Wildlife Conservation Strategies

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Chapter 1: Concept Note

QUESTION: Agent-Based Simulation of Wildlife Conservation Strategies: Utilizing agent-based models to simulate and optimize wildlife conservation strategies, considering habitat preservation and population dynamics.

Understanding the problem statement:

Let's begin with the basic understanding of wildlife i.e. what is wildlife and why do we need to conserve it.

Wildlife basically means all those species of flora, fauna, and animals which are not human-introduced. There are various types of wildlife in deserts, forests, rainforests, plains, grasslands, and other regions including some urban areas. Although this term mainly targets animals, most scientists believe that human beings and their activities influence a great deal of wildlife.

Wildlife Conservation preserves nature, soil, water, and all the elements of the environment for other species and supports our life system.

Through wildlife conservation, we also preserve the genetics of plants and animals, which further helps in breeding and improving species.

F**or wildlife Conservation, there were various acts and laws passed by the Indian Government which are listed below:**

1)Wild Life (Protection) Act, 1972: This act protects wild animals, birds, and plants, and regulates trade in products derived from wild animals. It was last amended in 2022.

2)Fisheries Act, 1897

3)Indian Forests Act, 1927

4)Mining And Mineral Development Regulation Act, 1957

5)Prevention of Cruelty To Animals, 1960

6)Water (Prevention and Control of Pollution) Act, 1974

SOME FACTORS WHICH AFFECT WILDLIFE:

1)Habitat loss: It happens when the natural environment or surroundings of an animal changes which eventually makes difficult for them to access to food, water, and shelter. It may also refer to the destruction of the environment, making it difficult for the animals to survive. Activities like Urbanization, Pollution, and Industrialization promote Habitat loss.

2)Climatic Changes: Climatic changes such as extreme cold or hot weather, and unseasonal rains are a result of Pollution and global warming by human beings, also affect the survival of animals and make it difficult for their body to adapt to the changes around them.

3)Poaching: Humans hunt animals and sell their skin and other parts illegally. Poaching is a threat to wildlife and results in biodiversity loss.

SOME HISTORY OF WILDLIFE CONSERVATION:

1)During COVID-19 LOCKDOWN, Yamuna River cleaned itself within the duration of 60 days. The government couldn’t clean up the River even in a time span of 25 years and with an investment of Rs5000 crores. When the industrial activities were halted, the river cleaned itself which allowed numerous Indian and migratory birds to flock to its water such as Grey Heron, Ibis, and Storks feasting on fish.

2)Spotted Dear and Sambhar were sighted at dawn in and around the temple town of Tirupati during the COVID-19 lockdown.

3)Project Tiger of 1973 had a great influence and helped in Wildlife Conservation. It aims to preserve biodiversity and safeguarding the national tiger’s population. With significant changes, the number went from 2461 in 2018 to 3080 in 2022, now more than 3/4th of the tiger population is found within protected areas.

Now, the project includes 53 tiger reserves sprawling over around 75,000 sq km of the region.

4)The Wildlife Conservation Act of 1972 protects wild animals, plants, and birds by providing a legal framework.

- This act provides licenses for the sale and transfer of some wildlife species.
- It provides the establishment of wildlife sanctuaries, national parks, and so on.
- There were only 5 national parks in India prior to this act so through this act, it increased the number of such parks and sanctuaries.

TECHNOLOGY IN WILDLIFE CONSERVATION:

- Drones: They are very helpful in tracking the real-life movement of animals and provide images.
- Artificial Intelligence: AI can analyze large amounts of data and provide predictions by analyzing images, audio, and videos.
- Camera Trapping
- Environmental DNA: Scientists and Researchers can use environmental DNA to identify the presence of species in their habitats.

  And there are more such examples of how technology helped in Wildlife Conservation.

CHALLENGES FACED FOR WILDLIFE CONSERVATION USING TECHNOLOGY:

- Unsustainable Financing: Technology is expensive to use, so we need a sustainable way to manage resources.
- The use of technology such as drones or tracking devices can cause harm to wildlife or disturb it.
- We need to constantly improve machine learning by continuously updating data for better analyses.

- One cannot fully rely on technology as it may fail or deploy at any moment.
- Public support is difficult because of a lack of education among people in general and not everyone will support conservation technologies.

Objective:

To develop an agent-based simulation to optimize wildlife conservation strategies for the ecosystem.

By understanding population trends, the simulation aims to provide insights into factors influencing species survival, reproduction, and overall ecological health.

Habitat preservation is crucial for wildlife conservation. The simulation aims to evaluate the effectiveness of various strategies, such as protected areas, habitat restoration, and land-use planning.

Conservation strategies need to adapt to changing environmental conditions and emerging threats. The simulation aims to facilitate decision-making by providing real-time insights into the effectiveness of ongoing strategies.

CONCLUSION:

In short, while technology has brought positive changes to wildlife conservation, it also presents its own challenges. Possible disruptions caused by invasive technologies, high costs, and ethical problems associated with disturbing nature are some of the issues we have to deal with. In addition, there is a risk of information overload and dependence on technology that may not always be reliable. Finding a balance, considering ethical implications, ensuring accessibility, and raising public awareness is critical to making technology a successful ally in our efforts to protect and conserve wildlife. It is a dynamic landscape that requires constant collaboration and thoughtful decision-making to ensure the best outcome for technology and wildlife.

LITERATURE REVIEW

Reference	Summary	Methodology	Key Findings	Relevance
The role of agent-based models in wildlife ecology and management DOI-https://doi.org/10.1016/J.ECOLMODEL.2011.01.020 Year-2011 Authors- Adam J. McLane, C. Semeniuk, G. McDermid, D. Marceau 189 Citations	The paper investigates the part of agent-based modeling as a promising approach for biological inquiry, especially in understanding natural life environment determination, and assesses the current and future parts these models can play in situations arranging for basic environments.	The methodology used in this study is to explore the potential of Agent-Based Models for Ecological Research, including their ability to distinguish between animal densities and habitat quality, which is explicitly environmental and dynamic, to adapt to spatial patterns of interspecies and intraspecies interactions, and to investigate feedback and adaptation mechanisms inherent in these systems.	The article supports the use of agent-based modeling (ABM) as a promising approach for ecological research, particularly in understanding wildlife habitat preferences and creating potential scenarios for important habitats. Agent-based models (ABMs) have the capability to effectively discern the densities of animals, while also evaluating the quality of their habitats. It reviews the existing empirical literature on ABMs in the field of wildlife ecology and management and assesses the present and future functions that these ABMs can serve.	ABMs are valuable for understanding habitat collection and administration. ABMs can mimic the attitude of environmental structures under different sketches. ABMs can help identify appropriate administration game plans for detracting habitats. ABMs can include adjusting animal-change conservation in a changing countryside. ABMs can investigate by virtue of what wildlife will put oneself in the place of other potential changes in incidental environments.
A spatially explicit agent-based model of the interactions between jaguar populations and their habitats DOI-https://doi.org/10.1016/J.ECOLMODEL.2014.10.038 Year-2015 Authors-A. Watkins, J. Noble, R. Foster, B. Harmsen, C. Patrick Doncaster	• Wildlife corridors connect isolated habitats to mitigate habitat fragmentation. • Corridors improve species' survival chances and increase gene pool size. • This paper presents an agent-based model of jaguar movement in Belize. • The model assesses the effectiveness of different corridor policies for jaguars. • Least-cost modeling is used to simulate movement paths through alternative landscapes. • Five narrow corridors may outperform one wide corridor for jaguars.	Agent-based model of jaguars in fragmented habitat in Belize Simulated movement paths through alternative landscapes using a least-cost approach Compared six different types of corridors and three control conditions Found that narrow corridors may out-perform one wide corridor Used a density of 7.84 jaguars per 100 square km in the simulation Simulated population of 100 jaguars represents medium to high-density	Agent-based model suggests narrow corridors may out-perform wide corridors. Corridor designs differ in effectiveness at mixing agents across the environment. The average landscape cost is explained by the availability of core forest grid squares. Five-corridor layout achieved high levels of cross-map migration. The model only compared six specific corridor layouts with three control conditions.	The current model only compared specific corridor layouts with control conditions. The model is in an exploratory mode and more research is needed. Real GIS data integration is a future step for the model. The model uses a timestep of 4 hours to simulate jaguar movement. Edge effects are considered in the initialization of the map.

