People and wildlife

Book

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PEOPLE AND WILDLIFE

EDITED BY: Becky Thomas and Mark Fellowes
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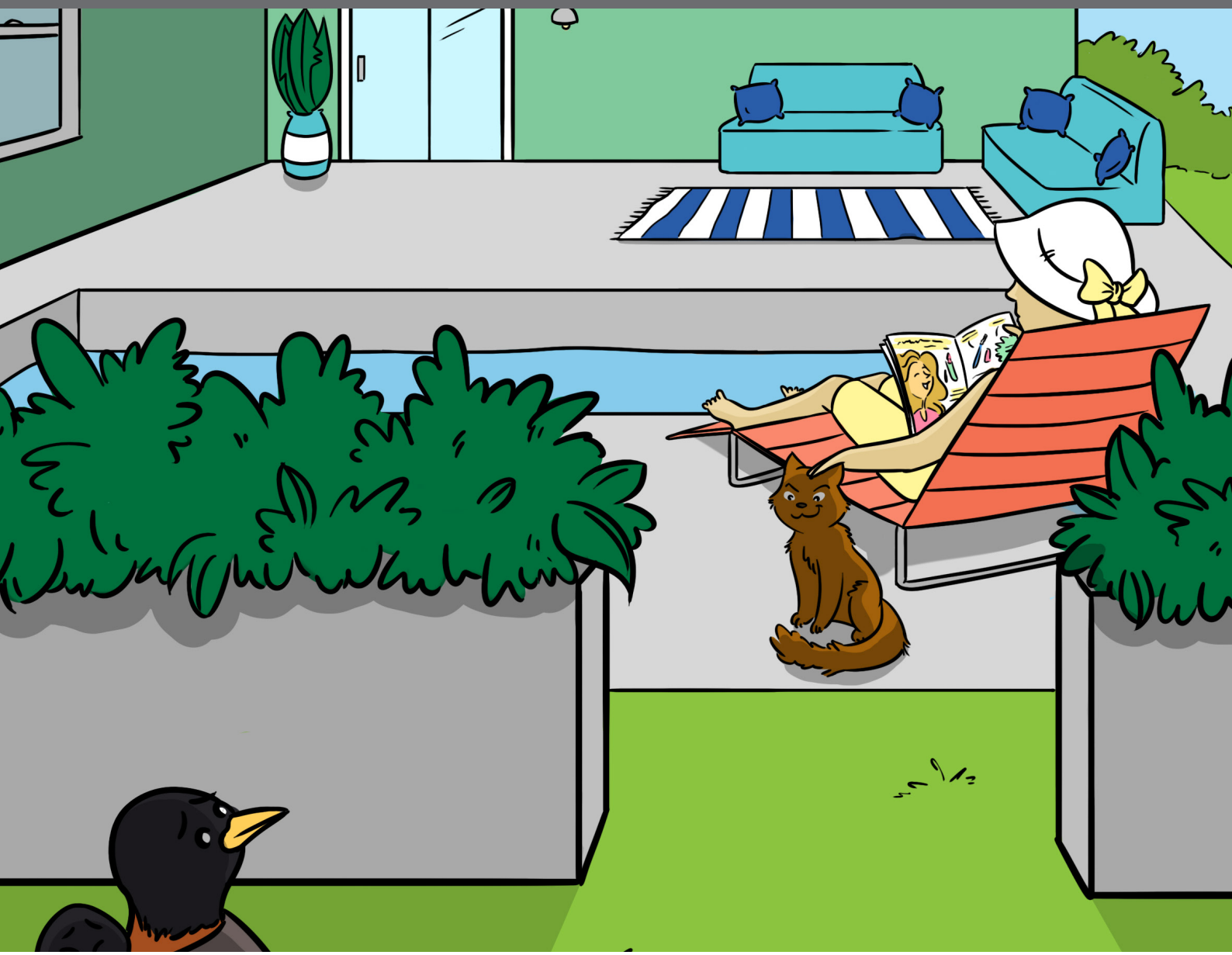

frontiers FOR YOUNG MINDS

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PEOPLE AND WILDLIFE

Topic Editors:
Becky Thomas, Royal Holloway University of London, United Kingdom
Mark Fellowes, University of Reading, United Kingdom

We live in a world filled with fascinating plants and animals, each adapted to environments that range from freezing arctic tundras to humid tropical forests. Our world is also home to more than seven billion people, a number added to every day. Each of us puts pressure on the environment and the space left for wildlife. At its most extreme, every aspect of the environment has been influenced by people's choices, and nowhere more so than the urban areas where most people live. Urban areas are full of people playing and working. They are also full of animals and plants, often living secret lives that go unnoticed. Our interactions with wildlife are often determined by our desire to get close to nature, or sometimes our fear of it.

When people think of urban areas they mostly imagine big cities, but these areas extend into more 'suburban' environments made up of houses, gardens, roads and parks. These landscapes are often filled with wildlife that represent a combination of local plants and animals with species from other places that are planted or escaped, creating a unique habitat linked directly with the people who live there. There are many challenges for the species found here, but many opportunities too. People can individually affect the environment, for example, by owning pet cats who are like mini tigers preying on the local birds; or by leaving out trash and drawing in herds of peccaries or families of raccoons. But it is in combination that we have the greatest impact. For example, houses and street lamps generate lots of light noise which can distract moths from their usual habits, and the roads and streets we build divide up the habitat making it harder for wildlife to move around and find resources. We in turn are also affected by the environment; living in nature-filled areas can positively affect our health and our well-being, yet interactions with certain species (like tics or mosquitoes) can bring disease or discomfort.

Scientists and 'citizen scientists' (expert members of the public) around the world are exploring our interactions with wildlife and nature in urban areas, and here we explore some of this research. This collection of articles aims to highlight some of the amazing wildlife that live alongside us and we explore how we can positively and negatively affect these species.

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BIODIVERSITY
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ARE CITY KIDS MISSING OUT ON NATURE?

Kathryn L. Hand[1*], Claire Freeman[2], Philip Seddon[3], Mariano R. Recio[4], Aviva Stein[2] and Yolanda van Heezik[3]

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YOUNG REVIEWER:

THEODOR

AGE: 12

More and more research is showing how spending time in nature is good for our health and development. Yet, children living in urban areas (towns and cities) may find it difficult to spend time in nature. Their neighborhoods may have little nearby nature to interact with, or they may not be allowed travel on their own to reach natural spaces. Missing out on spending time in nature means children are becoming more disconnected from the natural world. We wanted to understand if children living in urban areas have access to nature in their neighborhoods. Then, if they do have access to nature, do they prefer to spend time in nature, or in other kinds of spaces? What reasons either prevent or encourage use of natural spaces? Our work revealed some new findings on how children interact with nature and how we can improve our urban areas to support nature connection.

THE HUMAN HABITAT

URBAN AREA

An area dominated by man-made structures rather than greenspace.

RURAL AREA

An area away from towns and cities, without many people or buildings.

ABUNDANCE

The number of individuals of plant or animals in a habitat.

BIODIVERSITY

The richness and abundance of plants and animals in a habitat.

We are willing to bet that you live in an **urban area**, such as a town or a city. Most of the world's population does, and more and more people are moving into urban areas every year [1].

Urban areas are very different environments from those in which our ancestors lived. Our ancestors made their homes in woodlands, grasslands, wetlands, beaches, and scrubland. Most of us today live in environments dominated by man-made structures, like buildings and roads. While urban areas do contain nature of a kind, this nature is often very different from the "wild" nature we see outside of cities and towns in **rural areas**. For example, think of parks, gardens, or yards. These spaces are green and can contain many species of plants and animals. But the number of these species and their **abundance** (that is, their "**biodiversity**") is usually lower than that of natural environments like woodlands or beaches.

This shift from living in rural to urban environments means there has been a massive change in our surroundings and how we interact with nature in our daily lives. In our research, we wanted to look at how children growing up in urban areas interacted with the nature around them. We wanted to explore two key theories related to this question, which we will explain below.

A TALE OF TWO THEORIES

BIOPHILIA

An in-born love of nature, and an attraction to spending time in natural spaces and biodiversity.

HABITAT

The particular environment of an area, characterized by different plants and animals present within it.

NATURE DEFICIT DISORDER

The idea that children today are spending less time in nature than children from previous generations did. This causes children to develop problems such as difficulty concentrating, high stress, and poor mental and physical health.

The first theory is called the **biophilia hypothesis**. Proposed in the 1980s, it suggests that people have an in-born preference for nature ("bio-"), and an attraction (-"philia") to natural things or places [2]. The idea is that those areas that were richer in plants and animals were better places for humans to survive and thrive. This theory suggests that our ancestors developed an attraction to natural spaces, where they spent more time and were more likely to settle, and that this attraction remains in modern humans despite our drastic change in **habitat**.

The second theory is the **nature deficit disorder**. This theory came from the idea that children today are spending less time out in nature, and as a result are suffering more and more from problems such as difficulty concentrating, high stress levels, and poor physical health [3]. What is more, not spending as much time with nature means that children today are not learning as much about nature, nor establishing a connection to it.

There are interesting questions that come from these two theories. If biophilia is present in children today, and if urban areas contain some places that have more biodiversity than others, then children should

be attracted to spend time in these more natural places. By doing this, they maintain their connection to nature and perhaps reduce the possibility of developing nature deficit disorder. However, if biophilia is not present, then nature deficit disorder might become more difficult to prevent.

By exploring how children interact with urban nature, we hoped to better understand whether growing up in urban environments could be harmful to children's well-being.

TESTING THE BIOPHILIA HYPOTHESIS

We set out to ask the question, "Are children biophilic?" To do this, we wanted to examine children's use of the areas around them. If the biophilia hypothesis is true, we would expect children prefer to spend time in biodiverse areas in their neighborhoods. We were interested in where children go when they are with friends or on their own, not with adults. So, we designed a study to find out where children spent the most time outside, and whether they used the more biodiverse habitats in their urban neighborhoods.

To do this study, we first needed to understand the amount of biodiversity contained in different urban areas, how much of the biodiversity was accessible to children, and finally where children decided to spend their time outdoors. We used the five steps described below.

STEP 1: FINDING OUT WHAT NATURE IS PRESENT IN CHILDREN'S URBAN NEIGHBORHOODS

Our first step was to define the biodiversity value of different urban habitats. We developed a system for ranking habitats based on the features and numbers of the plants and animals that could be easily seen. Natural habitats, such as woodlands, scored highest; but "formal" greenspaces, such as parks, also scored highly and large, very green gardens also ranked among the highest. "Gray" habitats, such as streets and paved-over areas such as sports courts, usually ranked the lowest.

STEP 2: FINDING OUT WHERE CHILDREN ARE SPENDING THEIR TIME OUTDOORS

In the next step, we needed to find out where children were spending their time outdoors. We interviewed nearly 190 children across three cities in New Zealand. The children were aged 9–11 years and lived in a range of very green urban areas to more gray urban areas. We asked children to add a series of dots onto a map of their

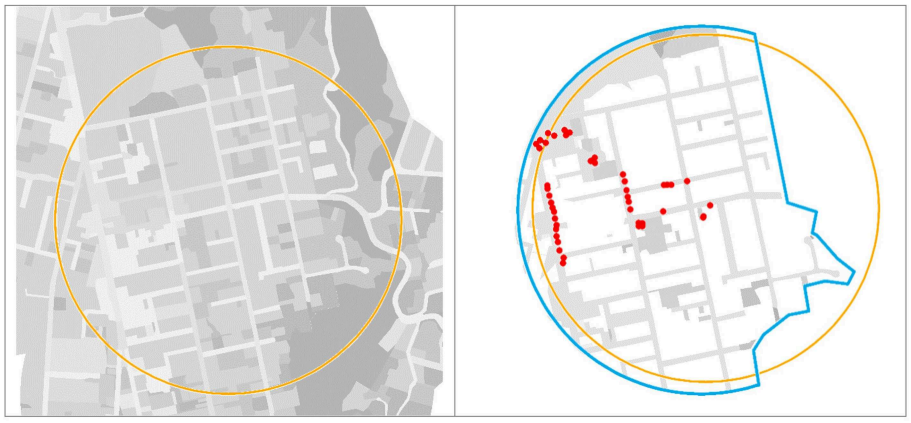

Figure 1

Left: One child's neighborhood range is shown as a 500-m radius circle around his home. The different types of area (habitats) were mapped. They are shown in shades of gray, to indicate their biodiversity value: darker grays indicate more biodiverse habitats than light grays. **Right**: This is the same area, but with the areas the child is not allowed to visit removed, such as private gardens. The blue boundary indicates the areas the child is normally allowed to go on his own. The red dots indicate where the child chose to spend most of his time outdoors.

neighborhood to indicate the amount of time they spent in different areas outdoors.

