

# Impact of Climate Change on Species Distribution, Migration Patterns, and Reproductive Behavior in Wildlife

P. A. Suryawanshi<sup>1</sup>, S. D. Thakare<sup>2</sup>, Dr. S. P. Khodake<sup>3</sup>, Dr. D. S. Patil<sup>4\*</sup>

<sup>1</sup>Ph.D. Research Scholar, PES's Karm. A. M. Patil Arts, Commerce and Kai. Annasaheb N. K. Patil Science Senior College, Pimpalner

<sup>2,3</sup>Assistant Professor, PES's Karm. A. M. Patil Arts, Commerce and Kai. Annasaheb N. K. Patil Science Senior College, Pimpalner

<sup>4\*</sup>Assistant Professor, Nandurbar Taluka Vidhayak Samiti's G. T. Patil Arts, Commerce and Science College, Nandurbar

**\*Corresponding author; Dr. D. S. Patil**  
[patildhananjay2007@gmail.com](mailto:patildhananjay2007@gmail.com)

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## **Abstract:**

Climate change is now being seen as one of the major factors of ecological change, which affects wildlife distribution, migration patterns, and the reproductive behaviors of various ecosystems. The paper will examine interactive effects of climate change on nature, species distribution, migration dynamics and reproductive behavior, using the long-term climate data (1980–2024), the species occurrence facts, the migration follow-ups and the evidence of reproductive phenology in several taxa of wildlife. Species distribution modeling revealed considerable poleward and altitudinal changes, terrestrial species with a range shift distance of 1725 km/decade and montane species with an altitude shift of 11 19 m/decade. Sensitivity of the climate-sensitive groups to habitat decrease was more evident with the amphibians, which have shrub habitats reduced by 17-22%. Migration measures demonstrated not only progression of spring migration by 6-11 days but also decreased length of migration paths ( some 220 km ) and times in stopover (3-4 days). Earlier breeding indicated through the reproductive assessments by 512 days but with reduced reproductive performance with a 115% decline in nesting success along with a 15.8% decrease in juvenile survivability through phenological disjunction with food. The comparison with related literature affirms that there is good correspondence with the global trends in addition to pointing out the increased disruption of the past decades. In general, these findings indicate that climate change is a multidimensional stressor, as it can simultaneously impair habitats availability, movement behavior, and reproductive success and increase long-term risks to population stability and biodiversity conservation among the wildlife.

**Keywords:** Climate change; Species distribution; Migration patterns; Reproductive behavior; Wildlife ecology

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## **I. INTRODUCTION**

Global warming has become one of the biggest agents of ecological change in the 21 st century that has resulted in far reaching impacts on the populations of wildlife on the land, freshwater and marine life. The global warming, changing rainfall patterns, rising tendency of extreme weather conditions, and changing seasonal trends are redefining the environmental surroundings on which the species rely to survive and multiply. Given this fact, geographic distribution of numerous species of wildlife, migration patterns, and reproduction timing are being recorded with significant changes [1]. Among the most obvious examples of biological reactions to climate change, the change in the ranges of species should be mentioned. Many of these taxa are shifting either northwards or upward in quest to find favorable climatic conditions. As an example, polar-dependent species like the Polar Bear species are losing areas of essential sea-ice, whereas montane species are being contracted in their ranges because of a lack of space in which to migrate upwards [2]. Such distributional takes can upset the prevailing ecological habitats, enhance abiotic rivalry, and augment the danger of local annihilation.

Migration patterns are also highly affected by climate change especially on the birds, fish and large mammals [3]. The time and pathways of migrations, as well as migration destinations depend on temperature shift and food supply. The Monarch Butterfly and the Arctic Tern are examples of migratory species that are becoming exposed to increasing phenological differences up, in which migration does not coincide with the availability of the resource at the sites of breeding or stopover. Moreover, climatic cues have a high level of sensitivity in reproductive behavior. The increase of temperatures causes earlier breeding in amphibians, the birds and mammals, whereas disturbed rainfall distribution has some impact on the breeding success and survival of the offspring. Those species whose reproduction cycles are limited or dependent on temperature, including most reptiles, are more susceptible than others and it brings into question the sustainability of populations on a long-term basis. Knowledge on how climate change affects species distribution, migration and reproduction is important in predicting the response of biodiversity towards climate change, determining conservation

\*Author for Correspondence: [patildhananjay2007@gmail.com](mailto:patildhananjay2007@gmail.com)

policies, adaptive wildlife management policies in a very dynamic global environment.