				The simulation starts with 100 jaguars, representing a medium to high population density.
Optimization of Forest Wildlife Objectives DOI-https://doi.org/10.1007/978-0-387-71815-6_21 Year-2007 Authors-John Hof, Robert G. Haight	The paper reviews methods for optimizing wildlife-related objectives. The methods focus on capturing spatial relationships in managed landscapes. The objective is to maximize or minimize an objective function subject to resource constraints. The paper distinguishes between spatial optimization and spatially explicit optimization. The complexity of ecological relationships in optimization formulations is limited.	Spatial optimization methods for wildlife-related objectives Capture of deterministic and stochastic spatial relationships Heuristic manipulation of simulation models for complex spatial relationships General treatment of stochastic variables in spatial optimization is in its infancy	Methods for optimizing wildlife-related objectives through spatial optimization are discussed. The ability to capture relevant ecological relationships in optimization analysis is important. Adaptive learning processes and optimization methods can aid in landscape management. Heuristic procedures can be used to direct predictions with different management regimes. The model structure has been applied to various problems in organism management.	Spatial optimization can help in learning about ecological systems. Adaptive management processes combined with optimization methods can make progress. Spatial optimization can generate new hypotheses for landscape ecology research. Heuristic procedures can be used to direct repeated predictions with different management regimes. Spatial optimization has been applied to habitat placement and management of various organisms
Modeling tiger population and territory dynamics using an agent-based approach DOI-https://doi.org/10.1016/J.ECOLMODEL.2015.06.008 Year-2015 Authors-Neil Carter , Simon Levin , Adam Barlow , Volker Grimm	Tigers are globally endangered and face threats from habitat loss and illegal killing. Understanding tiger population dynamics is crucial for conservation planning. Territoriality plays a crucial role in tiger population dynamics. Previous models of tiger population dynamics did not adequately incorporate territoriality. The paper presents a spatially explicit agent-based model of tiger population dynamics. The model is tested in Nepal's Chitwan National Park and matches closely with observed patterns. The model aims to explore human-tiger interactions and assess threats to tiger populations. The model can inform decision-makers on how to conserve tigers under changing conditions	Agent-based model of tiger population dynamics incorporating territorial behaviors Territories emerge from tigers' perception of habitat quality and interactions Model matched closely with observed patterns of real tiger population Model used to explore human-tiger interactions and assess threats to tigers Energy considerations regarding fitness not used in the model Females select territory based on prey availability and presence of other females Females can add up to 3 km2 to their territory in a time step	Model accurately matched observed patterns of tiger population in Chitwan National Park. Territory size is influenced by interactions among neighbors and potential settlers. Male-male competition affects dispersal, reproduction, and population size and structure. Territory dynamics and mortality processes regulated population size and structure. The model does not consider detailed energy considerations or learning behavior.	The model examines the territorial behaviors of male and female tigers. It closely matches observed patterns in the real tiger population. It can be used to study human-tiger interactions and estimate threats to tiger populations. It can help decision-makers conserve tigers in uncertain future conditions.

		Females die if total prey production within territory is below 76 kg/month Centroids of female territories used to assign females to male territories Male territories are established or updated based on proximity of female territories		
The use of agent-based modelling of genetics in conservation genetics studies. DOI-https://doi.org/10.1016/J.JNC.2003.12.001 Year-2004 Authors-Cino Pertoldi, Christopher John Topping	Conservation genetics helps keep different plant and animal species from disappearing. When the environment changes quickly, it can affect how genes are passed on and how animal populations grow. Older ways of studying populations and genetics have some problems when it comes to understanding how healthy an ecosystem is. Scientists look at DNA to see how different genes are in a population and how different groups of animals are related. A detailed method called agent-based modeling helps scientists test their ideas about genetics in a realistic way.	ALMaSS agent-based model used to simulate genetic and demographic characteristics. Three scenarios with increasing environmental disturbance simulated by population bottlenecks Model outputs validated qualitatively and showed differences in genetic and demographic measures Genetic estimates were less variable and more reliable than demographic estimates Agent-based models are flexible and can simulate population processes under different conditions Models incorporating explicit genetics can evaluate the impact of environmental changes on genetic composition	Scientists used agent-based modeling to see how environmental changes affect how populations grow and change. Estimates based on genetics were more consistent and dependable than those based on population numbers. The model confirmed what scientists already thought would happen in theory and gave them helpful insights into how populations respond to changes. DNA analysis can show changes in populations for a longer time than just looking at population numbers. Conservation genetics is crucial for keeping a variety of plants and animals from disappearing.	This topic is about using computers to understand and protect wildlife. Scientists use these computer programs to see how changes in nature affect animals. They also use genetics, which is like looking at animals' family trees, to study how wildlife is doing. By doing this, they can figure out better ways to take care of animals and keep them safe. It's all about making sure different kinds of animals can keep living in the wild.
Wildlife farming: Balancing economic and conservation interests in the face of illegal wildlife trade DOI-10.1002/pan3.10588 Year-2024 Authors-David P Edwards, Oscar Morton,Dominic Meeks	Paper explores wildlife farming as a conservation solution and economic opportunity. Three objectives: assess economic sustainability, evaluate potential for wildlife farming in illegal wildlife trade, develop decision framework. Collaboration with regulatory authorities and updated captive stocks records suggested. Consumer attitudes towards captive-bred products vary. Decision framework to create sustainable wildlife farming model. Factors like reproductive traits and	Quotas are sparingly used in wildlife farming. Captive Breeding Production Programme (CBPP) is designed to promote transparency. Consumer studies oversimplify consumer behavior and fail to incorporate diverse factors. CITES cannot unilaterally prohibit trade in a species. Broadening criteria for listing and quota decisions is crucial.	Wildlife farming can potentially be a conservation solution for overexploited wild populations. Chinese consumers are more willing to accept substitute medicines from wildlife farming. Captive-bred pets and clothing products are preferred due to hygiene regulations. Significant establishment costs are a barrier to widespread	The study highlights the need for reform in the regulation of wildlife farming. Regulatory authorities should increase scrutiny of international captive-bred trade. Resolution Conf.17.7 aims to reduce laundering in wildlife farming. Legislative constraints may hinder the restriction

	conservation statuses determine conservation and economic value.	Laundering compromises the credibility of claims that wildlife farming is sustainable. Prevalence of laundering threatens the population health of commercially valuable species. Paucity of data and genetic verification strategies are key challenges in resolving illegal captive stock acquisition. Exports of captive-bred species that exceed breeding facilities undermine conservation potential.	participation in wildlife farming. Wild-caught specimens are often used to reduce costs and increase profits. Global supply chains saturate economic benefits for small-scale breeders. Directly connecting suppliers to foreign markets would increase profitability.	of illegal activity in wildlife farming. Doubts remain over the effectiveness of Indonesia's Captive Breeding Production Programme. Trade routes passing through non-CITES Parties may not disclose trade data. Lack of data on existing captive populations and genetic verification strategies pose challenges. Exports of captive-bred species exceeding breeding facility capacity undermine conservation potential.
Dynamic conservation for migratory species DOI–https://doi.org/10.1126/sciadv.1700707 Authors-M. Reynolds, Brian L. Sullivan, Eric Hallstein, S. Matsumoto, S. Kelling, Matt Merrifield, D. Fink, A. Johnston, W. Hochachka, Nicholas E. Bruns, M. E. Reit Year-2017	• Global change is impacting ecological and social systems. • Migratory species face challenges due to habitat loss and climate change. • Protected areas alone are insufficient to meet habitat needs. • Dynamic conservation strategies can adaptively provide habitat for migratory species. • The study focuses on creating temporary wetlands for migratory waterbirds.	Used bird-monitoring data from eBird and satellite data from NASA. Developed predictive models of bird populations and wetland availability. Identified temporal and spatial gaps in habitat during migration. Used a reverse auction marketplace to incentivize landowners to create temporary wetlands. Cost-effective approach compared to traditional land purchase and retirement strategy.	The use of machine learning algorithms has shown promise in predicting the risk of cardiovascular diseases in patients with diabetes. A study found that a combination of genetic and clinical risk factors can improve the accuracy of predicting the risk of type 2 diabetes. Researchers have developed a deep learning model that can accurately predict the risk of developing Alzheimer's disease based on brain imaging data. A study found that the use of artificial intelligence algorithms can improve the accuracy of diagnosing breast cancer from mammograms. Machine learning techniques have been used to predict the risk of developing chronic	The study demonstrates the effectiveness of dynamic conservation strategies for migratory waterbirds. The approach involves using citizen science and satellite data to predict bird populations and habitat availability. Gaps in habitat during migration are filled by incentivizing landowners to create temporary wetlands. This approach is cost-effective and optimizes conservation outcomes relative to investment. The strategy can be applied broadly to other conservation challenges

			kidney disease in patients with diabetes. Researchers have developed a predictive model using machine learning algorithms to identify patients at high risk of developing sepsis. A study found that machine learning algorithms can accurately predict the risk of developing lung cancer based on genetic and clinical data. Researchers have developed a machine learning model that can predict the risk of developing Parkinson's disease based on voice recordings.	
A multi-model framework for simulating wildlife population response to land use and climate change DOI-https://doi.org/10.1016/J.ECOLMODEL.2008.08.001 Year-2008 Authors-B. Mcrae, N. Schumaker, R. McKane, R. Busing, A. Solomon, C. Burdick	The paper presents a multi-model framework for simulating wildlife population response. The framework incorporates habitat modifications and direct effects on species' life histories. It allows for relative comparisons among management alternatives rather than specific future conditions. The framework synthesizes existing empirical evidence and explores complex interactions. The framework integrates habitat maps with other factors driving animal populations. Model inputs and outputs are spatially explicit. The paper uses climate, land use, vegetation, and wildlife habitat models from previous studies.	Diseases like cancer, diabetes, and heart issues can be predicted with the aid of machine learning. To develop these forecasts, scientists employ a variety of data, including genetics, brain scans, and medical records. Machine learning increases the accuracy of illness prediction. This may enable medical professionals to diagnose and cure illnesses sooner. In the healthcare industry, machine learning may be very helpful in identifying personal risks and averting illness.	The model shows how animals are affected by changes in climate and land, like where they live and how many there are. Changes in good places for animals to have babies have a bigger impact on populations than changes in less suitable areas. It predicts how forests will change because of climate change, based on how each tree responds. The model can tell us how big forests will get, how fast they'll grow, and what kinds of plants will be there. It helps us compare different ways to take care of forests to see which ones are better, without saying exactly what will happen.	The paper discusses the relevance of using model-based comparisons in predicting future conditions. The land-use scenarios in the study reflect potential changes in urban and rural development, agriculture, and forestry practices. The different land-use scenarios have predicted impacts on vegetation in the USSW. The simulations were tailored to produce maps that would be interpretable as wildlife habitats. The PATCH model is a spatially explicit, individual-based, animal population simulator.