We then built up a map of that child's neighborhood. We identified all the areas available to and used by the children and gave each site a score that represented its biodiversity value.

We defined all sites within 500 m of a child's home as being "available" to the child. This was to get a measure of the potential biodiversity that surrounded each child in the nearby neighborhood.

The next step was to identify what areas of each site were "accessible" to each child. This meant removing all areas that were privately owned, such as other people's gardens, and areas the child said they were not allowed to go to on their own, such as the other side of a busy road. Figure 1 compares the different areas that were available and accessible for one child in the study. By examining what was available and accessible to children, we could see where children were choosing to spend their time outside.

RESULTS—WHAT ARE CHILDREN'S HABITAT PREFERENCES?

Our study of which areas children preferred to spend time in showed some mixed results. First, children did not show any preference for the most biodiverse area they could visit: woodlands. In fact, children seemed to avoid woodlands; that is, they used woodlands less than would be expected (see text Box 1). Children instead preferred to spend their time in gardens and also on sportsgrounds. Figure 2 shows the preferences of the children in our study to different urban habitats.

Box 1 | Understanding habitat use with Resource Selection Analyses

We used the dots in a technique known as a 'resource selection analyses', which is a method developed in wildlife ecology [4]. This method is used to identify the habitat preference of a species so, for instance, selected areas can be protected to help conserve that species. What is important about this technique is it considers the availability of the different habitats. If an animal or child is showing no preference for a particular habitat, then we would expect the proportion of time spent in that habitat to be equal to the proportion of area that habitat makes up of the animal's range. If an animal were to spend 70% of its time in a habitat that only made up 20% of the total area available for that animal to use, then that habitat is favoured by that animal.

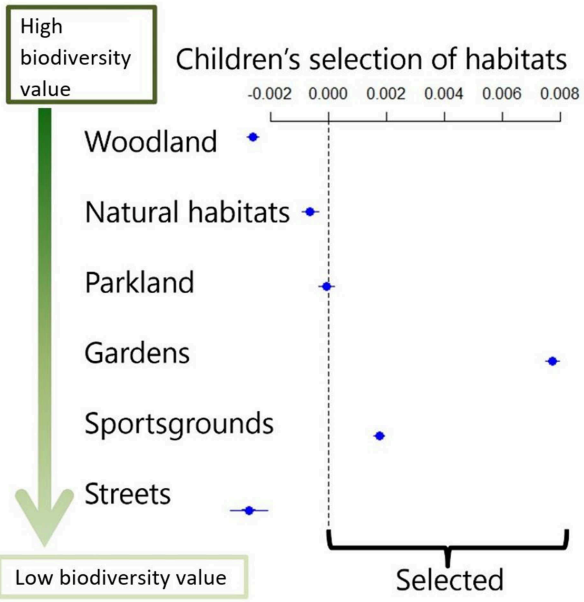

Figure 2

Figure 2

Where did children spend their time? Based on the scale at the top of the graph, dots with positive values indicate a "preference" for that habitat, and those with negative values indicate avoidance of that habitat. The lines either side of the dot indicate the amount of error around our estimates. Dots with smaller lines mean we can be more confident that our findings are correct. Children's selection was assessed for six habitats, ranked from most biodiverse at the top to least biodiverse at the bottom using the biodiversity scoring approach outlined in step 1. We can see here that gardens are the most preferred habitats, followed by sportsgrounds. In contrast, woodlands and streets tend to be avoided.

SO, ARE URBAN CHILDREN BIOPHILIC?

Upon first look, we did not find evidence to support the biophilia hypothesis in the urban children we interviewed—children did not show a greater attraction to the most biodiverse habitats that they could access.

However, we would not jump too quickly to write off the biophilia hypothesis. We first should consider other things that might influence children's use of the areas around their homes.

First, as you can see in Figure 1, that the habitats children actually access are very different from what is available in their neighborhood. We found that some of the biodiverse habitats close to where children lived could not always be used by them, because of the child's or their parents' concerns for safety.

What is the main reason that children use outdoor space? Play, of course! This might explain why habitats that are good to play in, such as sportsgrounds and gardens were most used.

Gardens represent safe places for children to play. Backyards can also be rich in biodiversity. For some children, gardens were the highest biodiversity habitats in their neighborhoods. Perhaps gardens are the best places to combine play, safety, and nature? If so, the biophilia hypothesis is not wrong, it is just one of the reasons for children's use of habitats.

ENCOURAGING BIOPHILIA IN CHILDREN

If we encouraged children to spend more time in nature and made biodiverse natural habitats more available, perhaps nature could become a stronger reason for deciding where to spend time outside. Spending more time in nature has been linked to many benefits for children, such as learning new skills, improved physical fitness, and good mental health.

In our research, however, we found that living in urban areas can mean it is difficult to access nearby natural areas. When we think about how our towns and cities are built, we need to also consider how children use and move around in these spaces. Making biodiverse areas more accessible to children could encourage their use and help prevent nature deficit disorder from setting in.

ORIGINAL SOURCE ARTICLE

Hand, K. L., Freeman, C., Seddon, P. J., Recio, M. R., Stein, A., and van Heezik, Y. 2016. The importance of urban gardens in supporting children's biophilia. *Proc. Natl. Acad. Sci. U.S.A.* 113:9210–5. doi: 10.1073/pnas.1609588114

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CONFLICT OF INTEREST STATEMENT: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWER

THEODOR, AGE: 12

My name is Theodor, and I live in a city near the coast in Central Norway. I love doing outdoor activities and sports, like cross-country skiing, hiking, and camping in the mountains. My favorite wildlife species is the cheetah. I also like reading books about how the natural world works.

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Kathryn Hand contributed to this research as part of her Master's degree at the University of Otago, New Zealand. She then returned to the UK and worked on projects on seabirds, woodland biodiversity, and environmental recording before returning to work on urban ecosystems. She has worked for the past 2 years to investigate the ecosystem services provided by urban trees with Forest Research in the UK. She plans to explore this area of research further, through a Ph.D. starting in 2019 with the Open University, UK. *kathrynlhand@gmail.com

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Claire Freeman is Professor in the Department of Geography, University of Otago, New Zealand, where she mainly teaches in the Master of Planning Programme. Her interests are in environmental planning, including sustainable communities, planning for children and young people, and planning with nature. She is author of several books exploring the relationship between planning, children and the environment. The latest, coauthored with Yolanda van Heezik, is Children, Cities and Nature, Routledge, 2018.

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Philip Seddon is a Professor of Zoology and Director of the Postgraduate Wildlife Management Program at the University of Otago, New Zealand. He has been a member of the IUCN SSC Reintroduction Specialist Group (RSG) since 1994 and has been involved in restoration projects for mammals, birds, and reptiles in Oceania and the Middle East. He has advised on reintroduction projects globally. He was a member of the working groups that drafted the IUCN Reintroduction Guidelines (2013), and the IUCN guidelines on De-extinction for Conservation Benefit (2016).

MARIANO RECIO

Mariano Recio—Originally from Madrid, Mariano moved to Dunedin, New Zealand, to conduct his Ph.D. on the space use of introduced predators, such as feral cats and hedgehogs. Since then, he has worked on how wildlife species use the space and distribute their populations. His research has included native species of New Zealand, such as the kaka, weka, tuatara or velvet worm, and species of European mammalian predators, like the wolf, brown bear, or the Iberian lynx. His research interest has even extended to another quite familiar species, the *Homo sapiens,* this time in its child version.

AVIVA STEIN

Aviva Stein was the research assistant for this project. She holds a Master's degree in Wildlife Management from the University of Otago, and has a background in environmental education.

YOLANDA VAN HEEZIK

Yolanda van Heezik is an Associate Professor at the University of Otago, Dunedin, New Zealand, where she teaches wildlife management and conservation biology. Her urban-based research has investigated wildlife in urban areas, biodiversity of private gardens and public green spaces, resident attitudes, motivations, and knowledge about biodiversity, cat ownership and control, and children's and older adults' interactions with nature.

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BIODIVERSITY
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HOW CAN WE ALL HELP CONSERVE NATURE?

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YOUNG REVIEWERS:

ABDUL
AGE: 12

MUHAMMAD
AGE: 10

When we speak about conserving nature, we are really talking about taking care of our future, because nature provides essential resources for our survival and enjoyment. We asked an international group of scientists working on different environmental issues worldwide to identify important practical actions that we can all do to help conserve nature. We obtained nearly 100 responses and grouped them into three main categories: (1) Actions to reduce our ecological footprint; (2) Actions to conserve nature; and (3) Actions that help us connect with nature. We briefly explain actions that can be performed daily to reduce our impact on nature, and provide some useful links for further reading.

PROTECTING NATURE TO ENSURE OUR FUTURE

We often forget how much humans depend on **nature**. Even city-dwellers living in modern skyscrapers need air to breathe, water to drink, and food to eat, all of which are provided by nature. True, you can buy bottled water and ready-to-eat meals in supermarkets, but they were not produced there. Some fruits and vegetables, for example, only grow in tropical countries and cross the globe in refrigerated ship containers, to arrive just ripe to your local supermarket. All drinking water ultimately comes from a natural source, since we still do not have the technology to manufacture large amounts of water in the laboratory [1]. The same applies to the air we breathe, which is purified and oxygenated by plants [2]. So, when we speak about preserving nature, we are really also talking about preserving ourselves.

Whereas nature encompasses the natural environment as a whole, the term **biodiversity** [3] is used to refer to all living organisms. Biodiversity is ultimately responsible for the services we receive from nature, which are also called **Ecosystem Services** [4] or Nature's Contribution to People [5]. For example, forests containing many different bee species provide pollination services to nearby crop fields. In places where natural forests have been cut down, beekeepers must bring in artificial beehives to guarantee that enough pollinators visit crop flowers to produce fruit [6]. Other wild organisms, like wasps and birds, act as pest-control agents for agricultural crops, reducing the population of pests that damage those crops, and resulting in higher crop yields.

You are probably thinking that you already knew about this, and that there is not much you can do to preserve air, water, or fruit trees. But even if you live in a big city, far away from oxygen-producing forests, natural water springs, or crop fields, your daily actions can have a strong impact on these natural resources. Spilling a single drop of cooking oil while cleaning the dishes contaminates a million drops of water. Traveling in a vehicle powered by fossil fuels contributes to air pollution and global **climate change** [7]. Buying certain processed food ingredients, like palm oil, can contribute to massive deforestation in the tropics, as farmers clear land to grow these crops for money. All these impacts together make up what is called our **ecological footprint** on nature [8], which is a measure to quantify our daily life's impact on nature.

We will now share with you some important practical actions that we can all do to help conserve nature, to preserve our own well-being, and to guarantee that natural resources are available for future generations.

NATURE

The term that encompasses living organisms and the forces responsible for the physical world, such as the weather, mountains, oceans, and landscapes.

BIODIVERSITY

The word biodiversity means the variety of all living organisms on Earth, and includes different levels of organization—from genes, species, and communities through to entire ecosystems.

ECOSYSTEM SERVICES

The many benefits that people get from natural ecosystems. These services can be broken down into provisioning (e.g., food and wood), supporting (e.g., soil formation and nutrient cycling), regulating (e.g., clean air and water purification), and cultural (e.g., recreation and eco-tourism).

CLIMATE CHANGE

Change in global or regional climate patterns, most due to increased levels of greenhouse gases produced by the burning of fossil fuels. Greenhouse gases, like carbon dioxide, act like a blanket, trapping heat near the Earth's surface, and raising the temperature.

ECOLOGICAL FOOTPRINT

This is a measure of how much people take from nature, which is then compared to what natural resources are available to provide for people.

WHAT ACTIONS CAN WE TAKE TO HELP CONSERVE NATURE?

We asked an international group of scientists, working on various environmental issues, to provide ideas on what young people can do to help conserve nature. We obtained nearly 100 responses and then organized all of the ideas by grouping them into three main categories: (1) Actions to reduce our ecological footprint (Figure 1); (2) Actions to conserve nature (Figure 2); and (3) Actions to connect with nature (Figure 3). Below we explain each.

