss Model is used to analyse the threats at the study site. The computation of overall risk impact score $(ORI_{c_j}^{Z_i})$ for each category is given in Appendix D.

- *Threats to habitats*

  Mature tree, old growth, dry and moist savanna, dense foliage cover, gardens, low stream, upstream, annual and perennial canals are among constant threat of *habitat fragmentation* ($ORI_{c2}^{Z_1}$: 52.56), *human intervention* ($ORI_{c2}^{Z_1}$: 66.09) and over exploitation ($ORI_{c2}^{Z_1}$: 43.61) with significant level of risk impact.

- *Threats to birds*

  Human intervention ($ORI_{c2}^{Z_1}$: 74.12) and *wildlife crimes* ($ORI_{c2}^{Z_1}$: 65.50) are the main risks to the birds at this site.

  The computed average risk impact score and the analysed population trend helped in determining the local conservation status of the birds. The species were categorised as least concern (LC), vulnerable (VU), near threatened (NT), endangered (EN) and critically endangered (CR) for local status (as shown in Figure E1 of the Appendix E).

- *Management effectiveness*

  Management effectiveness of the site was also evaluated using RAPPAM method. The protected areas of the study site are biologically important as it possesses all the important factors like rich taxa, diverse vegetable, and strong food chain.

  The relatively high market value of the protected area land and the ease of access make the site vulnerable. Law enforcement is needed, along with the intensive monitoring of the site for abolition of illegal activities (Figure 8 and Figure 9). Degree of efforts for site restoration and mitigation should also be taken in account. The protected areas are suffering from laxity of staff and habitat negligence. Infrastructure development, related to wildlife protection and conservation are also needed.

- *Determined relationship between the HSV and the bird population and threats*

  The relationship between HSV and the bird population is shown in Figure 10. A rapid deterioration in the suitability value at all the habitats can be observed.

Figure 8 Vulnerability at the study site (see online version for colours)

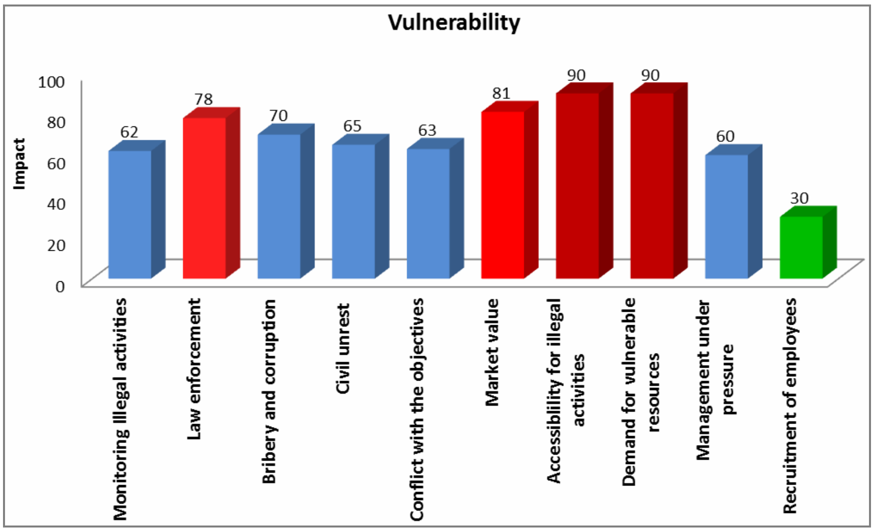


Figure 9 Management output (see online version for colours)

