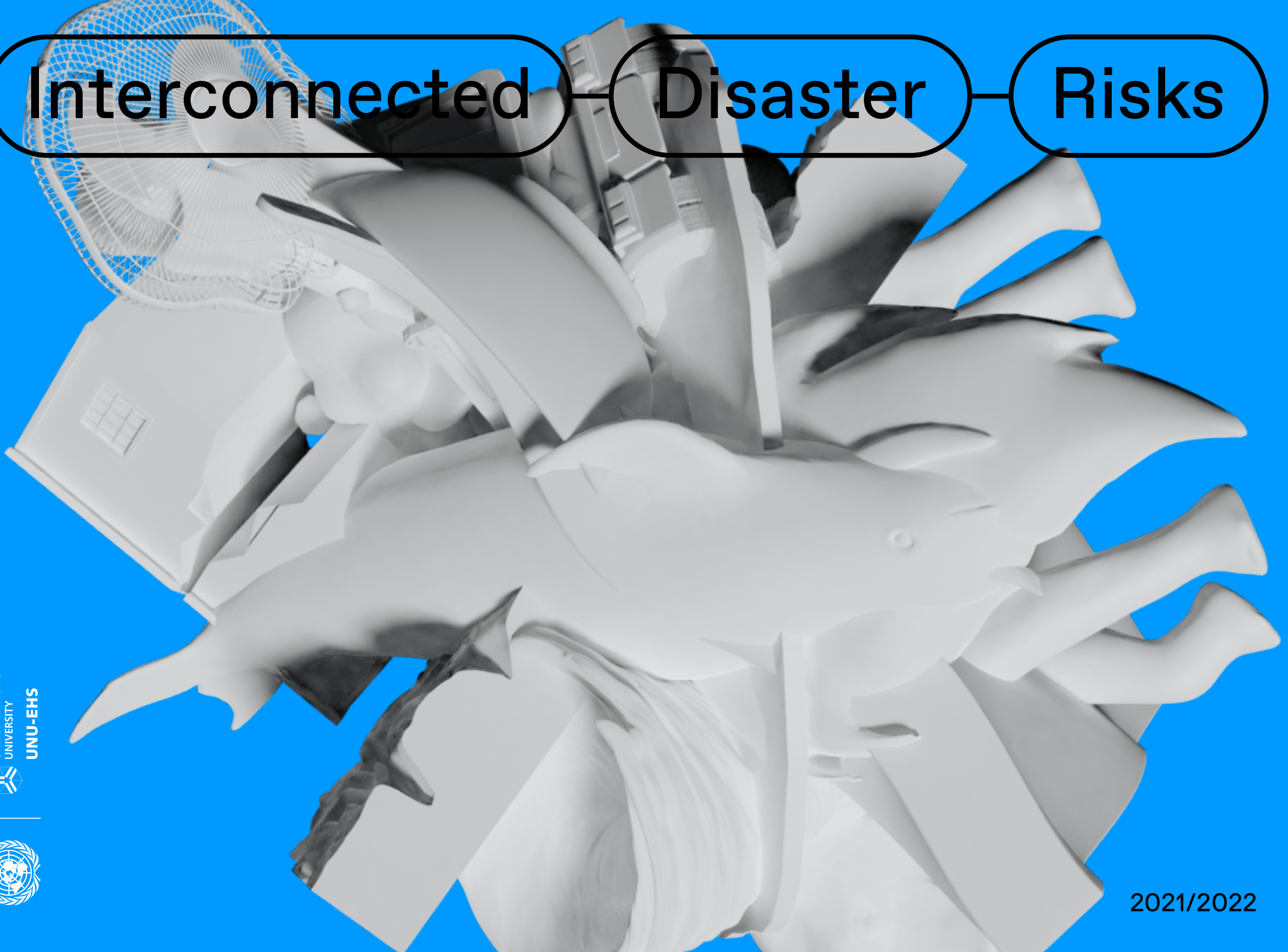
Interconnected Disaster Risks



UNITED NATIONS UNIVERSITY
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Executive Summary

In 2021/2022, the world yet again witnessed catastrophic disasters happening around the globe, from record-breaking heat to floods, extreme droughts, wildfires and earthquakes. From Europe to Asia, America to Africa, nowhere is immune. In the past year alone, disasters took around 10,000 human lives and cost over $280 billion in damage worldwide. Nature also continues to be under grave threat, as species are pushed from their habitats or towards extinction, the true costs of which are much harder to estimate.

Hazards, such as hurricanes and earthquakes, do not need to turn into disasters. Where and how people live, as well as their ability to respond, largely determine whether a hazard becomes a disaster. For example, this report analyses the disaster of Hurricane Ida, where the majority of those who died lived in illegal basement apartments in a flood-prone area of New York. These forms of accommodation are often sought by vulnerable people who do not have access to other types of housing; for example, undocumented immigrants or people who struggle to pay regular rental prices. At the same time, those vulnerable populations are in the weakest position to buffer themselves against the impacts of a disaster because they can, for example, neither afford to purchase insurance nor have the economic means to bounce back once a hazard strikes. The same applies to nature, where a healthy ecosystem can absorb the force of a storm or a flood better than a damaged one. The disasters seen in 2021/2022 could have been either avoided altogether or their impacts significantly reduced if the right kind of solutions had been in place to prevent or better manage them.

The 2021/2022 edition of the Interconnected Disaster Risks report analyses 10 disasters from around the world which were selected for their notoriety and representation of a larger global issue that has changed or will change lives across the world, and identifies solutions that can help to prevent or better manage them in the future. The 10 selected disasters for 2021/2022 are:

1. British Columbia heatwave – No plan for heat
2. Haiti earthquake – A disaster 300 years in the making
3. Hurricane Ida – Storm of the future catches New York unprepared
4. Lagos floods – Undermining futures
5. Mediterranean wildfires – Learning to fight fire with fire
6. Southern Madagascar food insecurity – Pushed to the limits by environmental extremes
7. Taiwan drought – When the typhoons stop coming, lives and livelihoods must change
8. Tonga volcano eruption – The Big Bang that took a nation off the grid
9. Vanishing vaquita – Walking into extinction with open eyes
10. Wandering elephants – No space left for wandering giants

To understand the underlying conditions that created the disasters in the first place, it is necessary to look below the surface and identify the drivers that cause disasters to develop, such as deforestation or urbanization. For example, deforestation leads to soil erosion, where a lack of trees and roots means that there is no protection from wind and rain, and the soil is easily washed or blown away. This creates the ideal conditions for multiple disasters, such as the devastating landslides during the Haiti earthquake, the formation of sandstorms in southern Madagascar and the sedimentation of water reservoirs in Taiwan. An even deeper analysis reveals that many drivers are formed by shared root causes, such as our economic or political systems. Deforestation as a driver, for example, can be traced back to the tendency to pursue economic interests without regard for environmental externalities, a root cause defined as "Undervaluing environmental costs."

These shared root causes and drivers of the disasters from 2021/2022 illustrate how seemingly disconnected disasters link back to the same sources but reveal themselves differently. The good news is that just as the disasters are interconnected, so are the solutions.

One type of solution can prevent or reduce a number of different disaster risks. For example, enhancing early warning systems would have reduced fatalities during the British Columbia heatwave, the Tonga volcano's tsunami and the flooding in Lagos. Similarly, consuming sustainably can not only reduce the strain on ecosystems we depend on for protection from hazards like the flooding seen in Lagos and New York but also preserve valuable food and water resources in times of scarcity, highlighted by the Vanishing vaquita and Taiwan drought, respectively.

Innovations can include the use of adaptive design, such as floating architecture, that can help reduce the vulnerability of homes to increasing flooding (as seen in the Lagos floods). Preventive techniques that are both effective and beneficial to farmers, such as beehive fences, have successfully been used in Kenya to prevent elephants from entering cropland while at the same time providing honey and improving crop pollination.

Solutions that let nature work include prescribed burning to prevent megafires (Mediterranean wildfires), restoring forest ecosystems to stabilize the soil and prevent land degradation (Haiti earthquake, Taiwan drought, Southern Madagascar food insecurity), or regenerating urban streams and rivers and applying risk-aware urban planning to reduce flood risk (Hurricane Ida). These are measures that harness nature's processes to reduce hazards.

Solutions in these categories not only can be applied to different types of disasters but also are at their most powerful when implemented in a "solution package," where multiple solutions work together to address the different elements of each interconnected disaster. For example, a solution package to address the looming extinction of the vaquita is to work together with local fisher communities to co-manage conservation areas, to innovate and implement more sustainable fishing methods, to raise awareness for sustainable consumption and to enforce regulations to prevent harmful overfishing and illegal trade. This solution package has a better chance of addressing the problem than if any of the solutions are implemented in isolation.

While the only way to prevent disasters in the future is through the design and implementation of solutions, it is also important to note that solutions cannot take place in a vacuum and have implementation barriers and trade-offs. These trade-offs can for example be environmental. In the case of the British Columbia heatwave, increased access to air conditioning would have reduced heat-related issues, but conventional air conditioning increases greenhouse gas emissions. Trade-offs can also be societal, as in the case of the Wandering elephants, where the creation of habitat corridors or protected areas for Asian elephants would benefit the elephants but might result in a loss of land for people living in those areas. Only by thinking of the interconnectivity of our actions can these trade-offs be properly understood and sustainable solutions found.

Sustainable solutions consider the interconnectedness of disaster risks across time and space, and work together to address different elements of disasters with a long-term perspective.

Different groups are also differently affected by different types of disasters, and any solution package needs to have a special focus on the most vulnerable. For example, children under the age of five are especially vulnerable to the long-term and lasting impacts of food insecurity affecting communities in southern Madagascar, whereas during the heatwave in British Columbia, people over the age of 50 were twice as likely to suffer from heat-related health issues as younger generations. The impacts of the volcanic eruption in Tonga left especially women without income as many of them depend on remittances from abroad, which could not be transmitted due to the interruption of the only undersea cable servicing Tonga. In the very young nation of Nigeria, where almost half of the entire population is under 14 years of age, future generations will suffer from the consequences of today´s sand mining.

Not all solutions will be convenient for everyone. The redistribution of resources among generations (Lagos flooding), countries (Haiti earthquake) and groups of people with different vulnerabilities (Hurricane Ida), or requesting the inclusion of stakeholders who are rarely heard (Vanishing vaquita) will mean that some will need to share their resources more broadly than they currently do. Other solutions are yet to be designed and will require a new way of thinking.

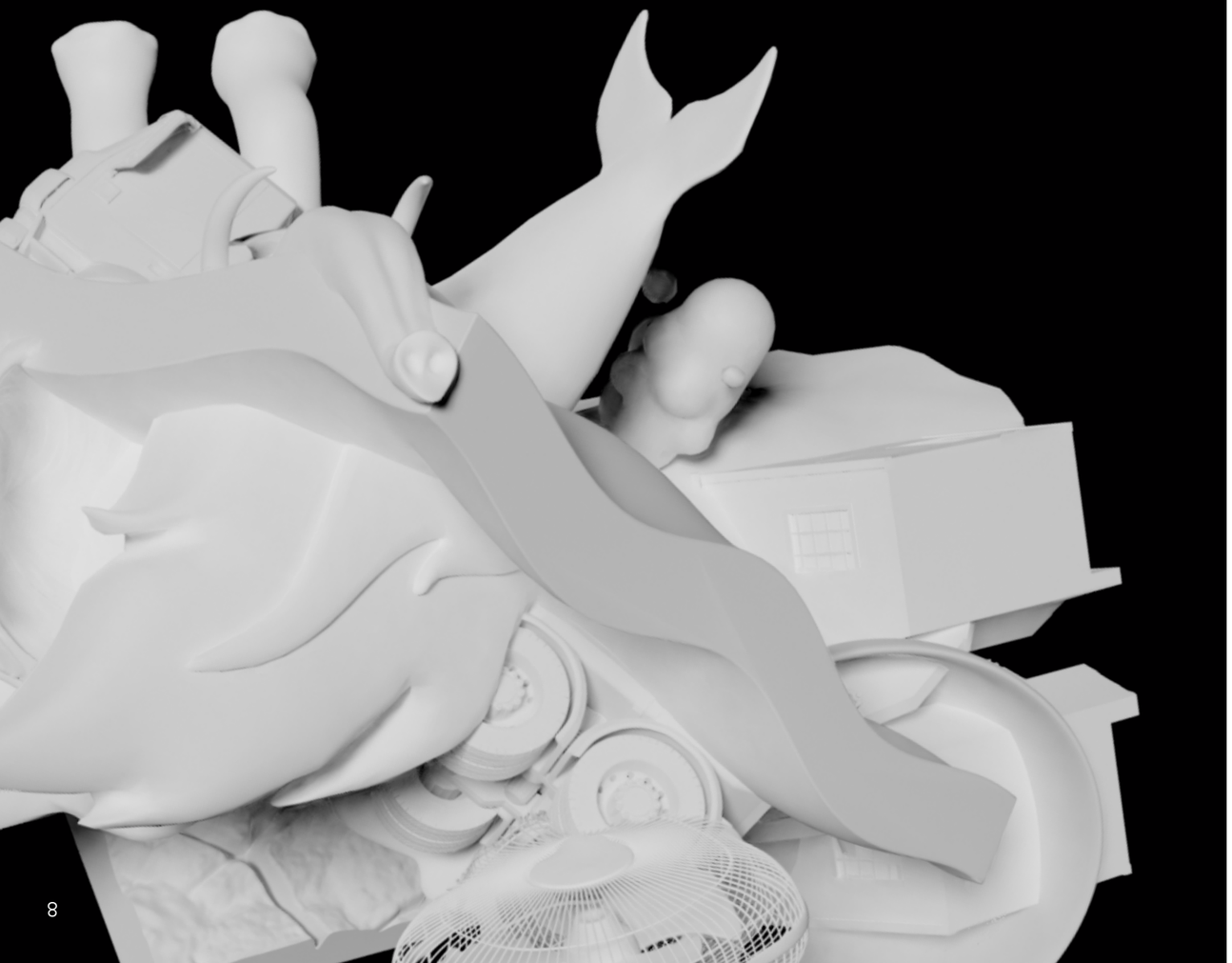
As climate change is here to stay and its impacts are increasingly felt, the challenges for disaster risk reduction will only grow in the future and be intensified by the impacts of loss of nature and vanishing biodiversity. Solutions are already being implemented around the world to address risks, but interconnectivity is not yet placed at the heart of solution design and implementation.

Nevertheless, the research on this is clear. Without investing and scaling up smart solutions, the disasters of 2021/2022 are just the beginning of a new normal. The responsibility to make changes rests with all parts of society: the private sector, governments, regional and local decision makers, but also with us as individuals. All of our actions have consequences for all of us. In an interconnected world, we are all part of the solution.

Chapter 1

Introduction

We are all interconnected in this globalized world. Through our technology, travel and trade, seemingly distant people, economies, ecosystems and cultures suddenly become intertwined with our daily lives, and ours with theirs. As we become ever more connected across the planet, so do the risks we share. This is becoming increasingly threatening for lives, livelihoods and nature, as 2021/2022 saw another year of record-breaking disasters. Temperatures are rising; nine of the last 10 years have been the warmest on record. Heatwaves, droughts and wildfires rage across the globe. Rainfall records are being broken as hurricanes, storms and floods become more intense. The costs of disasters are rising, both in terms of damage and adaptation burdens.



In this edition of the Interconnected Disaster Risks report, we focus on two key themes found in disasters around the world:

These disasters are not isolated incidents.
As a product of our increasingly connected world, our attention span for understanding disasters and their impacts is very short. As soon as we begin to pay attention to one issue, another quickly replaces it. As we are constantly bombarded with information, we are only ever able to receive details about a disaster at a shallow level, without being able to critically reflect on why it may have happened or what the continued or cascading impacts will be. As such, these disasters are still primarily perceived as isolated, random incidents rather than as socially-constructed systemic failures. This report revisits disasters from the past year to examine the root causes behind them and to improve and inform our resilience building before subsequent similar disasters. We challenge readers to do the same with any disaster around the world as we need to see the bigger picture of the interconnected systems that produce disaster risk in order to build more resilient communities and sustainable futures. Last year's edition of the Interconnected Disaster Risks report (2020/2021 IDR report) analysed 10 disasters and focused on revealing this concept of interconnectivity among disasters. Today, interconnectivity thinking is increasingly gaining traction worldwide and there is an increasing awareness for integration in planning and implementation processes.

Interconnected problems require interconnected solutions and changes.
Recognizing the progress made in interconnectivity thinking, the 2021/2022 IDR report shifts the focus to solutions by analysing the drivers, root causes, impacts and emerging risks of disasters and the respective needs to address them with targeted solutions. Disasters are by-products of our global system, revealing the complexities, interconnectivity and inequalities that already exist. Any attempt to remediate these disasters or their impacts must at least acknowledge that these systems exist and address them if we want to prevent something similar from happening again. Primarily, this involves changing our relationship with the world and with each other: to shift from thinking in fragmented, insular silos to opening ourselves up to new possibilities and perspectives.

In the 2021/2022 IDR report, we have selected the following 10 cases: the heatwave in British Columbia, the earthquake in Haiti, Hurricane Ida's effects on New York, flooding in Lagos, wildfires across the Mediterranean, the food insecurity crisis in southern Madagascar, the drought in Taiwan, the eruption of the Hunga-Tonga-Hunga-Ha'apai volcano in Tonga, the vaquita porpoise on the brink of extinction and the migrating herd of elephants in southern China. We selected these events as emblems for a wider picture of the interconnected global issues they represent and their high profiles (and therefore public awareness) through a media analysis, which will help to facilitate global learning. One disaster, the flooding in Lagos, was included as an "overlooked" event, highlighting the importance of issues outside the mainstream media cycle and the global implications of these disasters (in this case, the impacts of global sand mining). To explore the core message of global interconnectivity more comprehensively, we prioritized diversity in the selection process, with cases representing different types of extreme events or looming disasters selected from various regions around the world.

This report will guide the reader through the facts of each of the 10 cases beginning in **Chapter 2**, introducing them with narratives that connect them to the larger, global picture and with their relationships and commonalities between the other case studies. The fact sheets also present solution packages for each case study, identifying a set of interventions that can work well in combination to address disaster-specific problems. **Chapter 3** explores the different levels of interconnectivity among the 10 cases, including a "deep dive" into selected root causes and impacts. **Chapter 4** presents a synthesis of possible solutions and highlights, based on selected examples, how solutions can be tailored to address the interconnectivity of disasters. Additionally, we expand on best practices of implementing solutions, including developing the concept of solution packages and identifying barriers, trade-offs and enabling conditions.

This step-by-step approach to the analysis of disasters helps to develop a more comprehensive understanding of the disaster-related risks we face now and will face in the future. It facilitates the development of solutions and solution packages, and allows us to understand both the urgency of and need for global solidarity.

Chapter 2

10 disasters from 2021/2022

Disaster | British Columbia heatwave

No plan for heatwaves

Narrative

In summer 2021, air temperatures in Canada broke records multiple days in a row as a powerful heatwave spread over the Pacific Northwest. The town of Lytton, for example, set an all-time high-temperature record for Canada at 49.6°C (121.3°F). The heatwave's effects were estimated to be 150 times more likely and about 2°C hotter due to human-induced climate change.

The British Columbia Coroners Service registered over 500 heat-related deaths from 25 June to 1 July. Even after the hot spell ended, there was no immediate decrease in mortality, pointing toward the long-term health effects of heat stress. As with many disasters, the heatwaves disproportionately affected vulnerable populations, such as children, people with disabilities or chronic health conditions and those who were socially isolated or experiencing homelessness. Health risks also increased sharply with age, with the mortality rate doubling in every age group over 50 years old. Moreover, many of the deaths in individual residences occurred in lower-income neighbourhoods, where there is less of a cooling effect provided by surrounding greenery.

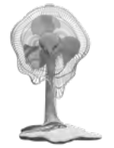
Overall, British Columbia was unprepared for heat as this level of heat was unprecedented in Canada. Unlike other hazards, no single organization or department in Canada is responsible for coordinating responses to extreme heat. The provincial government and many municipalities did not have heat action plans, cooling centres (such as libraries and recreation centres) had limited opening hours, and less than 35 per cent of private homes had access to air conditioning.

Heatwaves are among the deadliest natural hazards, and evidence shows that they will become more frequent and intense as the climate changes. Recognizing and responding to heat events as increasingly common public health emergencies are crucial to prevent further loss of life and well-being.

Wider picture

Global average temperatures have risen 1.1°C since 1880, and 9 of the last 10 years have been the warmest years on record. Extreme heatwaves will be three times more frequent in 2030 than in 2001, and the global average cumulative heat during heatwaves is increasing by as much as 4°C per decade in some regions. This changing climate creates new heat hazards in places that are unprepared and unaware of the dangers. Inexperience is not an excuse however; citizens, organizations and governments can better prepare for worsening weather extremes and keep people safe from preventable disasters.