Reduce our ecological footprint: Reducing our ecological footprint means placing less demand on nature (read here about the 3Rs—reduce, reuse and recycle; and get some ideas here on how you can help nature). Here are some ways that you can do this:

- Recycle your rubbish and participate in or help organize recycling campaigns.
- Avoid littering and participate in or help organize litter clean-ups (here you can link to a website for volunteering or starting your own beach clean-up).
- Use less plastic by, for example, carrying a reusable water bottle, saying no to disposable straws and cutlery, avoiding plastic toys, and bringing your own shopping bags (for further ideas on a plastic-free life take a look here).
- Swap toys, movies, and books instead of buying new ones.
- Donate, recycle, and repair electronic devices (see how here).
- Use less water when brushing teeth, taking a shower, or washing the dishes.
- Use less electricity by turning off lights and electronic devices when not in use, using energy-saving light bulbs, and hanging clothes to dry.

Figure 1

Figure 1

Word cloud showing the key actions that can be taken to reduce our ecological footprint.

- Use public transport, share a journey with friends (e.g., car-sharing), cycle, or walk when possible.
- Use less paper by not printing unnecessary things and reading e-books.
- Turn down the air conditioning when it is hot and use fans if you are still hot-they use much less power.
- Turn down the heat when it is cold and use sweaters, blankets, and socks to keep warm.
- Do not waste food and try to buy food that is grown locally and in season.
- Eat more non-meat proteins (like beans), less dairy, more vegetables, and more organic food when possible.
- Buy products that do not cause damage to the environment and that have certified labels (such as **Rainforest Alliance** and **Animal Welfare**).
- Refuse to buy what you do not need, because every item you do not buy reduces the demand for the production of that item. For example, if everyone stopped buying plastic bags, super markets would stop selling them.

Conserve nature: Conserving nature means to protect, preserve and restore biodiversity. Here are some ways that you can do this:

- Try to prevent your pets from killing/harming wildlife (for some specific advice to help your local birds, see this).
- Do not touch or take home wild animals or plants (see some advice here).
- Plant native wildflowers, fruit trees, and pollinator-friendly plants in your garden or yard (for some related gardening tips, check out this).

Figure 2

Word cloud showing the key actions that can be taken to conserve nature.

- Make compost to improve soil quality and to help insects (check out a guide to composting here).
- Build and place bat houses, bird houses, and "bee hotels" in your garden, school grounds, and local green spaces (here you can learn how make and manage a Bee hotel).
- Do not buy/keep wild pets at home (such as parrots, song birds, wild cats, or reptiles), in order to avoid supporting illegal trafficking of animals (here you can find more info about illegal wildlife trade).
- Be aware of wild animals crossing the road and respect their paths (here is some further information about the importance of wildlife crossings).

Connect with nature: Connecting with nature means setting aside time to interact with the natural environment. Here are some ways that you can do this:

- Play outside and spend more time in nature (read this link to find out why this is so important).
- Organize trips to explore the national parks/nature reserves close to you.
- Join conservation programs or eco-clubs (see how here).
- Participate in nature-focused citizen science initiatives (learn more about citizen science here and see actual projects you can join here and here).
- Use books or apps to identify the plants and animals around you (check out a cool app here).
- Play games to learn more about nature (check out some fun examples here and here).
- Use websites, blogs or social media to help raise awareness on the importance of conserving nature and share all these ideas).

Figure 3

Word cloud showing the key actions that can be taken to connect with nature.

Figure 3

CONCLUSION

Understanding the importance of nature and biodiversity for our own well-being can really help us to help nature. In this article, we have provided some practical ideas that we can all try to reduce our ecological footprint, conserve nature, and connect with nature. We encourage you to put these ideas into practice and share these actions with your family and friends.

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YOUNG REVIEWERS

ABDUL, AGE: 12

Abdul is very interested in biodiversity with special attention on extinct or endangered species. He likes learning about life in oceans, on mountains, and wishes to find life in space, if any. He loves drawing nature!

MUHAMMAD, AGE: 10

Muhammad loves to draw natural environments, hills, rivers, oceans, and prepare 3D structures airplanes, whales, small machines from playdough. He likes the wild animals living in faraway forests where they are not disturbed by humans.

AUTHORS

MARCIA C. MUÑOZ

Dr. Marcia Carolina Muñoz is a postdoctoral fellow at the Humboldt Institute in Bogotá, Colombia. Her research focus is centered on beneficial interactions between plants and birds, in particular, seed dispersal and pollination in tropical systems, and the consequences of these interactions on biodiversity. She likes hiking and taking pictures of birds, flowers, and natural landscapes.

MIREIA VALLE

Dr. Mireia Valle is a postdoctoral researcher from the Basque Centre for Climate Change (BC3) who has been awarded a postdoctoral fellowship by the Basque Government, which covers two years in a foreign research centre and a third year in a research institution in the Basque Country. She is currently performing her research at the National Center for Ecological Analysis and Synthesis at University of California Santa Barbara (EEUU). She wants to understand how and where marine fish will shift due to climate change and the implications of such shifts on the benefits we derive from these fish. She became mum in October 2018 and looks forward to helping to continue to protect nature and ensure a sustainable future for new generations.

RACHEL L. WHITE

Dr. Rachel L. White is a Senior Lecturer in Ecology and Conservation at the University of Brighton. Her research includes the ecology and conservation of birds, understanding extinction risk, environmental education, and human-nature interactions. She is passionate about sharing her sense of wonder and excitement

about the natural world with anyone, but particularly with children (who are the next-generation of conservationists).

RODOLFO JAFFÉ

Dr. Rodolfo Jaffé is a researcher/faculty at Instituto Tecnológico Vale, located at the mouth of the Amazon River in Brazil. He studies how human-led alterations of natural environments affect biodiversity, focusing on insects and plants. He enjoys spending weekends on the beach with family and friends, and hopes his 2-years old daughter enjoys reading this paper when she grows up. *r.jaffe@ib.usp.br

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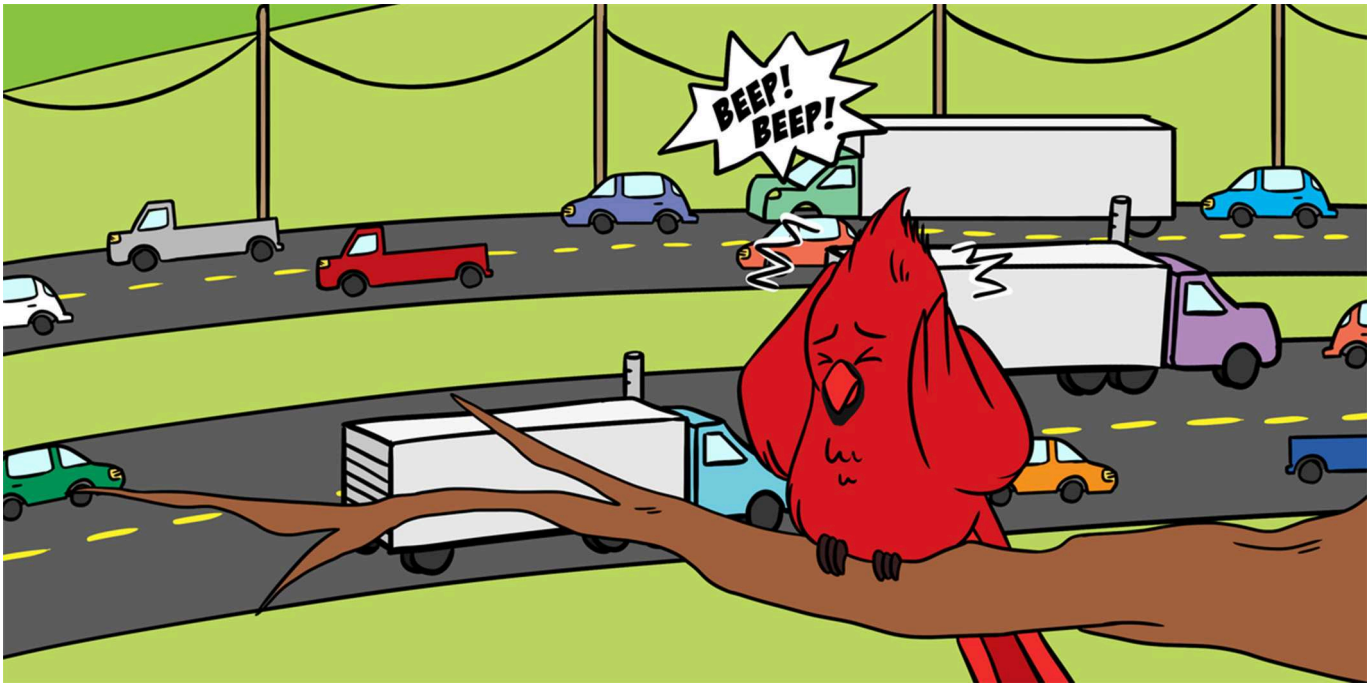

WHY DIDN'T THE BIRD CROSS THE ROAD?

Christopher D. Johnson**, Daryl Evans and Darryl Jones

Environmental Futures Centre, Griffith University, Nathan, QLD, Australia

YOUNG REVIEWERS:

SYRACUSE ARTS ACADEMY

AGES: 12–14

TALI

AGE: 13

Roads are very useful: we build them so we can travel to the grocery store, see our friends, and take day trips to the beach. However, when we clear land to build our roads, we destroy the homes of other animals. If your home was destroyed, what would you do? Find a new home of course! But roads make this very difficult for other animals, at least for larger animals. Not many studies have looked into the impacts of roads on smaller animals, such as birds. So, we decided to investigate this ourselves. Why birds? They have wings and can fly, right? Surprisingly, we found fewer birds crossed as roads became wider. We also found that the small birds that need forests to survive were the ones most impacted by roads. These findings show us that, despite appearances, birds are as vulnerable as other animals to human activities.

HOW DO ROADS AFFECT BIRDS?

What is it that is so awesome about birds? If you ask people that question, chances are they will likely respond with "they can fly!" Birds can fly away when chased by a dog, they can catch food in the air

(some are even quite acrobatic), and they can even fly above and around obstacles, such as buildings and trees. It appears that there is not much a bird cannot do (other than use a computer). Unfortunately, because many people have thought this in the past, very few studies have looked at birds in situations where they must move between **habitat** patches. However, recent studies have shown that birds may find it very difficult to cross even small open spaces like roads when moving between forest patches [1].

HABITAT

The natural home or environment of an animal, plant, or other organism.

HABITAT FRAGMENTATION

The breakdown of a large, continuous habitat into several smaller, separate habitats.

Scientists have suggested several reasons to explain why building roads may be bad for some birds. One theory is that, by building a road, we separate forests and reduce the area of habitat available for animals to live in, a process that we call **habitat fragmentation**. Habitat fragmentation is a big problem for many species, because conditions may change very quickly within the remaining habitat fragments and become unsuitable for the species, particularly around the edges (in this case, the areas nearby the road). Try to imagine waking up one morning to find that the roof of your house is gone, and for some reason you are unable to replace it. Let us say you decide to stick around for a bit. You will soon notice that nothing stays dry when it rains, it gets too hot in summer and too cold in winter (and you have no air conditioning), you have to share your house with some of the other local creatures (and you may not always get along), there never seems to be enough food in the pantry, and your friends would not come around because the place is a mess. You may be able to continue living in your old home for a while, but sooner or later you will want to move elsewhere! This is what it might be like to be a bird living in an area through which a road is built.

Other studies have found that when roads are heavy with traffic and noise, birds in the surrounding habitats are more likely to experience stress [2]. Exposure to loud noises is also known to mask the calls and songs of some birds [2]. For example, imagine you are trying to have a conversation with your friend out in front of your school and you are interrupted by a loud passing truck. This is very problematic for birds, because they use their songs to communicate with other birds and to defend their territories. So, if a bird species is unable to change the sound of its calls, then that species will be more likely to move to a quieter area where it can be heard [2]. The end result will be that the area near road will be left with only a few species—those that are noise tolerant.

However, all of this information comes from only a few studies. In fact, most studies have focused on the effects of roads on larger animals, such as bears, moose, and elephants. Of the few instances in which birds were studied, most were performed in the northern hemisphere, where both the forests and the birds are very different to those found in Australia. In Australia, for example (where our study was performed), many of the birds can fly great distances, sometimes across the whole of Australia, often because of unpredictable weather.

Birds in other parts of the world where the weather is more predictable, such as England and America, do not have to fly such long distances. No previous studies of the effects of roads on birds had been performed in Australia, and so this got us thinking, "maybe our birds are different from those in the other studies." With this in mind, we asked three questions:

1. Do different road sizes change the number of bird species found in the forests nearby?
2. Do different road sizes change to the number of bird species crossing the roads?
3. Are the types of birds crossing the roads different from the types found in the forest nearby?