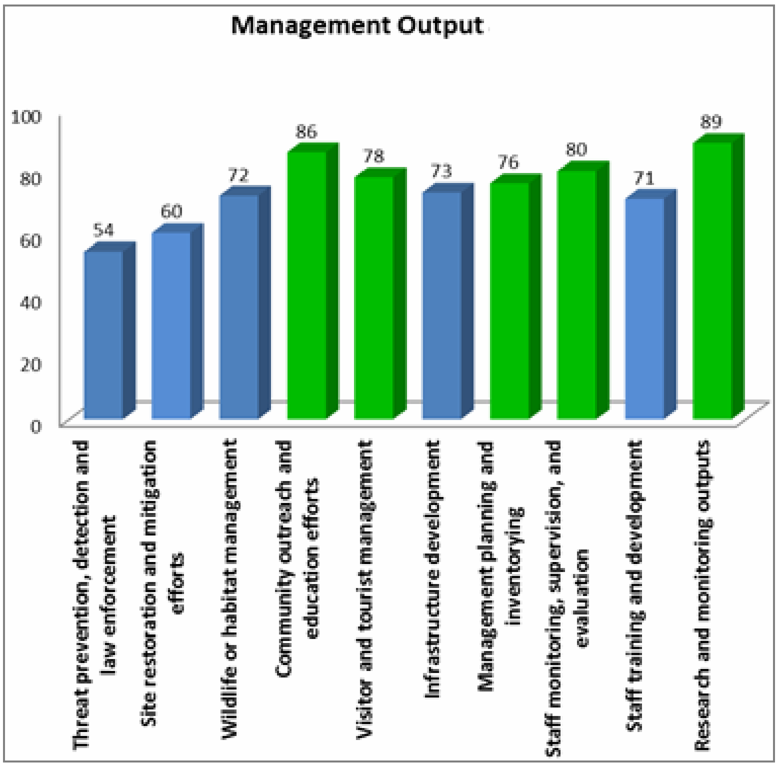


Table 6 SWOT matrices

Strengths (g_1)		*Weaknesses* (g_2)	
(p1)	*Dynamic habitat*: productive vegetation structure; controlled natural disturbance	(p7)	*Crowded*: mismanaged tourist crowd, surrounded by human habitations
(p2)	*Rich bird diversity*: diverse species; good number of native species population; good number of migratory birds		
(p3)	*Mixed vegetation*: long spread grassland, forest cover; aquatic plantation mosaic habitat	(p8)	*Drained water body*: problem of water fluctuation; Issues of continuous water stodgy source
(p4)	*Satisfactory infrastructure*: well boundary, gradient landscape; acceptable zoning research		
(p5)	*Knowledge oriented*: community schools for children; training centre for staff; base for wildlife research	(p9)	*Encroachment*: teeming buffer zone; rapid development around PA
(p6)	*Tourist friendly*: lodging facility; in park; eco guide facility		
Opportunities (g_3)		*Threats* (g_4)	
(p10)	*Area expansion*: chances to expend the area of lake; prospective forestation; increasing chance of boundary expend	(p14)	*Pollution*: chemical runoff from nearby agricultural land; noise pollution from nearby highway
(p11)	*Strong food pyramid within PA*: availability of fruit bearing trees; rich aquatic fauna and flora	(p15)	*Habitat disturbance*: timber cutting; livestock gracing
(p12)	*Better tourism*: chances to generate better tourism planning; area available for night safari	(p16)	*Misbalanced ecosystem*: species drift; reduction in vegetation
(p13)	*Rapid development*: increasing urbanisation; pacing industries		

On the basis of the computed HSV the bird population at SBS can be predicted using the following equation, where habitat types were treated as independent variable (x) and the total population as dependent variable (y):

$$y_{SBS} = 120x_{scrub} + 119.10x_{forest} + 302.43$$

Once the suitability and the threats were analysed, the ADC model was used to generate the strategies for effective C&M. The computations are specified in Appendix F.

Table 6 displays SWOT matrices for the study site. The identified SWOT parameters were grouped for making computation simple. This helped in generating the TWOS matrix (Table 7).

Figure 10 Suitability vs. population relation (see online version for colours)

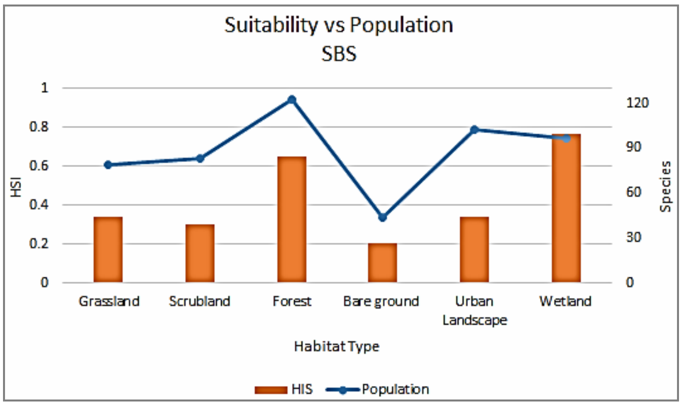


Table 7 TOWS matrix

	Strengths	*Weaknesses*
Opportunities	*SO: 'maxi-maxi' strategies*	*WO: 'mini-maxi' strategies*
	A_1: *strategy of restoration and reconciliation of the habitat*: examining the relationship between avian diversity population and habitat, this will generate the supportive data to identify suitable habitat for the species with precise habitat requirements of the bird.	A_2: *strategy of formulate and enact wildlife laws*: emphasising on new species that are recently fall under threatened bird list and generating critical laws for protecting neglected species. A_3: *strategy of conceptualise sustainable tourism approach*: redefining terms of sustainability in the area by over-arching paradigm, which incorporates new range of approaches for feasible tourism system
Threats	*ST: 'maxi-mini' strategies*	*WT: 'mini-mini' strategies*
	A_4: *strategy of maintaining large volume bird diversity*: bird diversity should be maintained by landscape management, driven by the novelty research efforts	A_5: *strategy of improving water policies for water birds protection*: integrating bird conservation concern to form dynamic wetland protection policy framework for better conservation and management