Disaster icon:



Location: British Columbia, Canada

Category: Extreme weather

Date/duration: 18 June – 12 August 2021

Key figures:

49.6°C
(121.3°F) Temperature

619
Heat related deaths

Disaster | British Columbia heatwave

Solution package:

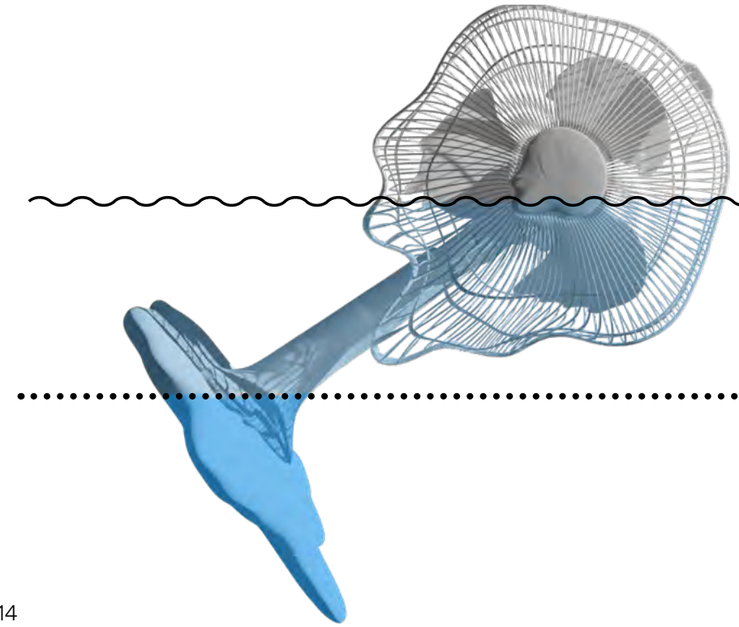
Green heat sinks:
Urban greening, such as small parks, green roofs or home gardens, harnesses the power of nature to cool and refresh cities. In addition to acting as a heat sink, green urban areas also support biodiversity, sequestrate carbon, improve human health and create more enjoyable places.

Neighbourhood safety net:
Mutual care during heatwaves has been shown to be effective to reduce risk for the most vulnerable. Initiatives, such as Be-A-Buddy in New York, allow local volunteers to educate, prepare and assist other citizens who may be at risk. This not only improves support networks but also helps build community and social resilience.

Develop heatwave communication tools:
Investing in ways to communicate risks and early warnings more effectively help to reduce heatwave impacts. Helpful tools include accurate extreme temperature prediction models, heatwave behaviour maps and warning systems linked to social media and mobile phones. In this way, residents can become more aware of risks while businesses can plan better to avoid losses.

Designate a heat response authority:
There should be an authority responsible for managing heatwave mitigation and response among the various sectors (e.g. health, insurance, urban planning, energy, social services). Additionally, a heat alert and response system should be developed to warn the public through a method of organized communication to help people prepare and protect themselves.

British Columbia heatwave:



Impacts
- Infrastructure damage
- Health impacts
- Ecosystem damage and biodiversity loss
- Livelihood loss
- Loss of life

Drivers
- Atmospheric warming
- Drought
- Insufficient early warning system

Root causes
- Human-induced greenhouse gas emissions
- Insufficient risk governance

Key interconnections:

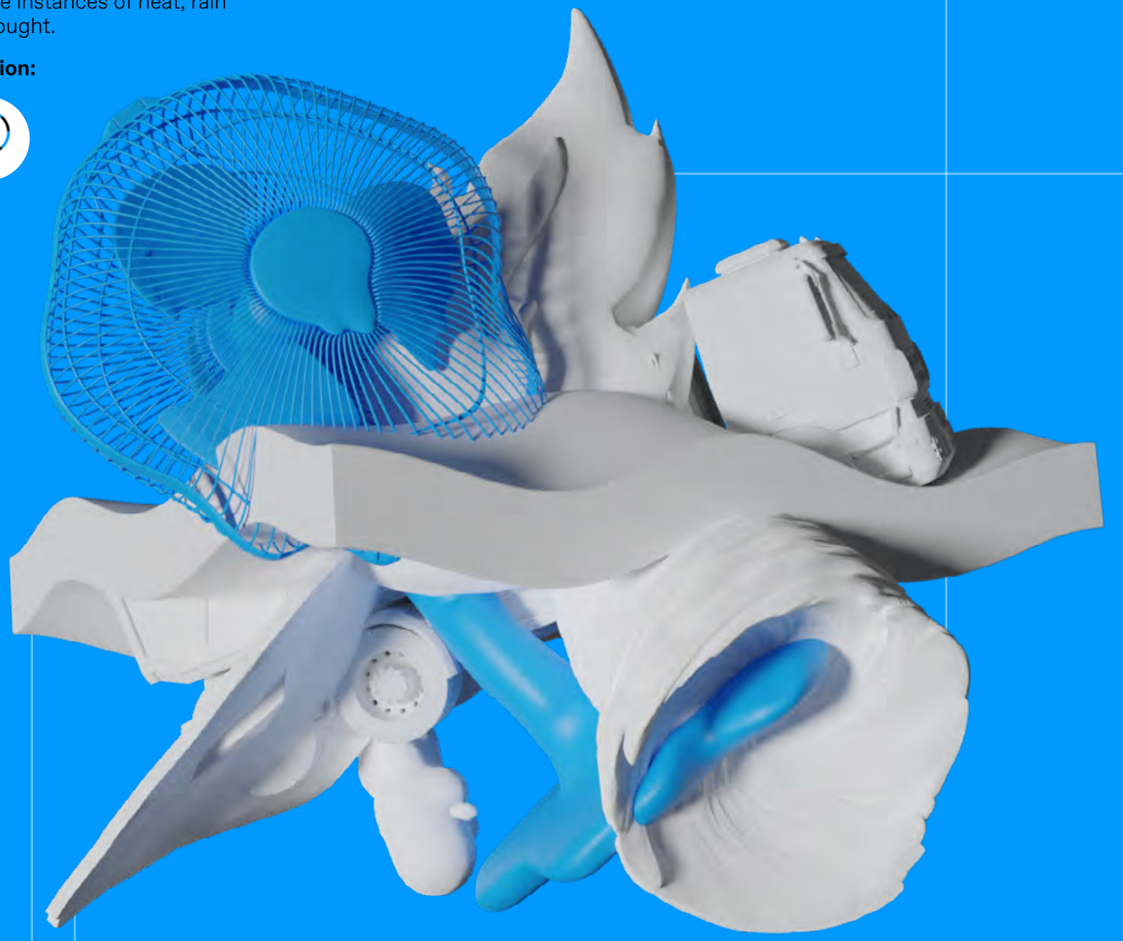
Shared root cause with:

Hurricane Ida

Insufficient risk governance

Governments were not prepared to handle increasingly severe instances of heat, rain or drought.

Solution:



Shared driver with:

Lagos floods

Tonga volcano eruption

Insufficient early warning system

Hazard information is not well communicated to the public.

Solution:

Shared driver with:

Mediterranean wildfires

Atmospheric warming

Warming atmosphere exacerbated existing high temperatures in both areas created by respective heat domes held in place by a weakened jet stream.

Disaster | Haiti earthquake

A disaster 300 years in the making

Narrative

On 14 August 2021, Haiti was hit by a magnitude 7.2 earthquake with an epicentre in the Canal du Sud (120 km west of the capital, Port-au-Prince). The quake killed over 2,200 people and injured more than 12,000.
The 2021 disaster quickly drew comparisons to a similar earthquake in 2010, which occurred on the same fault lines, the long cracks in the surface of the earth where earthquakes often occur. Not much has changed in the years since 2010 – Haiti is still in a state of disrepair; the national palace, for example, still has not been rebuilt. Though the magnitude of the seismic event was significant, earthquakes of similar strength cause much less damage in other parts of the world, exposing how Haiti is particularly vulnerable to disasters.

These vulnerabilities can be traced back through centuries and have only been compounding over time. Colonialization and slavery in the 1700s, the war for independence, subsequent diplomatic isolation in the 1800s and an unjustified reparations debt perpetuated systems of land degradation, peasant labour and extractive industries, creating systemic social and environmental issues. The following decades of corruption, military coups, dictatorships and foreign occupations created conditions of extreme political instability. This, combined with the cumulative effect of yearly hurricanes, floods, landslides and droughts, has created a vicious cycle of vulnerability to disasters.

Haiti is not poor; it is rich in culture, resources and value. But these resources have been exploited, misappropriated and mismanaged. Haiti's history is full of other countries and agencies putting the pursuit of profit over the needs of the Haitian people. Any solution to help Haiti recover from this crisis and to build resilience for the future must recognize that the current risks are deeply embedded in the social, economic and environmental history of the region, which have led to fragility and extreme vulnerability. This is true in many contexts around the world, whereby addressing these vulnerabilities means giving agency to the people, supporting them in finding their own solutions and re-examining the power structures that created these problems in the first place.

Wider picture

This event illustrates the social and historical construction of disasters and how a disaster is not isolated in time but instead connected to pre-existing and constructed vulnerabilities, the impacts of preceding disasters, decisions and environments.

Disaster icon:

Location: Canal du Sud, Haiti

Category: Geological event

Date/duration: 14 August 2021

Key figures:

7.2 magnitude
at shallow depth of 10km

2,200
deaths

Disaster | Haiti earthquake

Solution package:

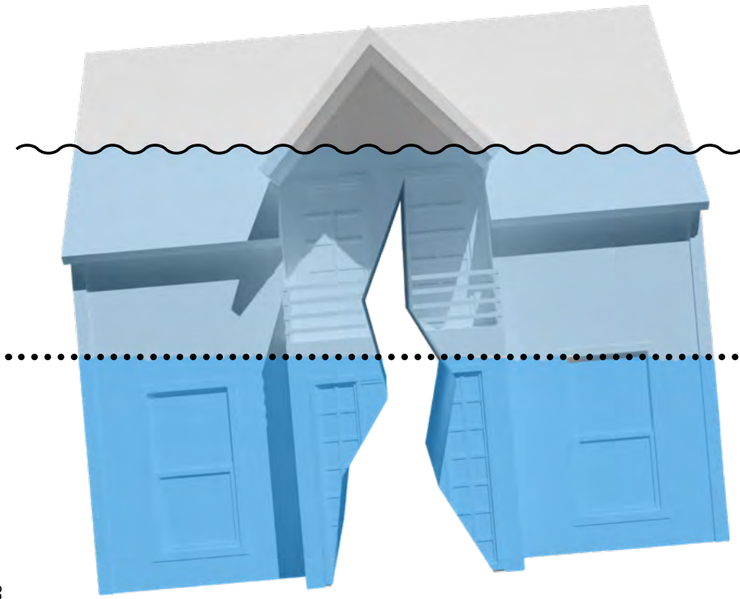
Agroforestry and soil stabilization:
Agroforestry has the combined effect of soil degradation protection and landslide risk reduction while also providing income to farmers from agriculture, timber and non-timber products, as well as promoting biodiversity. Species used must be adapted to local ecosystems and climate conditions now and in the future, as well as to the needs of farmers.

Earthquake-safe building:
In order to prevent collapse/injury, buildings must be designed with risks in mind. Traditional wattle and daub or wooden structures are not only more resistant to earthquakes and hurricanes than concrete but also made with lighter materials that are less deadly in the event of collapse.

Grass-roots governance:
Localization and devolution of government structures towards regional authorities can give power and agency to local people, potentially limiting the influence of corruption and neocolonialism. Haitian problems require Haitian solutions, and Haitian people should lead the way. Grass-roots initiatives must be formed, recognized and supported.

Land rights:
Insecurity over ownership of land can influence decision-making on management and investments into the future of a property. Formalizing the ownership of the land people live on would give them greater agency and determination of their own goals and aspirations, as well as likely paving the way to greater investment in long-term benefits.

Haiti earthquake:



Impacts
- Livelihood loss
- Health impacts
- Loss of life
- Migration/displacement
- Food insecurity
- Infrastructure damage

Drivers
- Lack of regulation/enforcement
- Organized crime
- Deforestation
- Vulnerable infrastructure

Root causes
- Undervaluing environmental costs
- Legacy of colonialism
- Insufficient risk governance
- Inequality of development and livelihood opportunities

Key interconnections:

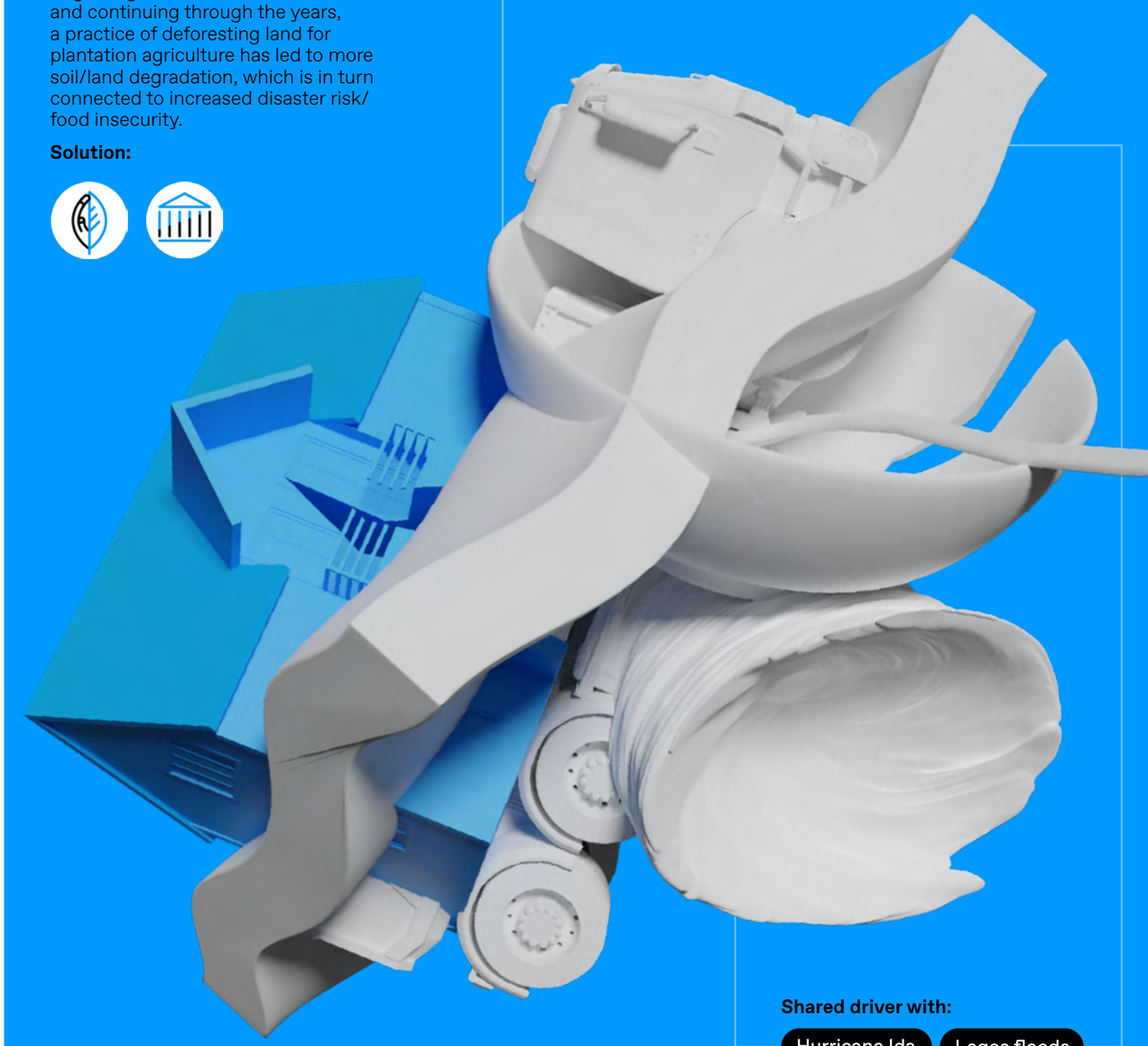
Shared root cause with:

Southern Madagascar food insecurity

Legacy of colonialism

Beginning with French colonialism and continuing through the years, a practice of deforesting land for plantation agriculture has led to more soil/land degradation, which is in turn connected to increased disaster risk/ food insecurity.

Solution:



Shared driver with:

Hurricane Ida | Lagos floods

Lack of regulations/enforcement

Despite the awareness and lessons learned after previous events, there is a lack of consistency regarding regulations in place and their enforcement in order to avoid future disaster risk scenarios.

Disaster | Hurricane Ida

Storm of the future catches New York unprepared

Narrative

On 1 September 2021, remnants of Hurricane Ida, having traveled over 2,000 km across the United States after making landfall in Louisiana, brought historic rainfall to New York City, triggering the city's first-ever flash flood alerts as water flooded streets, subway stations and apartments. Of the 95 people who died as a result of Hurricane Ida's path across the United States, 13 of them were in New York City alone, and the overall damage caused to infrastructure and housing was estimated to be up to $9 billion. The total cost of Hurricane Ida in the U.S. is estimated at around $75 billion, making it the costliest disaster of 2021.

New York has faced devastating hurricanes for a long time, including Hurricane Sandy in 2012, but Hurricane Ida was different, bringing flooding not from the coast, but from the sky, breaking rainfall rate records with over 8 cm in a single hour and catching New York's ageing urban infrastructure unprepared. In doing so, Ida exposed the shortcomings of the city in protecting those who live a shadow existence in the bustling metropolis. New York is home to an estimated 50,000 illegal basement dwellings, many of which are often inhabited by undocumented immigrants. Eleven of the 13 recorded deaths in New York City from flash flooding were located in such basement apartments, highlighting the gap in managing people and places for disaster risk when awareness at the government level is scarce.

Human-induced climate change is only predicted to make future storms more intense and more dangerous. By 2050, over 2 million people in the New York City area, 60 per cent of the region's power-generating capacity, as well as dozens of miles of critical roads and rail lines, will face a high risk of flooding – some of it permanently – if timely and proactive measures are not implemented. Until then, many residents remain fearful of the storms that are still to come.

Wider picture

New York's first ever flash flooding event was not the only case of urban areas being caught unprepared by increasingly extreme rainfall, with similar rain-based flooding wreaking havoc in Germany, Australia and Brazil, as well as other countries. Ageing urban infrastructure and disaster management plans are in urgent need of redesign to prevent future catastrophes, with an emphasis needed on engaging with vulnerable people in exposed areas.

Disaster icon:

Location: New York City, United States

Category: Extreme weather - Storm

Date/duration: 29 August - 1 September 2021

Key figures:

75 billion
USD in damages

95
total number of deaths in U.S.

8cm
hourly rainfall recorded

Disaster | Hurricane Ida

Solution package:

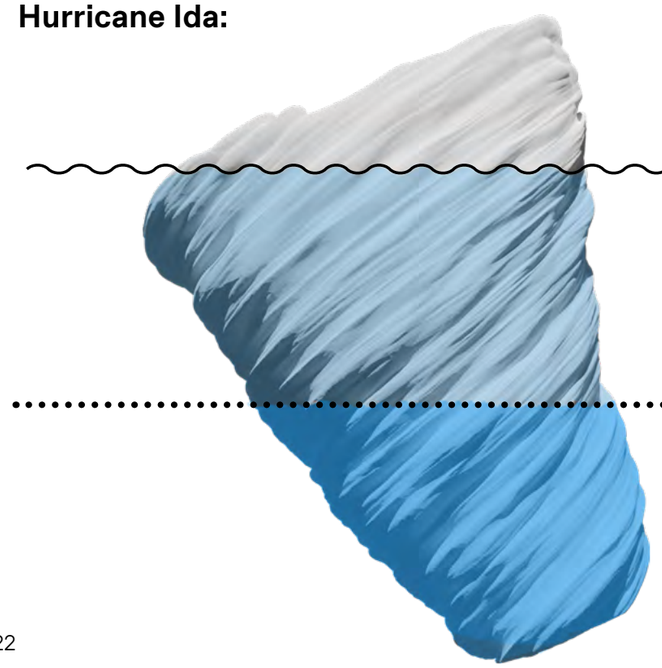
Rewilding natural waterways:
Rewilding focuses on humans stepping back and allowing natural processes back into urbanized areas. For example, “daylighting” involves the excavation of river and stream networks buried underneath cities and can assist in their capacity to handle excessive rainfall. Rewilded streams can also boost urban biodiversity and provide options for managing urban heat.

Green cities:
Green city designs, such as the “sponge city” concept, incorporate a combination of open green spaces like parks, gardens, wetlands, green roofs and porous construction materials into city planning to reduce the amount of potentially dangerous and polluting urban run-off during storm events. Such spaces also encourage urban biodiversity and mitigate urban heat.

Social protection:
Government programs taking anticipatory actions to protect vulnerable people, such as assisting landlords to make informal or neglected dwellings safer or facilitating the relocation of people to safer areas, can reduce risk in flood-prone regions. However, being able to engage underserved communities, such as undocumented migrants, remains a challenge.

Responsible waste disposal:
Changing the behaviour of residents in cities to avoid actions that can increase flood risk includes managing waste, such as flushed non-biodegradable material that forms large blockages (e.g. “fatbergs”). Unclogging vital sewer and storm water systems also reduces the amount of pollution entering our oceans and waterways.

