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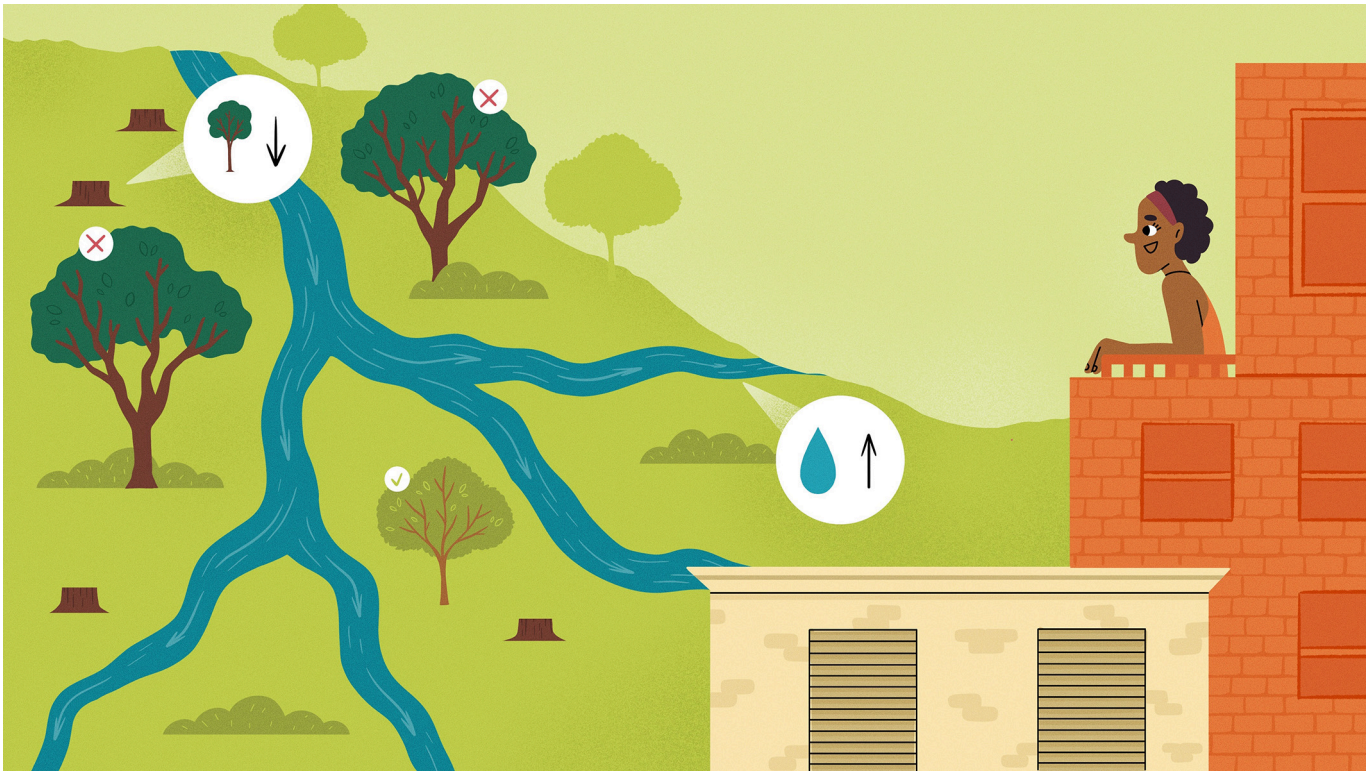

WORKING WITH NATURE TO REDUCE THE IMPACTS OF CLIMATE CHANGE

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MOMO

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Climate change is making extreme climate events, such as droughts and floods, more severe all over the world. Working with nature could help reduce or completely remove these dangerous impacts of climate change. We developed a way to measure how much working with nature can reduce the impacts of extreme drought on society. We applied it to one of the worst water crises experienced by a city: the Cape Town day zero drought, in which the taps of city dwellers almost ran dry. We found that clearing thirsty, non-native trees from the mountains that provide the city's water could have allowed more water to flow through rivers into the city's dams. But it would not have removed the full climate change impact. This tells us that working with nature is important in the fight against climate change, but that other types of solutions are also needed to protect societies, too.