Finally the computed strategy judgment weights are:

Strategy judgment weights:

A1	0.2266
A2	0.197
A3	0.2027
A4	0.1802
A5	0.1935

Thus the formulated C&M strategies are:

- Restoration and reconciliation of the habitat (A_1).
- Conceptualise sustainable tourism approach (A_3).
- Formulate and enact wildlife laws (A_2).

5 Discussion

The framework of the developed ACDSS involves measuring and mapping the biodiversity, analysing the avian diversity, identifying and analysing the threats, and formulating conservation and management strategies. The usefulness of the system is shown by analysing the birds at SBS, Agra. Rather than focusing on a single dimension (like analysing specific specie of bird, or a specific zone), this system provides multi-dimensional analysis:

- implementing strategies for gradually changing conditions of habitats
- quantifying habitat eminence and computing functionality of habitat at different scales
- analysing population fluctuation
- identifying disturbance gradients that with time become threats
- building the strategies that are formulated on the basis of birds' habitat in the semi-arid region, presence and absence of the species, and the threats to diversity.

The outcome of this system shows that cooperative efforts, contingent funding, legal authority, and enrichment practices can help in making comprehensive plans for the conservation and management of the avian species.

DSSs have benefited from over two decades of development as a set of tools with many potential conservation applications (Downs and Horner, 2008; Poirazidis et al., 2011; Guisan et al., 2013; Sutti et al., 2017), but have remained largely the purview of academic studies. The possible reason may be the gap between the DSS modeller and the decision maker.

The formulation of policies, goals, planning, co-ordination, balancing, prioritising different initiatives and actions regarding conservation and management can only be done by bringing C&M stakeholders at a common platform, thus bridging the existing gap between the decision maker and the modellers. The ACDSS is an effort in this direction.

6 Conclusions

This study was motivated by exploring and observing that redevelopment of human dominative environment can play an important role in conserving the Aves diversity. The developed DSS is an innovative tool in the sense that it combines three fields (DSS, operations research, and wildlife), gives decision based on the spatial and non-spatial data of a semi-arid region, and can be applied to analyse the avian diversity and suggest conservation measures for any semi-arid region.

The developed system provides

- a centralised repository to ensure longevity of data
- improved availability of data for scientific research
- advanced new analysis and visualisation techniques to analyse bird population
- an interactive decision-making tools for C&M stakeholders.

The limitations and future scope of the study are:

- The study was performed on sample population to check the presence absence of the species. This study can be extended for the entire population.
- The present system deals with conserving birds of semi-arid habitat, which could be extended for birds of other areas also.

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Appendix A

Decision support tools

A.1 Rapid ecoregional assessment

Rapid ecoregional assessment (REA) (Carr et al., 2013) synthesises exiting information for examining the ecological values, conditions, and trends within large connected areas that have similar environmental characteristics.

A.2 Rapid Assessment and Prioritisation of Protected Area Management (RAPPAM) Methodology

RAPPAM methodology (Ervin, 2003) is used for analysing and comparing the importance, and the management effectiveness of the protected areas.

A.3 Habitat suitability analysis

HSA is performed to determine habitat aptness and species' distributions at the study site by computing habitat suitability value (HSV). The HSV of the study site (z_i), represented by HSV^{z_i}, is computed by combining modified Delphi method, analytical hierarchy process (AHP) and simple additive weighting (SAW) Approach. HAS provides habitat information which can be used for impact assessment and habitat management. The suitability analysis is performed on the basis of biological surveys of the green reserves and the management priorities within the habitat.

The inputs (species data and biotic-abiotic parameters), habitat variation (spatial and temporal variability), and sampling variation (average, relative importance and habitat scores) were quantified for accuracy in HSVs results.

To compute the HSV, first the hierarchy of the habitat-scales is developed. Next, the Modified Delphi exercise is performed to score the habitat scales by taking into consideration the environmental variables (measures of climate, landscape structure, landscape heterogeneity, resources, and biotic information). The relative importance of the habitats was evaluated in next phase. Pairwise comparisons between all habitat factors were performed using Saaty's (1980) nine-point scale (Table A1) to calculate the Habitat Suitability Weights $(HW_h^{z_i})$ for habitat scale *h* using AHP.