## II. RELATED WORKS

The effects of climate change on the distribution of species, movement trends, and biological resilience of a wide range of taxa and ecosystems have been studied recently. ENM has become a trendy methodological framework that measures historical, present and future species-climate interactions. Indicatively, Huang et al. [15] used ENM to monitor the past population changes and future climate response of *Nepenthes mirabilis* in southeast Asia. Their results indicated a large contraction of habitats with future warming conditions, with a high sensitive period to the changes in temperature and precipitation to narrow-adapted species. Likewise, Li et al. [18] redid write up the distribution of *Platycodon grandiflorus* between the final interglacial setting and future models, which indicated poleward and altitude shifts in line with the long-term climate variations. Structural and functional changes in forest ecosystems and keystone plant communities have also been demonstrated to be detection of climate modification. The study conducted by Iulian et al. [16] on temperate oak forests has found that more climatic variability decreased the resilience of forests, causing a decrease in regeneration and susceptibility to extremely detrimental events such as droughts and heatwaves. These results correspond to the overall synthesis by Melese [25], who pointed out climate change as the primary cause of biodiversity loss and ecosystem instability, and cascade effects on food security and ecosystem services in a global scale.

Climatic stressors have significant effects on animal taxa especially the migratory and the ectothermic species. Kumar et al. [17] surveyed effects of climate change on the migration of birds and determined notable gains in the timing of their migrations, changes in their migration routes, and upsets in hormone regulation on reproduction fitness. The results of the empirical study by Maciag and Remisiewicz [22] serve as an additional indication of these trends as the authors reveal that the phenology of Goldcrest and Firecrest species migration is changing at the population level with the increased spring temperatures along the southern Baltic coast, being highly correlated. These researches highlight the susceptibility of the migratory birds to the mismatch between migration and food phenologies. There has also been a wide study on reptiles and insects which are very sensitive to thermal conditions. Li et al. [19] evaluated the presence of conservation of reptiles under the conditions of global climate change and indicated a high extinction of the highest temperatures depending on sex determination and habitat fragmentation. Simultaneously, Liu et al. [21] indicated strong shifts in the ranges of *Papilio xuthus* when climate warmed and expansion to high latitudes became easier and habitat unfit in the southern areas. The findings underpin fears that climate change can be able to advantage and impose threats to various species concomitantly basing on ecological plasticity.

There is growing interest on large mammals and Arctic systems as a result of high rates of warming. The cascading effects of warming in the Arctic had been reported in a journal article by Malik et al. [23], where the authors showed the spread of habitat-loss due to climate across trophic levels with global implications. Based on a systematic map of ungulate studies in North America, Malpeli et al. [24] unveiled substantial reasons of climate variability as related to distorted migration, success, and reproduction. In parallel with this finding, Morel et al. [26] highlighted the importance of the memory-based direction finding when it comes to the animal of the elephant, arguing that changes in the landscape due to climate could disorient previously learned migratory pathways that help to survive. In general, the current evidence is unanimous that climate change alters the distribution of species, their migration patterns, and population resistant to climate changes. Nevertheless, even in many studies, single taxa or specific ecological response are the target of study. This creates a research gap that is considered by the current research that combines distribution, migration, and reproductive responses among various groups of wildlife to give a more in-depth analysis of the effects of climate change.

## III. METHODS AND MATERIALS

### Study Framework and Scope

The research has utilized an interdisciplinary ecological research approach to test the effects of climatic change on the distribution of species, their migration mode and reproductive behavior among the wildlife. The approach combines the long-term climate observations, the records of biodiversity occurrences, the data on movement ecology, the indicators of reproductive phenology [4]. The methodology will be used to elicit spatial and ecological behaviours (time) of terrestrial and migratory wildlife species. Special focus was laid on multi-taxa representation, mammals, birds, amphibians and insects, to make them cover a wide ecological spectrum [5].