CLIMATE CHANGE IS MAKING EXTREME WEATHER AND CLIMATE EVENTS MORE SEVERE

Extreme weather and climate events include droughts, floods, heatwaves, and hurricanes. Some of the impacts from extremes are loss of life, damages to property, famine, water shortages, and disease outbreaks.

EXTREME WEATHER AND CLIMATE EVENTS

Unusual, intense weather and climate patterns like hurricanes, floods, or heatwaves that are much stronger than normal, and can cause big problems for people and nature.

Scientists have shown that these extremes are happening more often, lasting longer, and becoming more severe. Humans are the reason for these changes—burning fossil fuels releases greenhouse gasses into the atmosphere, changing Earth's climate and affecting local weather all over the world [1].

Working with nature can help reduce the impacts of extremes on humans. This is because the local environment also plays a role in how the impacts of extremes are felt. For example, heavy rain falling on areas of bare soil cause more flooding and greater soil loss compared to what would happen if the same area was covered with grasses, shrubs, or trees. Working with nature to solve some of the problems caused by climate change is called **nature-based solutions** [2]. Examples include planting vegetation in urban areas for local cooling; restoring vegetation along rivers, in wetlands, and in mountains to reduce floods; restoring coastal wetlands to protect against storms and sea-level rise; and planting trees and shrubs on farms to help farmers grow more food.

NATURE-BASED SOLUTIONS

Using nature, like planting trees or restoring wetlands, to solve environmental and societal problems, such as reducing floods, cleaning the air, or protecting animals plants and people.

In our study, we wanted to know *how much* nature-based solutions could help fight changes in extreme weather and climate events caused by climate change—something no one had ever studied before.

STUDYING THE CAUSES OF EXTREME WEATHER EVENTS

The reason scientists had never studied exactly how much nature-based solutions could help to reduce the impact of climate change on extreme weather events was because the methods to do so were not yet available. Fortunately, since the early 2000's, the science of figuring out the causes of changes in extreme weather events has rapidly advanced [3]. This is a complicated topic to study because every extreme weather event is unique. In a world without greenhouse gasses in the atmosphere, extreme weather would come from natural processes in Earth's climate. But in the world we live in today, extreme weather events have both natural and human causes, because the Earth's climate has been warmed by greenhouse gases in the atmosphere, which affects weather processes.

If we do not know how much an extreme weather event has changed because of climate change, it is impossible to measure the role of nature-based solutions in reducing or balancing out these impacts.

We came up with a way to identify the factors responsible for the impacts we experience from extreme weather and climate events. This approach has three main steps (Figure 1). The first is to compare what an extreme event would look like in a world *with* greenhouse gas emissions and a world *without* them. The second step is to determine how these changed extremes interact with local land and environmental conditions. The third step is to determine what happens if we deliberately change the local environment using nature-based solutions. These three steps can help researchers to answer two questions:

1. Has an extreme weather event changed due to human-caused changes to Earth's climate?
   And if the answer is yes, then,
2. How much could nature-based solutions help to reduce or remove the impacts due to climate change?

THE CAPE TOWN DAY ZERO DROUGHT

To test our ideas, we tried to identify the factors responsible for one of the worst water crises experienced by a city in recent times: the Cape Town day zero **drought**.

DROUGHT

When an area does not get enough rain for a long time, causing water shortages, dry land, and problems for plants, animals, and people who need water.

Cape Town, in South Africa, is a diverse multicultural city surrounded by natural mountainous areas. Cape Town's water supply comes from rivers that flow from these mountainous areas. When it rains, the rainfall runs off the land and into the rivers, flows along the rivers, and is finally captured and stored in six large dams. Water from these dams is carried through an intricate system of pipes to people's houses and community access points in and around the city.

During a 3-year drought from 2015 to 2017, the city's dam levels dropped to below 20% of their normal levels, which forced Cape Town to prepare for no water—the day when the taps would run dry, which was called day zero. The rains did finally come, and Cape Town averted day zero, at least this time.