Table A1 Scale for pairwise comparison

Intensity of importance	*1*	*3*	*5*	*7*	*9*	*2, 4, 6, 8*
Definition	Equal	Moderate	Strong	Very strong	Extreme	Intermediate value

Source: Saaty (1980)

A weighted linear combination approach was then used to evaluate the suitability value $(SV_h^{z_i})$ using equation (1).

$$SV_h^{z_i} = \sum_i HW_h^{z_i} \times x_h^{z_i} \tag{1}$$

where $x_h^{z_i}$ is the score of habitat scale *h* for the study sites (z_i).

Finally, the HSV was calculated using equation (2) where *n* represents different types of habitats.

$$HSV^{z_i} = \sqrt[n]{\prod_{h=1}^{H} SV_h^{z_i}} \tag{2}$$

A.4 RIA methodology

RIA methodology is formed for risk assessment of threats. The methodological steps of RIA are as follows:

Step 1 Identifying the threat classes for each category c_j.

Step 2 Scoring the threats classes for each c_j by expert assessment (EA) team using five-point scale (high-5, middle-3, and low-1) to get the threat influence score $(TI_{c_j}^{z_i})$ at each study site (z_i), $i = 1, 2, \ldots, 5$.

Step 3 Fuzzy pairwise comparison of threat class for each c_j to determine threat influence weights (TW_{c_j}) using following sub-steps:

a Conversion of fuzzy scale in triangular fuzzy number $\tilde{a}_m = (a_{1m}, a_{2m}, a_{3m})$ using nine-point fuzzy scale (Table A2). The triplet (a_{1m}, a_{2m}, a_{3m}) represents the lower, middle and upper triangular fuzzy number, *m* represents the threat class.

b Formation of fuzzy decision matrix to compute fuzzy decision weights $(\tilde{F}_m)$ using following equation (3).

$$\tilde{F}_m = \left(\frac{v_{1m}}{\sum_{i=1}^{p} v_{3m}}, \frac{v_{2m}}{\sum_{i=1}^{p} v_{2m}}, \frac{v_{3m}}{\sum_{i=1}^{p} v_{1m}} \right) \tag{3}$$

where $v_m = \left(\prod_{m=1}^{M} \tilde{a}_m\right)^{1/M}$.

c Computation of decision weights (D_m) for the fuzzy decision weights using equation (4) as given below.

$$D_m = \left[\beta c_\alpha \left(F_{ml}\right) + (1-\beta) c_\alpha \left(v_{mr}\right)\right], 0 \le \beta \le 1, 0 \le \alpha \le 1 \tag{4}$$

where $c_\alpha(F_{ml}) = [(F_{m2} - F_{m1})\alpha + F_{m1}]$ represents the left value of α-cut for $\tilde{F}_m$ and $c_\alpha(F_{mr}) = [F_{m3} - (F_{m3} - F_{m2})\alpha]$ represents the right value of α-cut for $\tilde{F}_m$.

d Determining the threat influence weights (TW_{c_j}) by normalising D_m.

Table A2 Nine-point fuzzy scale

Fuzzy scale	*Triangular fuzzy scale*	*Description*
$\tilde{1}$	(1,1,1) if diagonal (1,1,3) for equal importance	Equal importance
$\tilde{3}$	(1, 3, 5)	Moderate importance of one over another
$\tilde{5}$	(3, 5, 7)	Strong importance of one over another
$\tilde{7}$	(5, 7, 9)	Very strong importance of one over another
$\tilde{9}$	(7, 9, 9)	Extreme importance of one over another
$\tilde{2}, \tilde{4}, \tilde{6}, \tilde{8}$	(1, 2, 4), (2, 4, 6), (4, 6, 8), (6, 8, 9)	Intermediate values

Step 4 Determining the site-risk impact weights $(ZRW_{c_i}^{z_j})$ for the sites using following equation (5).

$$ZRW_{c_i}^{z_j} = TI_{c_j}^{z_i} \times TW_{c_j} \tag{5}$$

Step 5 Scoring the threat classes for each category by the EA team according to their timing, range and severity, in relation to how likely they 'trigger' the bird species' mortality at the study sites, to get threat trigger scores (TS, RS, SeS) of sites for each category. The scores are given in Table A3, Table A4, and Table A5.