DESIGNING THE EXPERIMENT

We used a simple study design: good old-fashioned bird watching and carefully recording what we saw. To be a little more specific, we:

1. Found 12 roads that were suitable for our study: four small, four medium, and four large;
2. Sat at each road for 20 min, counting the numbers and types of birds crossing from one side of the road to the other;
3. Walked 100 m off the road from both sides at each site and counted the types of birds living there, for 20 min; and
4. Revisited each site and repeated the counts eight times, between August 2015 and February 2016.

What made our study different from other related studies was that we decided to try something new: we looked at roads of different sizes (two, four, and six lanes) and analyzed the road-crossing abilities for species of different body sizes ($<$19, 20–29, $>$30 cm) and life-history traits (small forest-dependent, large forest-dependent, honeyeater, and urban-tolerant bird species). We also used some assessment tools and mathematical methods to ensure that we had similar forests and birds at each of our study sites.

FEWER BIRDS CROSSED WIDER ROADS

Would you be willing to cross a small street to get to your friend's house? Now, what if we replaced that street with a busy highway, would you still be willing to cross that road to get to your friend? It turns out that birds also do not like to cross wider, busier roads. Fewer species of bird were able to cross wider roads in our study (see Figure 1). What was even more surprising was that we also saw this pattern in the forests nearby these roads—fewer birds were present in the forests near large roads than in the forests near small roads. Astoundingly, it

Figure 1

Shows the total number of bird species to cross over small, medium, and large road types. Fewer species of bird crossed over large roads compared to small and medium roads.

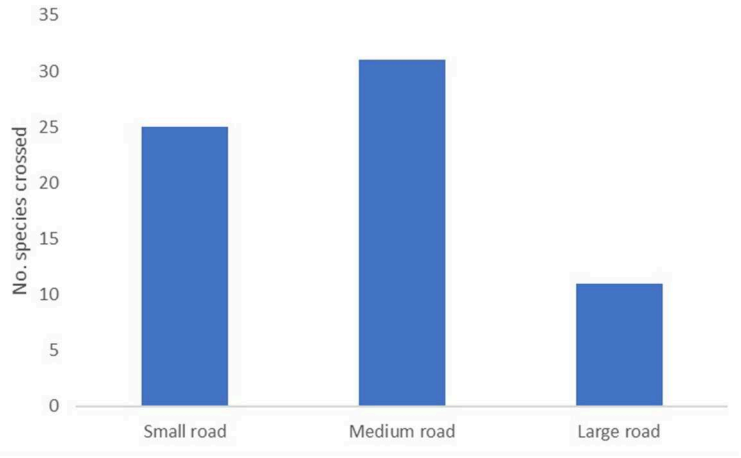

Figure 1

Figure 2

Shows the total number of bird species of different body types to cross over small (blue), medium (orange), and large (gray) road types. The number of small bird species that were seen to cross declined more rapidly as road type increased compared to medium and large birds. No small birds were seen to cross large roads.

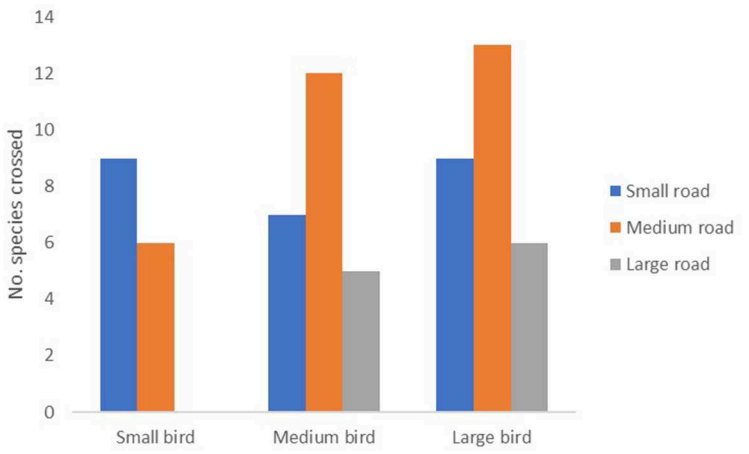

Figure 2

turns out that different types of birds are differently affected. We found that the birds most unlikely to cross roads (of any size) were birds that were small and loved to live in forests, whereas large birds did not seem to mind crossing roads all that much (see Figure 2). Importantly, the results we found in this experiment are similar to those found in other studies [1].

OKAY, SO FEWER BIRDS CROSSED ROADS. BUT WHY?

Why do you think the small forest birds were the most affected by roads? For starters, this group of birds really likes to live in areas with dense plant cover, where there is plenty of food and space available for their families (and enough for other birds, too), and shelter to hide from hungry predators [3]. Road construction often results in changes to the surrounding environment. For example, the dense forest next to the road may become a more open forest (something that we saw a lot of near our roads), and food and space that was previously there

becomes harder to find, so many different animals may be fighting over it. Traffic noise may also make life more difficult. Some of the birds may have trouble calling to and being heard by others and the traffic noise also helps the hungry predators that do not want to be heard when hunting [2]. To make matters worse, the new lights, powerlines, and gardens that often come along with new roads are perfect for some of the bigger and meaner birds, such as the noisy miner and magpie, and these large birds will happily kick the small birds out, to keep these areas for themselves [3].

These are some of the things that the small birds must deal with in the forest near the road. Even if these small birds do manage to survive these challenges, they still need to cross the road. Similar to the results of many previous studies, we counted many more large birds crossing roads than small birds, especially the larger roads. The wings of small forest birds are generally suited for short flights in dense tree cover, so a wide treeless gap, such as a road may be impossible for them to cross in a single flight, and therefore they avoid crossing roads [4]. Predator activity also makes crossing more perilous for small forest birds, because they are very easy for predators to catch when they are outside of tree cover [5].

WHY ARE OUR FINDINGS IMPORTANT?

ECOSYSTEM SERVICES

The direct and indirect contributions of ecosystems to human well-being.

ECOSYSTEM

A biological community of interacting organisms and their physical environment.

KEYSTONE SPECIES

A species that plays a unique and critical role in maintaining the health and function of an ecosystem; without this species, the ecosystem would be very different.

Habitat fragmentation is currently recognized as one of the greatest threats to the survival of many of Earth's species, birds included. What is even more worrying is that humans benefit from the many vital services, called **ecosystem services** that birds provide. For example, many birds are important predators of "pest" species, such as mosquitos and rodents, and birds can also be pollinators of many plant species [6]. In fact, one study found 33% of birds to be involved in spreading the seeds of plants that are medically and economically importance to humans [6]. There are even some birds that are so critical to the functioning of the **ecosystems** they live in that, without them, these ecosystems fall apart. We call these critical species that hold ecosystems together **keystone species**.

Unfortunately, as the human population continues to grow, so too does our demand for more houses and better roads. This has resulted in the widespread destruction and fragmentation of forests, which in turn threatens the survival of birds and the ecosystem services the birds provide us. It is therefore important to better understand how birds behave when they encounter man-made changes to the environment, such as roads.

We hope that our findings will help bring birds into the focus of future research. For example, it will be interesting to compare the way birds react to more natural openings in forest cover, such as clearings in the forest, or rivers. Our work, along with these future

studies, will hopefully give us a better chance at protecting our wildlife while we still meet our need to move from one place to another using roads.

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ORIGINAL SOURCE ARTICLE

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YOUNG REVIEWERS

SYRACUSE ARTS ACADEMY, AGES: 12–14

Syracuse Arts Academy is a public charter school near Salt Lake City in Syracuse, Utah. Students at SAA have a wide variety of interests and enrich their interests with an equally robust variety of arts and electives. These young reviewers are part of the eighth grade integrated science class.

TALI, AGE: 13

I am a 13 years old girl who loves drawing and reading. I am in the eighth grade and I like all of my classes. I also spend a lot of time training in competitive gymnastics.

AUTHORS

CHRISTOPHER D. JOHNSON

Christopher Johnson is a restoration ecologist in the early stage of his career, and recent Griffith University alumni. His passion for the environment comes from his long-standing interest in birds, in particular how their activities and behaviors may be influenced by people within the urban setting. Chris specializes in integrated ecosystem restoration, and over the past decade has worked in close unison with several entities, including government bodies, not-for-profit community groups, and private businesses, across several projects to promote ecological sustainability and achieve balanced outcomes. *christopher.johnson2@uqconnect.edu.au

DARYL EVANS

Daryl is an Ecologist with over 17 years' experience working across government, commercial, and not-for-profit sectors. He specializes in holistic approaches to land and river-scape scale restoration and management. Daryl has successfully integrated community, government and commercial interests to achieve ecologically sustainable outcomes across multiple projects. Daryl is experienced with community-based engagement programs working from the grass roots level through management committee positions. His work has been recognized via government, industry, and academic awards.

DARRYL JONES

Darryl Jones is an urban ecologist based at Griffith University in Brisbane Australia. He is particularly interested in how some species adapt to urban landscapes and why lots of others do not. His work tries to understand the many and complex ways that humans and nature interact, sometimes as conflict and sometimes as coexistence. Over the past decade his work has focused on the ecological impact of traffic and roads and on ways that allow animals to cross roads safely.

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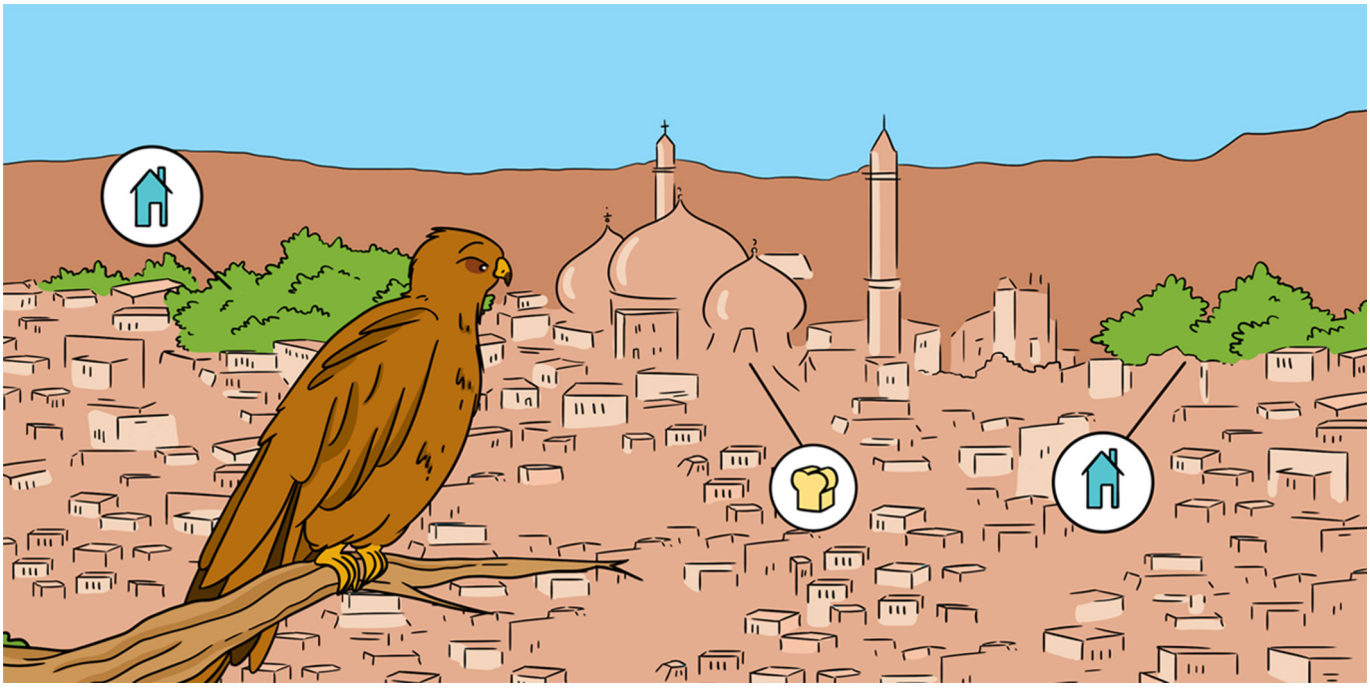

CITIES: HOW DO SOME BIRDS THRIVE THERE?