WORKING WITH NATURE BY CLEARING INVASIVE NON-NATIVE TREES

The natural vegetation in the Cape Town mountains is called fynbos. It is made up of shrubs and grass-like plants, with no large trees except in ravines (Figure 2A). Fynbos grows in part of the Cape Floristic Region, a global biodiversity hotspot with more than 9,000 plant

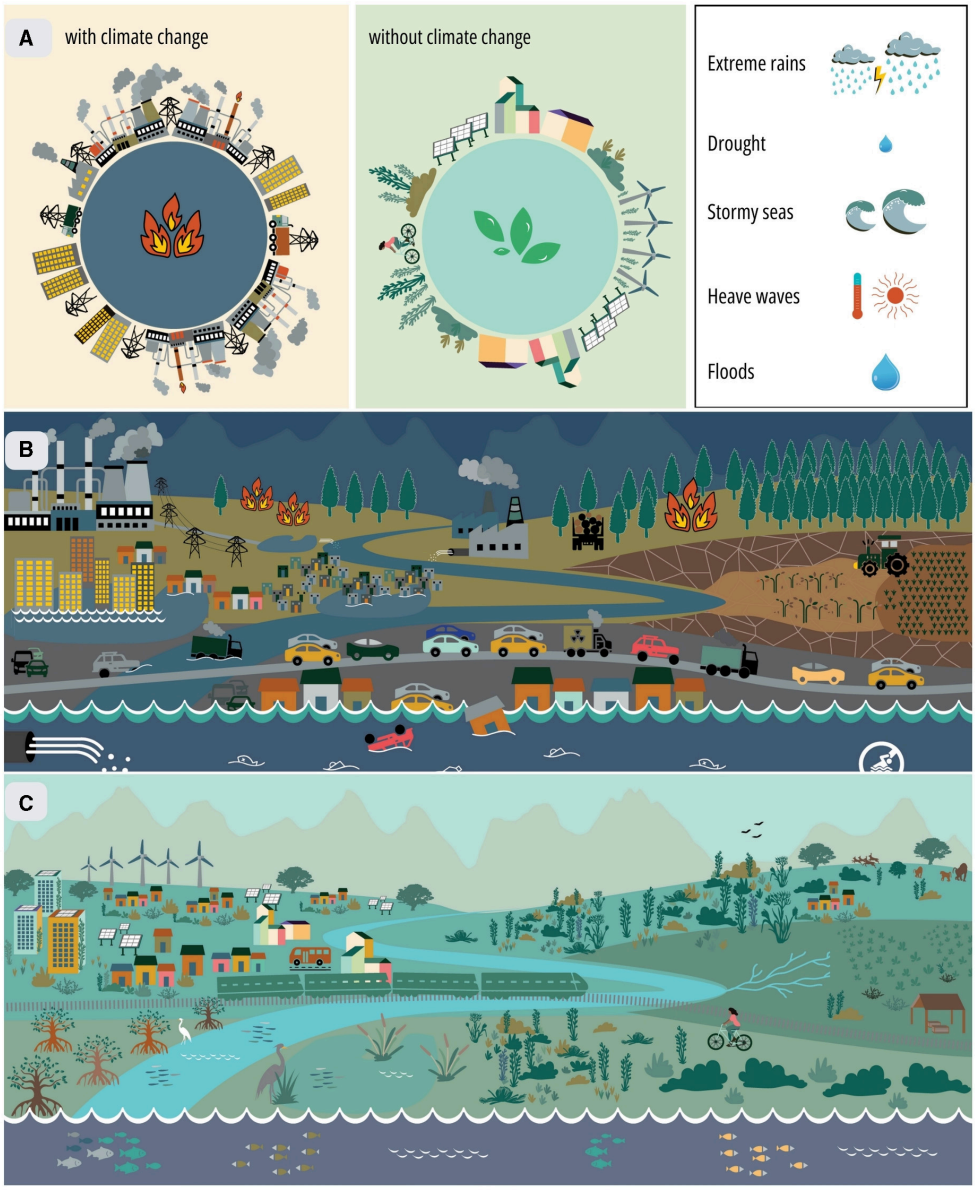

Figure 1

There are three main steps for identifying the factors responsible for changes in extreme weather and climate events. **(A)** First, we must compare what the extreme event would look like in a world with or without climate change. Then we compare what extreme events would look like **(B)** without nature-based solutions or **(C)** with nature-based solutions. This allows us to see whether nature-based solutions are helpful, and how much they might help (Illustrations: Theresa Wigley, Data Visualization: Tali Hoffman).

species. Because 70% of these plant species are only found here and nowhere else in the world, this region has been declared a UNESCO world heritage site—an area with outstanding natural, historical, and cultural value.