Hurricane Ida:



Impacts
- Infrastructure damage
- Loss of life
- Migration/displacement

Drivers
- Atmospheric warming
- Urbanization
- Vulnerable infrastructure
- Lack of regulation/enforcement
- Insufficient early warning system

Root causes
- Human-induced greenhouse gas emissions
- Insufficient risk governance
- Inequality of development and livelihood opportunities

Key interconnections:

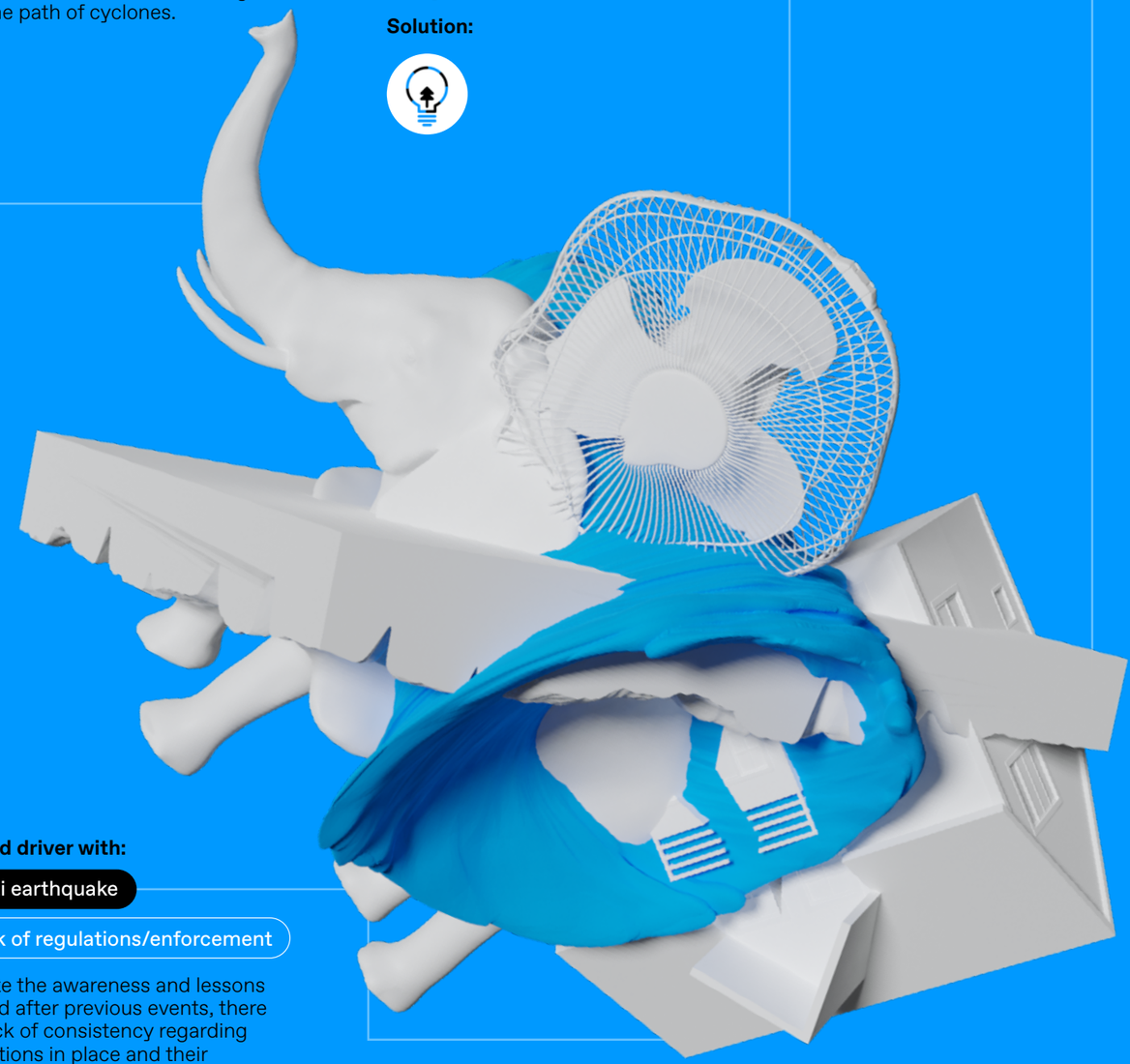
Shared root cause with:
- Wandering elephants
- Taiwan drought
- Human-induced greenhouse gas emissions

Increased effect of climate change on atmospheric warning exacerbates existing climatic patterns, such as the strength of hurricanes and droughts and the path of cyclones.

Shared root cause with:
- Taiwan drought
- British Columbia heatwave
- Insufficient risk governance

Governments were not prepared to handle increasingly severe instances of heat, rain or drought.

Solution:



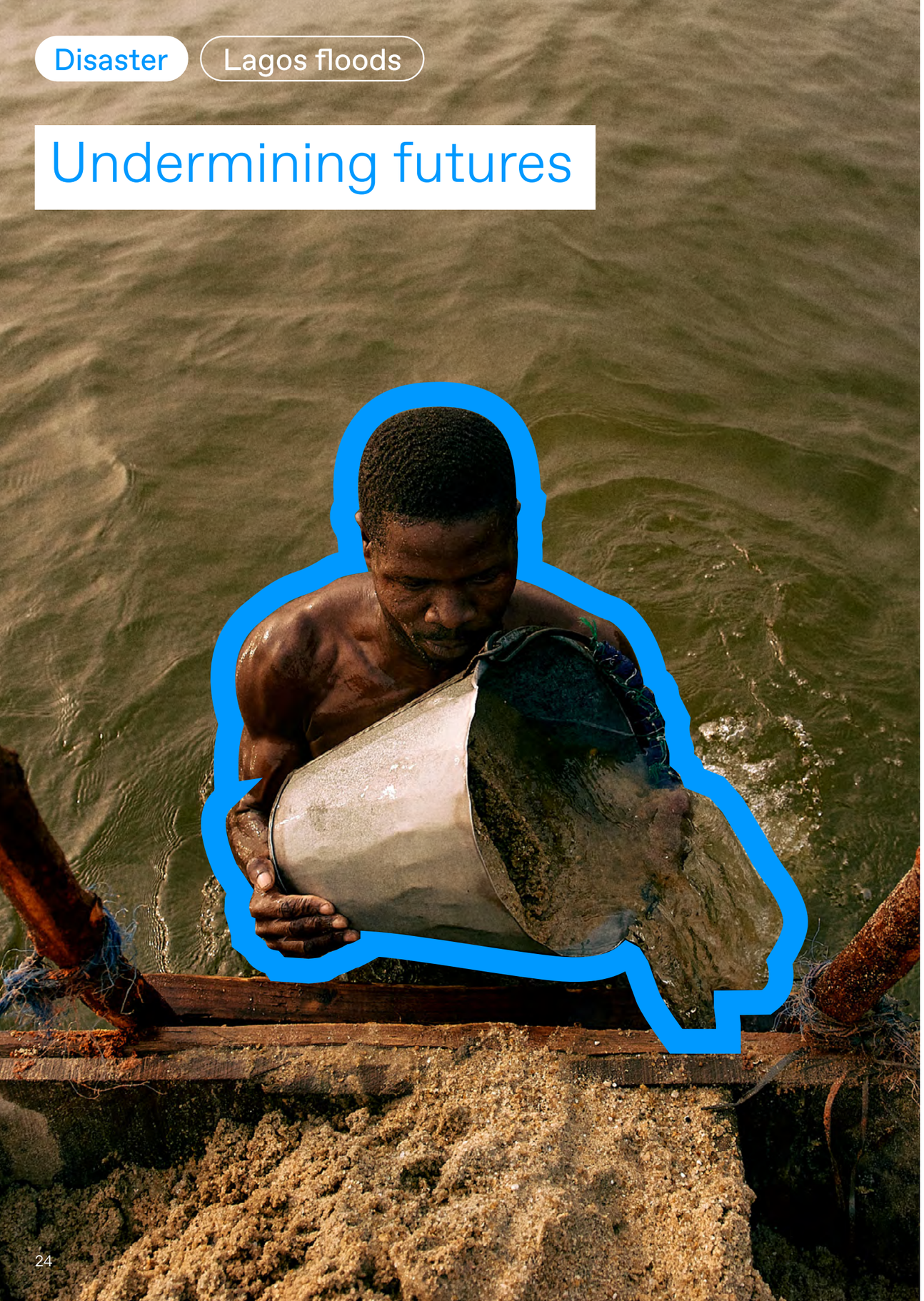
Shared driver with:
- Haiti earthquake
- Lack of regulations/enforcement

Despite the awareness and lessons learned after previous events, there is a lack of consistency regarding regulations in place and their enforcement in order to avoid future disaster risk scenarios.

Solution:

Disaster | Lagos floods

Undermining futures



Narrative

The residents of Lagos, one of Africa's biggest cities, are faced with increasingly severe annual flooding of their city, which is threatened by sea level rise and sinking at a rate of up to ~87 mm per year. The ability of this sinking city to cope with flooding is significantly hampered by poorly maintained waterways and drainage systems. The city is rapidly expanding as the population grows and people flock from rural areas towards urban centres in hopes of better economic opportunities.

Moreover, the city faces another deadly threat in the form of a hidden industry, sand mining. Sand mined at the country's shorelines to supply a construction boom in the area leads to eroding coastlines and the destruction of coastal ecosystems, which are critical components in protecting the inhabitants from storms and rising seas. In the past decade alone, 59 per cent of the wetlands in Lagos have been lost, a predicament directly linked to the worsening flood problem in the city, which displaces thousands of people, making it clear that the short-term economic gain of sand mining under lax regulation puts at risk the future of many communities in Lagos.

As grand building projects spring up for those that can afford them, the vulnerable people in the city are continually pushed to the margins and into harm's way by development and disasters. Sand mining exposes them further by undermining coastal protection and damaging ecosystems that they rely on for coastal protection and livelihoods (e.g. fisheries). The hidden industry of sand mining will become an even bigger threat to Lagos residents in the future. By 2050, climate change increasing precipitation rates and the risks of subsequent flooding will be twice as high as today and sea level rise will result in half of the city at risk of being underwater by 2100 and many people in vulnerable areas at risk of permanent displacement.

Wider picture

Global demand for sand and gravel to satisfy the booming appetite for construction materials is driving unsustainable and often illegal practices that are degrading ecosystems and increasing vulnerability to various hazards. Despite being one of the most sought-after and traded commodities on the planet, second only to water, it is still flying largely under the radar of government policy and public awareness, and addressing the problem is key for sustainability and reducing future risk, particularly in places such as Lagos.

Disaster icon:

Location: Lagos, Nigeria

Category: Extreme weather

Date/duration: July 2021

Key figures:

4,000
residents displaced

4 billion
USD damage per year

Disaster | Lagos floods

Solution package:

Floating architecture:
Designing floating structures in low-elevation coastal areas is an innovative approach for adapting to sea level rise and flooding. While prototypes from houses to neighbourhoods and even small cities are being developed, the research, regulations and policy needed for further development needs to keep pace with innovation.

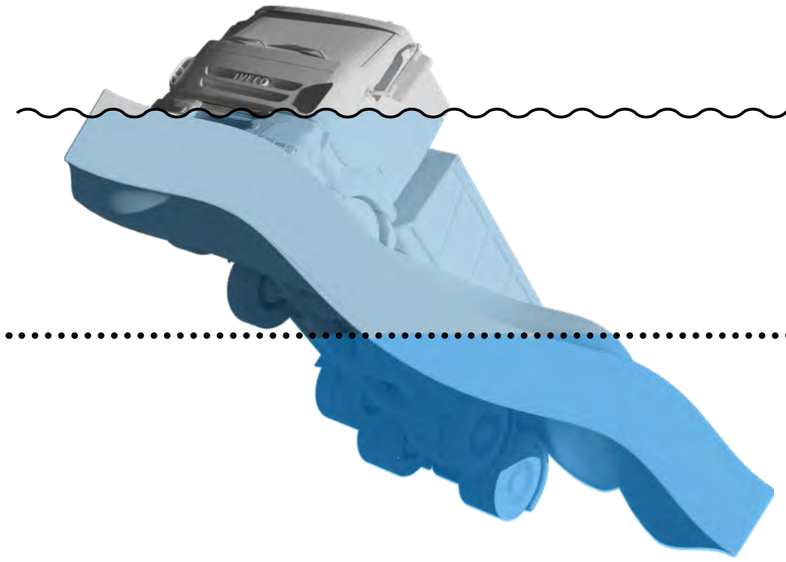
Participatory waste management:
Engaging communities in waste management planning is a cost-effective strategy to prevent flash floods related to drainage blockages. Integrating informal waste collectors or running training programs can turn local residents from part of the problem into part of the solution while also fostering material recycling and resource recovery, generating jobs and improving air quality.

Alternative construction materials:
Replacing traditional building materials with alternative, sustainable materials such as recycled aggregates, wood and other biomaterials can reduce flood risk by preventing sand mining and greenhouse gas emissions related to concrete production. However, it requires major reforms in construction regulations and building standards, as well as some financial incentives, for the construction industry.

Ecosystem restoration:
Vegetated coastal ecosystems help to enhance coastal protection by stabilizing shorelines, reducing erosion and diffusing wave energy. Conserving and restoring such ecosystems also supports biodiversity, local livelihoods and fisheries. Ecosystem restoration must be implemented on a large scale and with a long-term perspective to fully benefit from it.

Forecasting mobile applications:
By providing real-time flood forecasting, educational messages and awareness-raising notifications to users, mobile applications can help residents to better prepare and respond to flood events. A key consideration is the coverage of technology and awareness in vulnerable communities or at-risk areas.

Lagos floods:



Impacts
- Infrastructure damage
- Health impacts
- Ecosystem damage and biodiversity loss
- Migration/displacement
- Water insecurity

Drivers
- Atmospheric warming
- Urbanization
- Vulnerable infrastructure
- Organized crime
- Lack of regulation/enforcement
- Insufficient early warning system

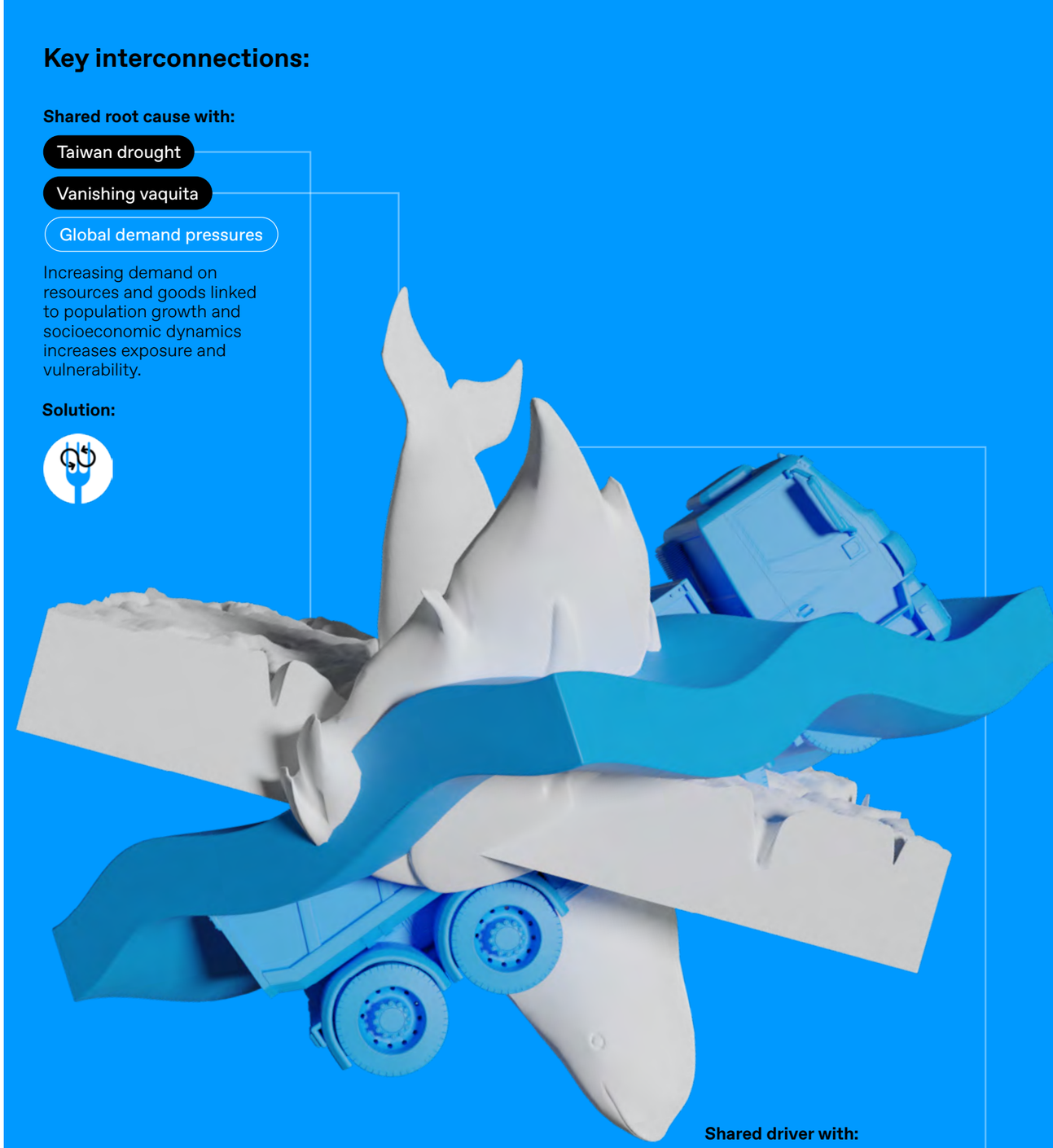
Root causes
- Human-induced greenhouse gas emissions
- Undervaluing environmental costs
- Global demand pressures
- Insufficient risk governance
- Inequality of development and livelihood opportunities

Key interconnections:

Shared root cause with:
- Taiwan drought
- Vanishing vaquita
- Global demand pressures

Increasing demand on resources and goods linked to population growth and socioeconomic dynamics increases exposure and vulnerability.

Solution:



Shared driver with:
- Mediterranean wildfires
- Urbanization

Expanding urbanization in areas at risk of extreme events; for example, in fire-prone forests or flood-prone areas.

Solution:

Disaster | Mediterranean wildfires

Learning to fight fire with fire

Narrative

In the summer of 2021, drought and low humidity combined with record-breaking heat of up to 48.8°C (119.8°F) led to fire outbreaks across the Mediterranean countries – including Italy, Greece, Algeria and Turkey – killing more than 100 people and burning more than 620,000 ha of land in July and August.

Although wildfires can be managed preventively, fire management policies in the Mediterranean are based on a model of suppressing fires before they become dangerous. However, evidence shows that this model counter-intuitively promotes extreme wildfire events. This happens because when a small or medium-sized fire is put out in an area, the unburnt vegetation just keeps accumulating – until there is so much material that the fire burns intensely and quickly, overwhelming the capacity to control it and becoming a "mega-fire."

In addition to increasing temperatures from climate change, tourism growth and urbanization have pushed people and assets increasingly close to forested areas with high fire risk. Combined with the model of fire suppression, the potential for mega-fire disasters has increased, leading to increased losses of lives and livelihoods.

Reducing the amount of dead vegetation in forests can be done with a variety of techniques, and often should be done in combination. One way is to allow pastoralists into forests and encourage their goats or sheep to graze on the underbrush. Another very important way to reduce the risk of mega-fires is to let the fire do the work for us. This strategy has been used for centuries by indigenous people in the United States and Australia and is beginning to gain more attention in governmental fire management plans. These plans usually include intentionally setting small, cooler fires that burn broken limbs and underbrush without killing trees. Fire is a natural part of the Mediterranean ecosystem, and allowing fires to burn in a safe and controlled way can reduce the likelihood of mega-fires burning out of our control.

Wider picture

According to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report, the Mediterranean, as well as other places around the world, will have an increase in temperature, droughts and fire weather conditions by the middle of this century. As climate change increases the chances for fire ignition and spread, we must cultivate a healthy relationship with fire before it becomes even more dangerously uncontrollable.

Disaster icon:

Location: Italy, Greece, Turkey, Algeria

Category: Fire

Date/duration: Summer 2021

Key figures:

48.8°C
(119.8°F) Temperature

620,000 ha
of land burnt

~100
deaths

Disaster | Mediterranean wildfires

Solution package:

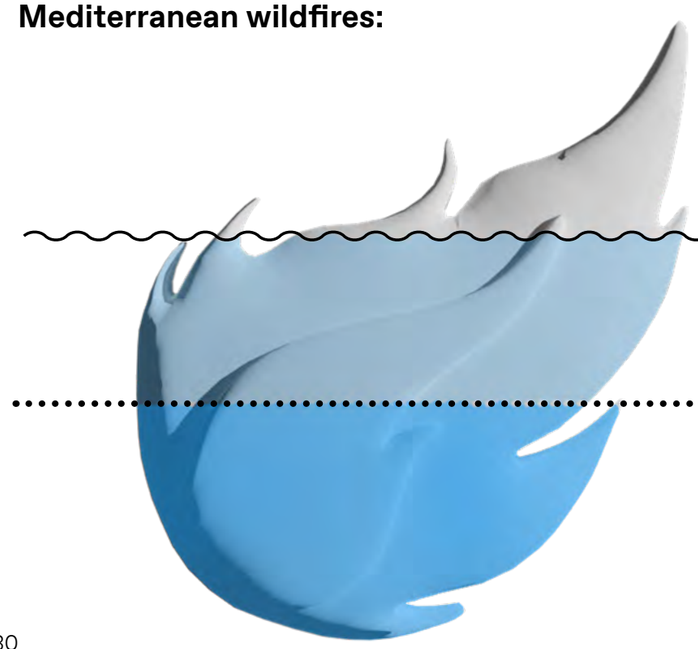
Ecologically-based management:
Extreme fires can be reduced by using natural processes as a management tool, either by strategically using fire through prescribed burning or a “let it burn” strategy, as well as using goats and other livestock to clear out built-up vegetation. Such practices not only help build ecosystem resilience and reduce the likelihood of mega-fires but also provide co-benefits for livelihoods and biodiversity.