Species Distribution Modeling for Conservation Educators and Practitioners. Stable URL: ncep.amnh.org/linc/ Year-2010 Author-R. Pearson	Paper focuses on species' distribution modeling for conservation educators and practitioners Introduces modeling approach, key concepts, and terminology Describes steps in building and testing a distribution model Discusses case studies on predicting species' distributions and impacts of climate change Aimed at teaching graduate students and conservation professionals	Species occurrence records are required to set the threshold for the model. False absences can bias analyses, so absence data should be used carefully. Mechanistic models identify a species' fundamental niche and potential distribution. Theoretical basis and framework are crucial for model application and interpretation. Various terms (ecological niche model, environmental suitability model) refer to the same approach. Steps to build a distribution model include selecting data, choosing a modeling algorithm, and assessing predictive performance.	This synthesis provides an overview of species distribution modeling. The models are useful in addressing conservation questions. Three case studies demonstrate the uses of species distribution models. Different modeling algorithms can produce substantial differences in predictions. The aim of the modeling can be to estimate the actual or potential distribution of a species. Correlative species distribution models rely on observed occurrence records.	The paper discusses the relevance of using species distribution models in conservation. It emphasizes the importance of a sound theoretical basis for model application. The paper provides steps for building a distribution model and assessing its predictive performance.
A review of Wildlife 2001: Populations. Year-1996 DOI-https://doi.org/10.1007/978-94-011-2868-1 Authors-Dale R. McCullough, Reginald H. Barrett	The paper covers a broad range of taxonomic groups. It includes sections on reptile and amphibian populations and avian populations. The book is organized into 15 sections, covering various species groups. The editors achieved a functional organization and uniformity of format. The book is comprehensive and expensive, lacking a subject area index.	The book covers important topics like model selection and proportional hazard modeling of survival. The section on population modeling is strong, especially the overview paper. The book lacks a subject area index, which would increase its functionality as a reference.	The book provides a functional organization of papers on population dynamics. The book covers a wide range of taxonomic groups and topics. The absence of a subject area index is a major failure. The "Small mammal populations" and "Large herbivores" sections are noteworthy. The "Reptile and amphibian populations" section is a refreshing addition. The "Population methods" section covers important topics on model selection. The "Population modeling" section is strong, except for one weak entry. The "Overabundant	The book provides a comprehensive overview of population dynamics and management. The book is well-organized and has a professional appearance. The book covers a wide range of taxonomic groups and topics. The absence of a subject area index is a major drawback. The section on small mammal populations is particularly strong. The section on large herbivores is also noteworthy. The section on reptile and amphibian populations is a refreshing addition. The section on avian

			populations" section is stimulating and covers problem areas.	populations covers various bird species. The paper on California condors seems out of place. The section on population methods covers important topics. The section on population modeling is strong, except for one weak entry. The section on threatened populations is lackluster. The section on overabundant populations is stimulating.
Agent-Based Modelling and Simulation Applied to Environmental Management DOI-10.1007/978-3-540-93813-2_19 Year-2013 Authors-Christophe Le Page,Didier Bazile,Nicolas Becu, Pierre Bommel,François Bousquet, Michel Etienne,Raphaël Mathevet, Véronique Souchère,Guy Trébuil, Jacques Weber	The paper discusses the shift in thinking in ecosystem management and ecological modeling. It explores the contribution of agent-based modeling and simulation (ABMS) to this shift. The paper reviews recent applications of ABMS in environmental management. ABMS is used to explore scenarios of co-management of forest resources. ABMS is also used to study coordination in irrigation systems and rangeland systems.	The FEARLUS model was developed to simulate land use selection in rural Scotland. The abstract regional environment is defined as a toroidal raster grid. Land manager agents decide land uses based on a specific selection algorithm. Simulation scenarios are defined using imitative and non-imitative selection algorithms. Generic simulation platforms like Ascape, Cormac, Mason, etc. used by users. Reproducing results is important for making ABMS a rigorous tool. ABMS platforms like NetLogo merge domain entities with simulation scenarios. Clear separation between model and simulation should be promoted. Focus on the internal structure and behavior of agents for reusability. Generating parameter values and creating an	ABMS is an umbrella term for agent-based modeling and multi-agent simulation. ABMS allows for explicit consideration of stakeholders in environmental management. Spatially explicit individual-based models (IBM) are widely used in ecological modeling. Traditional population-based models have simplified assumptions that limit their usefulness. Decision-making in ABMS involves sophistication and adaptiveness of agents' behavior.	ABMS is applied to a wide range of topics in environmental management. Topics include land use changes, water management, forest management, agriculture, and epidemiology. Some topics, like epidemiology, can be treated separately. Some case studies deal with multiple uses of the same renewable resource. LUCC is a research field in human geography related to land-use cover changes. Biodiversity case studies can be split into several other topics. Some ABMS examples address theoretical issues in ecological management. FEARLUS is an

		initial landscape is important.		abstract model of land use and land ownership. Simulation platforms like Ascape, Cormas, and Swarm are commonly used. Generic tools are compared and analyzed for their abilities and requirements. Technical aspects like floating point arithmetic and random number generators are considered. Existing models in online libraries can be used as a reference.
Eliciting cognitive processes underlying patterns of human–wildlife interactions for agent-based modelling. DOI-https://doi.org/10.1016/j.ecolmodel.2011.02.014 Year-2011 Authors-Clément Chion , P. Lamontagne , S. Turgeon , L. Parrott , J.-A. Landry , D.J. Marceau , C.C.A. Martins R. Michaud ,N. Ménard G. Cantin S. Dionne	Understanding human decision making in the context of wildlife interactions. Developed an agent-based model to simulate whale-watching vessel movements. Tested different models of cognitive heuristics to select the best-performing one. Validated the model using real observations of boat trajectories and whale distribution. Communication abilities between captains led to the emergence of persistent observation sites. Satisficing and tallying heuristics also showed relatively good performance. The study contributes to the management of human activities in natural environments.	A spatially explicit agent-based model simulating whale-watching vessel movements Model of whale-watching captains' decision-making using cognitive heuristics Models tested: satisficing, tallying, Take The Best, random choice Model selection based on comparison of simulated and real patterns Take The Best heuristic found to be the best-performing model Communication abilities between captains led to emergence of persistent observation sites Satisficing and tallying heuristics also supported by field evidence and literature The pattern-oriented modelling approach used for informative ABM development	Developed agent-based model simulating whale-watching vessel movements Tested three models of cognitive heuristics and a null model Take The Best heuristic was the best-performing model Satisficing and tallying heuristics also had relatively good performance Communication abilities between captains led to the emergence of persistent observation sites	The relevance of the Take The Best heuristic in the study of human decision-making in whale-watching captains' behavior. The impact of regulations on whales' cumulative exposure to boats during the summer. The goals of whale-watching captains: observe whales, observe the landscape, embark/disembark tourists, and return to homeport. The adoption of specific goals by captains based on remaining time and whale location.

Integrating Spatial Behavioral Ecology in Agent-Based Models for Species Conservation. DOI- Year-2011 Authors-Christina A.D. Semeniuk, Marco Musiani and Danielle J. Marceau	ABM used to analyze habitat selection and foraging theory in salmonid fish species ABM tested the impact of behavioral scenarios on population persistence of woodpeckers ABM explored behavioral mechanisms for home range overlap in a lizard Pattern-oriented modeling effective for evaluating behavioral mechanisms of habitat selection and animal movement	Multiple techniques for analyzing samples with specific probes Microorganisms form complex communities in nature and reactor systems Performance of microbial culture depends on community configuration Chromium conventionally treated by transforming Cr(VI) to Cr(III) Chromium extensively used in industrial processes and metallurgy	Agent-based modeling is an effective tool for understanding animal habitat selection. Integrating behavioral ecology with spatial ecology in agent-based models for conservation planning. Geographic and environmental predictors should be considered in species distribution models. The economy of Donana experienced a shift towards the tertiary sector. Preservation of biodiversity sources is key for satisfying future needs.	Molecular markers can help study small organisms that are difficult to characterize morphologically. Molecular markers can be used to differentiate subspecies in certain plants. Gram-positive bacteria have been used in vaccine production due to their immunological relevance. Surface display in gram-positive bacteria allows for the expression of proteins. Staphylococcal cells can be used as hosts for selecting antibody repositories. Techniques for analyzing multiple samples with specific probes are being developed. Mass screening of water samples for interesting marine species is possible. Yeast-displayed libraries can be analyzed and selected similar to bacteria. Surface display is a concept explained in previous work. Chromium can be treated by transforming Cr(VI) to Cr(III) through a redox reaction.