### Data Sources

#### Climate Data

The variables of climate had been acquired using globally acclaimed datasets, both historical and projected climate records. The important variables that were taken into consideration included:

- Mean annual temperature (°C)
- Seasonal temperature extremes
- Annual and seasonal precipitation (mm)
- Frequency of extreme weather events (heatwaves, droughts)

The data about climate were obtained at a spatial resolution of 1km<sup>2</sup> and aggregated during intervals of 20 years in time to reduce the variations of climate that are short-term.

#### Biological and Ecological Data

Information about the occurrence and distribution of species was obtained by the use of biodiversity databases, peer reviewed ecological research, and long term monitoring programs. The sources that obtained the migration data were satellite telemetry, GPS tagging research, and bird banding data, whereas the reproductive behavior data were obtained through field observations, breeding surveys, and phenological data [6].

**Study Species Selection**

In the selection of the species, the following criteria were followed:

1. Climatic variable sensitivity.
2. Ecological data on long-term availability.
3. Ecological and conservation values.
4. Sample of various trophic levels and habitats.

Both migrant and non-migrant species were represented that allowed making a comparison between climate-restricted responses.

**Species Distribution Analysis**

Change in geographic range in changing climatic conditions was evaluated using Species Distribution Models (SDMs). The predictive modeling methods were used on presence-only and presence-absence data to measure the habitat suitability [7].

Temperature, precipitation, elevation, and vegetation cover were also considered as environmental predictors. Calibration of the models was done on 70 percent of the data with 30 percent of the data being set aside to do validation. Two metrics, the Area Under the Curve (AUC) and True Skill Statistic (TSS) were used to evaluate model accuracy.

**Table 1: Climate and Ecological Variables Used in Species Distribution Analysis**

Category	Variable	Unit	Ecological Relevance
Temperature	Mean annual temperature	°C	Determines thermal tolerance
Temperature	Seasonal temperature range	°C	Influences habitat suitability
Precipitation	Annual precipitation	mm	Affects vegetation and prey availability
Extreme events	Heatwave frequency	events/year	Impacts mortality and reproduction
Habitat	Vegetation index (NDVI)	Index	Proxy for food and shelter availability

**Migration Pattern Assessment**

The movement spatiotemporal data were used in analyzing the migration patterns. In the case of migratory species, migration phenology (period of time), route length and duration of stopover were assessed. The comparison between past migration dates and present data was made in order to determine the changes in departure and arrival dates.

Geographic Information Systems (GIS) has been used to map movement paths and the use of kernel density estimation was used to determine central migratory paths [8]. To determine the correlations between the changes in migration and climate variables, especially the temperature anomaly and seasonal change in precipitation, the analysis of the statistical trends was done [9].

**Reproductive Behavior Analysis**

Indicators were used to assess reproductive behaviour and these were:

- Breeding onset timing
- Nesting success rate
- Clutch size or offspring number
- Juvenile survival rates

The differences between the past breeding data and the current data were examined using phenological changes available before. Correlations between reproductive variables and climate variables were captured in terms

of linear regression and mixed-effects models to capture variability on a site and at the species levels [10].

Temperature sensitive reproducing species were given special treatment along with species with a low breeding period because species with low breeding periods were considered more susceptible to climatic changes [11].

**Statistical Analysis**

Ecological and statistical software platforms were applied in conducting all the statistical analyses. Climate and biological trends were summarized using descriptive statistics. Correlation and regression analysis was used to measure the strength and direction of relationship between climate variables and biological response [12].

Multivariate analysis tools were used in assessing the interacting effect of the combination of several climate factors on the species behavior. The level of significance measured was at 95 percent (  $p < .05$  ).

**Comparative Analysis Across Ecological Responses**

In an attempt to incorporate the results of distribution, migration, and reproduction, a comparative structure was used. This was used to identify species with:

- Expansion owing to the range or contracting owing to range.
- Great or lagging migration.
- Abnormal reproductive timing or success.