The mountains critical for Cape Town's water supply have been invaded by non-native trees, like pine and eucalyptus (Figure 2B). Non-native trees such as these are called **invasive species** because they have escaped from plantations and replace natural vegetation. These trees were introduced by people two centuries ago for timber and because people thought they looked nice. The problem is that these trees use substantially more water than the native fynbos vegetation does [4]. This is because the trees are taller and have larger leaf canopies and longer roots. They take up so much water that they

INVASIVE NON-NATIVE SPECIES

A plant or animal that comes from a different place, spreads quickly, and harms the local environment by taking over and outcompeting native species.

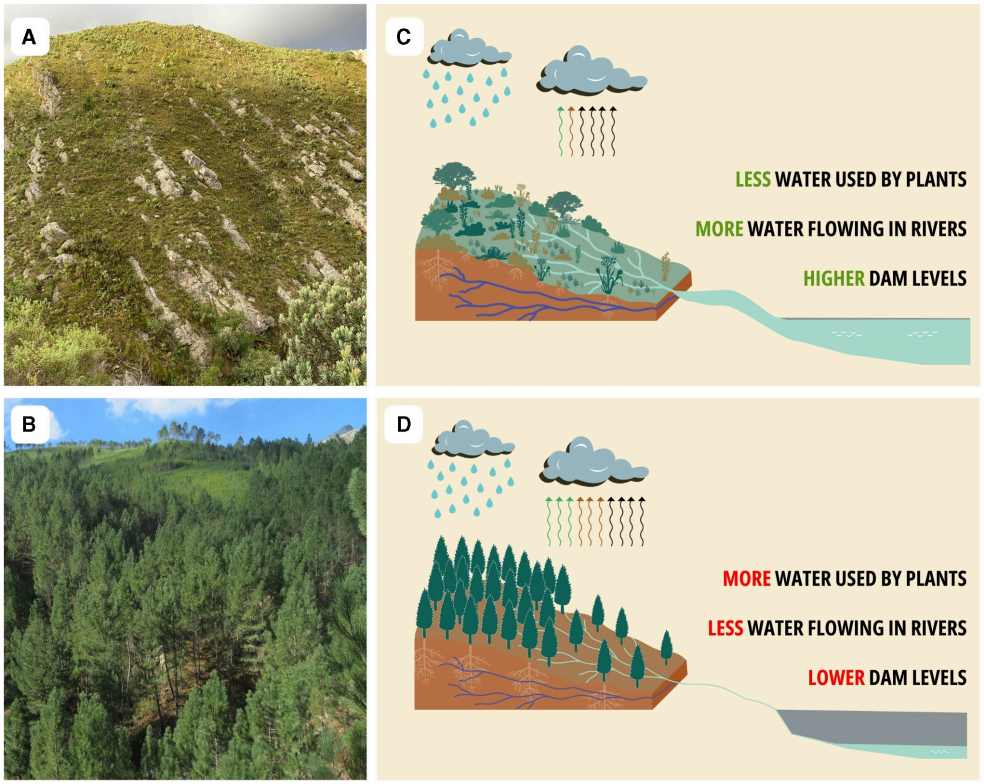

Figure 2

Figure 2

(A) A natural fynbos mountain slope in the Cape Town mountains. **(B)** Mountain slope where the natural fynbos vegetation has been invaded by non-native pine trees. **(C)** In areas with natural fynbos-type vegetation, less water is used by the plants so there is more water available in rivers to flow into dams. **(D)** In ecosystems where non-native trees are growing, more water is used because the trees are tall and have big leaves and long roots, and they lose lots of water to the atmosphere [Photo Credits: Petra Holden **(A)**; Martin Kleynhans **(B)**, Illustrations: Theresa Wigley, Data Visualization: Tali Hoffman].

reduce river flows to the dams that supply water to major cities (Figures 2C, D).

One nature-based solution is clearing these non-native trees from the mountainous areas of South Africa, to increase river flows and reduce extreme droughts. But does it work?

USING COMPUTER MODELS TO SIMULATE WORLDS

We used **computer models** to compare what river flows would be like during the Cape Town day zero drought in a world with and without greenhouse gasses in the atmosphere, and also in a world with and without the nature-based solution of non-native tree clearing. These computer models can predict water flows in and out of an area of land and through river channels in **watersheds**. The models were built based on data collected from the rivers themselves and from space, using satellites. Data included river width and depth, soil and vegetation properties, observed river flows, and the coverage of invasive non-native trees in the area [5]. This information, along with climate data, was used in the computer models to calculate the river flows.