HABITAT MODELING FOR BIODIVERSITY CONSERVATION Year-2006 DOI-https://doi.org/10.1898/1051-1733(2006)87[56:HMFBC]2.0.CO;2 Authors-B. Marcot	Paper discusses habitat modeling for biodiversity conservation. Reviews categories and examples of habitat models. Suggests the use of influence diagrams and structural equation modeling. Emphasizes the importance of habitat variables but acknowledges other factors. Provides insights for managers on realistic outcomes of habitat management programs.	Use of structural equation and information-theoretic modeling Quantify relations between habitat variables and biodiversity variables Uncertainties and measurement errors associated with variables and their relations Demonstrate causation among variable relations Habitat variables account for 20 to 50% of variation in wildlife populations Factors other than local measurable habitat variables influence variation Habitat quality as a surrogate or estimator of species presence or abundance Predictability of habitat attributes varies by type of statistics used Use of surrogate data to analyze the viability of endangered populations Use of surrogate data to evaluate threats to wildlife sanctuaries Surrogates for biodiversity include land classes and spatial configuration Degree of isolation of land classes does not account for variation in species assemblages	Influence diagrams are widely used in ecological modeling. Information-theoretic models can replace traditional statistical testing. Structural equation and information-theoretic modeling can quantify relations between variables. Habitat alone may not ensure the full array of biodiversity variables.	The paper discusses the relevance of habitat modeling for biodiversity conservation. It explores the use of structural equations and information-theoretic modeling. The paper highlights the limitations of using habitat variables to predict biodiversity variables. Examples of using surrogate data to analyze viability and evaluate threats are provided. The paper emphasizes the need for further modeling to account for isolation effects.

Modelling Biodiversity dynamics in Countryside and native habitats. Year-2023 DOI-10.1016/B978-0-12-822562-2.00351-0 Authors-Luis Borda de Agua,Henrique Miguel Pereira	Biodiversity continues to decline despite efforts to reduce loss. Land-use change is the main driver of biodiversity loss. Models are needed to assess the effects of land use on biodiversity. Phenomenological and process-based models are used to study biodiversity response. The species-area relationship (SAR) is a widely used phenomenological model. Process-based models capture the underlying processes of land use and biodiversity. Source-sink models describe population dynamics and movement of species. The countryside SAR tracks the number of species in different habitats. Equations can be refined to consider patch size and quality. A minimum area of source habitat is required to sustain species. The proportion of species going extinct can be estimated with habitat loss.	The paper discusses different models for multihabitat species-area relationships. Triantis et al. (2003) model substitutes area in the SAR with the product of area and number of habitats. Tjorve's (2002) model adds the SAR of each habitat and subtracts overlapping species. The paper also mentions three other classes of phenomenological models. The total number of species in the landscape is calculated using a formula.	Original projections of global extinction rates were based on forest loss estimates. There is a renewed interest in models linking biodiversity response to land-use change. Countryside habitats can support important levels of biodiversity. There is a need for models that capture the biodiversity consequences of forest loss and expansion. Different models have been proposed for a multihabitat species-area relationship (SAR). None of the models explicitly track groups of species with distinct habitat affinities.	Machine learning algorithms have been used in various studies to predict the risk of different diseases, including cardiovascular diseases, type 2 diabetes, Alzheimer's disease, breast cancer, chronic kidney disease, sepsis, lung cancer, and Parkinson's disease. These studies have utilized different types of data, such as genetic and clinical risk factors, brain imaging data, mammograms, voice recordings, and genetic and clinical data, to develop predictive models. The use of machine learning algorithms has shown promise in improving the accuracy of disease risk prediction, potentially enabling early detection and intervention. These findings highlight the potential of machine learning in healthcare for personalized risk assessment and disease prevention

REAL- WORLD PROBLEM

A real-world problem in the conservation of nature is the decline of certain species due to habitat loss, fragmentation, and degradation caused by human activities such as deforestation, urbanization, agriculture, and infrastructure development. This can cause a loss of biodiversity and ecosystem services and negative impacts on local communities and economies that depend on wildlife and natural resources. Conservation measures aim to protect and restore habitats, manage wildlife populations, and mitigate threats such as poaching and illegal wildlife trade. However, these efforts often face challenges such as limited resources, conflicting interests, and insufficient information on species populations and living conditions. Effective conservation of nature requires cooperation between governments, conservation organizations, local communities, and other stakeholders. Strategies include establishing protected areas, implementing sustainable land use practices, promoting conservation and awareness, and enforcing wildlife protection laws. Overall, wildlife conservation is a complex and dynamic issue that requires a holistic and interdisciplinary approach to ensure long-term conservation. of nature protection. nature reserves. wildlife species and ecosystem health.

PROBLEM - UNDERSTANDING

For saving wildlife, the second step in problem understanding and information gathering involves gathering important information to understand the dynamics of the target species and its habitat. This step is crucial to identify the key variables, parameters, and factors influencing the behavior of the conservation system. Here are some key aspects of this step:

- Species Data: Collect data on the target species, including population size, distribution, reproductive rates, mortality rates, and behavior. This data helps in understanding the species' ecology and population dynamics.

  Example:

  1. Bengal Tiger

Population size: According to the 2023 tiger census, the population of Bengal tigers in India is over 3,100

Distribution: in the Brahmaputra flood plains and northeastern hills tigers live in an area of 4,230 km^2 (1,630 sq mi) in several patchy and fragmented forests; in the Sundarbans National Park tigers live in about 1,586 km^2 (612 sq mi) of mangrove forest.

Reproductive Rates: On average, female Bengal tigers produce 3–4 cubs every 2–3 years. They come into heat every 3–9 weeks and are receptive for 3–6 days. After a gestation period of 104–106 days, 1–4 cubs are born in a shelter situated in tall grass, thick bush, or in caves.

On average, tigers give birth to two to four cubs every two years. If all the cubs in one litter die, a second litter may be produced within five months. Cubs remain with their mother until they are two years old.

Tigers can breed at any time of the year, but breeding is most common from November to April.

Mortality Rates: According to the National Tiger Conservation Authority (NTCA), 53.2% of tiger deaths in India take place within tiger reserves, 35.22% outside the reserves, and 11.58% are seizures.

Behavior: Bengal tigers are solitary animals that live in large territories and are active at night. They are carnivorous and use the "stalk and ambush" method to hunt prey, usually from behind. They are also powerful swimmers and can travel many miles to find buffalo, deer, wild pigs, and other large mammals.

- **Habitat Data:** Gather information on the habitat characteristics, such as vegetation cover, food availability, water sources, and landscape connectivity. This data helps in assessing habitat quality and identifying critical habitats for conservation.

  Example:

Vegetation Coverage of Bengal Tigers:

Bengal tigers are found in a wide range of habitats, including grasslands, savannas, mangrove swamps, tropical rainforests, evergreen forests, temperate forests, and at the base of the Himalayan Mountains. They are most commonly found in mangroves, marshes, and grasslands, especially in the Gangetic delta region of India and Bangladesh. The Sundarbans mangroves in West Bengal are a famous habitat for Bengal tigers.

Food Availability:

Bengal tigers are apex predators that primarily eat meat, especially from large ungulates, such as deer, wild boar, antelope, and buffalo. The specific prey species available to tigers may vary depending on the region and ecosystem they inhabit. For example, in Sunderbans, tigers mostly rely on fish.

Landscape Connectivity:

According to ntca.gov.in, tigers in India live in five major landscapes based on biogeography and interconnectivity:

- Shivalik-Gangetic plains
- Central India and Eastern Ghats
- Western Ghats
- North Eastern Hills
- Brahmaputra Flood Plains, and Sundarbans

Threat Data: Identify and quantify threats to the species and its habitat, such as habitat loss, poaching, pollution, and climate change. Understanding these threats is essential for designing effective conservation strategies.

Example:

The Bengal tiger faces many threats, including poaching, habitat loss, urbanization, and global warming. Poaching is the most immediate threat to tigers and includes hunting, taking game, and trading endangered species. Tigers are hunted for meat, luxury, decorative items, or to gather “cure” for diseases. Tigers are also hunted if they prey on domestic livestock, and because of this have even been declared "pests" in some areas.

According to World Land Trust, the Bengal tiger has the largest surviving population of any tiger sub-species. However, the population of tigers in the wild has decreased by 96% in the last century, with only 3,800 remaining.