Improve inter-agency coordination:
Forestry and fire authorities must improve their collaboration and communication in the prevention of and response to fires. Fire response plans will be notably better if these authorities, as well as other local and national entities, exchange wildfire-related data, share management tools, co-create risk maps and coordinate preventive and management measures.

Multi-stakeholder risk management:
Involving the private sector, civil society organizations and local communities in fire management planning and wildfire responses can effectively prevent fire incidences and damage. But to ensure effectiveness, stakeholder engagement at various levels requires strong institutional leadership, political commitment in the long term, trust and willingness.

Fire-safe development:
From changing the housing design to diversifying the landscape, communities at the wildland-urban interface can be safer from wildfire risks. For example, creating defensible fuel-free space from 10 m to 30 m around each home or mixing different land uses that provide firebreak areas can prevent fire propagation.

Mediterranean wildfires:



Impacts
- Livelihood loss
- Loss of life
- Ecosystem damage and biodiversity loss
- Infrastructure damage
- Health impacts
- Migration/displacement

Drivers
- Atmospheric warning
- Drought
- Urbanization

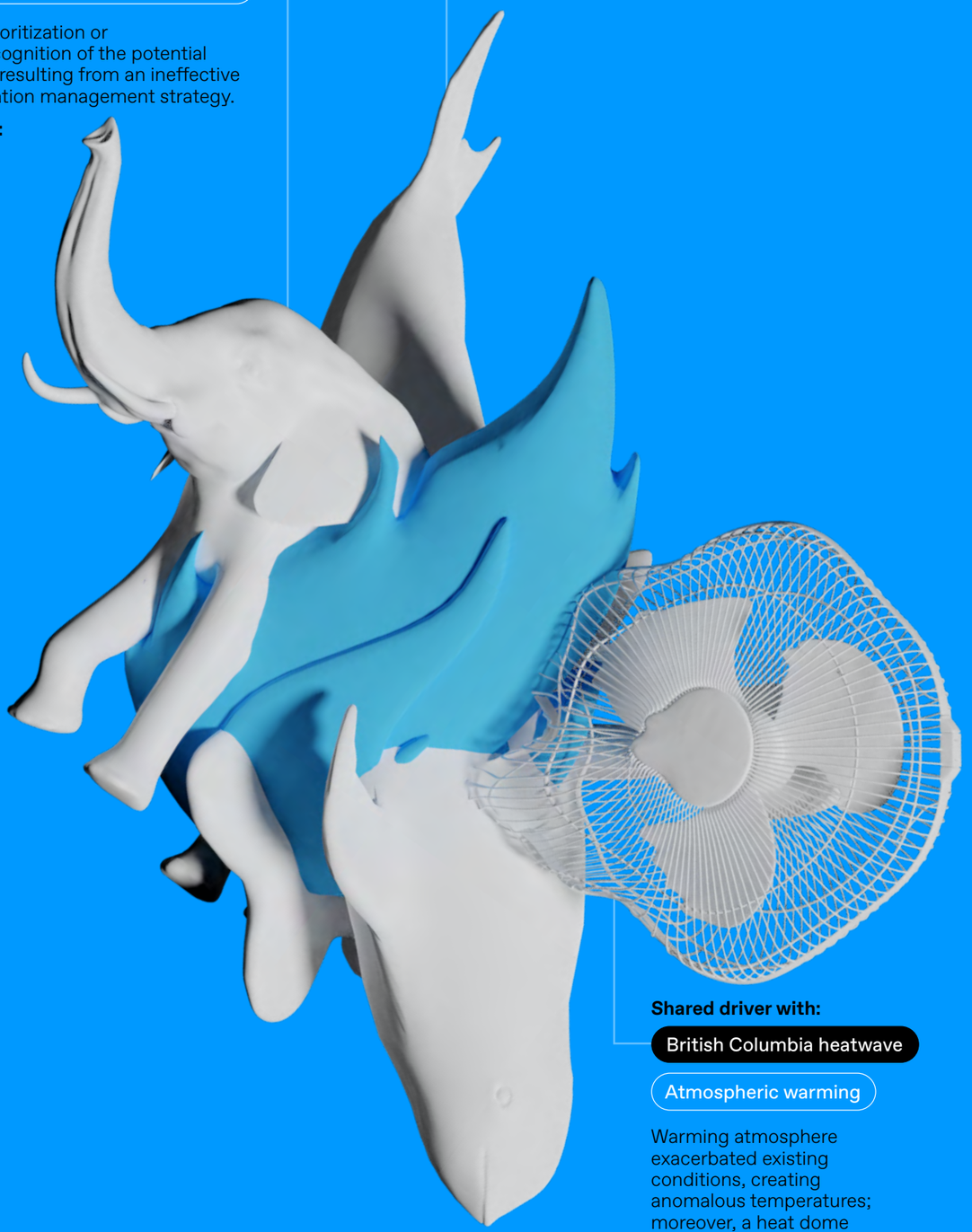
Root causes
- Undervaluing environmental costs
- Insufficient risk governance
- Human-induced greenhouse gas emissions
- Inequality of development and livelihood opportunities

Key interconnections:

Shared root cause with:
- Vanishing vaquita
- Wandering elephants
- Undervaluing environmental costs

Underprioritization or underrecognition of the potential damage resulting from an ineffective conservation management strategy.

Solution:



Shared driver with:
- British Columbia heatwave
- Atmospheric warming

Warming atmosphere exacerbated existing conditions, creating anomalous temperatures; moreover, a heat dome created areas of high pressure held in place due to jet stream dynamics.

Disaster

Southern Madagascar food insecurity

Pushed to the limits by environmental extremes

Narrative

By December 2021, more than 1.6 million people in southern Madagascar were estimated to have been suffering high levels of food insecurity, with hundreds pushed to leave their homes and migrate in search of more secure livelihoods. Children under five are among the most vulnerable: between April and June 2021, at least 14,000 were treated for severe acute malnutrition (which is typically the number of total children treated in a year), and around 515,000 were considered to be wasted (thinner than expected) during 2021. Environmental degradation and climate change have exacerbated the prolonged drought conditions, which in combination with other complex social drivers, have pushed the region into a humanitarian crisis.

Over the past four years, a progressive decrease of rain in southern Madagascar resulted in the country's worst drought in 40 years. This led to severe stress on vegetation, triggering a drastic decline in rice, maize and cassava production. Widespread deforestation in the region has led to severe environmental degradation, which has exacerbated the likelihood of sandstorms that inhibit growth of new seedlings and crops contributing to drying the soil, thus worsening the prolonged drought conditions. Additionally, pest infestations have impacted the main livelihoods of inhabitants, causing as much as 60 per cent of crop losses in some areas. Finally, the last cyclone season in the north and east of the country severely affected road networks, hindering the delivery of aid to drought-affected households in the south.

Social drivers have also strongly influenced the food insecurity conditions in the region. Particularly, the measures taken by the Malagasy Government between 2020 and 2021 to help contain the COVID-19 pandemic contributed to the livelihood crises and food inflation which reached 8 per cent in 2021; this was evident in increased food prices (e.g rice and oil) which further stressed struggling households' finances. All of these aspects have prompted an economic imbalance in an already unstable southern Madagascar, where more than 90 per cent of the population is living below the poverty line.

Wider picture

The southern Madagascar food insecurity is an example of how multiple, complex environmental and social factors can combine to trigger a profound crisis. Many regions around the world are exposed to multiple risks stemming from environmental degradation and socioeconomic and political dynamics, which will be exacerbated by climate change while magnifying its impacts.

Disaster icon:

Location: Grand South and Grand-Southeast, Madagascar

Category: Food crisis

Date/duration: Four years of consecutive drought - 2018 ~ Ongoing

Key figures:

1.64 million

experienced acute food insecurity (December 2021)

40 years

worst drought recorded (2019-2021)

Disaster

Southern Madagascar food insecurity

Solution package:

Ecosystem restoration:
Working closely with communities to restore ecosystems, with fast-growing species suitable for the prevailing environmental conditions, can help to reduce food insecurity. Forest and landscape restoration in Madagascar addresses the environmental problems deforestation has caused, going beyond planting trees to regain ecological functions and biodiversity while generating jobs and alternative food sources.

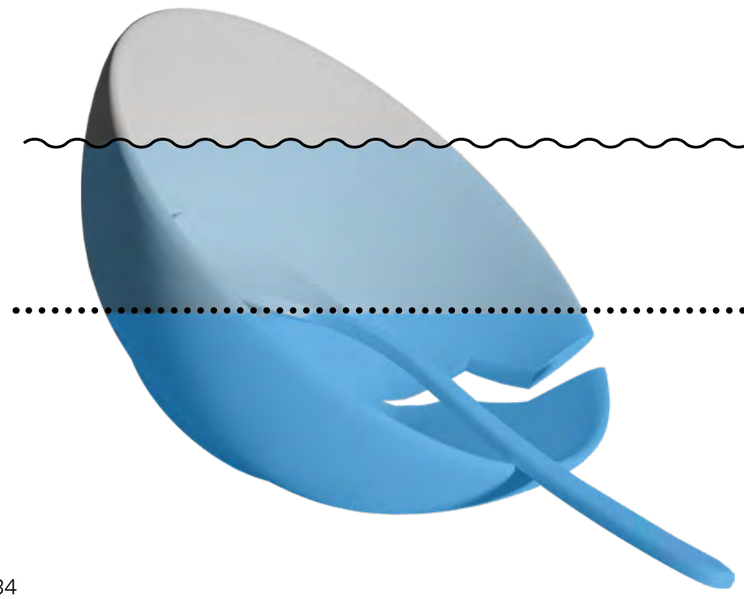
Climate-smart agriculture:
Landscape approaches focused on planting what works best in certain environmental contexts rather than designing crops solely based on economic factors can increase productivity and resilience in a changing climate while reducing greenhouse gas emissions. Local knowledge is essential to properly understand context, such as soil properties, drought resilience and nutritional needs; thus, community engagement is key.

Inclusive development:
Integrating gender issues, such as gender-based violence, into more inclusive development and adaptation approaches facilitates the empowerment of women and girls, who are more vulnerable to food insecurity impacts, to better manage food use in times of hardship and increase the quality of life for their families.

Social protection:
Ensuring access to essential care services, income security and security for children in terms of nutrition needs are a priority for building resilience to food system shocks. Support for value chain development, linked to markets, plus work under climate risk insurance for vulnerable farmers in the south are necessary.

Increase access:
Access to food and markets is an essential part of food security. Collaboration is needed between local and national governments to provide adequate basic infrastructure, such as roads, that can help people to better access food and aid while allowing more livelihood options.

Southern Madagascar food insecurity:



Impacts
- Livelihood loss
- Health impacts
- Loss of life
- Migration/displacement
- Food insecurity

Drivers
- Atmospheric warming
- Drought
- Deforestation

Root causes
- Human-induced greenhouse gas emissions
- Undervaluing environmental costs
- Legacy of colonialism
- Insufficient risk governance
- Inequality of development and livelihood opportunities

Key interconnections:

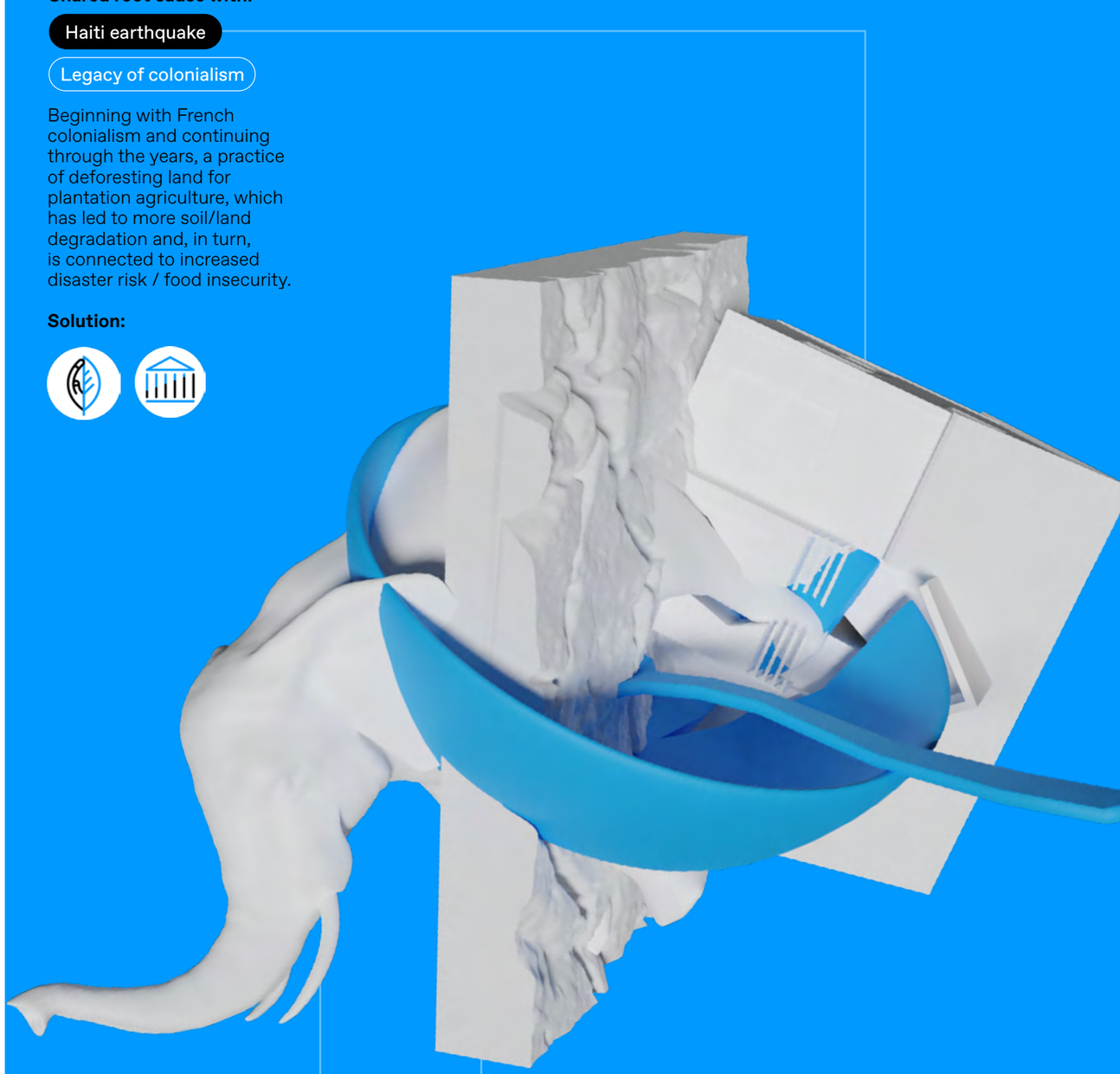
Shared root cause with:

Haiti earthquake

Legacy of colonialism

Beginning with French colonialism and continuing through the years, a practice of deforesting land for plantation agriculture, which has led to more soil/land degradation and, in turn, is connected to increased disaster risk / food insecurity.

Solution:



Shared root cause with:

Taiwan drought

Wandering elephants

Human-induced greenhouse gas emissions

Anthropogenic warming exacerbates existing climatic patterns, worsening the effects of drought.

Disaster | Taiwan drought

When the typhoons stop coming, lives and livelihoods must change

Narrative

Taiwan is one of the wettest places in the world, with an annual rainfall of 2,600 mm often brought to the island by seasonal typhoons. However, for the first time in 56 years, no typhoon made landfall, marking the first half of 2021 as one of the worst drought periods in the island's history. With water reservoirs below 5 per cent of their capacity, water rationing was ordered for more than one million households and businesses. The drought also affected the functioning of hydroelectric power plants, forcing outages that impacted both industries and consumers.

The water rationing was not without controversy, especially for Taiwan's most water-intensive industries: rice farming and semiconductor manufacturing. Technological industries, like the semiconductor manufacturers, were instructed to slash water usage by up to 15 per cent. Meanwhile, some farmlands were completely cut off from water and irrigation of more than 74,000 ha of rice (24 per cent of total planted area), destroying the second yield.

Although both sectors endured rationing measures, the semiconductor industry was clearly prioritized over rice production. Taiwanese Semiconductor Manufacturing Company (TSMC) produces nearly 25 per cent of the world's semiconductors and 92 per cent of the most advanced chips used in products like iPhones and automotive AI. The pressure to keep this high-GDP earning industry afloat while letting rice crops fail is an example of the hard choices that the impacts of climate change will continue to force.

Taiwan has relied on the consistency of typhoons to supply the water resources to meet their needs; and is not prepared for the consequences of a shifting normality. As climate change impacts the way freshwater resources are distributed on the planet, it has become more and more important to conserve and equitably allocate remaining resources. Where changing weather patterns are leading to a different level of access to natural resources, governments will face hard choices over what and whom to prioritize.

Disaster icon:

Location: Taiwan Province of China

Category: Drought/water shortage

Date/duration: June 2020 - June 2021

Key figures:

Worst drought in
56 years

0
typhoons in 2020

Reservoir capacity below
5%

Wider picture

As much as half of the world's population could be living in areas facing water scarcity by as early as 2025. Water management in a changing climate is incredibly important to ensure the life, health and prosperity of people on our planet. However, because the climate is shifting as in the case of typhoon pathways in Taiwan, we also need to shift water management strategies in order to cope with this.

Disaster | Taiwan drought

Solution package:

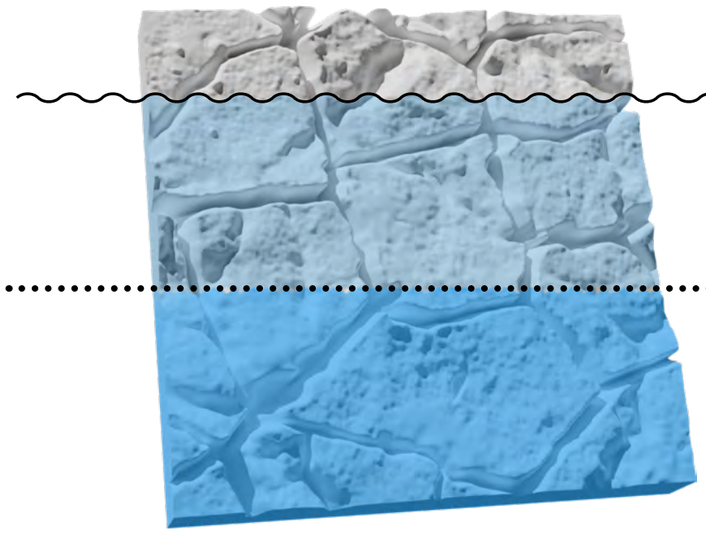
Update cleaning process for reservoirs:
Given high sedimentation rates in reservoirs in Taiwan and the ineffective cleaning techniques in place, there is room for adaptive planning in terms of water infrastructure on the island. Boosting reservoir capacity by removing sediment is a first step, followed closely by replacing leaking pipelines and outdated water infrastructure.

Improving water recycling:
Investing in water recycling could help Taiwan face future climate impacts by reducing the dependency on rain-fed water reservoirs. Starting with semiconductor industries, recycling industrial wastewater can work as a backup system during dry periods. Similarly, farmers and households need to change the way they value water in order to help reduce water waste.

Climate-smart agriculture:
Using climate-smart techniques, such as replacing crops with less water-intensive varieties or using precision irrigation, can help reduce water consumption. In combination with improved crop management, this could represent an alternative income source for rice farmers in Taiwan.

Ecosystem restoration:
Healthy forests and their root systems stabilize the soil. This mitigates erosion and sediment run-off, preventing Taiwan's reservoirs from siltation and leaving more room to fill with water during the rainy season.