Table A3 Timing of threat

Timing of threat	*Timing score (TS)*
Happening now	5
Likely in short-term (within four years)	3
Likely in long-term (beyond four years)	1
Past (and unlikely to return) and no longer limiting	0

Table A4 Range of threat

Range of threat	*Range score (RS)*
Whole population/area (>90%)	5
Most of population/area (50–90%)	3
Some of population/area (10–50%)	1
Few individuals/small area (<10%)	0

Table A5 Severity of threat

Severity of threat	*Severity score (SeS)*
Rapid deterioration (>30% over seven years)	5
Moderate deterioration (10–30% over seven years)	3
Slow deterioration (1–10% over seven years)	1
No or imperceptible deterioration (<1% over seven years)	0

Step 6 Scoring the threat classes using the five-point scale by the EA team to get the species threat influence score $(STI_{c_{1k}}^{z_i})$ and habitat threat impact score $(STI_{c_{2l}}^{z_i})$; where *k* represents the number of species, and *l* is the number of the habitat sub-types.

Step 7 Computing the total species threat impact score $(TSTI_{c_{1k}}^{z_i})$ and total habitat threat impact score $(TSTI_{c_{2k}}^{z_i})$ with the help of equations (6) and (7).

$$TSTI_{c_{1k}}^{z_i} = STI_{c_{1k}}^{z_i} \times (TS + RS + SeS) \tag{6}$$

$$TSTI_{c_{2l}}^{z_i} = STI_{c_{2l}}^{z_i} \times TS_{c_i}^{z_i} \tag{7}$$

Step 8 Calculating the overall risk impact score $(ORI_{c_j}^{z_i})$ for each category using equations (8) and (9).

$$ORI_{c_1}^{z_i} = TSTI_{c_{1k}}^{z_i} \times ZRW_{c_j}^{z_i} \tag{8}$$

$$ORI_{c_2}^{z_i} = TSTI_{c_{2l}}^{z_i} \times ZRW_{c_j}^{z_i} \tag{9}$$

A.5 SFS (SWOT-FAHP-SAW) methodology

SFS methodology is a foundation for evaluating the internal potentials and limitations, and the likely opportunities and threats from the external environment quantitatively.

SFS methodology is developed as an integration of strengths, weaknesses, opportunities and threats (SWOT) analysis, Fuzzy AHP (FAHP), and SAW approach for identifying and prioritising the strategies for a goal. With this methodology, the internal and external parameters, required for analysing a problem quantitatively, are identified and are used to form a TOWS matrix to develop:

- Offensive strategies (SO: including strengths to exploit opportunities).

- Reactive strategies (SW: aims to overcome the weakness by taking advantages of opportunities).
- Defensive strategies (ST: strengths to avoid threats).
- Adaptive strategies (WT: reduce the weakness to avoid threats).

Action plans were then generated to implement the strategies. Following are the phases of developed SAS methodology:

Phase 1 *Identification of SWOT parameters and alternative strategies*

Step 1 Identification of SWOT parameters (p_m, $m = 1, \ldots, M$).

Step 2 Organising these parameters in a SWOT matrix under each group (g_d, $d = 1, 2, 3, 4$).

Step 3 Establishment of TOWS Matrix to develop strategies (A_s).

Phase 2 *Prioritisation of SWOT groups and parameters*

Step 1 Rating and ranking of g_d and p_m using pairwise-comparison (PC) questionnaire.

Step 2 Generation of PC matrix for each g_d and their corresponding p_m using equations (10) and (11).

$$g_d^R = \left(\prod_{q=1}^{Q} x_{dq} \right)^{1/q} \tag{10}$$

$$p_m^R = \left(\prod_{q=1}^{Q} y_{mq} \right)^{1/q} \tag{11}$$

where x_{dq} is pairwise rating of the d^{th} group by q^{th} respondent, and y_{mq} is pairwise rating of the m^{th} parameter by q^{th} respondent.

Step 3 Computation of group judgment weights (gW_d) and parameter judgment weights (pW_m).

Step 4 Computation of global judgment weights (pJ_m^w) using following equation (12).

$$pJ_m^w = gW_d \times pW_m \tag{12}$$

Phase 3 *Rating alternative strategies (A_s) using following step:*

Step 1 Linguistic ranking of A_s based on the p_m.

Step 2 Conversion of linguistic terms in triangular fuzzy number $(\tilde{a}_m)$ using nine-point fuzzy scale as given in Table 2.

Step 3 Formation of fuzzy decision matrix to compute fuzzy decision weights $(\tilde{F}_m)$ using equation (4).