Nishant Kumar [1,2,3*], ***Urvi Gupta*** [2], ***Yadvendradev V. Jhala*** [2], ***Qamar Qureshi*** [4], ***Andrew G. Gosler*** [1,3,5] ***and Fabrizio Sergio*** [6]

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YOUNG REVIEWER:

LUANA
AGE: 14

Do you know that most humans now live in cities? This has caused a lot of trouble for many animal species. But a few opportunistic animals, like crows and pigeons that you commonly encounter in cities, benefit from dense human habitation. How does a very urbanized, paved, and populated landscape manage to support enormous flocks of birds in tropical cities? This is mostly unknown for urban birds like me: the Black Kite *Milvus migrans*. Researchers studying me in Delhi show that I depend on the food provided by humans and I prey on other common urban animals, such as pigeons and rats. The researchers of this article looked at the food that Muslims in the Indian subcontinent ritually offer kite birds and the impact these meat offerings have. Their analyses show that kite birds take cues from human activity, preferring densely populated areas in the city, with trees capable of holding a large nest, or

road configurations that allow for easy access to human waste and ritual food.

ABOUT ME

ECOSYSTEM

The functional units of nature, comprised of living organisms (plants, animals and microbes) in a particular area, in conjugation with the nonliving components of the interacting system.

VERTEBRATES

Animals with a spinal cord surrounded by cartilage or bone.

Do you know that many animal species take care of their young ones, much like humans? Humans have, however, singularly dominated the planet for thousands of years and more recently devastated most **ecosystems**. This is typically visible when looking at the steady increase of built-up spaces, such as cities. Within only a few centuries, humans have depleted (by weight) almost 99% of **vertebrates**, either through hunting or deforestation [1]. Despite this, there are a few animal species that take advantage of garbage-based food and their populations can also reach high numbers. Humans often see such urban exploiters as pests that occasionally cause trouble or damage properties.

I am one such species. Frequently misidentified as an "Eagle" by city-dwellers in India, kites successfully live alongside humans, opportunistically seeking the availability of food from human generated garbage. Kite birds are reported to be one of the most common and successful birds of prey in the world. Black Kites *Milvus migrans* (Figure 1) are found throughout Eurasia, Africa, and Australia. They almost exclusively live in villages, towns, and cities in India [2]. In Delhi, where kites primarily build their nests on trees, religious kite-feeding practices also provide food. Are you aware of the centuries-old religious Islamic practice of feeding meat scraps to kites for blessings, and to seek relief from sins [3, 4] (follow the video link)? People of Islamic faith live in concentrated and well-defined areas of Delhi (hereafter "Muslim colonies") (Figure 2). Researchers have shown that enormous food-subsidies may explain Delhi's capacity to host so many urban animals [2].

I must stress that there are very few studies that focus on the impact of increasingly built-up spaces in previously non-human populated tropical regions. Most of this urban change is taking place closer to the equator [5]. Animals that are found in these cities play an important role in people's sense of connection with nature. They also remove tons of decaying garbage from the streets and provide a vital sanitary service for humans. One way to address the lack of knowledge on animals that live in cities and villages is researching their choice of suitable living areas and how human activities make cities a useful habitat for animal species. A group of researchers led by Nishant Kumar studied how a parent kite pair identified an urban space in Delhi to live in.

WHAT DO RESEARCHERS EXAMINE WHEN STUDYING A COMMON URBAN BIRD?

What prompted these researchers to study the ecological aspects of a common species? Citizens often assume "obvious roles" for

Figure 1

(A) An urban Black Kite *Milvus migrans govinda* breeder with a twig in its beak is an opportunistic predator that capitalizes on human food subsidies. Photo Credit: F Sergio. We fixed GPS platform terminal transmitters on a few breeding kites to understand their movement with respect to the distribution of food resources. Photo Credit: U Gupta. **(B)** A view from a Black Kite nest on a telephone-tower in Delhi. A heterogeneously developed city needs a multitude of strategies for opportunistic acquisition of urban resources. These strategies are fine-tuned, collectively, on local habitat structure and human activities that provide edible-waste and site-specific ritualized meat feeding. Photo Credit: L Narayan.

urban species, based on occasional observations or common sense. Interestingly, for the citizens of Delhi, and even for Kumar himself, the idea that a (large) **raptor** could nest in huge numbers within a city was unimaginable. Kumar's initial idea of a raptor was a fierce eagle that breeds in some remote, pristine forest, in small numbers, much like tigers. But reality often challenges human simplifications, and this speaks volumes about the wonders and actual machinery of nature waiting to be unraveled.

RAPTOR

Birds of prey.

Once the team noticed sharp variations in the density of kite-nests, they systematically studied the number and productivity of nests between 2013 and 2016 at 24 sampling-plots, each of 100 hectares. These plots covered most of the possible urban settings within Delhi,

Figure 2

Schematic depiction of the major difference between the spatial proximity of mosques (depicted in red, with Islamic symbol) to **(A)** a sampling unit, the National Zoological Park, and **(B)** a random location chosen by the computer in Delhi. Black Kites *Milvus migrans* capitalize on ritual meat tossing near mosques which were less likely to be found in the vicinity of a random location, implying their importance for kites' habitat preferences. Credit: Google Maps.

Figure 2

from semi-natural to extremely built-up sites. This resulted in a sample of 154 nests, checked every 7–10 days until they had chicks of at least 45 days, i.e., ready to fly and become fledglings. For each nest, the effort provided data on the number of young birds that were successfully raised until the flight-stage.

Now, considering that parent kites strategically choose a nesting-site, one would expect successful breeding-investment. Logically, such a strategy should simultaneously take into consideration the proximity

to reliable food sources and safety from potential predators and harsh weather. Researchers had to imagine what a city would look like to me from various altitudes, much like the outer view during the takeoff or landing of an airplane. Quite similarly, while flying at different heights, birds notice and choose from apparent features of a landscape. Researchers also considered **variables** to represent human socio-cultural activities, such as the religious ceremonies that provide kites with food and other resources.

VARIABLE

An attribute that describes a person, place, thing, or idea.

In particular, researchers understood my nesting-habitat selection criteria within different developed pockets of a megacity. A typical way to determine such selection criteria is a comparison of actual nest locations (154) within the 24 sampling study plots, with a matching number of locations randomly chosen by a computer program (ArcGIS, a computer program for geographic analysis, i.e., a Geographic Information System, also called a GIS). At each computer-generated random-location, researchers selected the nearest tree or tower judged capable of supporting a kite nest. Logically, researchers expected kites to be choosy and thus they expected the site-based properties considered important for kites to differ significantly between actual nest locations and computer-generated random-locations. Researchers were additionally helped by remotely available data from a few kites that were carrying GPS-transmitters (transmitters that, once placed on a bird, record its location every few minutes, just as your mobile phone does) and confirming site-based properties important for kites, such as a circular area made up of a 500 m radius, frequently explored around the nest (called a "breeding territory") (Figure 1A). Kites regularly visited ritual feeding sites near mosques with very deliberate, directed journeys.

The site-based properties that allowed for comparisons of nest-locations with random points were primarily of three types: (a) at or around the nest level, e.g., the tree species and height, area of the woodlot around the nest, intensity of human street use around the nest, and the proximity to water and a waste dump, (b) within 500 m radial area around each nest and random site, such as the urban architecture or extent of tree cover and the built-up space, local density of buildings or roads, and (c) at each nest and random location, they also collected representative spatial data for ritual feeding activities, such as the proximity to large Muslim colonies. Further, at each nest or random location, the focal tree's situation with respect to surrounding trees was defined important in the following increasing order: an isolated nesting tree < in a linear roadside avenue plantation < within a park or woodlot. Researchers also classified the nests or random locations in two categories, depending on a high or low amount of edible food-waste (Figure 2).

Figure 3

A broad analogy can be found in the work of a readymade garment tailor and a field-researcher who starts a new research on a species. Both use models to test the fit: a tailor uses wooden-models to stitch clothes of various sizes, while a researcher uses mathematical-models that help them choose from the set of propositions (hypotheses) about the ecological criteria, as observed in the field. Sketch credit: Poonam Pal.

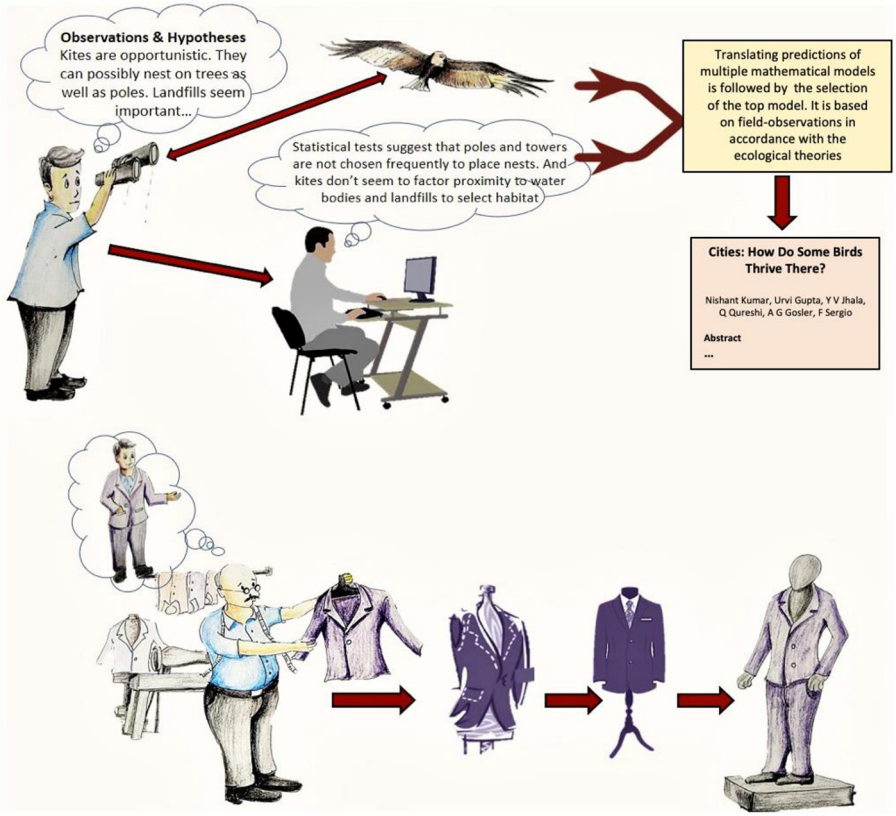

Figure 3

HOW DO RESEARCHERS INVESTIGATE MY PREFERENCES?

You must have observed clothed, human-like mannequins in clothing stores. Do you know that regular tailors stitch clothes for unknown buyers? They actually make use of similar "wooden-models" of various size categories (small, large, extra-large, etc., Figure 3) to stitch garments. Much like the tailor who stitched the readymade shirt you are wearing, a researcher who begins an ecological study is unaware of the preference criteria of non-human organisms. Considering that humans cannot look into my (kite) mind, field-researchers make meticulous observations to prepare a set of guiding propositions called **hypothesis** with respect to kite activities (Figures 1, 2). Subsequently, using data, they test the validity of these propositions using statistical programs and various "mathematical models" which are expected to best reflect my urban ecology. Ultimately, the research team arrives at the simplest final model that adheres well with the real, on-field observations on kites. Researchers validate such models using mathematical **algorithms** to reflect bird choices. Models inform why certain urban choices by the experienced and dominant breeding-kites make them more successful parents (Figure 3).

HYPOTHESIS

A suggestive idea to explain phenomena under observation.

ALGORITHM

A set of rules that must be followed when solving a particular problem.

WHY DO KUMAR AND COLLEAGUES' MATHEMATICAL MODELS STAY JUSTIFIED?

BROODING/ INCUBATION

Acts of sitting on eggs or chicks by the female bird to maintain uniform heat and humidity.

ADAPTIVE/ ADAPTATION

An evolutionary process where populations of a species become better suited to their habitat.

Living in cities is a challenge for non-humans. Most of us kites build nests on trees, but not all trees have kite nests on them. This is because we "choose" to live in certain habitats. During **incubation** and initial **brooding**, the female kite is restricted to the nest for about 2 months. During this time the male takes charge of feeding the whole family. Researchers found that we avoided areas in the city that are contiguously built-up. We are more likely to identify nesting-habitat in safe clusters of trees in a park or woodlot that allow easy access to food coming from garbage piled informally on roadsides, and ritual offerings of meat within densely populated Muslim colonies. In addition, those among us that could breed in the areas with a greater extent of tree-cover in proximity to the sites of ritual feeding managed to raise more young-kites. We would, of course, like to identify habitable patches that are simultaneously associated with ample tree cover near multiple, large Muslim colonies. Thus, researchers defined this strategy of exploiting food near humans to be **adaptive/adaptation**, considering it was associated with higher nesting-success. The simplest and most-accurate mathematical model was based on 4 years of data, and observant-researchers (Figures 2, 3). In a way, the variation of food availability across the city was uniquely tied to complex human themes, which included (1) the complex history of *Muslims* in India; (2) planning of refuse disposal and urban-constructions useful for kites; and (3) cultural and religious practices.