Taiwan drought:



Impacts
- Livelihood loss
- Water insecurity

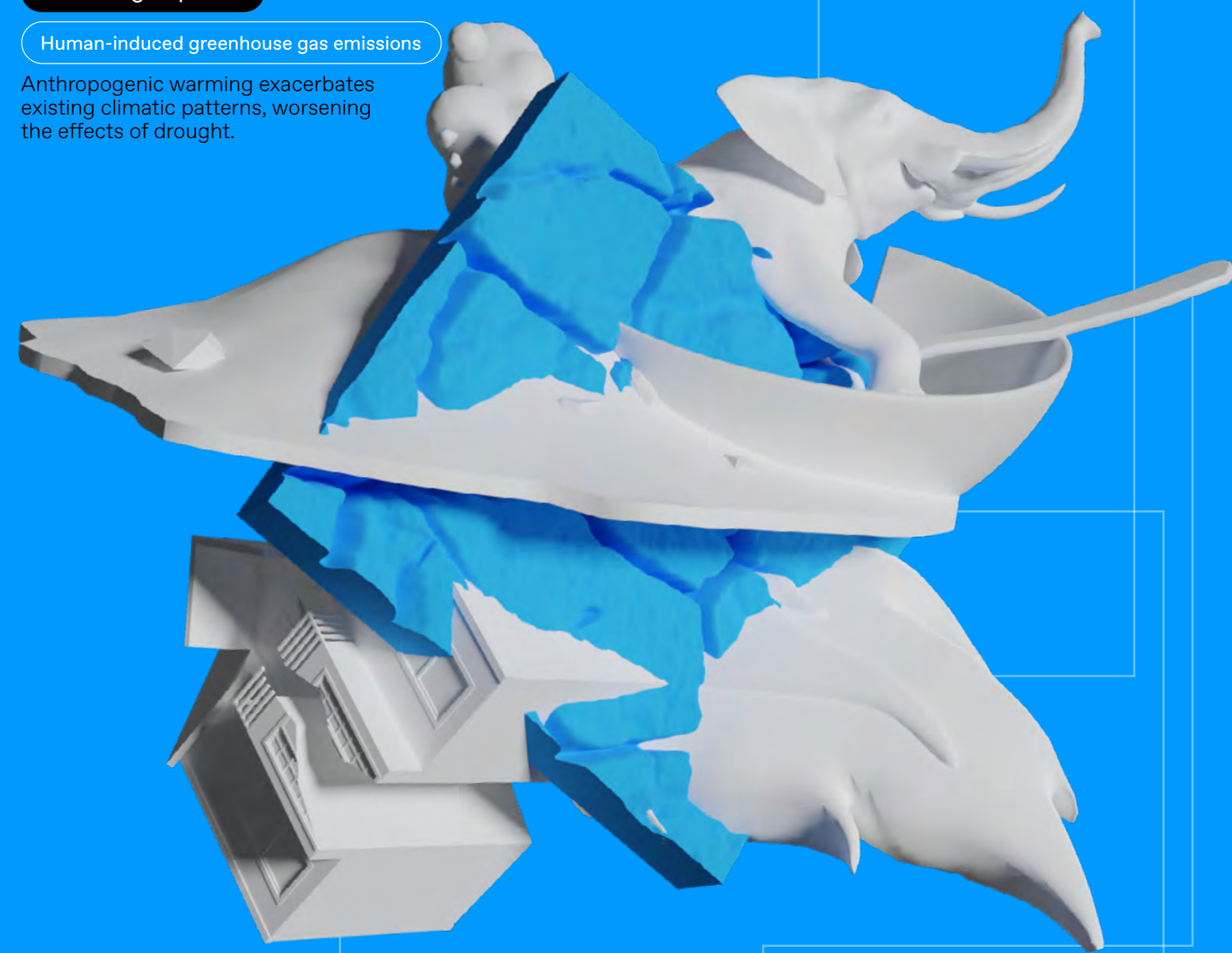
Drivers
- Vulnerable infrastructure
- Deforestation
- Atmospheric warming
- Drought

Root causes
- Global demand pressures
- Undervaluing environmental costs
- Insufficient risk governance
- Human-induced greenhouse gas emissions

Key interconnections:

Shared root cause with:
- Mediterranean wildfires
- Wandering elephants
- Human-induced greenhouse gas emissions

Anthropogenic warming exacerbates existing climatic patterns, worsening the effects of drought.



Shared driver with:
- Southern Madagascar food insecurity
- Drought

Extreme drought conditions exacerbated existing vulnerabilities of communities and systems.

Solution:

Shared driver with:
- Haiti earthquake
- Tonga volcano eruption
- Deforestation

The loss of forest has led to environmental degradation, which has compromised water resources and natural protection offered by ecosystems.

Solution:

Disaster | Tonga volcano eruption

The Big Bang that took a nation off the grid

Narrative

The strong submarine Hunga-Tonga-Hunga-Ha'apai volcano eruption and the subsequent tsunami and shock waves were felt across the Pacific Ocean and beyond. This “Big Bang” released mechanical energy equivalent to hundreds of Hiroshima nuclear explosions, creating supersonic air pressure waves that were observed from space.

In the Kingdom of Tonga, the volcanic ash, tsunami and shock waves caused widespread devastation in several islands, and, in particular, destroyed the only fibre-optic cable that connects the islands with the rest of the world, leaving the country offline for more than three weeks. Four months later, communication between islands is still not fully restored. Disruption of Internet connectivity with Tonga had serious implications on its economy: about 30 per cent of household consumption and 40 per cent of national GDP in Tonga depend on remittances from international migrants sent via the Internet. The disruption particularly affected women, who are highly dependent on remittances and have to deal with the increases in water and food prices during the emergency.

Additionally, the relief and recovery efforts of the Tongan government and emergency services were hampered by the inability to communicate. Access to satellite connectivity is limited, and even with it, communications failed due to the volcanic ash. Undersea fibre-optic cables are crucial for the communication of the Pacific Islands with the rest of the world. Like Tonga, many other islands rely on a single cable, increasing their vulnerability not just to volcanic eruptions or tsunamis but also to more frequent disturbances, such as damage from fishing boats. While adding an additional cable seems an easy solution, countries face many challenges, starting with the high financial investment needed (e.g. the construction of the cable to Tonga cost $15 million in 2013) but also concerns related to foreign surveillance and ownership of data by the countries providing more cables.

Wider picture

In a world highly interconnected by communication and technology, the inability to “be online” becomes a vulnerability in the context of extreme events as the case of the Hunga-Tonga-Hunga-Ha'apai volcano eruption showed. Many Pacific Island countries, such as Vanuatu and Samoa, also depend on a single submarine cable, and satellite services are restricted and not widespread enough to cover basic connectivity needs. Damage to critical telecommunication infrastructure not only hinders response actions but also minimizes the effectiveness of early warning systems, compromising disaster risk management strategies and triggering offline scenarios as in Tonga.

Disaster icon:

Location: The Kingdom of Tonga, South Pacific

Category: Volcano eruption; Tsunami

Date/duration: 15 January 2022

Key figures:

90.4 million
USD in damages

18.5%
of Tonga's GDP compromised

84%
Tonga's population effected (approx. 85,000 people)

500 times
as powerful as the atomic bomb dropped on Hiroshima

Disaster — Tonga volcano eruption

Solution package:

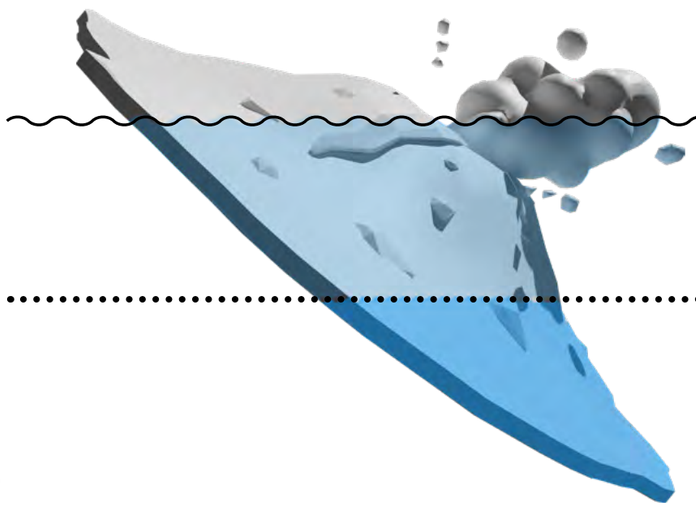
Ecosystem restoration:
Coastal ecosystem restoration, especially involving robust, native species, can build protective “green belts” along vulnerable coastlines to protect from storm surge. Used sustainably in combination with traditional sea walls or dykes, such green belts can help to increase carbon sequestration and biodiversity while also continuously adapting to climate change impacts.

Social protection:
Programmes to foster the capacity of people to respond to hazards when they strike are critical for reducing risk for vulnerable (e.g. female-headed households) or marginalized groups (e.g. people on remote islands). Accessible financial support, such as social protection, climate risk insurance or credit, can help in areas with limited livelihood opportunities to build resilience.

Diversify infrastructure:
As critical infrastructure is also susceptible to the impacts of hazards, diversification of systems allows for redundancy, which can be an important factor in reducing risk. In places like Tonga, where the reliance on a single undersea cable led to cascading impacts, expanding satellite services can be part of the solution. However, issues of cost and geopolitical considerations need to be addressed.

Satellite monitoring:
Obtaining early warning signals through improved observation technologies and education to prepare people to act effectively translates into saving lives and reducing related damage. In Tonga, the tsunami alert system was effective; however, improving collaboration across sectors and institutions can enhance technology for detecting different kinds of eruptions and warn other countries that could be impacted in a timely manner.

Tonga Volcano eruption:



Impacts
- Livelihood loss
- Loss of life
- Ecosystem damage and biodiversity loss
- Food insecurity
- Water insecurity
- Migration/displacement
- Health impacts
- Infrastructure damage

Drivers
- Insufficient early warning system
- Vulnerable infrastructure
- Deforestation

Root causes
- Undervaluing environmental costs
- Insufficient risk governance
- Inequality of development and livelihood opportunities

Key interconnections:

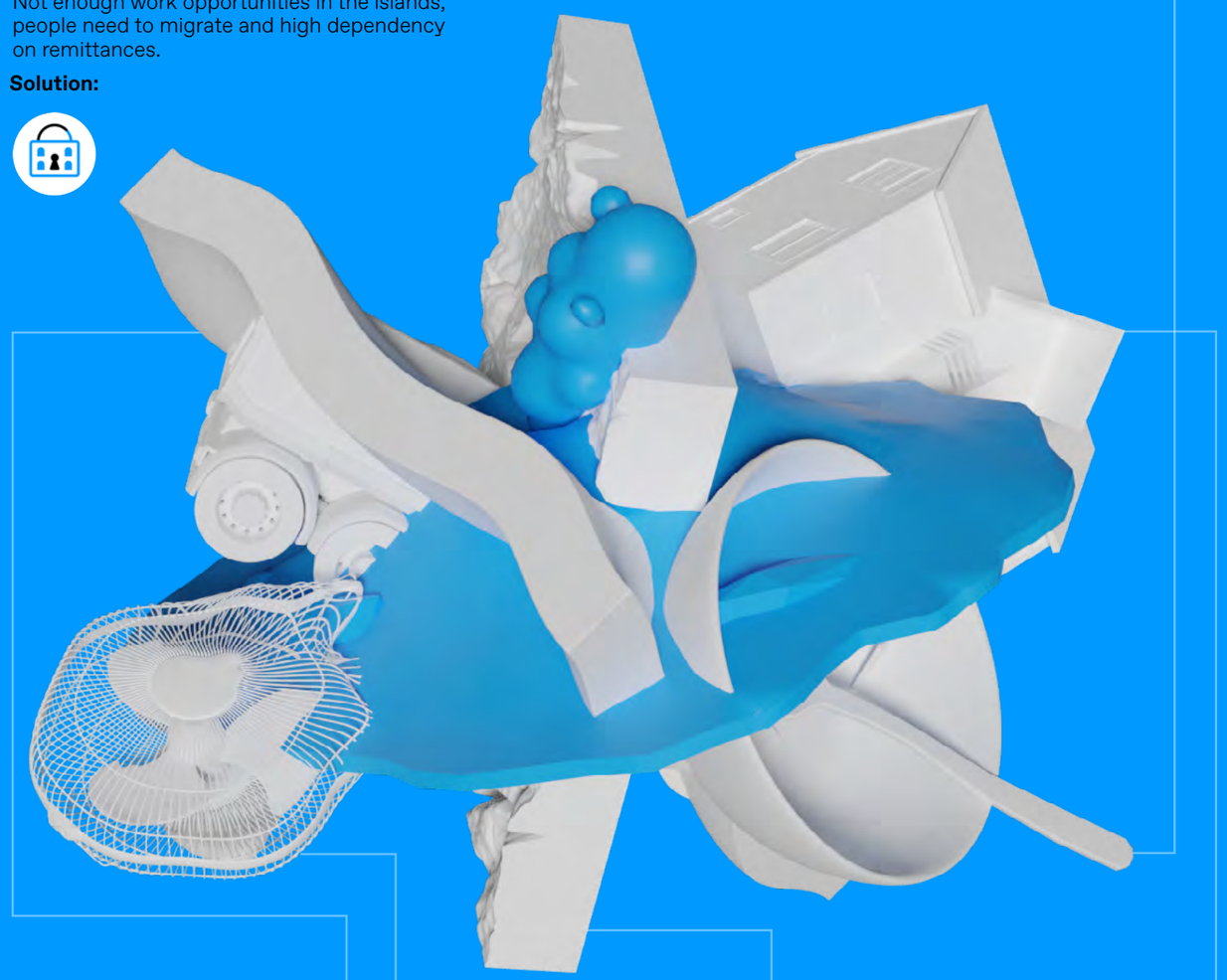
Shared root cause with:

Southern Madagascar food insecurity

Inequality of development and livelihood opportunities

Not enough work opportunities in the islands, people need to migrate and high dependency on remittances.

Solution:



Shared driver with:

British Columbia heatwave

Lagos floods

Insufficient early warning system

Hazard information is not well communicated to the public.

Solution:

Shared driver with:

Haiti earthquake

Taiwan drought

Deforestation

The loss of forest has led to environmental degradation, which has compromised water resources and natural protection offered by ecosystems.

Solution:

Disaster | Vanishing vaquita

Walking into an extinction with open eyes

Narrative

The vaquita (*Phocoena sinus*), a species of porpoise that can only be found on the northern end of the Gulf of California, is currently the most endangered marine mammal. The vaquita is one of 8,722 species worldwide listed as critically endangered or at “extremely high risk of extinction.” As both a predator and prey species, vaquitas serve as important food sources for top predators and keep populations of smaller species such as fish, squid and crustaceans in check, promoting a healthy balance in the region's interdependent food web.

However, unlike many other species on this inauspicious list, the main driver of its disappearance is relatively clear: fishing nets. Although the vaquita is not a commercial species, it is collateral damage of poaching and illegal trade of the totoaba (*Totoaba macdonaldi*), another species at risk of extinction. Being approximately the same size as the totoaba, vaquitas are entangled and drowned by illegal nets that seek to capture the totoaba for their highly prized swim bladders which are illegally trafficked via black markets to China, where they fetch a price equivalent to gold, earning it the nickname of “cocaine of the sea.”

Despite the vaquita estimated to being down to its last few individuals, there is reason for hope. Research recently concluded that there is enough genetic diversity in the small remaining population of vaquita to allow for recovery, but illegal fishing would need to end immediately.

So far, conservation efforts have not been effective despite international advocacy efforts and celebrity involvement. The lack of political will to enforce environmental laws, strengthen biodiversity conservation and maintain free-fishing areas around the vaquita's habitat has only reinforced the history of distrust between fishers and government. Meanwhile, illegal fishing continues. Time is running out for the vaquita and if conservation efforts continue to be unsuccessful, another species will go extinct, leading to far-reaching consequences on oceanic ecosystems and related food webs.

Wider picture

The continuing practice of illegal species trafficking around the world not only threatens species like the vaquita but also whole ecosystems as species disappear from webs. As an estimated 3 billion people worldwide rely upon marine ecosystems and seafood as a major part of their diets, the risk to ecosystems has flow-on effects for human health and local economies. Beyond this, the current continuance of illegal fishing despite clear legislation undermines state authority.

Disaster icon:

Location: Gulf of California, NW Mexico, North America

Category: Biodiversity crisis

Date/duration: 1990s - today

Key figures:

10 individuals
left in the wild

98%
population decline in the past decade

Disaster

Vanishing vaquita

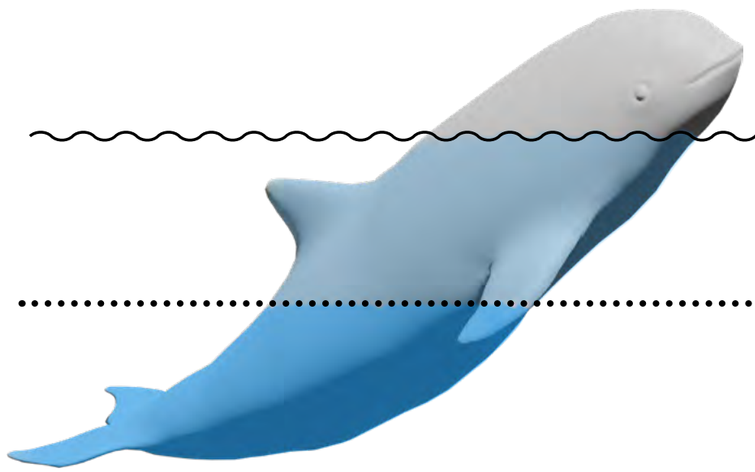
Solution package:

Sustainable fishing gear:
Replacing harmful fishing gear with more sustainable methods, such as small trawls or rigid traps, helps to minimize by-catch of non-target species like the vaquita. This reduces biodiversity loss and secondary impacts from discarded gear (e.g. “ghost nets”), but concerns around cost and effectiveness from fishers must be properly addressed by fisheries managers.

Sustainable aquaculture:
Farming species such as the totoaba for food or resupply of wild stocks can help to relieve pressure on endangered species and food security while providing more livelihood options. This must be closely regulated to ensure environmental sustainability and equitable access for local communities

Collaborative resource management:
A participatory approach involving local fishing communities and the local culture/knowledge they represent in the design of fisheries management helps to achieve long-term buy-in for conservation measures, and should target the culture of distrust between the government and fishers by incorporating respect and sustainable incentives as part of the process.

Vanishing vaquita:



Impacts

- Livelihood loss
- Loss of life
- Ecosystem damage and biodiversity loss
- Food insecurity

Drivers

- Lack of regulation/enforcement
- Organized crime

Root causes

- Global demand pressures
- Undervaluing environmental costs
- Insufficient risk governance
- Inequality of development and livelihood opportunities

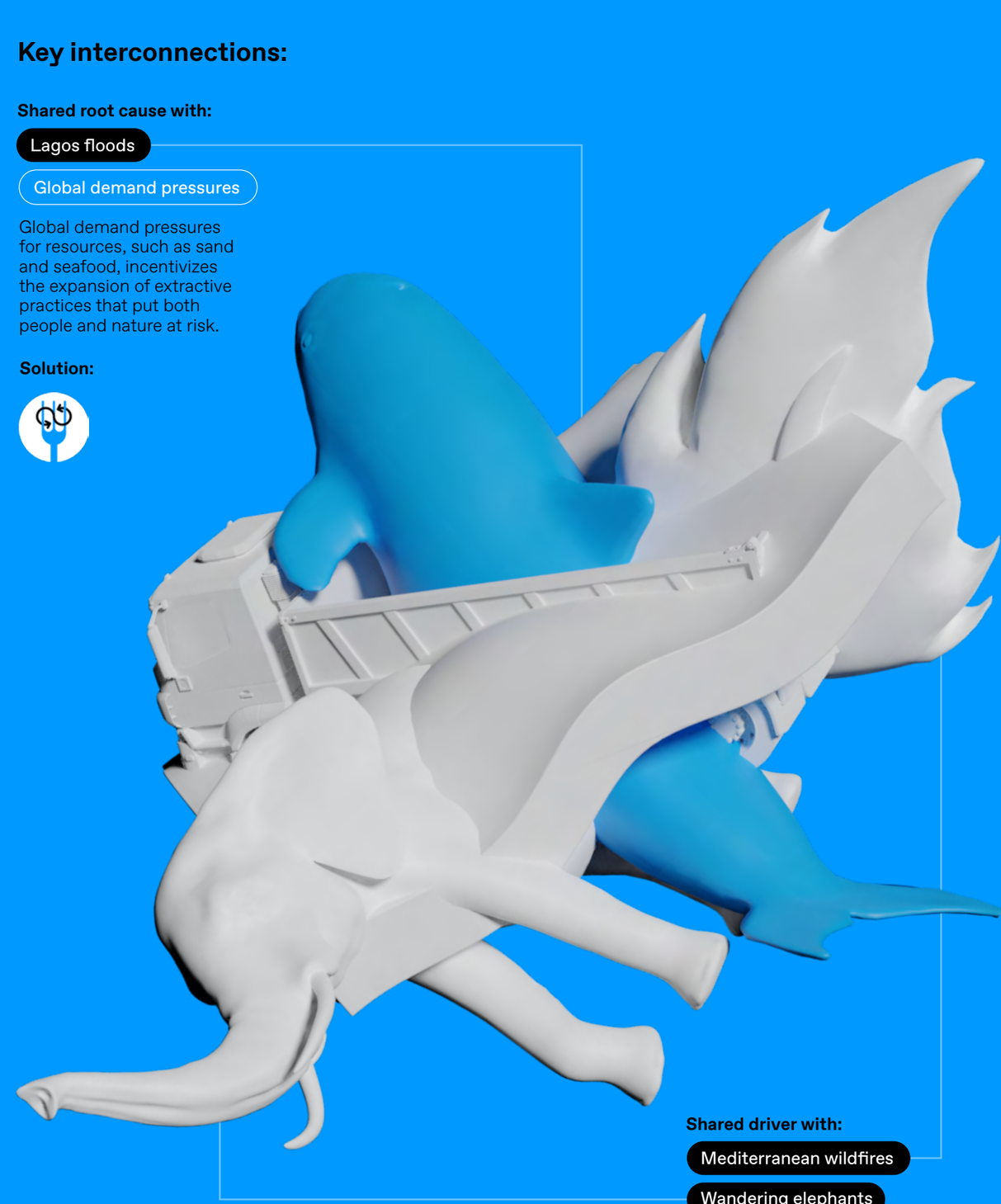
Key interconnections:

Shared root cause with:

- Lagos floods
- Global demand pressures

Global demand pressures for resources, such as sand and seafood, incentivizes the expansion of extractive practices that put both people and nature at risk.