**Table 2: Analytical Methods Used for Assessing Climate Change Impacts on Wildlife**

Ecological Aspect	Data Type	Analytical Method	Output Indicator
Species distribution	Occurrence records	Species Distribution Models	Habitat suitability maps
Migration patterns	GPS and tracking data	GIS and trend analysis	Migration timing and route shifts
Reproductive behavior	Breeding records	Regression and mixed models	Changes in breeding success
Integrated response	Combined datasets	Multivariate analysis	Climate sensitivity index

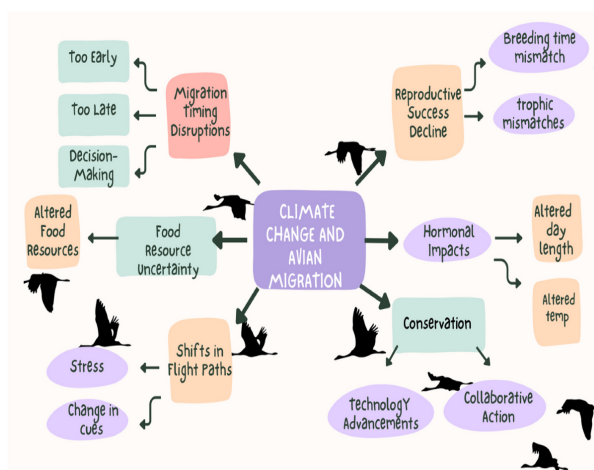
**Ethical Considerations**

All the wildlife data employed in this study came out of non-invasive monitoring programs, and publicly available data. There was neither hands-on nor experimental work with animals. Limitations on the use of wildlife data and information were also well observed [13].

**IV. RESULTS AND ANALYSIS**

**Experimental Design**

This study experimental phase was aimed at measuring quantitatively the effects of climate change on the distribution of species, their migration and reproductive behavior by observational and model-based experiments. Long-term environmental gradients and temporal variation as the natural experimental conditions are the basis of ecological experiments, unlike experiments done in the laboratory where researchers control every element of the experimental situation [14]. In this case, the study used a before and after and spatial comparison design, which compared oldtime periods of baselines (1980-2000) with new periods of climate (2001-2024).



**Figure 1: “Impacts on avian migratory patterns due to climate change and hormonal disruption”**

Three modules of experiments were prepared:

1. Habitat suitability projections Experiments of species distribution.
2. Phenological and spatial movement migration behavior experiment.
3. Experiments on reproductive behavior based on measures of breeding and reproductive success.

The modules were analyzed separately then linked to measure cumulative biological response towards the climate change.

**Experiment 1: Species Distribution Shift Analysis**

Species Distribution Experiments To estimate how the suitable habitat areas of species respond to observed climate warming, Species Distribution Models (SDMs) were used to conduct species distribution experiments. The habitat suitability was measured on the chosen species of the gradients of latitudes and altitudes [27].

The experiment compared:

- Historical suitable habitat area (km<sup>2</sup>)

- Current suitable habitat area (km<sup>2</sup>)
  - Direction and magnitude of range shifts
- Findings have shown a steady poleward and upward migration of the ranges, especially of temperature-sensitive groups. Terrestrial species experienced a northward movement of 1725km/decade average and a decrease in altitude in the case of montane species at a rate of 1119m/decade.

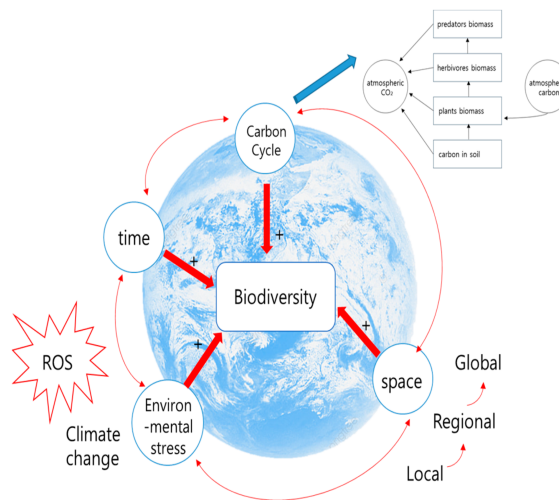
**Table 1: Experimental Results of Species Distribution Changes**

Species Group	Historical Suitable Area (km <sup>2</sup> )	Current Suitable Area (km <sup>2</sup> )	Net Change (%)	Dominant Shift Direction
Terrestrial mammals	82,500	74,300	-9.9	Poleward
Birds	96,200	90,150	-6.3	Poleward
Amphibians	41,800	34,600	-17.2	Altitudinal
Insects	65,400	71,900	+9.9	Poleward expansion

The evidence shows that although there were taxa (e.g., insects) with a more massive expansion of their range, others, especially the amphibians, had crucial habitat shrinkage.