People have an innate love for living creatures called Biophilia (bios: living; philia: love of) that is further diversified by religious beliefs in South Asia, where animals are considered as God's vehicles, or messengers from God. Like any megacity, Delhi will witness rapid change in the coming decades in terms of structure, management, and culture [4, 6]. Kumar and his colleagues have noticed the poor prevalence of the meat offering practice in youngsters, a generational shift that will eventually alter cultural tolerance for backyard-biodiversity [3]. In particular, our dependency on ritual feeding could be seen as a local uniqueness that connects citizens with nature and is thus vital research that should actively be promoted.

AUTHOR CONTRIBUTIONS

NK and UG led the writing of the first draft. All authors contributed to aspects of preparation and writing of the paper and approved the final version.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWER

LUANA, AGE: 14
I like to roller skating, ride a bike, watch movies, and hang out with my friends.

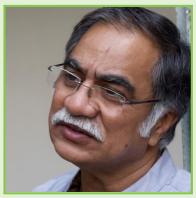
AUTHORS

NISHANT KUMAR
Nishant is a researcher jointly based at the Department of Zoology (University of Oxford) and the Wildlife Institute of India. In Delhi, he tries to understand opportunistic animal responses to resources provided by humans, and how centuries of coexistence have tied urban ecology of commensals with religiously founded patronage and ritual animal feeding by people. He is currently interested in understanding the socio-economic impacts of scavenging ecosystem services provided by opportunistic commensals and how their biocultural links are vital for a sustainable urban future in South Asia. *nishant.kumar@zoo.ox.ac.uk; ryu.nishant@gmail.com

URVI GUPTA
A wildlife enthusiast since childhood, Urvi is the Project Biologist at the Wildlife Institute of India and leads the Black Kite Project. A traveler who likes to see new places, nature-reserves and cultures, Urvi has always been an environmentalist, exemplifying carpooling, waste reduction and minimalism to influence family and friends to live sustainably. Having a background in Zoology from Delhi University and a Masters in Biodiversity, Conservation and Management from Oxford as a Chevening Scholar, she hopes to bridge the gaps between disciplines for wildlife conservation. She is interested in conservation, evolutionary ecology, human-animal interactions and science communication.

YADVENDRADEV V. JHALA
Yadvendradev is a carnivore biologist based at the Wildlife Institute of India. He has been passionate about animals and wilderness since his childhood and wanted to become a zookeeper. His current interest domain covers population ecology, behavioral ecology, and conservation biology and genetics. He leads multiple research programs on the predator-prey dynamics within the Indian protected area network, e.g., the tiger and its prey, and Asiatic Lions. He is also leading the Great

Indian Bustard conservation breeding program and is involved in the countrywide estimation and monitoring of the tiger and its prey species.



QAMAR QURESHI

At the Wildlife Institute of India, Qamar jointly leads the famed All India Tiger Monitoring Project with Yadvendradev. With expertise in landscape ecological methods, he has worked on habitat use patterns using remote sensing and GIS. He is currently involved with projects dealing with biodiversity assessment at the landscape levels. He leads the research on Gangetic Dolphin, working throughout rivers Ganges and Brahmaputra. He also works on rhesus macaques, blue bulls, and wild pigs to understand the human-animal interactions and conflicts. Besides wildlife research, Qamar is an avid reader with a wide taste that he considers essential for every science enthusiast.

ANDREW G. GOSLER

Andy researches questions in Ornithology and Ethno-ornithology concerning Nature Conservation in the broadest terms. He holds a joint position between the Zoology and Anthropology departments at the University of Oxford. He studied the Great Tit population of Wytham Woods and how finely tuned adaptations of the birds fitted them to their ecological community. This work has also contributed to environmental monitoring and conservation. His work now is focused on the significance of birds in engaging people with nature, both for their benefit and the benefit of wildlife, and helping people to understand how their dependence on nature means they must protect nature.

FABRIZIO SERGIO

A book gifted by his father, based on the tigers of Ranthambore National Park-India, catalyzed Fabrizio's childhood passion for wildlife. He is based at Doñana Biological Station-CSIC, Spain. He has researched several diurnal and nocturnal raptor species, with a special interest in species interactions, climate change and demography.

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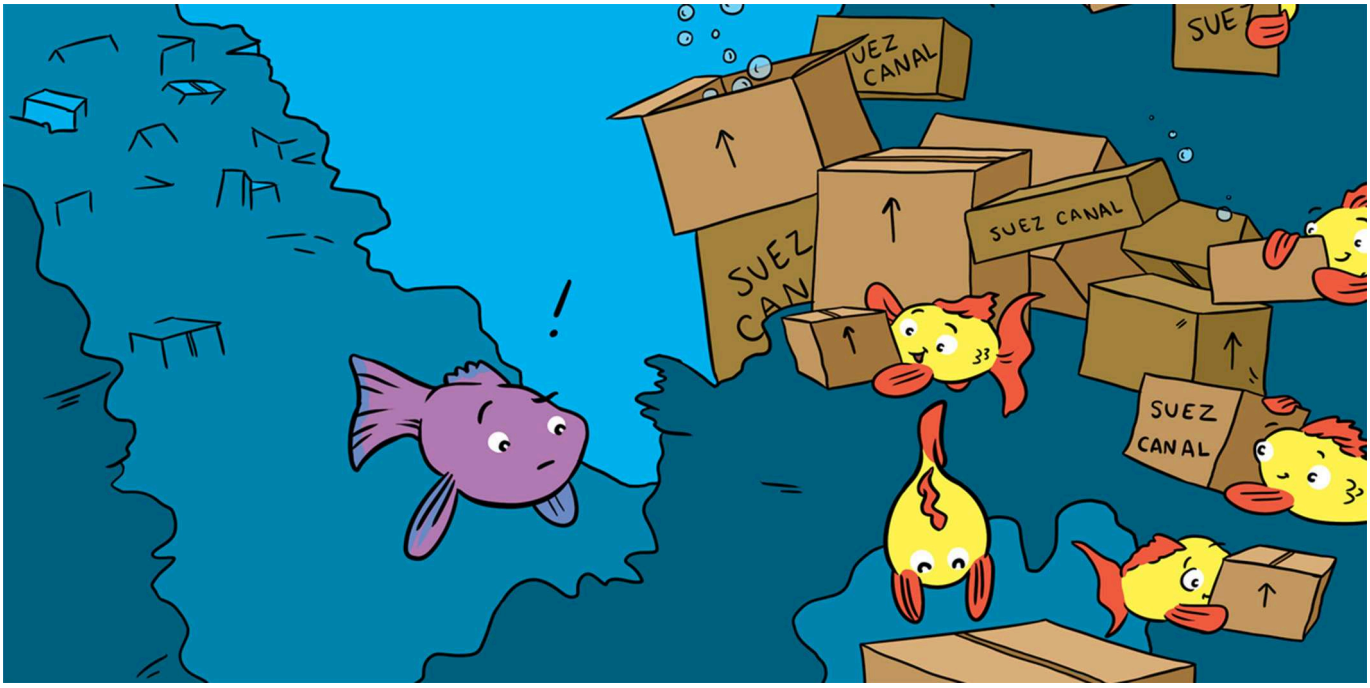

HUMAN ACTIVITIES HELP ALIEN SPECIES TO INVADE THE MEDITERRANEAN SEA

Ioannis Giovos[1]*, Stelios Katsanevakis[2], Marta Coll[3,4], Chiara Piroddi[5], Jeroen Steenbeek[4], Frida Ben Rais Lasram[6], Argyro Zenetos[7] and Ana Cristina Cardoso[1]

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YOUNG REVIEWERS:

KOREA FOREIGN SCHOOL

AGES: 12–13

The Mediterranean Sea is one of the largest seas in the world and has a great diversity of marine species. Currently, the Mediterranean Sea is facing various threats, with alien species being one of the most important. To address this problem, it is very important to understand how alien species arrive and where they are in the Mediterranean Sea. Furthermore, it is necessary to evaluate whether alien species affect native marine species, and if so, what kind of effects they have. This article will describe our current knowledge about the effects of alien species in the Mediterranean Sea.

Figure 1

Ways that citizens can contribute to the sightings of alien species. **(A)** Students and teachers can take samples and study them in the school lab. **(B)** SCUBA divers or **(C)** snorkelers can make visual observations and take pictures with underwater cameras. **(D)** Fishermen can study their catches to see whether the species in an area are changing. By reporting their findings on citizen science platforms, all citizens can contribute to the early detection of alien species.

MEDITERRANEAN SEA AND ITS MARINE SPECIES

The Mediterranean Sea is one of the largest seas in the world, surrounded by 22 different countries from three different continents, Europe, Asia and Africa. The Mediterranean Sea is a unique place, with about 17,000 different marine species. Of these species, about 3,500 live only in the Mediterranean Sea and nowhere else in the world.

Despite its uniqueness and the high number of organisms that live there, the Mediterranean Sea is endangered, because of human activities. Some human activities, like fishing or tourism, overuse of marine resources, pollution of the marine environment can cause the direct destruction of marine ecosystems (communities of interacting species and their environment). Some human activities, such as shipping, have resulted in the introduction of species from other seas. We call these species **alien species**, and they can create serious problems for the **native species** living in the Mediterranean Sea [1].

ALIEN SPECIES

Species found out of their native home range, moved to new areas due to human activities.

NATIVE SPECIES

Species that occur naturally in an area.

WHAT IS THE PROBLEM WITH ALIEN SPECIES?

Once in their new environment, some alien species do not manage to survive, because the conditions of the new environment might be too different from those of their previous homes. Other alien species, those that are more adaptable, might really like the new conditions and start reproducing, increasing in numbers and expanding throughout the area they occupy. In some cases, alien species are beneficial to their new homes, taking up useful ecological roles and supporting their native neighbors (for example, becoming a source of food for the

native species or cleaning up polluted water). But, in many cases, alien species have a negative impact on native ecosystems. For example, alien species may compete for food and space with native species, or may be voracious predators of native species. Often, alien species do not have any enemies in their new environment, which gives them an advantage over native species and, in the end, alien species may cause the extinction of some native ones. When an alien species causes big problems in an ecosystem, it is called an **invasive alien species**.

INVASIVE ALIEN SPECIES

Species introduced to an area that survive, reproduce, and expand, causing problems in the new ecosystem.

INTRODUCTION PATHWAYS

The modes of introduction of a species to a new location outside its native range.

BUT HOW DO ALIEN SPECIES ARRIVE IN THEIR NEW HOMES?

A marine species can move into a new area in many different ways, which are called **introduction pathways** [2]. It is important to identify the introduction pathway that each alien species has used to reach a new area, because this knowledge may help us to stop or control the arrival of new alien species. One way that alien species can reach the Mediterranean Sea is through the Suez Canal, which is a man-made canal connecting the Mediterranean Sea to the Red Sea. The species that reach the Mediterranean through the Suez Canal are called Lessepsian species, from the name of the engineer (Ferdinand de Lesseps) who oversaw the construction of the Suez Canal. Shipping can also assist the introduction of alien species from distant places, as stowaways either within the ballast waters that ships store in special tanks for stability, or attached to the surface of the ship's hull. Humans have also introduced some species to the Mediterranean Sea on purpose, to breed them in aquaculture facilities, and some alien species escaped or were released from public or private aquariums [3].

HOW DO WE KNOW THAT AN ALIEN SPECIES HAS ARRIVED IN THE MEDITERRANEAN SEA?

In the Mediterranean Sea, new species are frequently arriving through various introduction pathways. Because of the large number of new alien species and the large size of the Mediterranean Sea, it is very difficult to detect new alien species. Scientists from many countries work hard to find, observe, and monitor the alien species here, and collect as much information as possible. However, not only scientists can spot alien species. Many people visit the Mediterranean Sea for swimming, diving, or fishing (Figure 1). These citizens are also invited to report alien species to the blogs and authorities responsible for dealing with this threat. We call this citizen science—the contribution of citizens to the collection of data, which helps scientists. To bring together all the alien species data from various sources so that it is easy to find, the European Commission created the European Alien Species Information Network (EASIN), where people can share information about alien species across Europe, including the Mediterranean Sea.

Figure 2

Examples of Alien species that have been introduced in the Mediterranean through various pathways.