Once we were satisfied that our computer models could accurately simulate the actual river flows in the mountains, we then used these models to answer our research questions. We ran 290 **simulations**

COMPUTER MODELS

A virtual simulation that uses math and data to imitate real-world processes, like weather, river flows or how diseases spread, helping scientists predict, and understand complex systems.

WATERSHED

An area of land where all the rainwater and streams flow into a common body of water, like a river or lake.

SIMULATIONS

Virtual experiments or tests that use computers to mimic real-life situations, like predicting weather or river flows, helping people test ideas, and predict outcomes.

of the drought weather (rainfall and evaporation) for the day zero drought through the computer models. Half of these simulations (145) represented rainfall and evaporation (the drought weather) for our current world, with greenhouse gases/climate change. The other half (145) represented the drought weather in an "imaginary" world without climate change.

We ran two further experiments using the computer models, by varying the vegetation cover. The first experiment represented clearing all the invasive, non-native trees and restoring the natural fynbos vegetation. The second represented the *entire* watershed fully invaded with non-native trees. We compared the river flows between all the modeled worlds, which told us how much climate change influenced the drought and whether nature-based solutions could have reduced this.

WHAT DID OUR COMPUTER MODELS SHOW?

Climate change reduced river flows by 22% compared to our computer model of a world without human-caused climate change (Figures 3A, B). In other words, there would have been 22% more water flowing in the rivers during the Cape Town day zero drought if there had been no climate change.

If we had cleared the non-native trees before the Cape Town day zero drought hit, we could have avoided 9% of the losses in river flows due to climate change (Figure 3C). But clearing the trees would not have completely balanced out the decrease in river flows caused by climate change. Encouragingly, however, preventing non-native trees from totally taking over the area avoided an additional 21% loss of river flows (Figure 3D).

The 9% increase in water due to nature-based solutions is critical. But we still would have 13% less water in the rivers because of climate change under current levels of global warming (Figure 3C). Higher levels of warming would lead to even less water in the rivers during drought years. This highlights the importance of keeping global warming levels below 1.5 and 2.0° to support nature-based solutions in their job of protecting society from extremes.

CONCLUSION

Working with nature is important for reducing climate change impacts on extreme weather and climate events. We found that clearing non-native trees could have prevented *some* of the climate change-driven losses of river flows experienced during the Cape Town day zero drought—one of the worst water crises experienced by a city in recent times. However, clearing non-native trees could