Solution:



Shared driver with:

- Mediterranean wildfires
- Wandering elephants
- Undervaluing environmental costs

Underprioritization or underecognition of the potential environmental damage resulting from an ineffective conservation management strategy.

Solution:

Disaster | Wandering elephants

No space left for the wandering giants

Narrative

From March 2020 to September 2021, a herd of approximately 15 Asian elephants (Elephas maximus) left their home in Xishuangbanna National Nature Reserve. Their migration was likely linked to a drought that affected the region in March 2020, the same month the herd started their northward migration.

The elephant population in Xishuangbanna has steadily increased in the past century due to its protected status in China, from around 100 elephants in the 1970s to around 300 elephants in 2020. At the same time, the elephants in southern China lost 62 per cent of their habitat in just three decades due to expanding human settlements and rubber or tea plantations, resulting in less than 4 per cent of Xishuangbanna's area remaining as suitable habitat for elephants.

As protected habitats become increasingly reduced and fragmented, the home range of elephant populations extends into villages and farmlands, increasing the incidence of crop raiding and human-elephant conflict. Asian elephants need to eat around 300 pounds (150 kg) of food per day, meaning that an afternoon in a pineapple field for 15 elephants can be financially devastating for farmers. Along their journey, the migrating herd of elephants broke into homes, damaged buildings and infrastructure, and destroyed crops, totaling estimated damage of 6.8 million yuan (over $1 million).

Due to the diligence and efforts of the officials managing the elephants' path and early warning systems alerting people of the danger, there were no human injuries or casualties. This is often not the case when elephants and humans interact; since 1991, more than 60 people have been killed during encounters with Asian elephants in Xishuangbanna, with 12 deaths recorded in 2019 alone. Elephants are a protected species and therefore not usually killed during a conflict with humans, but they are often subject to electrocution or physical distress as humans try to drive them away.

As human and elephant populations grow, there is increasing stress on the area's resources in terms of food, water and space to live and roam. The best solutions need to provide better support for both human and elephant communities and consider long-term goals of shared resources and coexistence, leaving enough space for the elephants to live their lives away from human settlements.

Wider picture

Human-wildlife conflicts will increase in number and intensity due to factors including climate change, urbanization and population growth; and a new system of thinking is needed where human can co-exist with wildlife in safe and mutually beneficial ways.

Disaster icon:

Location: Yunnan province, China

Category: Human-wildlife conflict

Date/duration: March 2020 – September 2021

Key figures:

15
elephants

500 km
(300 miles)

180 tonnes
of food

1 million
USD in damages

Disaster

Wandering elephants

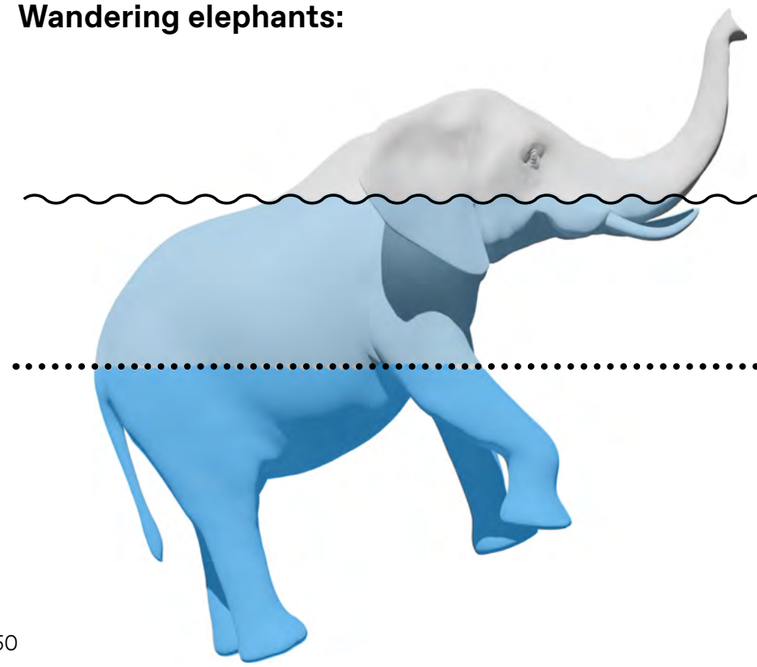
Solution package:

Improve habitat suitability:
Human-wildlife encounters can be reduced by improving ecosystem health, expanding natural areas, connecting protected areas and designing spaces for coexistence. Because of their large scale, these measures deliver important co-benefits, such as livelihood options, carbon sequestration, reduction of land degradation and even local employment, which will become more prominent in the long term.

Holistic conservation:
Conservation plans that address the needs of both biodiversity and local communities are more effective in defusing human-wildlife conflicts. Based on coexistence rather than isolation, integrating traditional farming into protected natural areas (e.g. in buffer and transition zones) can make elephant habitat larger and safer from confrontation with humans while also meeting villagers' needs and managing land sustainably.

Natural barriers:
Using natural elements, such as beehive fences and deterring crops (e.g. onion, garlic, chilies, lemongrass) for elephants, can avoid human-wildlife confrontation. It also supports and diversifies livelihoods, as well as improving food security. For this solution to succeed, environmental education of farmers, technical assistance and transparent compensation schemes are key.

Wandering elephants:



Impacts
- Livelihood loss
- Infrastructure damage

Drivers
- Atmospheric warning
- Urbanization
- Drought

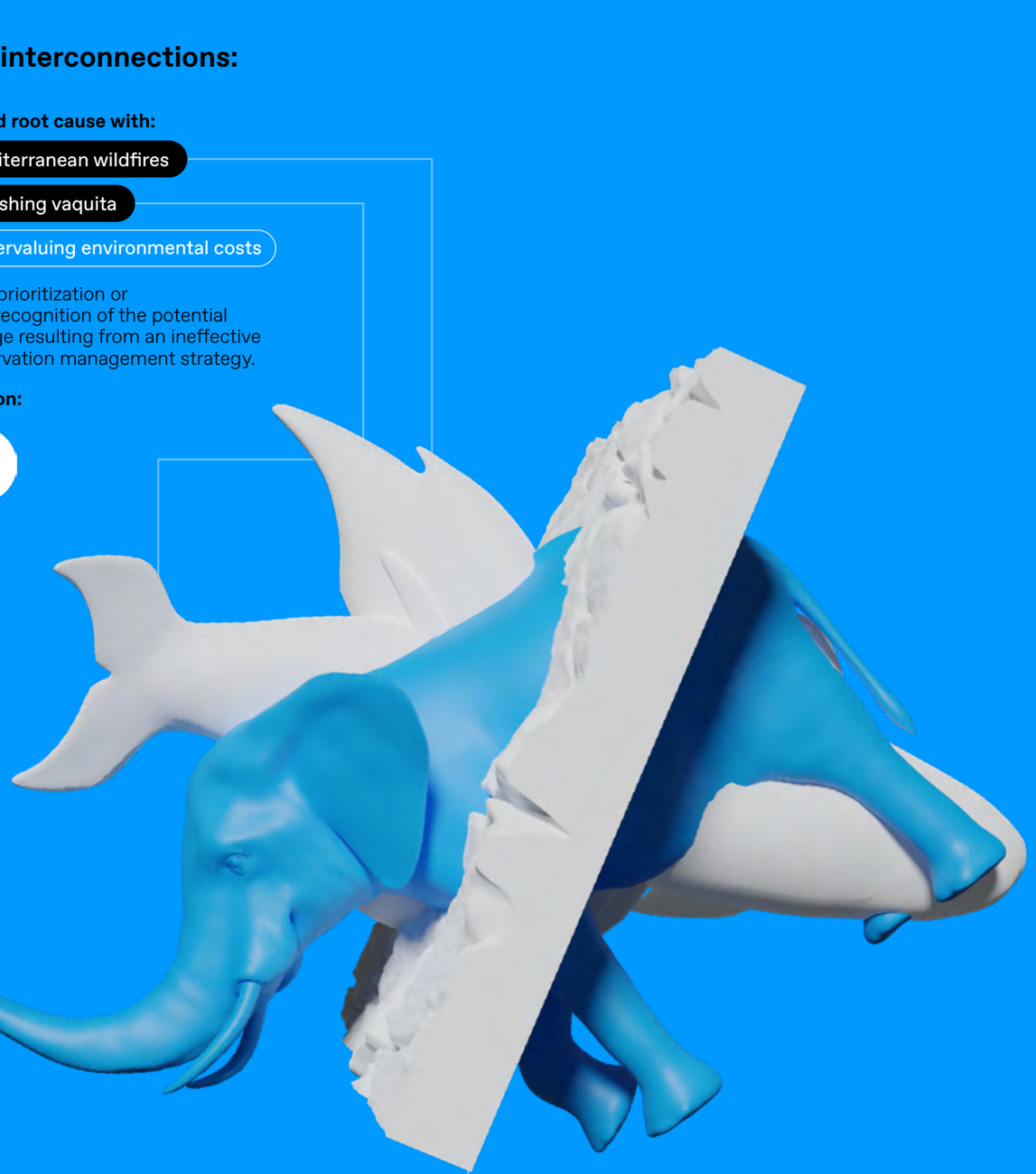
Root causes
- Human-induced greenhouse gas emissions
- Undervaluing environmental costs
- Global demand pressures
- Inequality of development and livelihood opportunities

Key interconnections:

Shared root cause with:
- Mediterranean wildfires
- Vanishing vaquita
- Undervaluing environmental costs

Underprioritization or underrecognition of the potential damage resulting from an ineffective conservation management strategy.

Solution:

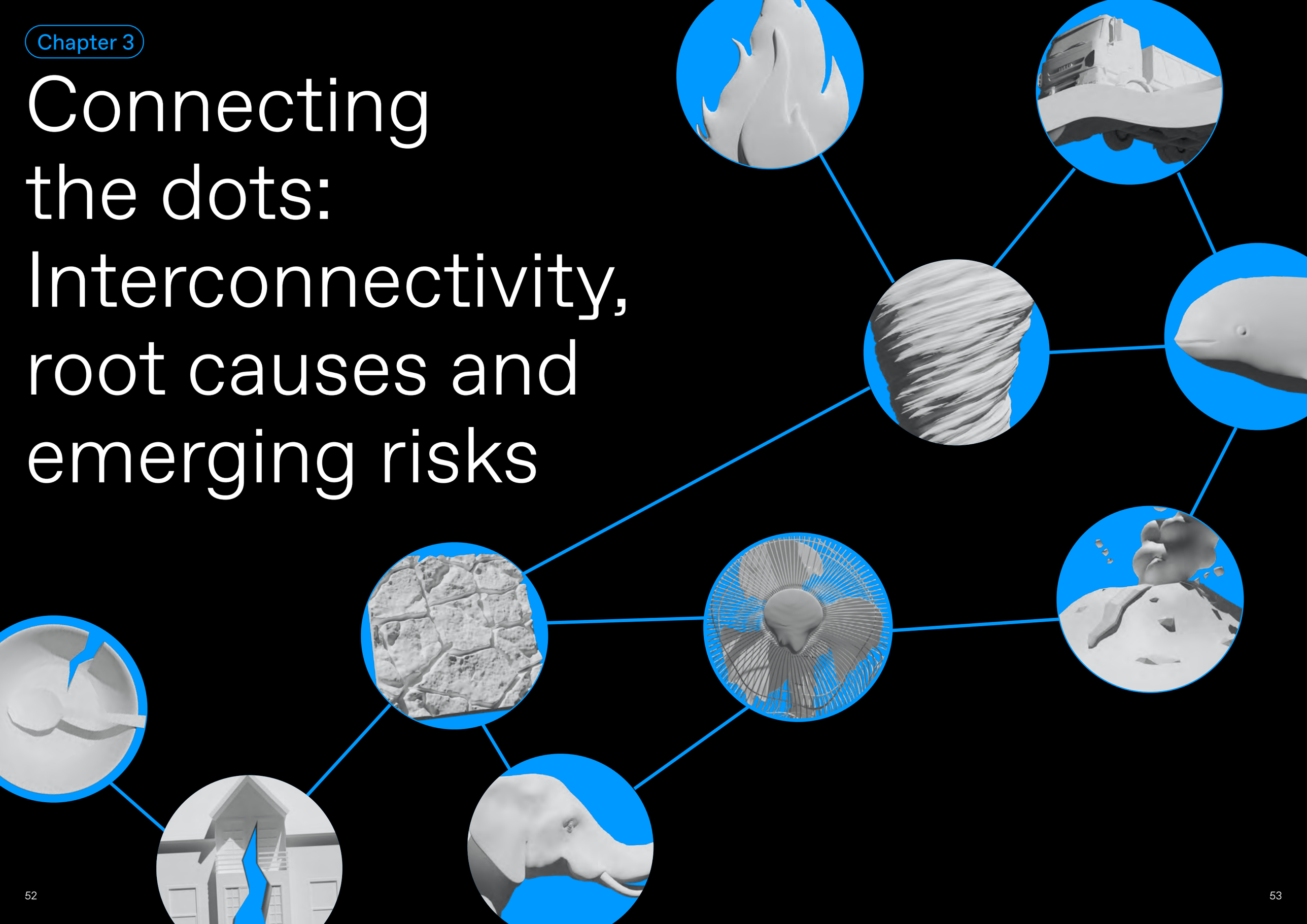


Shared root cause with:
- Mediterranean wildfires
- Taiwan drought
- Human-induced greenhouse gas emissions

Anthropogenic warming exacerbates existing climatic patterns, such as La Niña, worsening the effects of drought.

Chapter 3

Connecting the dots: Interconnectivity, root causes and emerging risks



Section 3.1 Interconnectivity

The 10 disasters investigated in this report directly result from the choices and priorities of our social, economic and cultural systems that interact with environmental or physical systems. Our risk is a function of the intensity of the hazard, either natural (e.g. storms or earthquakes) or anthropogenic (e.g. building collapse or chemical spill), combined with our exposure (the state of people and places being in harm's way) and vulnerability (the predisposition to be adversely affected) to the hazard. We must understand the nature of these systems and identify how they interact with hazards, exposure and vulnerability to produce risk to people and places.

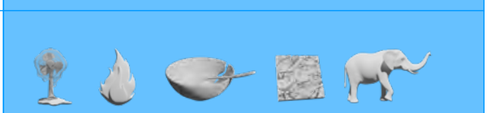
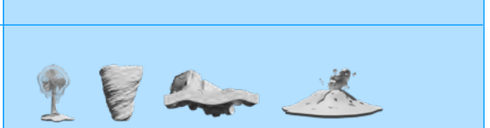
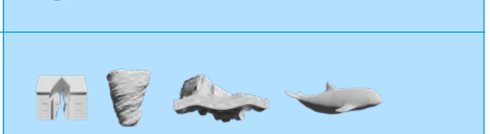
Interconnectivity of the 10 different cases from 2021/2022 were investigated at five different levels. We analysed the underlying factors for each case, first looking at the deeper **root causes** and then the more direct **drivers** of disaster. Next, we briefly looked at how one disaster can **influence** another, either where one disaster directly contributes to the hazard of another or where one disaster increases the exposure or vulnerability of people or places. Additionally, we listed similar **impacts** shared among different disasters and assessed where they overlap to create future risks. Lastly, we looked at **solutions** that could help address some of the root causes, drivers and impacts of each event and looked for similarities and themes that emerged across solutions.

Section 3.1.1 Root causes and drivers

We may be familiar with the impacts and aftermath of the disaster, as these are commonly presented in the media coverage of the event, but this is only the tip of the iceberg. To understand the underlying conditions that created the disasters in the first place, we have to look below the surface at the societal processes and behaviours that create risk.

The proximal causes of disasters reveal trends and patterns in their drivers – the more immediate factors that cause disasters to develop, such as deforestation or urbanization. Some events had very similar drivers (see **table 1**), illustrating how specific drivers can manifest different outcomes based on different contexts. For example, deforestation contributed to the devastating landslides during the Haiti Earthquake, the formation of sandstorms in southern Madagascar and the sedimentation of water reservoirs in Taiwan. If we dive deeper, we can see the drivers are formed by the root causes of various systems and structures, such as our economic or political systems (see **table 2**). Deforestation as a driver can be traced back to the tendency to pursue economic interests without further regard for environmental externalities, a root cause we call Undervaluing environmental costs.

These shared root causes illustrate how seemingly disconnected events link back to the same sources but reveal themselves differently. The root cause of Global demand pressures created increased flood risk in **Lagos** from the excavation of sand for construction and contributed to a decline in the **vaquita** porpoise population from collateral damage due to demand for the totoaba fish. Just as in the first edition of the IDR report, Insufficient risk governance, Undervaluing environmental costs, and Human-induced greenhouse gas emissions were among the top root causes. Though we chose 10 completely different events for each edition, Human-induced greenhouse gas emissions was again found in 7 out of 10 disasters, indicating that climate change is an ever-present cause of disasters that must be addressed immediately to reduce their incidence and impacts. A selection of these root causes and drivers are explained further in **Chapter 3.2**.

Table 1	Shared drivers 2021/2022	Shared cases
(7/10)	**Atmospheric warming** (Greenhouse gases trapping sunlight and warming the atmosphere)	
(5/10)	**Vulnerable infrastructure** (Infrastructure susceptible to extreme events, e.g. transport, communications of housing)	
(5/10)	**Drought** (Prolonged shortage of water supply)	
(4/10)	**Deforestation** (Intentional mass removal of trees)	
(4/10)	**Insufficient early warning system** (An absent or poorly communicated warning of a hazard's impending arrival)	
(4/10)	**Lack of regulations/enforcement** (Absence or ineffective enforcement of regulations connected to other risk drivers)	
(4/10)	**Urbanization** (Landscape change via increasing growth and expansion of cities and neighbourhoods)	
(3/10)	**Organized crime** (Planned and controlled criminal activities that perpetuate a hazard or vulnerability)	

Importantly, each disaster is caused by a combination of different root causes that overlap at a specific point in time and space. For example, the **wandering elephants'** migration occurred as a result of the convergence of Human-induced greenhouse gas emissions, Undervaluing environmental costs, Global demand pressures and Inequality of development and livelihood opportunities. In this case, habitat degradation and fragmentation from increasing encroachment of rubber plantations, driven by demand for natural rubber from global industries, created an inequality of opportunities in different areas in terms of habitat quality for the elephants. As their local habitats became increasingly degraded, a drought (influenced by climate change) was likely all the push they needed to seek opportunities for their basic needs elsewhere, much like people in many parts of the world. **Figure 1** shows which root causes overlap in which case, and more information on how these root causes manifested in each case can be found in their respective **technical reports**.

Though disasters may seem like they are isolated and distinct events that disrupt our societal systems, in fact, they are products of those systems and have shown themselves as a symbol of a systemic issue. That is to say, disasters are not a flaw in the system, but rather a product of the system (Oliver-Smith and others, 2016). These underlying processes all tie back to a collective mindset and moral framework that underpins a system of maximization, the belief in economic growth at all costs with little consideration for the impacts left in its wake. Addressing these root causes of disasters requires commitment and dedication to a sociocultural transformation in order to reframe our morals to better see and account for the whole system of life and work to make this system better for the whole rather than the few (United Nations Office for Disaster Risk Reduction (UNDRR), 2022).