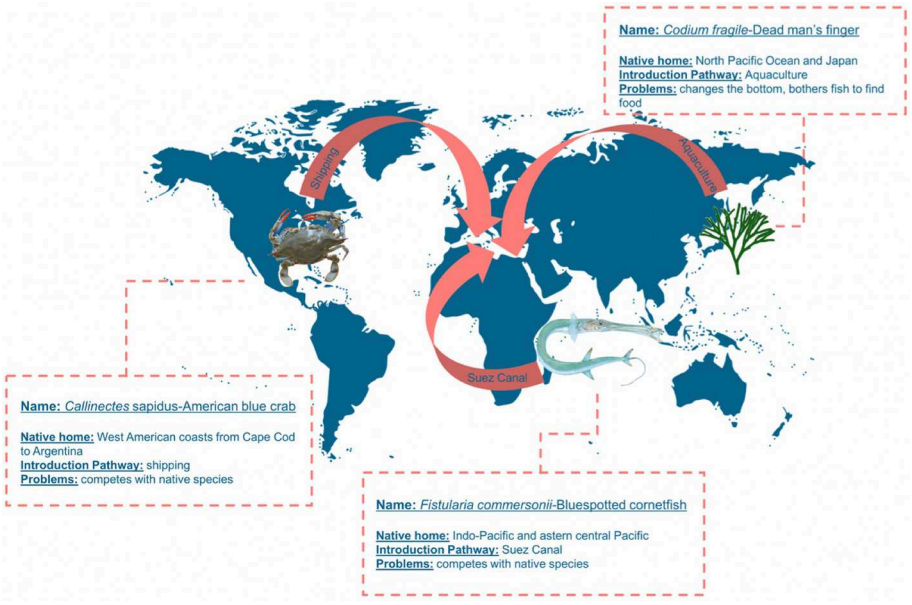

Figure 2

Access is provided via a website (https://easin.jrc.ec.europa.eu/) that is available to everyone who is interested.

WHAT ARE THE MAIN INTRODUCTION PATHWAYS FOR ALIEN SPECIES IN THE MEDITERRANEAN SEA?

In order to answer this question, we used all the records of alien species from the EASIN database up to January 2014. We found 986 alien species in the Mediterranean Sea. Then, we linked each alien species with at least one introduction pathway. Sometimes this was easy, while for some alien species it was very difficult. To discover introduction pathways, first we need to know the native home of the alien species. Then, depending on where we spotted the alien species the first time, we can deduce the introduction pathway. For example, if we find an alien species, whose native home is the Red Sea, in an area close to the opening of the Suez Canal, we can conclude that this species probably entered the Mediterranean Sea by moving from the Red Sea through the Suez Canal. Similarly, if we see an alien species, whose native home is the Atlantic Ocean, in an eastern Mediterranean port, we can conclude that it probably got there on a ship. However, sometimes it is more complicated, and two or more introduction pathways could be responsible for the introduction of an alien species. In our study, we managed to find one introduction pathway for 799 alien species, and two or more possible pathways for 114. We could not make reasonable assumptions about the introduction pathways for 73 alien species.

We found that the most important introduction pathway into the Mediterranean Sea is the Suez Canal, which was responsible for the

Figure 3

The number of alien species found in the Mediterranean Sea. You can see that there is an increase in the number of alien species as we move south-east.

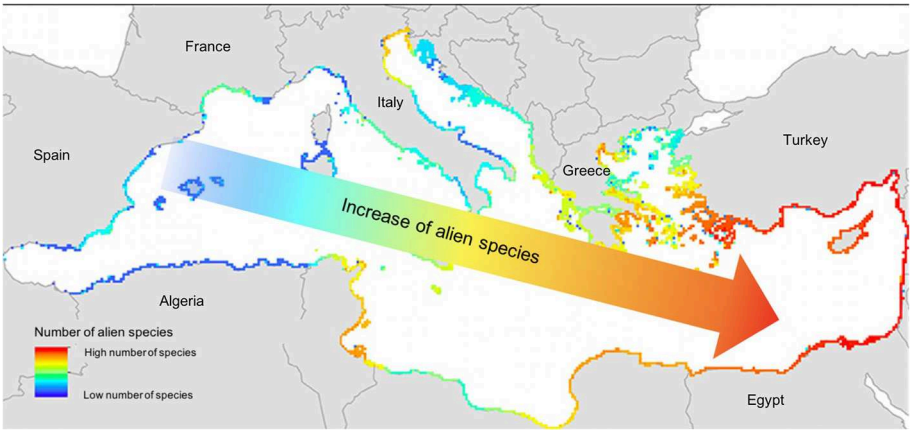

Figure 3

introduction of 420 Lessepsian species. Most of these species are now present in the Eastern part of the Mediterranean Sea [3] (Figure 2). The second most important pathway was shipping, responsible for the introduction of 308 alien species that are scattered all over the Mediterranean, especially close to harbors (Figure 2). Aquaculture was responsible for the introduction of 64 alien species, which are mainly found in two areas with aquaculture facilities, the Thau lagoon (Gulf of Lion, France), and the Venice lagoon (northern Adriatic, Italy) (Figure 2).

DO THESE ALIEN SPECIES AFFECT THE BIODIVERSITY OF THE MEDITERRANEAN SEA?

BIODIVERSITY

The variety of species living in an area.

We discovered that more alien fish species are present in certain parts of the Mediterranean, like the Levantine Sea and the southeastern Aegean Sea, than in other regions. Alien invertebrate species (animals without spines) exhibited a similar pattern, but also had a high presence along the French coastline, in the Thau lagoon, along the northern Adriatic and the eastern Sicily. Alien algae showed the opposite pattern, with more alien algae species in the western Mediterranean regions. So, our analysis told us that the distribution of alien species differs according to the introduction pathway used and is dependent on the type of alien species (fish, invertebrates, algae). We also found that alien species composition, the pool of all the alien species present in an area, differed among the different regions. Finally, by analyzing the pool of native fish and invertebrates, we found a pattern that was opposite to the pattern of the alien species. In the western Mediterranean, there are more native species than in the eastern Mediterranean, while the eastern Mediterranean has more alien species than the western Mediterranean (Figure 3). So yes, alien species significantly affect the **biodiversity** of the Mediterranean Sea.

HOW CAN YOU HELP?

Scientists and citizens alike need to chip in to help prevent the continued invasion of alien species! But how can regular people help? First, citizens must adopt responsible behaviors that will reduce the introduction of alien species into the Mediterranean Sea. For example, people with home aquariums must never release their marine organisms into the wild. Fishermen, when traveling long distances for fishing, must thoroughly clean their equipment before using it again, because contaminated equipment can transfer organisms from one place to another.

Also, citizens should become informed about the different Citizen Science projects that exist in their countries, through which they can contribute to the early detection and monitoring of marine alien species. In this way, citizens can meaningfully contribute to the prevention of biological invasions, by informing the scientists and the appropriate authorities.

CONCLUDING REMARKS

Biological invasions are one of the biggest threats for the native ecosystems and species of the Mediterranean Sea. During the last three decades, Mediterranean biodiversity has changed rapidly, more than any other marine region in the world, as a result of human activities, such as shipping, aquaculture, and the opening of the Suez Canal. The Suez Canal and the resulting Lessepsian migration is the most important reason for this rapid introduction of alien species into the Mediterranean. Over the last two decades, the water temperature of the Mediterranean has been warming, especially in the eastern regions, and this trend is expected to continue in the future. These higher temperatures favor the establishment and spread of species that like warm waters, such as Lessepsian immigrants, which normally live in warmer seas. These days, alien species are an important part of many ecosystems, and they may change the way ecosystems function. Knowing the number of alien species in every ecosystem is important, both to understand the trend of change and to also monitor the effects of the alien species and the effectiveness of steps taken to prevent new introductions. It is very important to understand the impact that alien species have on ecosystems, because some alien species can have benefits for native species and their habitats, so those alien species do not need to be controlled. However, other alien species are dangerous for ecosystems. Understanding which species help and which harm an ecosystem helps scientists to prioritize alien species for control or eradication.

ORIGINAL SOURCE ARTICLE

Katsanevakis, S., Coll, M., Piroddi, C., Steenbeek, J., Ben Rais Lasram, F., Zenetos, A., et al. 2014. Invading the Mediterranean Sea:

biodiversity patterns shaped by human activities. *Front. Mar. Sci.* 1:32. doi: 10.3389/fmars.2014.00032

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YOUNG REVIEWERS

KOREA FOREIGN SCHOOL, AGES: 12–13

Steve likes memes. Haider likes the color orange and soccer. Atilla loves math and being a humorous, positive person. His hobbies are building a different kind of mechanisms and robots. Hayato loves to read and eat sushi and hamburgers. Lina loves to play competitive tennis. She also likes dogs. Nadya likes pig-sloths, dogs, art, mythology, and magical things. Humayra loves cats, unicorns, pastel fashion, digital painting, and writing in her free time.

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Ioannis Giovos is the Fisheries Director of iSea, an Environmental Organization based in Thessaloniki Greece. He is interested in the conservation of marine biodiversity in the Mediterranean with an emphasis on marine megafauna and alien species. His research focuses on citizen science, local ecological knowledge, public perceptions, and rapid fishery assessment for collecting biodiversity records and monitoring illegal practices. In the past he also worked for the Tethys Research Institute in Italy.
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Marta Coll is a Researcher of the Institute of Marine Science (ICM) at the Spanish National Research Council (CSIC) in Barcelona (Spain). Her research focuses on understanding patterns and processes that characterize marine ecosystems and, in particular, changes of, and threats to, marine biodiversity. She studies community and food-web dynamics linked with human activities (such as fisheries, climate change, eutrophication, and invasive species), and how these translate into changes in ecosystem structure and functioning, and services that humans obtain from the ocean.

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Chiara Piroddi is a Scientific Officer in the Unit of Water and Marine Resources at the Joint Research Centre, European Commission. Her main interests are related to the conservation of marine biodiversity, the impacts of cumulative stressors (e.g., fishing, climate change, plastic) in the marine environment and the use of ecosystem modeling tools to support policy decision. The European Seas, particularly the Mediterranean Sea, are her principal case studies.

JEROEN STEENBEEK
Jeroen Steenbeek is a classically trained software engineer with over 25 years of experience in software development in industrial, commercial, and academic settings. Since 2006 he is one of the core programmers of Ecopath with Ecosim, which is a free and open-source ecosystem modeling software mostly used to better understand how fishing, climate change, and other anthropogenic disturbances affect marine ecosystems. Jeroen really likes his job, and is based at Ecopath International Initiative in Barcelona, Spain.

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Argyro Zenetos is a Research Director at the Hellenic Centre for Marine Research. Argyro, who is actively involved with marine alien species since 1997. She has research experience on zoobenthos, environmental impact studies and biodiversity indicators. She is the coordinator of the Hellenic Network on Aquatic Invasive Species (ELNAIS) http://elnais.hcmr.gr/ and Chief Editor of the Mediterranean Marine Science Journal. Argyro is a consultant to the European Environment Agency, UNEP/MAP and JRC; also member of the EASIN Editorial Board, ESENIAS network, ICES/WGBOSV, and Management Committee member in COST1209 and COST17122.

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THE MYSTERIOUS CASE OF THE DISAPPEARING JAVAN RHINO: USING CLUES FROM RHINOS' EVERYDAY HABITS AND HOBBIES TO FIGURE OUT HOW TO HELP THEM RECOVER

Erin Rose Harrington * ***and Brian Daniel Gerber***

Department of Natural Resources Science, University of Rhode Island, Kingston, RI, United States

YOUNG REVIEWERS:

FAZZ
AGE: 11

LYALL
AGE: 11

Javan Rhinos are interesting and mysterious creatures. These rhinos used to live all throughout Northeast India and Southeast Asia. But, the rainforests they need are disappearing. This loss of their habitat, in addition to human development and hunting, are the main reasons they are now only in one spot in the world. A few scientists put on their detective thinking caps and came up with the idea of using "camera traps" to count rhinos. The scientist-detectives ended up getting 1,660 video clips of Javan rhinos from these cameras. Based on the clues they got, they estimated that there are 62 rhinos in the park. Now that the scientist-detectives have a solid estimate about the size of the population, the different ages and sexes of the rhinos, and where they like to hang out, we can come up with a plan to help them recover!

Figure 1

Map of large area where Javan rhinos used to live vs. the small area where they live now. Adapted from Groves and Leslie [1].