- **Conservation Actions Data:** Compile data on past and ongoing conservation actions, such as protected areas, habitat restoration efforts, and community-based conservation initiatives. This data helps in evaluating the effectiveness of conservation measures.

Example:

- In 2022, 785 tigers were reported in Madhya Pradesh, the highest number of tigers in India. Karnataka had 563, Uttarakhand had 560, and Maharashtra had 444.
- The National Tiger Conservation Authority (NTCA) and the Wildlife Institute of India (WII) released a report on tiger conservation.
- As of April 2022, India has 53 tiger reserves, with 2,967 tigers.
- The 2018 tiger census estimates that India has over 2,967 tigers, up from 1,411 in 2006.
- The tiger population has recovered due to the efforts of the Indian government, conservation groups, and local populations.
- The country has allocated $11 million to tiger conservation.
- The tiger occupancy has increased from 1,758 cells of 100 km2 in 2018 to 1,792 in 2022.
- The country has more than 70% of the world's wild tigers.

Spatial Data: Use geographic information system (GIS) data to map the distribution of the species and its habitat, as well as to analyze spatial patterns and connectivity. This data is crucial for habitat conservation planning and prioritization.

- Monitoring Data: Implement monitoring programs to collect data on species populations, habitat conditions, and the effectiveness of conservation actions over time. This data helps in assessing the impact of conservation efforts and adjusting strategies as needed.

  Example:

The National Tiger Conservation Authority (NTCA) of India monitors Bengal tiger data using camera traps, tracking technologies, and DNA collected from scat. The data is used to analyze the progress of tiger populations, which helps to adapt conservation strategies and make decisions based on science and field experience.

The NTCA has observed that tiger occupancy has increased by 6% per year since 2006, and in 2022, the tiger occupancy increased from 1,758 cells of 100 km2 in 2018 to 1,792. In 2022, 3,080 unique tigers were photographed, while in 2018, 2,461 unique tigers were captured.

- **Stakeholder Data:** Identify and engage with relevant stakeholders, including local communities, government agencies, NGOs, and researchers. Understanding their perspectives and involvement is critical for successful conservation planning and implementation.

  Example:

According to WWF India, the major stakeholders in tiger conservation in India are:

- Government of India (Ministry of Environment and Forests)
- State Forest Departments
- The National Tiger Conservation Authority
- Local communities
- Tourism Departments
- Media
- NGOs such as WWF-India

WWF India has been working with Project Tiger, the National Tiger Conservation Authority, state forest departments, local communities, and other stakeholders to address conservation issues in different tiger landscapes.

Overall, thorough data collection and analysis are essential for gaining a comprehensive understanding of the wildlife conservation problem and developing effective strategies to address it.

MODELING APPROACH SELECTION

We will use Agent-based modeling to resolve this issue.

Agent-based modeling (ABM) can be a powerful tool for simulating nature conservation strategies, especially in complex systems where individual agents (eg animals, and humans) interact with each other and their environment. ABM can be used to protect wildlife in the following ways:

- **Agent Representation:** Agents in the model can represent individual animals, humans, or other entities relevant to the conservation problem. Each agent has attributes (e.g., age, behavior, location) and can interact with other agents and the environment.
- **Environment Representation:** The environment is represented as a spatially explicit grid or network where agents interact. The environment can include habitat patches, resources, threats, and conservation interventions.
- **Behavior Modeling:** Agents' behaviors are modeled based on their attributes and the rules governing their interactions with other agents and the environment. For example, agents can move between habitat patches, reproduce, forage for food, or avoid threats.
- **Population Dynamics:** The model can simulate the population dynamics of the target species, including birth, death, and movement patterns. This can help in understanding how populations respond to changes in habitat quality, threats, and conservation actions.

- **Habitat Dynamics:** The model can simulate changes in habitat quality over time, such as habitat loss, degradation, or restoration. This can help in assessing the impact of habitat changes on species populations.
- **Conservation Interventions:** The model can simulate different conservation strategies, such as establishing protected areas, implementing habitat restoration, or reducing threats. This can help in identifying the most effective strategies for achieving conservation goals.
- **Scenario Testing:** ABM allows for testing different scenarios by adjusting parameters or introducing new variables. This can help in exploring the consequences of different management decisions and uncertainties in the system.
- **Data Integration:** ABM can integrate data from various sources, such as field surveys, remote sensing, and expert knowledge, to inform the model and improve its accuracy and relevance to real-world conditions.

By using ABM, wildlife conservation practitioners can simulate complex ecological systems, explore the effects of different management strategies, and inform decision-making processes for more effective conservation outcomes.

ALGORITHM

1. **Initialization**
    - Initialize the simulation environment with parameters such as habitat size, carrying capacity, initial population size, reproduction rate, mortality rate, habitat degradation rate, and conservation efficiency.
    - Create themes that represent individual animals of the target species, each with characteristics such as age, reproductive state, energy level, and habitat location.
    - To place agents in a habitat randomly or based on known distribution patterns.
    - Define the spatial and temporal scale of the simulation (eg grid cells representing habitats, annual time steps).

2. **Simulation Steps**

- Repeat the following steps for each time step: For each agent: Determine the agent's behavior based on its attributes, environmental conditions, and conservation efforts.
- Update the agent's attributes (e.g., age, energy level) based on its behavior and interactions with the environment.
- Update the habitat quality based on factors such as habitat degradation, food availability, and conservation efforts.
- Apply conservation efforts to improve habitat quality and/or reduce threats.
- Record the population dynamics, habitat quality, and conservation efforts for analysis.

3. **Optimization Steps**

    - Based on simulation results, adjust conservation measures (eg location and intensity of conservation measures) to optimize population size and habitat quality.
    - Repeat the simulation with different conservation strategies to find the most efficient approach.

4. **Termination**

    - End the simulation after a predefined number of time steps or when a specific condition is met (e.g., population stabilization, habitat degradation beyond a threshold).

5. **Output Analysis**

    - Analyze the simulation results to evaluate the impact of different conservation strategies on population dynamics, habitat quality, and other relevant metrics.
    - Identify key factors influencing the effectiveness of conservation strategies and make recommendations for real-world conservation efforts.

This algorithm provides a framework for simulating and optimizing wildlife conservation strategies using ABM. It can be customized and expanded based on specific conservation goals, target species, and ecological systems.

Let's incorporate Monte Carlo Simulation with ABM:

To incorporate a Monte Carlo simulation approach into the agent-based model for wildlife conservation, we can use it to introduce stochasticity and uncertainty into certain parameters or processes. Here's how you might modify the algorithm:

1. **Initialization:**
    - Initialize the simulation environment and agents as before.
    - Additionally, define the parameters or processes that will be varied stochastically using Monte Carlo simulation (e.g., reproduction rate, mortality rate, habitat quality).

2. Monte Carlo Simulation Steps:

- For each iteration of the Monte Carlo simulation:
    i. Sample values for the stochastic parameters from their respective probability distributions.
    ii. Run the agent-based simulation using these sampled values.
    iii. Record the outcomes of interest (e.g., population size, habitat quality) for analysis.

3. Analysis:

- Analyze the outcomes of the Monte Carlo simulations to understand the range of possible outcomes and the uncertainty associated with the conservation strategies.
- Use the results to refine the conservation strategies and make informed decisions.

By incorporating Monte Carlo simulation, the model can account for variability and uncertainty in the system, providing a more robust assessment of the effectiveness of different conservation strategies.

CONCEPTUAL MODEL

Here's an example of a conceptual model for simulating wildlife conservation strategies using agent-based modeling, focusing on the conservation of a hypothetical species of endangered birds in a fragmented habitat:

1. Entities:

- Birds (agents)
- Habitat patches
- Food sources
- Predators
- Conservation interventions (e.g., habitat restoration areas, predator control measures)

2. Attributes:

- Bird: Age, reproductive status, energy level, location
- Habitat patch: Quality (e.g., suitable for nesting, food availability)
- Food source: Availability
- Predator: Presence, hunting behavior
- Conservation intervention: Effectiveness, location

3. States:

- Bird: Alive/dead, reproductive/non-reproductive
- Habitat patch: Intact/degraded
- Predator: Active/inactive
- Conservation intervention: Implemented/not implemented

4. Events:

- Birth: Increase in population size

- Death: Decrease population size
- Movement: Birds move between habitat patches
- Reproduction: Birds reproduce based on age and energy level
- Habitat degradation: Habitat patches degrade over time due to factors like human activities or natural processes
- Conservation actions: Implementation of conservation interventions to improve habitat quality or reduce threats.

5. Interactions:

- Competition for food: Birds compete for limited food resources
- Predation: Birds are preyed upon by predators
- Habitat quality: Habitat quality affects bird behavior, reproduction, and survival
- Conservation interventions: Interventions can improve habitat quality and reduce threats, impacting bird populations.

6. Model Structure:

- Use flowcharts or diagrams to represent the relationships and interactions between entities and events in the model, showing how they influence population dynamics and habitat quality over time.

This conceptual model provides a framework for developing an agent-based simulation model to study the effects of different conservation strategies, such as habitat restoration and predator control, on the population dynamics of endangered birds in a fragmented habitat.