Root causes

Figure 1: Root cause

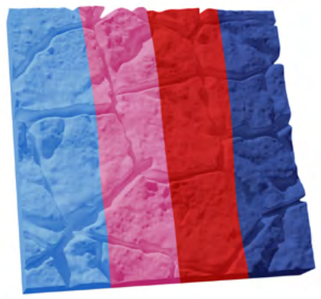
Madagascar food insecurity

Tonga volcano eruption

British Columbia heatwave

Wandering elephants

Taiwan drought



Mediterranean wildfires

Vanishing vaquita

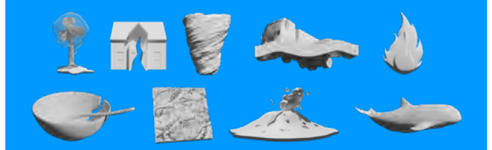
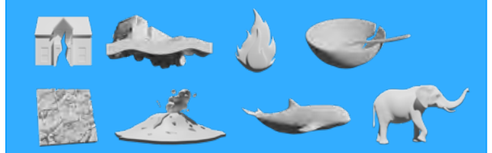
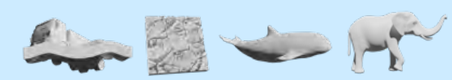
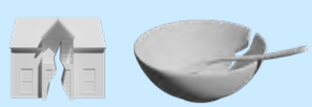
Haiti earthquake

Hurricane Ida

Lagos floods

Key:

- Human-induced greenhouse gas emissions
- Insufficient risk governance
- Legacy of colonialism
- Undervaluing environmental costs
- Global demand pressures
- Inequality of development and livelihood opportunities

Table 2	Shared root causes 2021/2022	Shared cases
(9/10)	**Insufficient risk governance** (A lack of perception, awareness or preparation in governance relating to risk management and response)	
(8/10)	**Undervaluing environmental costs** (Pursuit of economic or developmental interests with a lack of consideration for impacts on the environment)	
(8/10)	**Inequality of development and livelihood opportunities** (Unequal distribution of economic opportunities and limited livelihood options)	
(7/10)	**Human-induced greenhouse gas emissions** (Gases released into the atmosphere by human activities contribute to increasing global warming and climate change)	
(4/10)	**Global demand pressures** (Pressure related to increasing consumptive demands for goods, such as food, energy and industrial materials)	
(2/10)	**Legacy of colonialism** (The continued effects of exploitation by a foreign power)	

Section 3.1.2 Direct and indirect influence

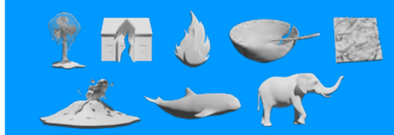
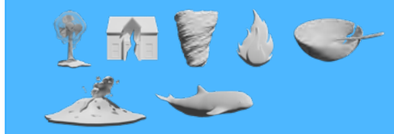
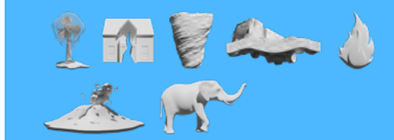
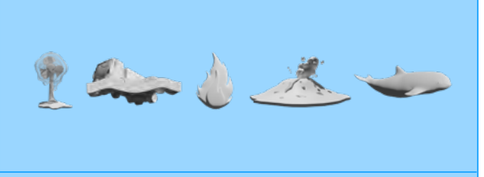
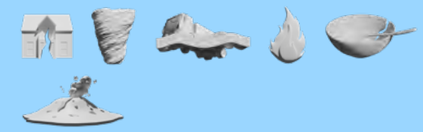
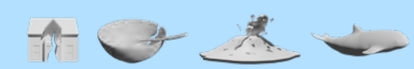
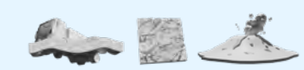
Some disasters from 2021/2022 also influenced or exacerbated conditions for distant disasters. For example, the eruption of the Hunga Tonga-Hunga Ha'apai volcano in the south Pacific nation of **Tonga** created tsunami waves that travelled across the ocean to the coast of South America, with major impacts in Peru. There, the tsunami waves caused two people to drown and likely influenced a massive oil spill of around 6,000 barrels, affecting 18,000 m2 of Peru's coastline (Taj, 2022; Mejia, 2022). The oil company Repsol said the tsunami waves damaged a system of underwater pipes and hoses that oil tanker ships used to pump crude oil into a nearby refinery (Taj, 2022). In **British Columbia**, the heatwave in June 2021 combined with dry conditions to spark several wildfires. As these fires destroyed vegetation and scorched the ground, susceptibility to landslides and floods increased as damaged roots could not stabilize the soil. The charred ground became impermeable and unable to soak up rainwater. When a rainstorm dropped around 250 mm of rain in 48 hours over central British Columbia, the effects were devastating. Highways and bridges washed away, landslides buried cars and damaged rail lines, oil pipelines ceased operations for fear of a spill, the port of Vancouver closed with no way to transport goods and over 12,000 people were displaced from their homes (Austen, 2021; Thompson, 2021).

Indirectly, the ongoing COVID-19 pandemic continued to influence the response and resilience of people in many of our case studies. Incomes and livelihoods were affected by the decrease in tourism around the globe, but notably harshly in southern Madagascar, the Mediterranean and Tonga (Faliarivola and others, 2022; Caglayan and Erkoyun, 2021; Möller and others, 2022). Travel restrictions limited food aid delivery in **southern Madagascar**, which, combined with the health impacts of the viral infection, exacerbated the effects of malnutrition (Faliarivola and others, 2022; United Nations International Children's Emergency Fund (UNICEF) and World Food Programme (WFP), 2021). During the **British Columbia heatwave**, residents were uncomfortable going to cooling stations for fear of contracting the virus (LaFortune and others, 2021). In **Haiti**, the earthquake diverted medical supplies and staff to emergency response and put a halt to vaccination campaigns. Destroyed homes pushed people into temporary shelters with poor physical distancing conditions and disrupted water infrastructure, making handwashing nearly impossible (Bagaipo and Janoch, 2021). Pandemic-prompted budget cuts in New York City took away funding to legalize and implement safety upgrades for many illegitimate basement apartments that flooded during **Hurricane Ida** (Abraham, 2021). After having been nearly COVID-19-free for the entirety of the pandemic, **Tonga** has now started facing the first outbreaks of the virus. Along with recovering from the impacts of the volcano eruption and tsunami, Tonga has implemented serious lockdown restrictions, which have hindered both recovery operations and the stability of the economy for the island state (International Federation of Red Cross and Red Crescent Societies (IFRC), 2022; Lourens, 2022).

> "The internal machinery of life, the chemistry of the parts, is something beautiful. And it turns out that all life is interconnected with all other life."
>
> - Richard P. Feynman

Section 3.1.3 Impacts

The disasters we highlighted in 2021/2022 are also interconnected through their effects on people and the environment, both in the immediate aftermath of the disaster and their cascading effects. For example, the **Southern Madagascar food insecurity** not only had direct health impacts, such as hunger and malnutrition, but also cascading effects of livelihood loss, where people were unable to work because of their hunger. This year, we identified eight categories of impacts shared across the 10 events (see **table 3**). It is important to remember these impacts and attempt to remediate them and the root causes that brought them about. They can create conditions of further vulnerability or exposure to a hazard and could become building blocks of a disaster in the future.

Table 3	Shared impacts 2021/2022	Shared cases
(8/10)	**Livelihood loss**	
(7/10)	**Loss of life**	
(7/10)	**Infrastructure damage**	
(5/10)	**Ecosystem damage and biodiversity loss**	
(5/10)	**Health impacts**	
(5/10)	**Migration/displacement**	
(4/10)	**Food insecurity**	
(3/10)	**Water insecurity**	

Section 3.1.4 Solutions

As we have seen in the above sections, the disasters from 2021/2022 were all interconnected through their root causes, drivers and impacts. Interconnected disasters require interconnected solutions, meaning that interventions must be able to address the multifaceted and complex nature of the problem. Firstly, nothing exists in a vacuum; to prevent a solution from becoming a disaster, there must be recognition that a solution can also have cascading effects. These may be positive effects at the same place or cascading benefits to other places and times that should be encouraged or negative effects (trade-offs) that should be managed. The potential for a solution to provide co-benefits uses interconnectivity to our advantage to address multiple problems at once. For example, using concrete alternatives such as sustainably-sourced wood can help reduce the pressure of sand mining in places like **Lagos** and can make a building more earthquake-resilient in places like **Haiti**. Additionally, using one methodology or framework for a solution can inform how other solutions can be applied in different contexts. For example, the concept of Let nature work can apply both to fires (prescribed burning) and floods (restoring natural waterways), whereby letting them occur in a controlled way can actually reduce the incidence of either getting out of control at some point in the future.

In comparing these categories of collected solutions across each of the 10 case studies, several interconnected themes emerged (see **table 4**). The most common solution themes shared across the 10 cases were Let nature work (7/10), Innovate (7/10) and Work together (6/10). These solutions are further expanded on and explained, along with an overview of the other solution categories we identified, in **Chapter 4.2**. The solutions identified for each disaster specifically target the identified root causes, drivers or impacts. For example, though using and improving early warning systems are essential during disasters such as wildfires and hurricanes, this was not identified as a particular point of concern during the **Mediterranean wildfires** or **Hurricane Ida**.

However, improving early warning systems was identified as a key priority to reduce impacts in cases like the **Tonga volcano eruption**. Notably, the solutions presented in this report are not intended to be an exhaustive summary, but rather a snapshot highlighting some of the work being developed in different fields that can reduce our risk across various disaster types. Expanded solution tables can be found in the **technical reports**, with additional solutions that did not find a place in this main report for each case.

Table 4	Primary solutions 2021/2022	Shared events
(8/10)	**Let nature work** (Coexisting with natural processes for our overall benefit)	
(7/10)	**Innovate** (Using new ideas and challenging established norms to adapt to or mitigate risk)	
(6/10)	**Work together** (Enhancing collaboration across disciplines/stakeholders to view a more holistic picture)	
(4/10)	**Secure livelihoods** (Having established safety nets to protect people from adverse impacts)	
(4/10)	**Consume sustainably** (Modifying our consumption patterns to reflect more sustainable choices)	
(4/10)	**Strengthen governance** (Increasing capacity of institutions to create and enforce risk-reducing initiatives)	
(4/10)	**Plan for risks** (Developing risk-aware infrastructure and land-use planning)	
(3/10)	**Boost early warning** (Enhancing our capacity to predict and communicate risks)	

Section 3.2 Root causes and drivers

Two of the three most common root causes in the 2021/2022 IDR report are common to last year's report, namely Insufficient risk governance (formerly "Insufficient disaster risk management") and Human-induced greenhouse gas emissions. This edition returns to Insufficient risk governance as the most common root cause and focuses on two causes not yet featured in this series: Global demand pressures and Inequality of development and livelihood opportunities. For more on the Human-induced greenhouse gas emissions root cause, see the **2020/2021 IDR Report**.

"True compassion is more than flinging a coin to a beggar. It comes to see that an edifice which produces beggars needs restructuring."

– Dr. Martin Luther King Jr

Section 3.2.1 Root cause 1

Insufficient risk governance

The root cause of Insufficient risk governance was by far the most commonly shared, reflecting the issues of governance which were related to vulnerability and exposure in 9 out of 10 of the cases this year. Stemming from insufficient political will, or a lack of capacity or effective cooperation among institutions, the influence of insufficient risk governance gave rise to drivers such as a lack of regulation or enforcement and unsustainable land-use planning.

Lack of regulation and enforcement is a major barrier to more effective risk reduction, undermining the effectiveness of laws and policies implemented to protect people and ecosystems and reduce their vulnerability to extreme events. This is at least part of the answer to the puzzle of why, despite increasing activity across all levels of government in implementing sustainable policies, progress towards climate change and biodiversity conservation goals are falling short of their targets (United Nations Environment Programme (UNEP), 2021; Stokstad, 2020). Weak enforcement was a worldwide trend identified in a recent global assessment as a critical issue restraining the effectiveness of environmental laws, thereby identifying political will as one of the major factors impacting more effective management of risks (UNEP, 2019). A lack of clear standards and necessary mandates, along with not being tailored to the local context, was also listed as contributing factors to poor implementation. Moreover, environmental ministries' relative underfunding and political weakness compared to those responsible for economic or resource development was also common.

This trend is reflected in the progress made towards the United Nations Sustainable Development Goals (SDGs), whereby targets related to economy and industry show more progress globally, whereas environmental targets are less prioritized and lag behind (Xu and others, 2020; Halkos and Gkampoura, 2021). In the case of the **vanishing vaquita**, despite decades of research alerting

the Mexican government of the imminent extinction risk, the causes and the courses of action to take, as well as conservation measures being periodically announced, effective enforcement is still lacking as illegal fishing continues to thrive in designated sanctuary zones (Bernd and others, 2021). Meanwhile, in **Lagos**, unregulated sand mining remains a problem, eroding coastal ecosystems and the natural coastal protection line against coastal hazards even as the sinking city increasingly floods. Additionally, the drought in **Taiwan** showed how poorly designed water policies can lead to major issues when the rain stops coming, particularly in terms of outdated water infrastructure and strategies to deal with water shortages (Aviso and others, 2021).

The lack of government oversight in cases like these, when there are profits to be gained by exploiting weak enforcement of regulations around resource extraction, gives rise to the involvement of organized crime and corruption which erodes environmental and social balances and strengthens resistance to effective governance, in some cases embedding into government itself (Aguirre-Ochoa and Gómez, 2021). We need to better engage with politicians to dispel the disconnected, even adversarial, perception of economic and environmental policies. While the visible short-term gains of economic development are popular with governments, people are becoming increasingly aware that they are not in our long-term best interests. In reality, the economy and the environment are inextricably linked. Climate change is an illustrative example; this human-induced global environmental change contributed to 7 of the 10 disasters in this report and could wipe out up to 18 per cent of the global GDP by 2050 if our activities allow temperature to rise by 3.2°C (Guo and others, 2021).

Insufficient risk governance in land-use planning, in particular in terms of adaptation to increasing risks stemming from climate change, has resulted in a deadly combination of urbanization in hazard-prone areas and ageing infrastructure that is ill-equipped for increasingly intense and unpredictable extreme weather events. City and national governments around the world are struggling to manage the global megatrend of urbanization that will see around 70 per cent of people living in cities by 2050, and the expansion of urban sprawl has historically neglected the impacts of this land-use change on the surrounding environment (Ritchie and Roser, 2018). Land-use planning that does not account for the benefits and risks associated with local topography and ecosystems not only exposes people to increased risk from known hazards, but also generates new risks, such as landslides and increased flooding. Building in floodplains is an example of narrow-minded land-use planning that can lead to disaster as it not only increases exposure but also destroys an ecosystem's natural buffer capacity for water retention. The effects of increasing human population and rising inequality on housing pressure often drives the need for cheaper housing options. Urban areas in cheaper neighbourhoods are also likely to have less access to critical green and grey infrastructure that can buffer the impacts of extreme weather events like heatwaves (Pallathadka and others, 2022). It is no wonder then that minority groups and lower socioeconomic groups are often disproportionately impacted by disasters, as occurred when the remnants of **Hurricane Ida** hit New York City with historic flash flooding. Going hand-in-hand with weak governance, allowing building in these areas – especially of houses that are vulnerable or without safe escape routes – is tantamount to putting people in harm's way.

> "Political will is now critical to making sure our laws work for the planet."
>
> – United Nations Environment Programme 2019

Section 3.2.2 Root cause 2

Global demand pressures

In 4 out of 10 events, Global demand pressures contributed to the disaster, where the value put on materials Increases pressure on their production or acquisition and overshadows the potential cost of external impacts. For example, the swim bladders of the Mexican totoaba fish (*Totoaba macdonaldi*) are considered a delicacy in China and treasured for their perceived medicinal properties. The swim bladders fetch incredibly high prices on the black market and are often referred to as the "cocaine of the sea" (Pressly, 2021). The profits generated by demand in China support organized international criminal networks operating in Mexico, making it harder to manage illegal fishing in areas of the Gulf of California that have already struggled for decades with effective fisheries governance. Besides this demand making totoaba vulnerable to extinction, the gillnets used to catch them also entangle and kill the **vaquita** porpoise. Between 2011 and 2019, the vaquita population declined by over 98 per cent, with likely only 10 individuals left (Cardoso and others, 2021). This story is illustrative of a global problem where "illegal, unregulated and unreported (IUU) fishing" is estimated to account for up to 26 million tons of fish caught each year (Agnew and others, 2009). As with other forms of organized crime, the lack of oversight that comes along with IUU fishing allows for destructive, indiscriminate techniques and the involvement of other crimes, such as forced labour, giving the potential for wide-ranging impacts on environmental and social justice (Selig and others, 2022). Coastal rural populations in vulnerable areas are particularly vulnerable to IUU fishing, where foreign vessels outcompete and deplete local resources that communities depend on, drawing a link between the fish on your plate and the level of devastation from an extreme event on the other side of the world (Glaser and others, 2019).

In the case of the **wandering elephants** in China, one of the main habitat pressures they face is from the increasing encroachment of rubber plantations. The pace of expansion in the elephant's region of Xishuangbanna has increased rapidly, from 87,000 ha in 1992 to 424,000 in 2010, more than quadrupling in size (Xu and others, 2014). This expansion was largely driven by demand for natural rubber tires; rising as the global demand for cars and other motor vehicles increases. Around 20 million tons of rubber are produced each year in fragmented smallholder plantations all across Thailand, Indonesia, China and West Africa (Swain, 2021). Global demand pressures can also cause more subtle effects that influence decision-making processes. For example, in the case of the **Taiwan drought**, during 2020, the Taiwan Semiconductor Manufacturing Company (TMSC) alone produced around 24 per cent of the world's semiconductors (or "chips") and 92 per cent of the most advanced chips used in electronics like smartphones, TVs and cars (Schoolov, 2021). The value chain of chips has been disrupted by skyrocketing demand during the pandemic combined with external shocks, such as disasters, operational error and COVID-related lockdowns (Kleinhans and Hess, 2021). As Taiwan faced its worst drought in 56 years, the pressure was on to keep the semiconductor industry afloat, especially difficult when production in one science park can use more than 60,000 tons of water per day (Zhong and Chang, 2021). To ensure adequate water supplies, irrigation was stopped for 74,000 ha of 2021 first rice crop, which represent around 25 per cent of the total planted area (Reidy, 2021), cutting off taps twice a week for three months for citizens of central Taiwan while also ordering a 17 per cent reduction in water consumption for the two industrial parks where TMSC has factories (Berry, 2021).

Progress in economic development is driving a global trend of urbanization booms that will see urban land cover triple by the year 2030 compared to 2000 (Seto and others, 2012). This drastic expansion of cities not only results in considerable loss of habitats and biodiversity as they are transformed into urban landscapes but also leads to a surge in demand and subsequent extraction of resources required to facilitate urban construction which will take its own hidden toll that could be exponentially worse. A prime example of this that is still flying under the radar is sand. Used in everything from buildings and roads to toothpaste and phones, approximately 40 billion tons of sand and gravel are mined annually, mostly for construction, making it second only to water as the most consumed natural resource in the world (UNEP, 2022). The involvement of sand mining in disaster risk is complex and connects disasters like the **Lagos floods**, where mining is eroding coastal protection, to the **Taiwan drought**, where the water-intensive semiconductor industry was a central factor in the water management crisis. Sand is the primary ingredient in these computer chips, essential components of our phones and cars, connecting every one of us to the global impacts of sand mining. The mining of sand is largely unregulated in many parts of the world, and as with the **vanishing vaquita** and the issue of illegal fishing, this has led to environmental and social consequences, and opening the door for organized crime to profit (Peduzzi, 2014). Sand mining, often focused where the most sought-after sand is found (i.e. rivers, coasts and the seafloor), destroys ecosystems and pollutes water, affecting biodiversity and livelihoods that depend on it. It also drives erosion, which diminishes the ability of coasts and riverbanks to buffer flood risks. This is particularly critical in a city with high flood risk, such as **Lagos**, yet the coast is continually mined to feed urban development. In fact, sand is mined from various sites in Nigeria, meaning the impacts of the urbanization boom in this city are spread throughout the country, however much of the money to fund it is coming from overseas (United Nations Human Settlements Programme (UN-Habitat), 2018). In 2021, Lagos received the vast majority (87 per cent, or $5.8 billion) of total foreign direct investment (FDI) into Nigeria. Top foreign investors included the United Kingdom, the United States of America, Mauritius and South Africa (National Bureau of Statistics (NBS), 2021). This demand for sand and urban development funded by overseas money is resulting in policies that work against the urban poor, pushing vulnerable people into areas with increasing flood risk (Olajide and others, 2018).

> "The future of globalism looks pretty sure and well laid out ... The main difficult question is the future of the people."
>
> – Göran Therborn, Cities of Power

Section 3.2.3 Root cause 3

Inequality of development and livelihood opportunities

Systemic inequality resulting in drastic contrasts between areas with many opportunities for profitable, diverse livelihoods and those without was one of the most common root causes in this report, playing a role in 8 out of 10 disasters, from **Hurricane Ida** to the case of the **Wandering elephants**. Inequality of opportunity drives vulnerability to hazards by leaving certain groups with fewer options to manage their risk before a disaster strikes or buffer the impacts in the aftermath. For example, farmers in **southern Madagascar** are highly dependent on agriculture and have few options for alternative livelihoods to provide other income when extreme weather wipes out crops, and many are unable to afford or access some types of insurance that could recover losses incurred. In areas with limited livelihood opportunities, groups marginalized by systemic exclusion understandably continue to prioritize meeting their basic needs rather than efforts towards risk reduction, particularly if the impacts of these actions seem distant in space and time. For example, the immediate benefits of mining sand or maximizing fishing profits for poor or marginalized communities outweigh the increased risk of flood impacts due to coastal erosion, as in the **Lagos floods**, or decline of ecosystem services due to disappearing species, as with the **vanishing vaquita**.