Step 4 Computation of the decision weights (D_m) using equation (5).

Step 5 Computation of SWOT weights using the following equation (13).

$$SW_m = pJ_m^w \times D_m \tag{13}$$

Phase 4 Computation of strategy judgment weights (SJ_s^w)

The strategy judgment weights (SJ_s^w) are computed using the equation (14), as given below.

$$SJ_s^w = \sum_{m=1}^{M} SW_m \tag{14}$$

Appendix B

Case-based reasoning process

Steps in case-based reasoning

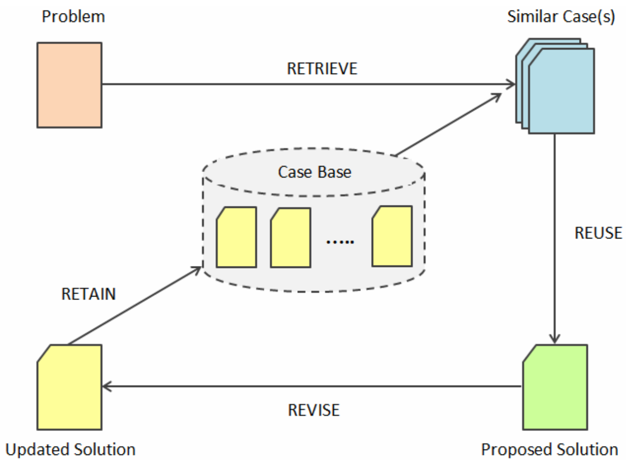
The solution of a new problem involves four steps, as shown in Figure B1.

1 *Retrieve*: when a new problem (case) occurs, it is compared with existing cases in the case-base and most similar case(s) is/are selected. Similarity can be assessed based on similarity of each feature, which depends on the feature value. If the degree of similarity of the feature (d_c, c is number of cases) is 0 (not similar) or 1 (very similar), and priority weight of the feature is w_c (value ranges from 0 to 1) then the similarity is computed as:

$$\text{Similarity} = \frac{\sum_{c=1}^{C} w_c \times d_c}{\sum_{c=1}^{C} w_c} \tag{15}$$

2 *Reuse*: the retrieved (similar case(s) is/are reused to suggest as the solution of new problem.

Figure B1 Steps in case-based reasoning process (see online version for colours)



Source: Aamodt and Plaza (1994)

3 *Revise*: the solution which was presented by utilising the retrieved cases is evaluated according to its level of success. If the solution is fully successful then there remains no need for revision. If however, the solution failed to achieve its required goal, then it is revised according to certain rules.

4 *Retain*: the new solution (resulting experience) as a new case is retained in case-base to learn and refine the knowledge for future applications.

Appendix C

Analysis of suitability of habitats

The suitability of habitats was scored linguistically on the basis of the criteria specified in Table C1. For example, the demographic condition of grassland was scored very high, and so on. This scoring was then converted to numeric data as shown in Table C2 to get $x_{h_j}^{z_i}$, as presented in Table C3.

Table C1 Modeling parameters and their attributes

Parameters	*Attributes of parameters*
Population count	Number of sites, years, and number of counted individuals
Birds demography	Population abundance, living status
Presence/absence data	Occurrence at site, occurrence in month
Threats	Threats to birds, threats to habitats

Table C2 Scoring scheme for the criteria

Value	*1*	*.75*	*.5*	*.25*	*.1*
Term	Very high	High	Medium	Low	Not suitable

Table C3 $x_{h_j}^{z_i}$ scoring

Grassland	*1*	*Dry Savanna*	*0.75*		
		Moist Savanna	1		
Scrubland	1	Xeric Shrubs	1	Dense foliage cover	1
				Mid-dense foliage cover	0.75
				Sparse foliage cover	0.75

Next, the relative importance of the habitats were scored and were averaged to find the habitat suitability weights $(HW_h^{z_i})$ as shown in Table C4. Similarly, the matrices for all the scales were obtained.

Table C4 Relative importance matrix for first scale habitats (after averaging)

	Grassland	*Scrubland*	*Forest*	*Bare ground*	*Urban landscape*	*Wetland*	*HS weights*
Grassland	1.00	0.42	0.15	3.43	1.86	0.16	0.076
Scrubland		1.00	0.22	3.71	0.45	0.20	0.087
Forest			1.00	6.43	5.14	1.29	0.361
Bare ground				1.00	0.22	0.16	0.032
Urban land					1.00	0.15	0.09
Wetland						1.00	0.354

These weights are used to calculate HSV (HSV^{z_i}).