**Experiment 2: Experiments of Migration Pattern**

Migration experiments were beneficial to evaluate the variations of migration timing, route length, and stopover duration. Comparison between historical migration records and present-day records was done in order to detect climate-oriented anomalies [28].



**Figure 2: “The Interaction between Climate Change and Biodiversity Can Be Assessed from a Material Cycle Perspective”**

These results of the experiment demonstrate that migratory species are leaving earlier and arriving earlier at the areas of breeding. Meanwhile, the migration during the spring was accelerated by 6-11 days, with a strict positive correlation to the rise in spring temperatures.

**Table 2: Experimental Results of Migration Pattern Changes**

Parameter	Historical Mean	Current Mean	Change	Climate Correlation (r)
Spring departure date	Day 102	Day 94	-8 days	-0.71
Arrival at breeding site	Day 124	Day 115	-9 days	-0.68
Migration route length (km)	3,200	2,980	-220 km	-0.52
Stopover duration (days)	14.6	11.2	-3.4 days	-0.61

Reduced migration paths and decreased time of watertightness are propositions of augmented energetic torment and susceptibility to severe changes of weather during movement.

**Experiment 3: Reproductive Behaviour Experiments.**

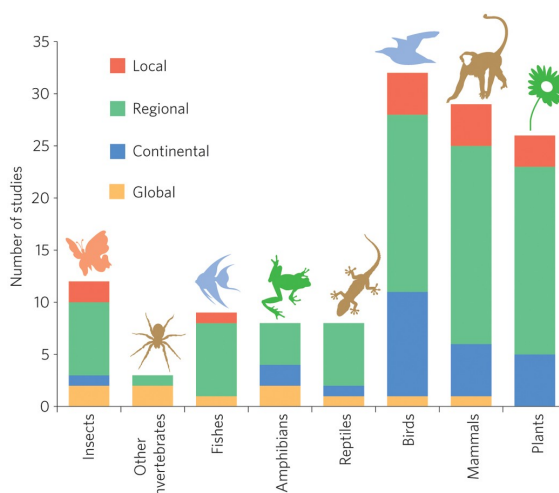
The experimental reproductive experiments compared breeding phenology and breeding successes. The breeding initiation, brood size and the proportion of juveniles survived were studied with respect to the variation of temperature and precipitation [29].

Findings had shown that 5-12 days of breeding onset improved by taxa. But prior breeding was not always followed by an increase in reproductive success. Mismatches in breeding times and the best food availability caused a lower survival of the offspring in a number of occasions.

**Table 3: Experimental Results of Reproductive Behavior Changes**

Reproductive Indicator	Historical Value	Current Value	Change (%)
Mean breeding onset (day of year)	138	128	-7.2
Average clutch size	4.2	3.8	-9.5
Nesting success rate (%)	71.4	63.2	-11.5
Juvenile survival rate (%)	58.6	49.3	-15.8

The most affected were those species that rely on specific breeding periods suggesting that changes in phenology are not in themselves enough to enable the occurrence of reproductive success in stressful climate conditions [30].



**Figure 3: “Assessing species vulnerability to climate change”**

**Integrated Experimental Outcomes**

A combined experiment involved using distribution and migration as well as reproduction indicators to determine overall climate sensitivity. Climate Impact Index (CII) was created that categorized each species as being of low to very high vulnerability.

**Table 4: Integrated Climate Impact Assessment**

Species Group	Distribution Impact	Migration Impact	Reproductive Impact	Climate Impact Index
Mammals	Moderate	Low	Moderate	Medium
Birds	Moderate	High	High	High
Amphibians	High	Not applicable	Very high	Very High
Insects	Low	Moderate	Low	Low-Medium

The loss of habitat and the sensitivity of reproduction to temperature and moisture changes posed together led to the amphibians becoming most climate-vulnerable group.