PSEUDO STEPS FOR MONTE CARLO SIMULATION:

Here's the algorithm of the code for simulating wildlife population growth using Monte Carlo simulation in C:

Initialization:

- Seed the random number generator.
- Define the number of simulations (`NUM_SIMULATIONS`), initial population size (`INITIAL_POPULATION_SIZE`), number of years (`NUM_YEARS`), and

parameters for reproduction and mortality rates (mean and standard deviation).

Monte Carlo Simulation Steps:

- For each simulation:
    - Sample reproduction rate and mortality rate from normal distributions with means and standard deviations.
    - Initialize the population size for the first year.
    - For each subsequent year:
        - Calculate the number of births and deaths based on the reproduction and mortality rates.
        - Update the population size for the next year.
        - Ensure the population size is non-negative.

Output:

- Print the results of each simulation, including the simulation number, year, and population size.

This algorithm outlines the steps involved in simulating wildlife population growth using Monte Carlo simulation with stochastic reproduction and mortality rates.

TOOLS, TECHNIQUES AND COMPUTATIONS

1. MONTE CARLO SIMULATION

The integration of Monte Carlo simulation and Agent-based modeling (ABM) in the field of wildlife conservation yields a more realistic representation of ecological systems by incorporating stochasticity and uncertainty into the model. The assessment of conservation is improved by monitoring changes in the key parameters.

TOOLS:

1. Programming Languages: We can use programming languages such as Java or Python to implement ABM and Monte Carlo simulation. These languages offer libraries and frameworks for simulation and statistical analysis.

2. Statistical Software: We can use MATLAB for generating random numbers and sampling from probability distributions for Monte Carlo simulations.

TECHNIQUES:

1. Define Parameters: Define parameters or processes in the ABM that will be varied stochastically using Monte Carlo simulation. These parameters could include reproduction rates, mortality rates, habitat quality, or other factors affecting species populations.

2. Monte Carlo Sampling: Sample values for the stochastic parameters from their respective probability distributions for each iteration of the Monte Carlo Simulation.

3. Model Initialization: Initialize the simulation environment and agents, including setting up the initial conditions for the ABM.

COMPUTATIONS:

1. Agent Behaviors: We need to define the behaviors of the agents in the ABM based on the sampled parameter values, simulating their interactions and responses to environmental factors.
2. Simulation Execution: Run the ABM using the sampled parameter values for each iteration of the Monte Carlo simulation, recording the outcomes of interest (e.g., population size, habitat quality) for analysis.
3. Outcome Analysis: Analyze the outcomes of the Monte Carlo simulations to understand the range of possible outcomes and the uncertainty associated with the conservation strategies. Use statistical measures such as mean, variance, and confidence intervals to quantify uncertainty.

KEY CONCEPTS:

1. Random Sampling: Monte Carlo simulation uses random sampling to generate inputs for the model. This sampling can follow various probability distributions, such as uniform, normal, exponential, or custom distributions.

2. Modeling Complex Systems: Monte Carlo simulation is used to model complex systems where the behavior of individual components is uncertain or variable. By

simulating many possible scenarios, it provides a comprehensive view of the system's behavior.

3. Statistical Analysis: After running the simulation, statistical analysis is performed on the results to estimate the likelihood of different outcomes. This includes calculating means, variances, confidence intervals, and other statistical measures.

4. Applications: Monte Carlo simulation is widely used in various fields, including finance, engineering, physics, and biology. In finance, it is used for risk analysis and option pricing. In engineering, it is used for reliability analysis and optimization.

Example of Monte Carlo Simulation:

One simple example of a Monte Carlo Simulation is to consider calculating the probability of rolling two standard dice. There are 36 combinations of dice rolls. Based on this, you can manually compute the probability of a particular outcome. Using a Monte Carlo Simulation, you can simulate rolling the dice 10,000 times (or more) to achieve more accurate predictions.

2. MATLAB

MATLAB is a high-level programming language and interactive environment developed by MathWorks. It is widely used in engineering, science, and mathematics for numerical computation, data analysis, visualization, and algorithm development.

KEY FEATURES:

1. Matrix Operations: MATLAB's core strength lies in its ability to perform matrix operations efficiently. This makes it well-suited for solving linear algebra problems, such as solving systems of equations and performing eigenvalue calculations.
2. Plotting and Visualization: MATLAB provides powerful plotting and visualization tools for creating 2D and 3D plots, histograms, scatter plots, and more. This makes it easy to visualize data and analyze results.

3. Toolboxes: MATLAB offers a wide range of toolboxes for specific applications, such as signal processing, image processing, control systems, and optimization. These toolboxes provide specialized functions and algorithms to solve complex problems in these areas.
4. Programming Environment: MATLAB provides an interactive programming environment with a command-line interface and a graphical user interface (GUI). This makes it easy to explore data, test algorithms, and develop code iteratively.

Application in Monte Carlo Simulation:

MATLAB is commonly used for implementing Monte Carlo simulations due to its powerful numerical computation capabilities and rich set of plotting functions. It allows researchers and engineers to easily generate random samples, run simulations, and analyze results, making it an ideal tool for Monte Carlo simulations in various fields.

In conclusion, Monte Carlo simulation is a powerful technique for modeling complex systems with random variables, and MATLAB provides a versatile platform for implementing and analyzing Monte Carlo simulations in a wide range of applications.

MATLAB examples are code files that show how to solve problems such as curve fitting, plotting, and image processing.

CODE:

```
#include <stdio.h>

#include <stdlib.h>

#include <math.h>

#include <time.h>

// Define constants for the simulation

#define NUM_SIMULATIONS 5
```

```c
#define INITIAL_POPULATION_SIZE 100

#define NUM_YEARS 10

#define REPRODUCTION_RATE_MEAN 0.1

#define REPRODUCTION_RATE_STDDEV 0.05

#define MORTALITY_RATE_MEAN 0.05

#define MORTALITY_RATE_STDDEV 0.02

// Function to generate a random number from a normal distribution

double normal_random(double mean, double stddev) {

    // Generate two random numbers between 0 and 1

    double u1 = rand() / (RAND_MAX + 1.0);  // U(0, 1)

    double u2 = rand() / (RAND_MAX + 1.0);  // U(0, 1)

    // Box-Muller transform to convert uniform random variables to normal random variables

    double z = sqrt(-2.0 * log(u1)) * cos(2.0 * M_PI * u2);  // N(0, 1)

    // Scale and shift the normal random variable to the desired mean and standard deviation

    return mean + stddev * z;  // N(mean, stddev^2)

}

int main() {

    // Seed the random number generator

    srand(time(NULL));
```

```
    // Loop over each simulation
    for (int sim = 0; sim < NUM_SIMULATIONS; sim++) {
        // Print simulation number
        printf("Simulation %d:\n", sim + 1);
        // Initialize population size for the current simulation
        int population = INITIAL_POPULATION_SIZE;
        // Print initial population size
        printf("Initial Population Size: %d\n", population);
        // Loop over each year
        for (int year = 1; year <= NUM_YEARS; year++) {
            // Sample reproduction and mortality rates from normal distributions
            double reproduction_rate =normal_random(REPRODUCTION_RATE_MEAN, REPRODUCTION_RATE_STDDEV);
            double mortality_rate = normal_random(MORTALITY_RATE_MEAN, MORTALITY_RATE_STDDEV);

            // Calculate number of births and deaths
            int births = reproduction_rate * population;
            int deaths = mortality_rate * population;
            // Update population size for the next year
            population += births - deaths;
```

```
            // Ensure population size is non-negative

            if (population < 0) {

                population = 0;

            }

            // Print population size for the current year

            printf("Year %d - Population: %d\n", year, population);

        }

        // Print a newline to separate simulations

        printf("\n");

    }

    return 0;

}
```

OUTPUT:

```
Simulation 1:
Initial Population Size: 100
Year 1 - Population: 107
Year 2 - Population: 102
Year 3 - Population: 109
Year 4 - Population: 115
Year 5 - Population: 124
Year 6 - Population: 135
Year 7 - Population: 150
Year 8 - Population: 153
Year 9 - Population: 147
Year 10 - Population: 153

Simulation 2:
Initial Population Size: 100
Year 1 - Population: 99
Year 2 - Population: 107
Year 3 - Population: 111
Year 4 - Population: 113
Year 5 - Population: 130
Year 6 - Population: 143
Year 7 - Population: 144
Year 8 - Population: 149
Year 9 - Population: 165
Year 10 - Population: 177
```

```
Simulation 3:
Initial Population Size: 100
Year 1 - Population: 111
Year 2 - Population: 117
Year 3 - Population: 121
Year 4 - Population: 114
Year 5 - Population: 115
Year 6 - Population: 116
Year 7 - Population: 121
Year 8 - Population: 132
Year 9 - Population: 140
Year 10 - Population: 158

Simulation 4:
Initial Population Size: 100
Year 1 - Population: 106
Year 2 - Population: 117
Year 3 - Population: 127
Year 4 - Population: 144
Year 5 - Population: 150
Year 6 - Population: 145
Year 7 - Population: 162
Year 8 - Population: 158
Year 9 - Population: 164
Year 10 - Population: 167


Simulation 5:
Initial Population Size: 100
Year 1 - Population: 107
Year 2 - Population: 121
Year 3 - Population: 130
Year 4 - Population: 140
Year 5 - Population: 142
Year 6 - Population: 139
Year 7 - Population: 145
Year 8 - Population: 150
Year 9 - Population: 158
Year 10 - Population: 148

Program ended with exit code: 0
```

RESULTS AND CONCLUSION:

1. Population Dynamics: The simulation demonstrates the dynamic nature of wildlife populations, which are influenced by reproduction and mortality rates. The population size changes over time in response to these rates.