Appendix D

Computation of overall risk impact score

The threat categories are scored for each category (Table D1), which resulted in threat influence score $(TI_{c_j}^{z_i})$, as shown in Table D2.

Table D1 Threat classes scored (for birds)

	SBS
WC	H
C	M
EID	M
HI	H
T	H
NT	H

Table D2 $TI_{c_j}^{z_i}$

	SBS
WC	5
C	3
EID	3
HI	5
T	5
NT	5

Next, threat influence weights (TW_{c_j}) were determined (listed in Table D3) using the steps specified in Appendix A.

Table D3 Threat influence weights (TW_{c_j})

WC	0.2911
C	0.0821
EID	0.1035
HI	0.3294
T	0.1177
NT	0. 0762

The site-risk impact weights $(ZRW_{c_i}^{z_j})$, given in Table D4, were computed using equation (5) given in Appendix A.

Table D4 $ZRW_{c_i}^{z_j}$ for threat (for birds)

WC	*C*	*EID*	*HI*	*T*	*NT*
1.456	0.246	0.311	1.647	0.588	0.381

Next, the threat classes were scored by the EA team to get the species threat influence score $(STI_{c1k}^{z_i})$ which was used to calculate total species threat impact score $(TSTI_{c1k}^{z_i})$, presented in Table D5, using equation (6) given in Appendix A.

Table D5 $TSTI_{c1k}^{z_i}$ for few birds

Bird code	*Species*	*WC*	*C*	*EID*	*HI*	*T*	*NT*
PSAc247	Bank Myna	11	7	9	39	75	7
AAAn001	Bar headed goose	33	35	9	13	15	35
PHHi193	Barn swallow	11	7	27	13	15	7
TTTu295	Barred buttonquail	55	7	9	13	15	7
PPPl222	Baya weaver	11	7	9	13	15	7
FAAc116	Besra	11	7	9	13	75	7

Using the equation (8) of Appendix A, the overall risk impact scores $(ORI_{c_j}^{z_i})$, listed in Table D6, were calculated for category 1.

Table D6 $ORI_{c_j}^{z_i}$ for few birds

Bird code	*Species*	*WC*	*C*	*EID*	*HI*	*T*	*NT*
PSAc247	Bank Myna	9.607	1.723	0.932	38.545	44.130	1.600
AAAn001	Bar headed goose	28.822	8.615	0.932	12.848	8.826	7.998
PHHi193	Barn swallow	9.607	1.723	2.795	12.848	8.826	1.600
TTTu295	Barred buttonquail	48.036	1.723	0.932	12.848	8.826	1.600
PPPl222	Baya weaver	9.607	1.723	0.932	12.848	8.826	1.600
FAAc116	Besra	9.607	1.723	0.932	12.848	44.130	1.600

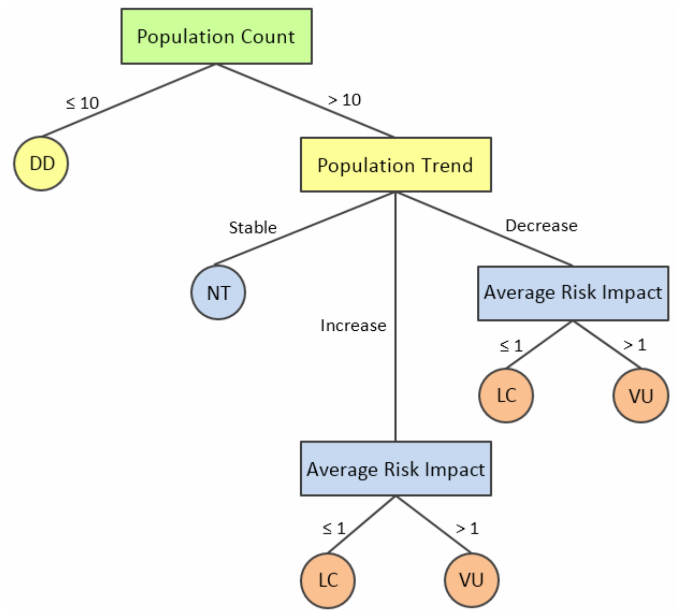
Similarly, the $ORI_{c_j}^{z_i}$ were computed for all habitats and all bird guilds. These values helped in determining the major threats to habitats and bird of Agra.

Appendix E

Determining conservation status

The global conservation status of the birds of the study site is determined as per the IUCN guidelines. The local conservation status of the birds is determined on the basis of population trend, and average risk impact score (Figure E1). The species are categorised as least concern (LC), vulnerable (VU), near threatened (NT), endangered (EN) and critically endangered (CR) for local status.