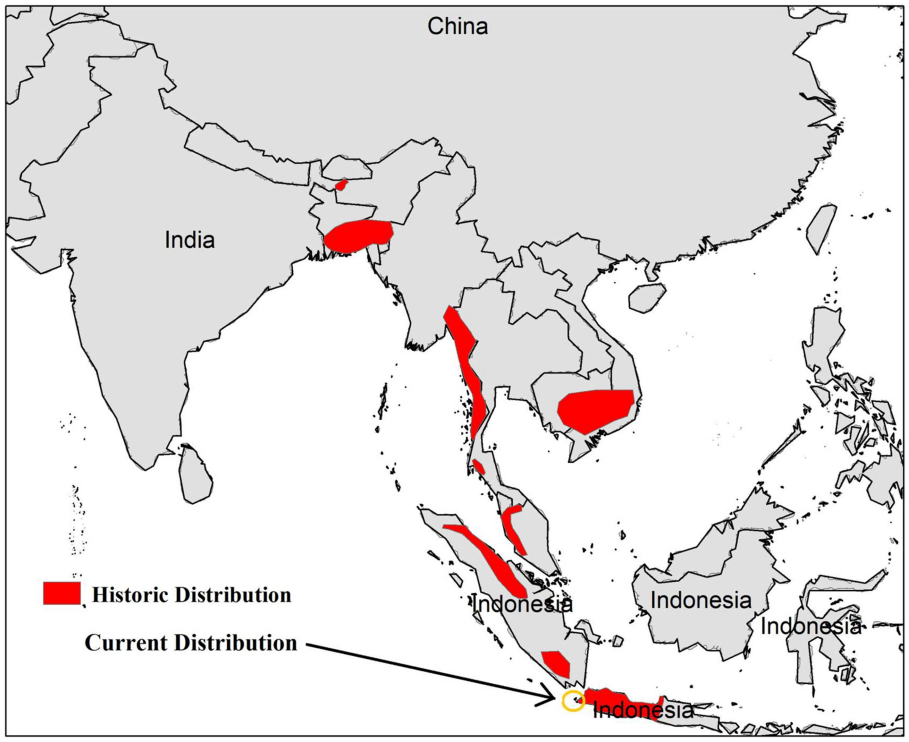

Figure 1

WHAT IS SPECIAL ABOUT JAVAN RHINOS?

Javan rhinos are interesting and mysterious creatures. They only live in one teeny spot on the island of Java (Indonesia) and are critically endangered. They are really big—somewhere between 4.5 and 5.8 feet tall, and they weigh between 2,000 and 5,000 pounds (that is about the size and weight of a Volkswagon beetle!). But they are secretive animals—so scientists have a really hard time finding them, despite their large size. Perhaps most mysterious though is that the Javan rhino population is disappearing and we are not sure what to do about it.

Javan rhinos used to live all throughout Northeast India and Southeast Asia. In other words, they used to roam an area that was quite large—about the size of Europe. Unlike its rhino cousins in Africa that live in the dry deserts, the Javan rhino needs rainforests. But the rainforests they need are disappearing. This loss of their habitat, in addition to human development and hunting, are the main reasons Javan rhinos are now only found in one spot in the world (Figure 1).

The place that Javan rhinos live is called Ujung Kulon National Park and it is about the size of a large city—think of New York City or London. That is not very much space for a bunch of huge rhinos to live. In order to survive and thrive, Javan rhinos need lots of space to roam around in, plants to eat, and mud to bathe in. Many scientists, conservationists,

and community members in Indonesia really care about saving the Javan rhino. These people decided the best way to help would be to do scientific research to find out how many Javan rhinos are left, what they need, and where they like to spend their time. So, scientists are on the case to solve this mystery!

HOW DO YOU COUNT RHINOS?

Counting rhinos is hard work! Think of what would happen if you went into the woods and tried to count all of the birds around you. Some birds would be flying all over the place, and some would hide as soon as they saw you. Other birds would be up in trees and you would never even know they were there. So, if you went into the rainforest and tried to count all the Javan rhinos, you would most likely count zero!

Obviously, rhinos cannot fly, but you get the picture—rhinos can be very secretive and do not like to be around humans. What is more, the rainforest is thick with thousands of trees and plants bunched together. So, we needed to come up with creative ways to use science to count the rhinos, similar to the way a detective uses clues and logic to solve a mystery!

In the past, scientist-detectives have used clues like rhino footprints (and even rhino poop!) to estimate how many Javan rhinos live in the park. But those things cannot give a very accurate estimate. For example, how can a scientist be sure each set of footprints belongs to a different rhino? Also, poop and footprints cannot tell us about the specific areas that Javan rhinos like to hang out. Plus, what about rhinos who have not pooped or moved around in a while?! We would not be able to count them!

In other words, the clues we have been collecting were not working very well for the questions we want to answer: How many rhinos are there are? What resources do they need? And where do they like to hang out? Plus, these clues are rather smelly! So, some clever scientist-detectives have come up with a new and improved way to collect better clues: camera traps.

WHAT THE HECK IS A CAMERA TRAP?!

A few scientists put on their detective thinking caps and came up with the idea of making camera traps to count rhinos. Do not worry, it is not how it sounds—scientists are not actually trapping the rhinos in cages.

Camera traps are special, sturdy cameras that can handle the mud and muck of the rainforest (Figure 2). They do not require humans to be

Figure 2

Camera traps are used to collect videos of Javan rhinos in their natural habitat, in order to allow scientists to count them and answer questions about the resources they need and the areas they like to spend time in.

Figure 2

present to take videos. They have sensors on them that can detect the heat of an animal when it passes by, and then the camera is activated and starts filming. The animal does not know it is being filmed and goes back to its rhino business (probably wallowing in the lovely rainforest mud to keep cool, maybe eating some plants, or taking a poop the size of a small dog!). We suspect the rhinos know that something is there, and maybe even associate the cameras with humans. But they do not seem to care about the cameras being there—the presence of cameras does not appear to affect the rhinos' behavior.

VIDEO 1

Video of a Javan rhino from a camera trap in Ujung Kulon National Park, West Java, Indonesia.

The videos end up looking something like this (see **Video 1**).

The scientist-detectives then use these video clues to determine which rhino is which. It is a bit tricky, but think about how people have certain things on their bodies that make them unique—for example, birthmarks, height, and different hair colors. Well, rhinos have different things on their body that make them unique from other rhinos, too. Some examples of these features include horn shape, facial wrinkles, and the size of the rhino. Once the scientist-detectives knew for sure they were not counting the same rhino twice, they had a much more accurate count of the number of rhinos in the park.

It was tough to figure out exactly how many cameras were needed to gather enough clues. Each camera costs between $100–250, plus the cost of repairs and set up. The scientists figured out that 150–200 cameras would be ideal to cover the entire area and still be affordable. Scientists think it was worth the cost, because without these cameras they would only be guessing at how many Javan rhinos there are!

So, after they figured out how many cameras they needed and got enough clues from the 178 different camera locations (Figure 3), they discovered some very interesting things about Javan rhinos!

Figure 3

Map of where the camera traps were placed throughout the park. The different colors indicate how high up (or low) the cameras were. Scientists figured out that rhinos prefer to spend their time in the lower areas.

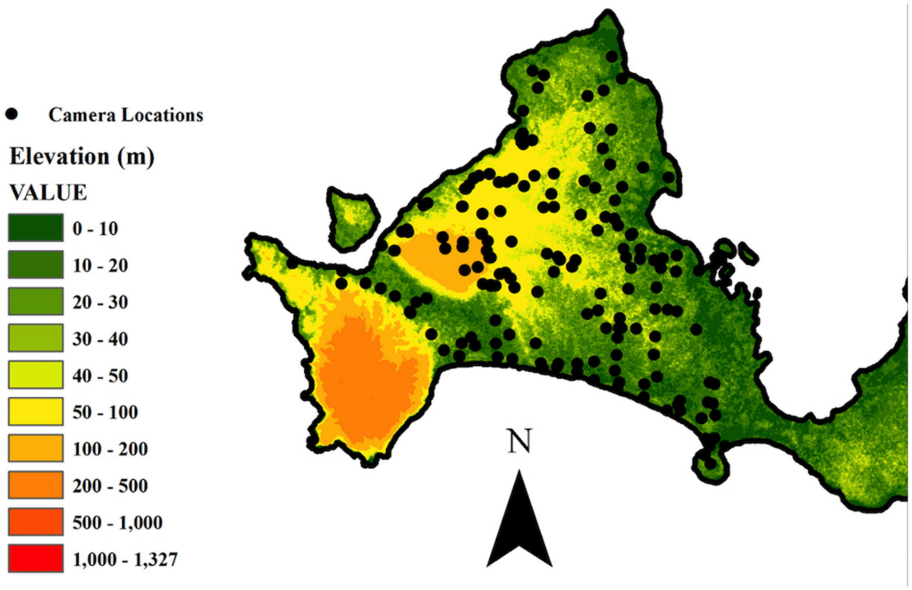

Figure 3

WHAT DID THE SCIENTISTS DISCOVER?

The scientists ended up getting 1,660 video clips of Javan rhinos! Using these clips, they found 22 females and 32 males. Of course, it is impossible to put a camera trap in every single spot in the park and capture every single rhino present. So, scientists used these video clues and a few different mathematical equations to estimate that there were ~62 rhinos in the park (and of those 62, there are slightly more males than females) [2]. The scientists also discovered that the closer a mud wallow is (a muddy area full of plants that rhinos like to hang out and bathe in), the more likely rhinos are to show up in that area.

In addition, the scientists discovered that Javan rhinos like to hang out in low elevation areas. Elevation refers to how high up something is—so a mountain would be high elevation, and a coastline would be low elevation. Based on the camera trap clues, it seems that the rhinos enjoy being at low elevations, near coastlines, and not high up (Figure 3). Scientists think this might be because waves crash on the coastline and create a salt spray. The salt spray builds up on the land, and rhinos like to lick the salt!

Living at low elevations puts Javan rhinos at risk for a few reasons. First, it means they are closer to contact with humans and could be harmed from human disturbance. For example, shy rhinos might spend too much of their time running away from humans. This would take away from their time eating plants and enjoying mud baths. It also means that if there is a big ocean storm (what we call a tsunami) much of their habitat could be destroyed and many of the rhinos could be killed because they are close to the water. A rhino likely cannot make it to higher ground quickly enough to escape a tsunami.

So, if we want to come up with a solid plan to help the Javan rhinos, we can use these new clues that the scientists found. We can make what is called a conservation plan. A conservation plan is a multi-year plan that uses scientific clues to help a population of animals increase.

THE NEXT MYSTERY TO SOLVE: WHAT CAN WE DO TO HELP?

Because there is such a small number of rhinos left in only one location on earth, unexpected disasters could make the entire population disappear. For example, if there is a storm, many rhinos could be injured or killed overnight. Or, if just a few rhinos get some sort of disease, it could spread quickly to all of the other rhinos nearby. Or, if a hunter shoots the last few female rhinos, the males will roam around alone and there would not be any rhino babies. It seems grim, but this is important information for us to know!

Now the scientist-detectives have a solid estimate of the size of the Javan rhino population, the ages and sexes of the rhinos, and where they like to hang out. We can use these clues to create a new population of rhinos in a different area that is less at risk for unexpected disasters. Or, maybe we could create new habitat somewhere within Indonesia, with the necessary amount space to roam in, plants to eat, and mud to wallow in, and move some of the rhinos from the park to this new space.

There are some helpful things that you can do too! You can teach your friends and family what you have learned about the Javan rhino. You can also visit the World Wildlife Foundation website, [3] or even your local zoo, to learn more about rhinos. But maybe the most helpful thing you can do is to grow up to be a scientist-detective and solve your own science mysteries!

ORIGINAL SOURCE ARTICLE

Setiawan, R., Gerber, B. D., Rahmat, U. M., Daryan, D., Firdaus, A. Y., Haryono, M., et al. 2018. Preventing global extinction of the Javan Rhino: tsunami risk and future conservation direction. *Conserv. Lett.* 11:e12366. doi: 10.1111/conl.12366

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future conservation direction. *Conserv. Lett.* 11:e12366. doi: 10.1111/conl.12366
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YOUNG REVIEWERS

FAZZ, AGE: 11
Hi my name is Fazz, I live in Edinburgh and I enjoy rugby.

LYALL, AGE: 11
Hi my name is Lyall! I live in a family of six with two dogs in Edinburgh. I go to a great school which I have been at for 5 years now. My favorite sport is rugby, I play at least play three times a week! I really like all sports. I am really interested in this dicovery about Javan Rhinos and am really exited to find out more about them!

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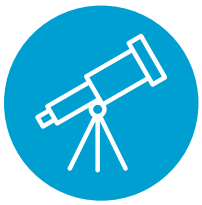

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