2. Variability: Due to the random sampling of reproduction and mortality rates from normal distributions, each simulation produces different population trajectories. This variability reflects the inherent uncertainty in population growth.

3. Impact of Parameters: The mean and standard deviation of the reproduction and mortality rates determine the overall population trend. Higher reproduction rates and

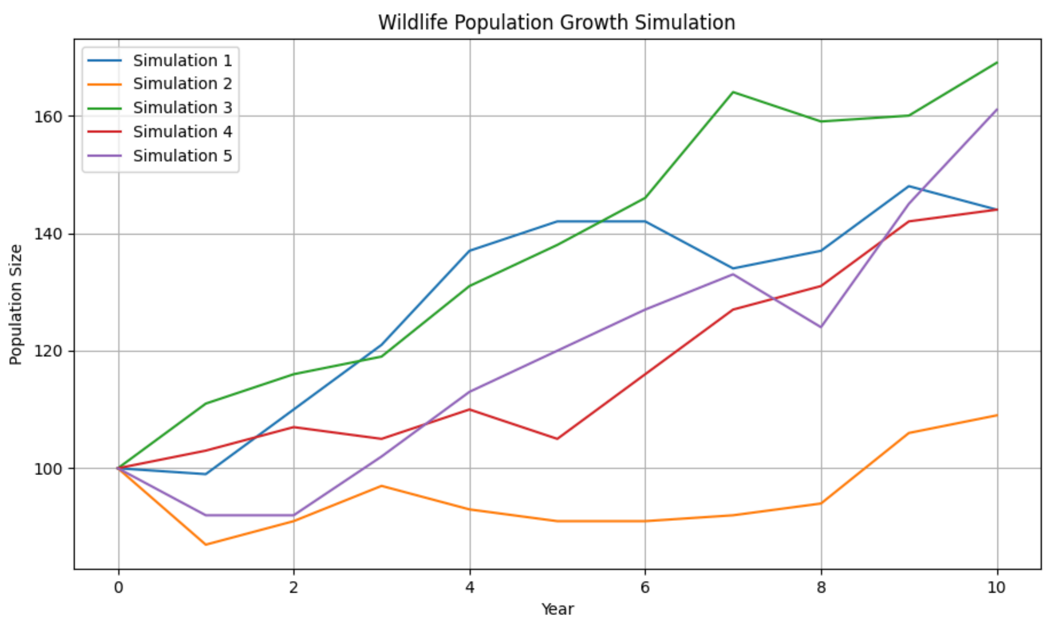
lower mortality rates tend to lead to larger populations, while the opposite leads to smaller populations.

4. Stochasticity: The simulation highlights the stochastic nature of population growth. Even with the same initial conditions, different simulations can result in vastly different population sizes due to random variations in reproduction and mortality rates.

5. Long-Term Trends: By running the simulation over many years and averaging the results over multiple simulations, we can observe long-term population trends and assess the stability of the population over time.

6. Management Implications: The simulation can help wildlife managers and conservationists understand the potential effects of different management strategies on wildlife populations. For example, it can inform decisions regarding hunting quotas, habitat preservation, and other conservation efforts.

VISUALISATION:



WHAT CONCLUSION CAN WE DRAW FROM THE GRAPH:

1.Population Fluctuation: The population size of the wildlife fluctuates over the years, showing variations in growth and decline. Each simulation (represented by a different line) demonstrates a unique pattern of population change.

2.Impact of Random Factors: The use of normal random variables for reproduction and mortality rates results in stochasticity in the population growth simulation. This reflects the influence of random factors on wildlife populations in real-world scenarios.

3.Simulation Variability: Each simulation run produces a different population growth trajectory, highlighting the variability in wildlife population dynamics even under the same initial conditions and parameter settings.

4.Population Stability: Despite fluctuations, the population tends to stabilize or reach an equilibrium over time in some simulations, indicating a balance between birth and death rates.

5.Visualization Clarity: The graph effectively visualizes the population dynamics, with clear labeling and grid lines aiding in the interpretation of the data.

REFERENCES AND CITATIONS

1.Wauchope, H. S., Jones, J. P. G., Geldmann, J., Simmons, B. I., Amano, T., Blanco, D., ... & Sutherland, W. J. (2022). Protected areas have a mixed impact on waterbirds, but management helps. Nature, 605, 103-107.

2.Biomass residues for energy production and habitat preservation. Case study in a montado area in Southwestern Europe, authored by I. Malico and J. Carrajola and C. P. Gomes and J. C. Lima, was published in 2016. featured in the Journal of Cleaner Production journal. falls under volume 112. It can be found on pages 3676-3683.

3.Applying the Delphi method to assess impacts of forest management on biodiversity and habitat preservation, authored by A. Filyushkina and N. Strange and M. Löf and E. Ezebilo and M. Boman, was published in 2018. featured in the Forest Ecology and Management journal. falls under volume 409. It can be found on pages 179-189.

4.Conservation Strategies for Orangutans: Reintroduction versus Habitat Preservation and the Benefits of Sustainably Logged Forest, authored by H. B. Wilson and E. Meijaard and O. Venter and M. Ancrenaz and H. Possingham, was published in 2014. The work is part of the PLoS ONE book. featured in the PLoS ONE journal. falls under volume 9.

5.More losers than winners: investigating Anthropocene defaunation through the diversity of population trends, authored by C. Finn and F. Grattarola and D. Pincheira‐Donoso, was published in 2023. The work is part of the Biological Reviews of The Cambridge Philosophical Society book. featured in the Biological Reviews journal. falls under volume 98.

6.Stability of SARS-CoV-2 in different environmental conditions, authored by A. Chin and Julie T S Chu and M. Perera and K. P. Hui and H. Yen and M. Chan and M. Peiris and L. Poon, was published in 2020. The work is part of the The Lancet Microbe book. featured in the The Lancet. Microbe journal. falls under volume 1. It can be found on pages e10 - e10.

7.Integrating behaviour and ecology into global biodiversity conservation strategies, authored by J. Tobias and A. Pigot, was published in 2019. The work is part of the bioRxiv book. featured in the bioRxiv journal.

8.Animal agency in wildlife conservation and management, authored by É. Edelblutte and R. Krithivasan and Matthew Hayek, was published in 2022. The work is part of the Conservation Biology book. featured in the Conservation Biology journal. falls under volume 37.

9.Koshelev, V. N., Didenko, D. S., Zykov, L., & Shmigirilov, A. (2022). Evaluation of a poaching catch for kaluga Huso dauricus and amur sturgeon Acipenser schrenckii (Acipenseridae). Izvestiya TINRO.

10.Poaching of protected wolves fluctuated seasonally and with non-wolf hunting, authored by F. Santiago-Ávila and A. Treves, was published in 2022. The work is part of the Scientific Reports book. featured in the Scientific Reports journal. falls under volume 12.

11.The tide of tiger poaching in India is rising! An investigation of the intertwined facts with a focus on conservation, authored by George Nittu and T. T. Shameer and N. Nishanthini and R. Sanil, was published in 2022. The work is part of the GeoJournal book. featured in the GeoJournal journal. falls under volume 88. It can be found on pages 753 - 766.

12.Progress developing the concept of other effective area-based conservation measures., authored by C. Cook, was published in 2023. The work is part of the Conservation Biology book. featured in the Conservation biology : the journal of the Society for Conservation Biology journal.

13.A Numerical Study of Several Species Population Models, authored by F. J. Sánchez-Bernabe and Maria del Rosario Escalona-Magdaleno, was published in 2023. The work is part of the Journal of Applied Mathematics and Physics book. featured in the Journal of Applied Mathematics and Physics journal.

14.A quantitative global review of species population monitoring, authored by C. Moussy and I. Burfield and P. Stephenson and Arabella F E Newton and S. Butchart and W. Sutherland and R. Gregory and L. McRae and P. Bubb and I. Roesler and Cynthia A. Ursino and Yanqing Wu and E. Retief and J. Udin and R. Urazaliyev and L. M. Sánchez-Clavijo and E. Lartey and P. Donald, was published in 2021. The work is part of the Conservation Biology book. featured in the Conservation Biology journal. falls under volume 36.

15.Statistics For Spatial Data, authored by L. Vogt, was published in 2016.

16.Minin, E. D., Soutullo, Á., Bartesaghi, L., Ríos, M., Szephegyi, M., & Moilanen, A. (2017). Integrating biodiversity, ecosystem services and socio-economic data to identify priority areas and landowners for conservation actions at the national scale. Biological Conservation, 206, 56-64.