Figure E1 Criteria for determining local conservation status (see online version for colours)



Appendix F

Computation of strategy judgment weights

Phase 1 Identification of SWOT parameters and alternative strategies

The opinion of EA Team helped in identifying parameters (p_m) relevant to internal and external C&M environment. These parameters were categorised into four groups (g_d): strengths, weaknesses, opportunities and threats. A SWOT matrix was formed using g_d together with their corresponding p_m. Table F1 displays SWOT matrices for the study site. The identified SWOT parameters were grouped for making computation simple.

Next the EA team investigated the alternative strategies based on TOWS matrix (Table 7) to identify offensive strategies, reactive strategies, defensive strategies, and adaptive strengths.

Phase 2 Prioritisation of SWOT groups and parameters

Pairwise-comparison (PC) ranking was performed for the g_d and p_m. These were then averaged to find the PC matrix for each group:

Table F1 PC matrix for g_1

	p_1	p_2	p_3	p_4	p_5	p_6	*Weights*
p_1	1.000	2.250	3.000	4.880	5.000	3.130	0.375
p_2		1.000	1.000	3.880	2.880	5.000	0.219
p_3			1.000	2.000	3.000	4.750	0.182
p_4				1.000	2.880	2.500	0.102
p_5					1.000	3.130	0.073
p_6						1.000	0.049

Similarly the PC Matrices were generated for g_2, g_3, and g_4. These gave the local weights for all the SWOT parameters (Table F2).

Table F2 pJ_m^w of SWOT parameters

SWOT groups	*Weights*	*SWOT parameters*	*Local weights*	*Global weights*
(g_1) strengths	0.469	(p1) dynamic habitat	0.375	0.1759
		(p2) rich bird diversity	0.219	0.1027
		(p3) mixed vegetation	0.182	0.0854
		(p4) satisfactory infrastructure	0.102	0.0478
		(p5) knowledge oriented	0.073	0.0342
		(p6) tourist friendly	0.049	0.0229
(g_2) weaknesses	0.132	(p7) crowded	0.532	0.0702
		(p8) drained water body	0.331	0.0437
		(p9) encroachment	0.137	0.0181
(g_3) opportunities	0.284	(p10) area expansion	0.553	0.1571
		(p11) strong food pyramid within PA	0.292	0.0829
		(p12) better tourism	0.155	0.0440
(g_4) Threats	0.114	(p13) rapid development	0.478	0.0545
		(p14) pollution	0.157	0.0179
		(p15) habitat disturbance	0.095	0.0108
		(p16) misbalanced ecosystem	0.270	0.0308

Phase 3 Rating alternative strategies A_s

Linguistic ranking of A_s based on the p_m was performed which were converted into triangular fuzzy number, for example, the linguistic term VH will be converted to triangular fuzzy number $\tilde{9} = (7, 9, 9)$. The terms in the triplet (a_{1m}, a_{2m}, a_{3m}) represent the lower, middle and upper triangular fuzzy number respectively. Fuzzy decision matrix was formed to compute fuzzy decision weights (Table F3). These were then used to calculate $c_\alpha(F_{il})$, $c_\alpha(F_{ir})$.

Table F3 Fuzzy decision matrix

	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8
A1	0.073	0.100	0.127	0.086	0.086	0.100	0.046	0.023
A2	0.049	0.049	0.049	0.024	0.024	0.024	0.128	0.108
A3	0.048	0.048	0.048	0.024	0.024	0.024	0.126	0.107
A4	0.059	0.116	0.072	0.085	0.116	0.099	0.045	0.023
A5	0.112	0.112	0.070	0.082	0.095	0.095	0.044	0.044
	p_9	p_{10}	p_{11}	p_{12}	p_{13}	p_{14}	p_{15}	p_{16}
A1	0.023	0.117	0.100	0.100	0.046	0.023	0.046	0.046
A2	0.128	0.108	0.108	0.128	0.049	0.024	0.024	0.049
A3	0.126	0.126	0.107	0.126	0.048	0.024	0.024	0.048
A4	0.023	0.045	0.045	0.023	0.099	0.085	0.085	0.116
A5	0.023	0.023	0.044	0.023	0.095	0.112	0.082	0.112

Next, global judgment weights are multiplied by decision weights using equation (14) to get SWOT weights. Finally, the strategy judgment weights are computed using equation (15). Next the strategies were also generated.

Strategy judgment weights:

A1	0.2266
A2	0.197
A3	0.2027
A4	0.1802
A5	0.1935