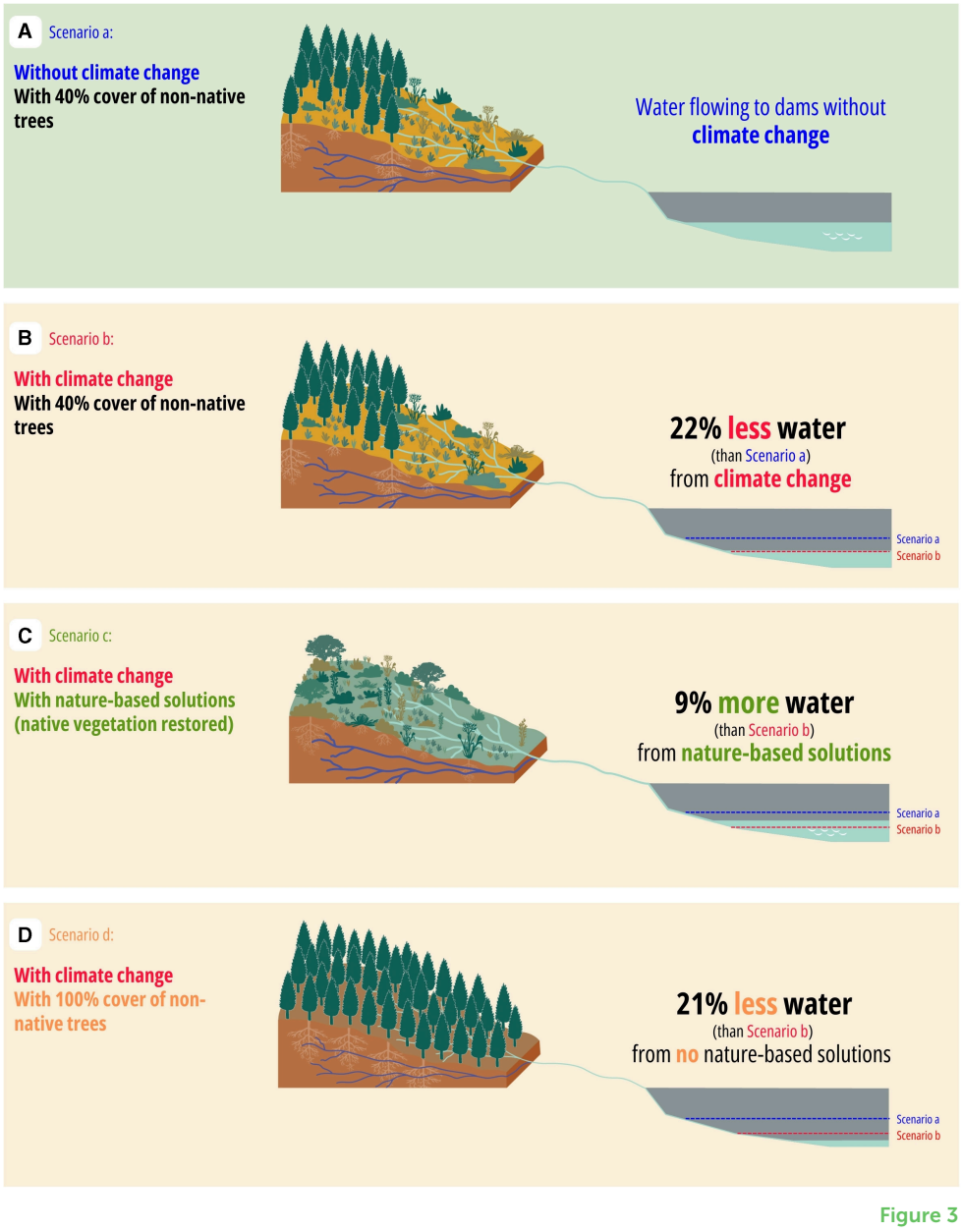

Figure 3

We used our approach to explore whether Cape Town could have used nature-based solutions to reduce the severity of its day zero drought. We calculated river water flowing to dams under different climate and land scenarios. **(A, B)** When compared with water levels that might be seen without climate change, climate change decreased river flows. **(C)** Using a nature-based solution (clearing non-native trees) could have reduced this impact. **(D)** Without any efforts toward a nature-based solution, the impact of climate change would have been even worse (Illustrations: Theresa Wigley, Data Visualization: Tali Hoffman).

not remove all the climate change impact, which highlights the importance of working to combine nature-based solutions with other types of solutions, like water demand management, improvement of water transfer pipes, and desalination.

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ORIGINAL SOURCE ARTICLE

Holden, P. B., Rebelo, A. J., Wolski, P., Odoulami, R., Lawal, K., Kimutai, J., et al. 2022. Nature-based solutions in mountain catchments reduce impact of anthropogenic climate change on drought streamflow. *Commun. Earth Environ.* 3:51. doi: 10.1038/s43247-022-00379-9

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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 REVIEWERS

MOMO, AGE: 12

Momo loves to travel the world and see new places. Even so, she is a self-proclaimed couch potato when she is at home. The two extremes can coexist in one person! Her favorite couchmate is her fuzzy and affectionate dog, Lita.

SEA CREST SCHOOL, AGES: 12–13

We are a curious group of 6th grade science students who live in coastal California. While we all have individual interests, we are united by a shared passion for environmental stewardship and, in all things, we are determined to "leave it better than we found it": our school's mantra. Our group members are guided by our humanities teacher, Leslie G., and include: Oliver, Mackey, Rowan, Stella, Daphne, Leena, Abigail, and Malina.

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Petra Holden is a senior researcher based at the African Climate and Development Initiative at the University of Cape Town. She specializes in research on nature-based solutions. Crossing natural and social sciences, her work deals with social equity, water security, ecosystem services, biodiversity, and climate change. Currently, her focus is on research to inform nature-based solutions that are more equitable and sustainable at local levels while accounting for changes in the climate. Petra provides direct nature-based solution science advisory support into policy and practice including serving on international and national advisory panels and steering groups for nature-based solutions. *petra.holden@uct.ac.za

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