17.Integrating biodiversity, ecosystem services and socio-economic data to identify priority areas and landowners for conservation actions at the national scale, authored by E. D. Minin and Á. Soutullo and Lucía Bartesaghi and Mariana Ríos and M. Szephegyi and A. Moilanen, was published in 2017. featured in the Biological Conservation journal. falls under volume 206. It can be found on pages 56-64.

18.Principles of Population Dynamics and Their Application, authored by A. Berryman, was published in 2020.

19.An Introduction to Agent-Based Modeling: Modeling Natural, Social, and Engineered Complex Systems with NetLogo, authored by U. Wilensky, was published in 2015.

20.Decision letter for "Species data for understanding biodiversity dynamics: The what, where and when of species occurrence data collection", authored by Tanja K. Petersen and J. Speed and V. Grøtan and G. Austrheim, was published in 2020. The work is part of the Ecological Solutions and Evidence book. featured in the Ecological Solutions and Evidence journal.

21.McLane, A. J., Semeniuk, C. a. D., McDermid, G. J., & Marceau, D. J. (2011). The role of agent-based models in wildlife ecology and management. *Ecological Modelling*, *222*(8), 1544–1556. https://doi.org/10.1016/j.ecolmodel.2011.01.020

22.Watkins, A., Noble, J., Foster, R. J., Harmsen, B. J., & Doncaster, C. P. (2015). A spatially explicit agent-based model of the interactions between jaguar populations and their habitats. *Ecological Modelling*, *306*, 268–277. https://doi.org/10.1016/j.ecolmodel.2014.10.038

23.Hof, J., & Haight, R. G. (2007). Optimization of forest wildlife objectives. In *Springer eBooks* (pp. 405–418). https://doi.org/10.1007/978-0-387-71815-6_21

24.Carter, N., Levin, S. A., Barlow, A., & Grimm, V. (2015). Modeling tiger population and territory dynamics using an agent-based approach. *Ecological Modelling*, *312*, 347–362. https://doi.org/10.1016/j.ecolmodel.2015.06.008

25.Pertoldi, C., & Topping, C. J. (2004). The use of agent-based modelling of genetics in conservation genetics studies. *Journal for Nature Conservation*, *12*(2), 111–120. https://doi.org/10.1016/j.jnc.2003.12.001

26.Meeks, D., Morton, O., & Edwards, D. P. (2024). Wildlife farming: Balancing economic and conservation interests in the face of illegal wildlife trade. *People and Nature*. https://doi.org/10.1002/pan3.10588

27.Reynolds, M., Sullivan, B. L., Hallstein, E., Matsumoto, S. S., Kelling, S., Merrifield, M., Fink, D., Johnston, A., Hochachka, W. M., Bruns, N. E., Reiter, M. E., Veloz, S., Hickey, C. M., Elliott, N., Martin, L. A., Fitzpatrick, J. W., Spraycar, P., Golet, G. H., McColl, C., . . . Morrison,

S. (2017). Dynamic conservation for migratory species. *Science Advances*, *3*(8). https://doi.org/10.1126/sciadv.1700707

28.McRae, B. H., Schumaker, N. H., McKane, R. B., Busing, R. T., Solomon, A. M., & Burdick, C. A. (2008). A multi-model framework for simulating wildlife population response to land-use and climate change. *Ecological Modelling*, *219*(1–2), 77–91. https://doi.org/10.1016/j.ecolmodel.2008.08.001

29.*CBC: Lessons in Conservation | AMNH*. (n.d.). American Museum of Natural History. https://ncep.amnh.org/linc/

30.McCullough, D. R., & Barrett, R. H. (1992). Wildlife 2001: Populations. In *Springer eBooks*. https://doi.org/10.1007/978-94-011-2868-1

31.Page, C. L., Bazile, D., Bécu, N., Bommel, P., Bousquet, F., Étienne, M., Mathevet, R., Souchère, V., Trébuil, G., & Wéber, J. (2013). Agent-Based modelling and simulation applied to environmental management. In *Understanding complex systems (Print)* (pp. 499–540). https://doi.org/10.1007/978-3-540-93813-2_19

32.Chion, C., Lamontagne, P., Turgeon, S., Parrott, L., Landry, J., Marceau, D. J., Martins, C. C. A., Michaud, R., Ménard, N., Cantin, G., & Dionne, S. (2011). Eliciting cognitive processes underlying patterns of human–wildlife interactions for agent-based modelling. *Ecological Modelling*, *222*(14), 2213–2226. https://doi.org/10.1016/j.ecolmodel.2011.02.014

33.Semeniuk, C. a. D., Musiani, M., & Marceau, D. J. (2011). Integrating spatial behavioral ecology in Agent-Based models for species conservation. In *InTech eBooks*. https://doi.org/10.5772/23055

34.Marcot, B. G. (2006). HABITAT MODELING FOR BIODIVERSITY CONSERVATION. *Northwestern Naturalist*, *87*(1), 56. https://doi.org/10.1898/1051-1733(2006)87

35.Pereira, H. M., & Borda‐de‐Água, L. (2024). Modeling biodiversity dynamics in countryside and native habitats. In *Elsevier eBooks* (pp. 548–557). https://doi.org/10.1016/b978-0-12-822562-2.00351-0

36. Origin and distribution pattern of pelvic limb nerves of a Bengal tiger (Panthera tigris tigris), authored by H. Sánchez and Norberto Massone and Francisco Alarcón and M. Rafasquino and Juan José Diorio and G. Zuccolilli and Enrique Leo Portiansky, was published in 2023. The work

is part of the Anatomia, Histologia, Embryologia. Journal of Veterinary Medicine Series C book. featured in the Anatomia journal. falls under volume 53.

37.Can Bengal Tiger (Panthera tigris tigris) endure the future climate and land use change scenario in the East Himalayan Region? Perspective from a multiple model framework, authored by J. Deka and Sk Zeeshan Ali and Mujahid Ahamad and Priyanka Borah and G. V. Gopi and R. Badola and Rabindra Sharma and S. A. Hussain, was published in 2023. The work is part of the Ecology and Evolution book. featured in the Ecology and Evolution journal. falls under volume 13.

38. A Reality Check of the Global TX2 Goals of Doubling the Bengal Tiger (Panthera tigris tigris) Population by 2022 in the Sundarbans Mangrove Forest, authored by Md. Ziaul Islam, was published in 2023. The work is part of the Contemporary Problems of Ecology book. featured in the Contemporary Problems of Ecology journal. falls under volume 16. It can be found on pages 868-885.

39. Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999-2010., authored by K. Flegal and M. Carroll and Brian K. Kit and Cynthia L Ogden, was published in 2012. The work is part of the Journal of the American Medical Association (JAMA) book. featured in the JAMA journal. falls under volume 307 5.

40. Physisorption of gases, with special reference to the evaluation of surface area and pore size distribution (IUPAC Technical Report), authored by M. Thommes and K. Kaneko and A. Neimark and J. P. Olivier and F. Rodríguez-Reinoso and J. Rouquerol and K. Sing, was published in 2015. featured in the Pure and Applied Chemistry journal. falls under volume 87. It can be found on pages 1051 - 1069.

41. Stochastic variation in gut bacterial community affects reproductive rates in the water flea Daphnia magna, authored by Kathrine Obrestad and S. Einum and O. Vadstein, was published in 2022. The work is part of the FEMS Microbiology Ecology book. featured in the FEMS Microbiology Ecology journal. falls under volume 98.

42. Sánchez, H., Massone, N., Alarcón, F., Rafasquino, M., Diorio, J. J., Zuccolilli, G., & Portiansky, E. L. (2023). Origin and distribution pattern of pelvic limb nerves of a Bengal tiger (Panthera tigris tigris). Anatomia, 53

43. Spatial-temporal variations of vegetation coverage and its driving factors in the Yangtze River Basin from 2000 to 2019, authored by 易浪, 孙颖, 尹少华, 魏晓, 欧阳晓 YI Lang, was published in 2023. The work is part of the Acta Ecologica Sinica book. featured in the Acta Ecologica Sinica journal.

44. Landscape genomics to enable conservation actions: The California Conservation Genomics Project., authored by H. B. Shaffer and E. Toffelmier and Russell B. Corbett-Detig and Merly Escalona and Bjorn Erickson and P. Fiedler and M. Gold and R. Harrigan and S. Hodges and T. K. Luckau and Courtney Miller and Daniel R Oliveira and Kevin E. Shaffer and B. Shapiro and V. Sork and Ian J. Wang, was published in 2022. The work is part of the Journal of Heredity book. featured in the The Journal of heredity journal.

45. Food availability, accessibility and dietary practices during the COVID-19 pandemic: a multi-country survey, authored by A. Jafri and N. Mathe and E. Aglago and S. Konyole and M. Ouédraogo and K. Audain and U. Zongo and A. Laar and Jeffrey R. Johnson and Dia Sanou, was published in 2021. The work is part of the Public Health Nutrition book. featured in the Public Health Nutrition journal. falls under volume 24. It can be found on pages 1798 - 1805.