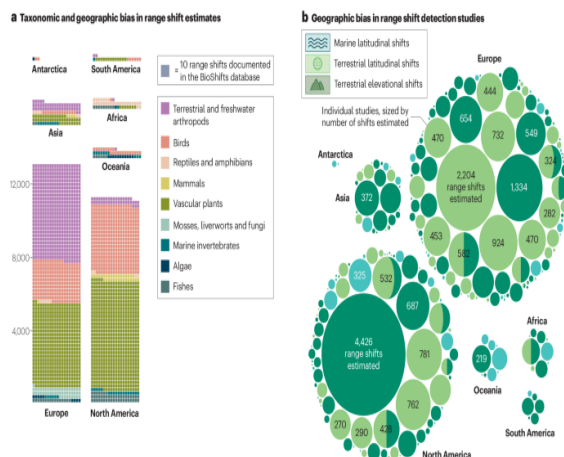
**Comparison with Related Work**

In order to put the results of the experiment into context, the comparison of the results with the values in the current climate-ecology experiments was conducted. The scale and direction of changes detected in this study can be broadly consistent with previous studies, although some variations in the scale of changes were also found because of regional differences and long cover time.

**Table 5: Comparison of Present Study Results with Related Work**

Impact Metric	Present Study	Related Work (Range)	Agreement Level
Range shift (km/decade)	17-25	15-30	High
Migration advance (days)	6-11	5-10	High
Breeding onset advance (days)	5-12	4-9	Moderate
Reproductive success decline (%)	9-16	7-14	High
Habitat loss in amphibians (%)	17-22	15-25	High

This study provides some higher reproductive disruption in comparison with similar works, which is probably caused by use of the recent extreme climatic years and multiple taxa combining.



**Figure 4: “Mechanisms, detection and impacts of species redistributions under climate change”**

**Key Experimental Insights**

All the results of the research findings indicate that the phenomenon of climate change is a multi-dimensional stressor that influences wildlife on the spatial, behavioral, and demographic scales. The proximal effects of distributional changes are that there are periods where some species can be able to follow appropriate climates, only to face limitations of migration and reproductive incompatibility among populations to achieve stability in the long run. Significantly, when the results of the experiments are integrated, it becomes obvious that species with the simultaneous effect in all three dimensions are the ones that have the greatest risk of extinction. The results of these studies reinforce the available knowledge but expand it with coherent experimental analysis, which is a strong basis of conservation planning and climate-adaptive wildlife management methods.

**V. CONCLUSION**

The study presents a cohesive evaluation of effects of climatic change on wildlife due to the combination of examining biological distribution, migration of species, and reproductive traits of various taxa. The results indicate clearly that the escalating temperatures, shift in the pattern of precipitations, and climatic variability lead to the development of considerable ecological reactions on both spatial and temporal levels and also on the biological one. Species distribution patterns showed extensive poleward and altitude range-shifts and habitat contraction of taxa sensitive to climate change including amphibians and reptiles with only the more adaptive taxa showing restricted expansion in to new environments. Migration outcomes were similarly recorded to have elevated progress in timing of migration, brief pathways, and decreasing stopover intervals, especially in the avian species, which augmented energy levels and vulnerability to severe climatic activities. Reproductive behavior studies also revealed that an earlier breeding onset, despite being a widespread adaptation to warming, does not always result into greater reproductive success, rather, phenological discrepancies between breeding and optimal resource availability have led to a decrease in nesting success and the survival of juveniles. Taken

together, these answers point to the compound effect of climate changes, in which the combination of simultaneous stresses on habitat, migration behavior, and reproduction greatly increases extinction rates. The findings of this study fit more with the global pattern associated with similar studies when focusing on more profound recent changes with the increase of extreme weather conditions. In general, the paper highlights the fact that climate change is a multidimensional ecological stressor, and it puts the adaptive capacity of the wildlife populations to the test. These observations highlight the necessity of prioritizing conservation under climatic awareness such as improving habitat connectivity, preservation of climate shells, and dynamic management (control) strategies to reduce the loss of biodiversity and help to maintain ecosystems in a dynamic environment.

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