The inequality of development and economic opportunities is particularly pronounced in rural areas compared to cities and, combined with greater vulnerability of rural livelihoods to the impacts of climate change, is driving a global trend of rural-urban migration. As people immigrate to cities often with little in the way of money, required skills for city jobs, social networks or housing options, they arrive in a way that entails heightened vulnerability to shocks and extreme events. Many lack official documentation to access public services or the housing market, and so gravitate to cheaper, unregulated housing where communities sharing similar backgrounds reside and give support. In cities around the world, unregulated housing is proliferating to accommodate the population growth, often in areas that are more exposed to the risk of hazards like flooding (**Hurricane Ida**, the **Lagos floods**), fires (**Mediterranean wildfires**) and landslides (**Haiti earthquake**), leaving people in harm's way when hazards hit. The movement of people due the inequality of economic opportunities between where they live and in the world was also a factor in the **Tonga volcano eruption**, as a whopping 40 per cent of Tonga's GDP relies on remittances from overseas workers who had migrated in search of other livelihood options, creating an economic risk that was exposed when the country's Internet connection was knocked out by a volcanic eruption. The places left behind when inequality of opportunity influences the movement of people can also drive risk, as seen in the **Mediterranean wildfires**, where the abandoned farmlands left in the wake of increasing immigration of farmers to cities became overgrown, increasing the wildland-urban interface and bringing fire to the doorstep of many European cities.

The concept of inequality of development and livelihood opportunities is very closely linked to another one of our root causes, the Legacy of colonialism. Colonial exploitation began centuries ago in some places, such as Madagascar and Haiti, but its effects are still seen and perpetuated today. Since colonial times, the historical opposition of the communities in **southern Madagascar** to be conquered seems to have influenced how they are seen by the rest of the country. For example, during the French occupation, they were described as being "uncivilized" or untrustworthy by the colonists, which is believed by some experts to still play a role in the current marginalization of this part of the country (Healy, 2018). The French colonial government also gave plots of land to settlers who deforested the land to extract precious timber and implement cash crop plantations of vanilla, coffee and sugar. This process of deforestation eroded food security, degraded the environment and siphoned the wealth from the island to Europe (Randrup, 2010). A similar process also occurred in **Haiti**, where France primarily treated Haiti as an extractive colony, different to the neighbouring Spanish-colonized Dominican Republic, which was primarily used as a trading hub (Caplan, 2021). After securing their independence in 1804, the French imposed a reparations debt of 150 million francs on Haiti for their "lost property" of slaves and land. To satisfy these debt obligations, the Haitian government and elites sustained the system of peasant labour and extractive industries. Additionally, during the United States' occupation of Haiti from 1915 to 1934, Port-au-Prince received much of the infrastructural improvements while the rural peasantry gained nearly nothing, exacerbating poverty and income inequality (Charles, 2021). The United States Agency for International Development (USAID) also ordered the slaughter of all of Haiti's pigs in response to a swine flu outbreak, which was a source of emergency capital and sustenance for rural populations, and the International Monetary Fund (IMF) facilitated flooding Haitian markets with rice surpluses from the U.S., further undermining local producers (Oliver-Smith and others, 2016). Colonialism has driven this inequality of opportunities between people and places in Madagascar, Haiti and many other former (and current) colonies. These topics are not easy to talk about, but learning about and acknowledging the impacts of colonialism and neocolonial power structures is the first step to dismantle these systems that reinforce and perpetuate systemic inequalities across the globe.

Section 3.3.1 Health impacts

Health is one of the main areas in which disasters have distinct impacts. In some cases, disasters directly impact physical well-being, such as in the case of **Haiti**, where more than 12,000 people were injured during the earthquake (Boiselet, 2021). Additionally, the heatwave increased anxiety, specifically climate anxiety, among the population of **British Columbia** (Bratu and others, 2022). Other times, the disaster posed a health risk to those with existing health conditions, such as during the **Mediterranean wildfires** and the **Tonga volcano eruption**, where gases and particulate matter were emitted that can aggravate cardiovascular or respiratory illnesses (Abnett, 2021; Roberts, 2022). Still further, one health impact can create more health impacts. For example, in **southern Madagascar**, children were particularly susceptible to malnutrition and vitamin deficiencies, which increase the risk of stunted growth, anaemia and diseases such as the measles (Desrosiers, 2019). Even disasters that didn't create immediate health impacts can produce risks to health in the future. The floods in **Lagos** primarily caused infrastructure damage, but flood waters can also carry sewage and garbage that can lead to disease outbreaks, such as cholera, diarrhoea and typhoid, as well as creating favourable breeding grounds for disease vectors like mosquitoes (Olanrewaju and others, 2019).

These health impacts can lead to continued and chronic health problems that last long after the immediate danger has passed, either by making existing health conditions worse over time or people more susceptible to other health impacts in the future. Damage done to critical infrastructure such as health facilities or water supply and sewage systems can disrupt access to medical care or interrupt the control of communicable diseases (Disease Control Priorities Project, 2007). In **Haiti**, for example, the earthquake disrupted the COVID-19 vaccination campaign (Bagaipo and Janoch, 2021). As such, disasters increase health burdens for people, especially in the realm of mental health. In addition to directly harming people and the environment, a disaster poses a threat of harm, losses or death on whole populations. This threat of danger, combined with a sense of grief, and the disruption of social support networks and services, can leave lasting psychological impairment or mental disorders, such as post-traumatic stress disorder or depression (Goldmann and Galea, 2014). Mental health has a significant bearing on resilience to disasters, as trauma from one disaster can negatively impact a person's ability to cope with the next. As many people in **Tonga** consider relocating in the aftermath of the volcano eruption, they have to weigh the options of rebuilding in a vulnerable place or relocating to a new place and leaving behind all the memories and attachment to their original home (Vaswani, 2022). Losing one's sense of place and social networks after relocating may cause further trauma on top of the effects of the disaster itself (Binder and others, 2019).

Section 3.3.2 Ecosystem tipping points

Many of the disasters in 2021/2022 had impacts on biodiversity and ecosystem integrity. These effects are devastating in and of themselves, such as the loss of over 1 billion intertidal animals, such as mussels, clams and snails, during the heatwave in **British Columbia**; but equally as alarming is the future consequences such an impact could bring (Westfall and Coletta, 2021). These intertidal animals, for example, play an important role in the food chain and filter high volumes of water. Their deaths could affect the water quality in the area for a significant period of time (Migdal, 2021).

These deaths and disappearances of species signify a larger emerging risk of species extinctions and ecological tipping points. Human actions have already caused the extinction of at least 680 vertebrate species since the 1500s, and around 25 per cent of all known species are threatened, with around 1 million facing extinction within decades (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), 2019). The global rate of species extinctions is accelerating, particularly in the past 40 years, reaching rates hundreds of times higher than the past 10-million-year average (IPBES, 2019). This process, the sixth mass extinction of species, is the direct result of human actions. The process of extinction is gradual; it starts with declines in the geographic range of species and their abundance. As such, smaller populations become isolated from each other, decreasing genetic diversity in populations and increasing vulnerability. This is particularly true for the Asian elephant (Elephas maximus), as the species now occupies only 5 per cent of its historic range, becoming increasingly fragmented in small, isolated populations around South-East Asia (Chen and others, 2021). As seen in the case of the **wandering elephants** in southern China, competition with humans and their domesticated plants and animals for space and resources drives increasing conflict, often pushing species to endangerment or extinction. Other times, a species can be brought to the brink of extinction as a mere by-product of human extractive activities, such as the case of the **vaquita** porpoise in the Gulf of California. The issue of by-catch, whereby creatures are caught in nets intended for other target species and usually killed or discarded, is one of the major threats to marine biodiversity globally. Small cetaceans (marine mammals such as dolphins and porpoises) like the vaquita are one of the most vulnerable groups to gillnet by-catch, with the number of critically endangered species rising from 1 to 13 since the 1980s, with by-catch as the main threat (Brownell and others, 2019). The first species on that list, the Yangtze River dolphin, was declared extinct in 2007 – the first cetacean species to be driven to extinction by human activity, but perhaps not the last (Turvey and others, 2007).

The cascading consequences of the loss of a certain species can be catastrophic, not only due to it being intrinsically concerning but also in terms of the loss of genetic diversity, phenotypes, behaviours and interspecies relationships. Each species (and an individual within a species) is unique and fills a specific niche in an ecosystem; so every time a species disappears, it erodes the Earth's capacity to maintain ecosystem services that humans depend on, such as food provision, water purification, pollination and pest control, as well as our inspiration, learning and cultural identities (Ceballos and others, 2020; IPBES, 2019). There is significant risk especially when species are ecosystem engineers, or organisms such as sea grass, oysters, coral and salt marsh grasses that form habitats for other species as their loss can trigger the disappearance of many other resident species (Hoegh-Guldberg and Bruno, 2010). The loss of other "keystone" species, which have relatively low abundance but a disproportionately high influence on the ecosystems around them, can cause trophic cascades, whereby ecosystem functioning breaks down and loses species richness (Wright, 2022). This close interaction of species means that when one species disappears, many others are likely to follow. In fact, 84 per cent of species with less than 5,000 individuals were found in the same regions as species with less than 1,000 individuals, indicating regional biodiversity collapse in those areas (Ceballos and others, 2020). Even if we manage to pull the vaquita back from the brink of extinction, they may become what have been termed "ecological zombies," whereby tiny populations of animals returning from extinction may persist but no longer have a significant ecological function in their ecosystems (Janzen, 2001).

Section 3.3.3 Disaster feedback loops

Our analysis of the 10 disasters from 2021/2022 shows a pattern whereby the cascading impacts in each case lead back towards the same root causes and drivers behind their occurrence. For example, climate change is a driver connecting many extreme weather events, increasing their frequency and intensity beyond natural variability (Intergovernmental Panel on Climate Change (IPCC), 2022), as reflected in this report, where it contributed to 7 out of 10 cases. The heatwave in **British Columbia** was 150 times more likely due to climate change and about 2°C warmer, **Hurricane Ida** was able to retain intensity over land for an unusually long time due to the influence of climate change, and anthropogenic warming doubled the likelihood of drought occurring in the **wandering elephants'** habitat (Philip and others, 2021; Faranda and others, 2022; Ma and others, 2020). This has the potential to create a feedback of cause and effect, whereby disasters feed into cycles of vulnerability that accelerate risk of even worse impacts from similar events in the future. Disasters like the **Mediterranean wildfires** and the **British Columbia heatwave** damage forest ecosystems and release greenhouse gases while reducing the ability of these ecosystems to sequester carbon, a mechanism critical for the mitigation of climate change. In 2021, wildfires around the world caused an estimated 1.76 billion tons of carbon emissions, or 148 per cent more than total EU fossil fuel emissions in 2020, making such fires a significant driver of climate change (Copernicus, 2021). This reinforcing loop shows that measures to reduce disaster risk are a critical part of climate action and vice versa – without one, the other stands little chance of success.

Another impact of disasters that can amplify root causes is their effect on global supply chains and Global demand pressures. The COVID-19 pandemic and the resulting restrictions have wreaked havoc on global supply chains, leading to cascading economic impacts around the world and shifting global demand drastically in various sectors (United Nations University – Institute for Environment and Human Security (UNU-EHS) and UNDRR, 2022). Droughts and wildfires threaten critical resources, such as water, food and timber, creating pressure points in supply chains and driving hard decisions with trade-offs for different sectors as conflicts in demand arise, as seen in the **Taiwan drought**, where farmers, industries and city dwellers were engaged in a high-stakes balance of water resources. Cases like the **vanishing vaquita** and the **Lagos floods** illustrate that when illegal trade in black markets is connected to the drivers of environmental degradation and biodiversity loss, the profit from engaging in these activities rises as the natural resource declines due to scarcity, only accelerating the demand further (Challender and MacMillan, 2014). This feedback loop in the use of natural resources not only contributes to the biodiversity crisis but also increases vulnerability of the millions of people who depend at least in part on nature and natural resources for sustenance and livelihoods (TRAFFIC, 2008).

Disasters and their direct and indirect impacts act as magnifiers of Inequality of development and economic opportunity, particularly in vulnerable areas. For example, poor countries disproportionately suffer the impacts of climate change. Many regions experiencing poverty, governance challenges, historical and ongoing impacts of colonialism or violent conflict have a high vulnerability to climate hazards and costs associated with mitigating or coping with their effects. For example, between 2010 and 2020, mortality from floods, droughts and storms was 15 times higher in vulnerable regions than in regions with low vulnerability (IPCC, 2022). Though inequality between rich countries and poor countries is relevant, it is also important to note that within the same country, the same city or the same household, there are differences in vulnerability and exposure to climate hazards that disproportionately affect the most marginalized. For example, the environmental and social conditions during the lengthy drought in **southern Madagascar** led to a near-complete collapse of livelihoods, pushing the population further into poverty. Poverty reinforces hunger and malnutrition by increasing the risk of food insecurity, and malnutrition produces conditions of poverty by reducing the economic potential of the population – creating a cycle of poverty, hunger and malnutrition in a near-continuous loop (Ralaingita and others, 2022; Hänke, 2016; Siddiqui and others, 2020). This type of cycle can occur in many vulnerable populations, such as people who experienced poverty or homelessness during the **British Columbia heatwave** or poorer immigrant communities within New York City during the flash floods brought by **Hurricane Ida**. These geographically and socially disadvantaged people are often caught in a vicious cycle, where the initial inequality disproportionately causes them to suffer and, in turn, the impacts of disasters further exacerbate existing inequalities (Islam and Winkel, 2017). In this way, we see disasters reinforcing themselves every year, wreaking more and more damage while our vulnerability is on the rise. Finding ways to break this cycle and target the root causes and drivers of risk must be our world's top priority.

Chapter 4

Interconnected Solutions

Section 4.1 Introduction

As science is clear about the consequences if we continue business as usual and about the actions we must take to reduce the occurrence of future disasters and global turmoil, a question that may naturally come to our minds is: if we know what we need to do, why aren't we doing it? Seeing the news about these disasters may be disheartening, and it may feel like there is nothing being done to fix these problems, but there are three critical points to make here:

- *We are doing it.* While much more action is required to tackle climate change, biodiversity loss and the increasing risk of disasters, this should not obscure the fact that people worldwide are hard at work developing innovative ways to help address these problems, and progress is being made. Both research and media often focus disproportionately on the need to spread the message of how dire a situation humanity faces if these problems are not fixed, such that "good news stories" of work being done by people on solutions are underrepresented. This year, the Interconnected Disaster Risks report aims to **highlight the good news along with the bad**.

- *Knowing how to do it* is as important as knowing what to do when considering solutions to such complex, interconnected problems. Through the process of researching and collaborating with experts to develop this chapter, it is clear that any solution we currently have, or will have in the future, comes with its own set of trade-offs, barriers to implementation and enabling social, political and/or environmental conditions required to be effective (see below). **Solutions must be tailored to specific contexts by incorporating knowledge of these local conditions** and ensuring their development is a participatory process with local stakeholders, particularly those from the most vulnerable communities, who are often excluded from the decision-making process. In other words, to quote the recent Bali Agreement for Resilience from the 2022 Global Platform for Disaster Risk Reduction: "nothing about us without us."

- *Accounting for interconnectedness* in today's world is a more complex, but ultimately critical, part of approaching solutions to help address interconnected risks. Through a better understanding of systems' characteristics and societal actions and behaviours that connect the causes and impacts of different kinds of disasters, we can go beyond just preparation and response as we have traditionally done. Instead, we can develop interconnected solutions that lead up to long-term resilience to reduce vulnerability and exposure of people and ecosystems. In other words, in addition to preparation and response plans for an extreme weather event, we can target solutions towards why the event was so severe in the first place and why certain people may have been particularly vulnerable to its impacts. **Addressing these different aspects means thinking about interconnected solutions, rather than attempting solutions in isolation**, designed so that methods complement each other and manage a spectrum of challenges.

> "There are no passengers on spaceship earth. We are all crew."
>
> - Marshall McLuhan

Section 4.2 Deep dive into interconntected solutions

For each of the 10 case studies in 2021/2022, we identified several different solutions that could address certain elements of the problems that each disaster brought to the surface. All solutions were consolidated into eight larger conceptual categories, each representing a more general idea of how to approach solutions. The next sections present the top three solution categories found across our 10 case studies in detail, followed by a summary of all other solution categories, illustrating how each concept can be applied in different ways. As is the case with the root causes, drivers and impacts of this report, these solution categories are themselves interconnected. For example, implementing ecosystem restoration may include Strengthening governance and Planning for risks in land-use policies. Creating an early warning system likely involves Working together across disciplines and certain Innovations. These categories should only be viewed as a means for reframing how solutions are approached conceptually and should ideally be used in combination for the best outcome.

> "When we respect nature, and our planet, we are respecting ourselves. And when we fail to, we are in fact disrespecting ourselves or certainly the next generation and their life."
>
> – Inger Andersen

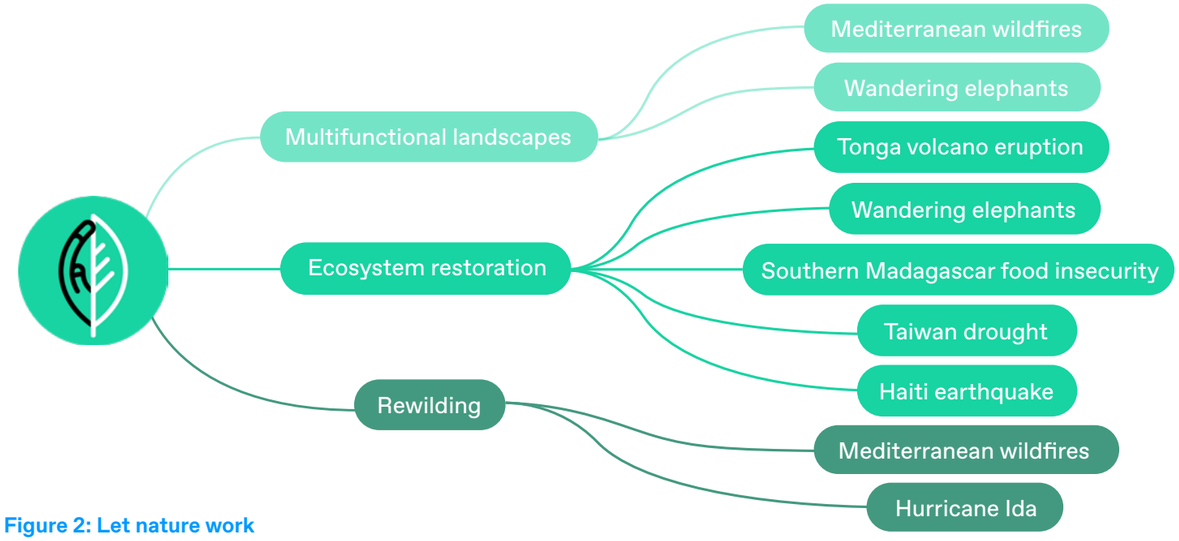


Figure 2: Let nature work

Section 4.2.1 Let nature work

As climate change brings increasingly extreme events that threaten our ecosystems and societies, we are becoming aware that our tendency to ignore or disregard environmental processes in our policies, industries and behaviours comes at the cost of our capacity to buffer these oncoming threats. As we look for ways to combat climate change and the continued degradation of our planet as a whole, we must rekindle our understanding of natural processes of the environment. Allowing nature back into our cities, towns, policies and planning gives us more sustainable tools to better adapt and to reduce disaster risks. In many cases, this requires a transformative shift in our relationship with nature, to consider the rights of nature as we attempt to meet human needs and desires. This does not necessarily mean that we must stop managing natural ecosystems and "give back to nature"; quite the opposite. Nature needs our collaboration, not just our protection. We need to forge "public-planet partnerships" that are regenerative for the Earth and inclusive of both human and non-human stakeholders, such as an elephant or a river (Public-Planet Partnerships, 2022; Al-Olaimy, 2020). When different needs overlap and conflict, management is needed to find a solution that can work for everyone, including nature.

One good example of Letting nature work is in creating multifunctional landscapes. This approach can work to address multiple problems, mainly by allowing human uses and natural functions to overlap and synergize. For example, "agro-silvo-pastoralism" is a type of multi-use landscape, integrating crops and livestock into forests that is useful in preventing large wildfires. In fact, grazing as a tool for wildfire control in the **Mediterranean** goes back centuries but decreased over time as populations moved from rural to urban (Colantoni and others, 2020; Bergmeier and others, 2021). Nomadic pastoralists, such as the Sarıkiçililer Yörüks, often use goats as livestock to eat the ground shrubbery that otherwise provides fuel for wildfires as well as trampling forest surfaces, creating corridors that provide small firebreaks (Zogib, 2014). Of course, this can't be done too intensely as negative consequences of overgrazing pressures, such as soil compaction or species selectivity, can occur (Duane and others, 2019). Another important component of Letting nature work is restoring ecosystems in recognition of the needs of the organisms that live there. For example, one of the proposed reasons why the herd of **elephants** left their home in southern China was due to the lack of food and water resources available. Though 14 per cent of Yunnan province's area is classified as nature reserves, less than 5 per cent of the province is considered optimal or relatively suitable for elephants (Xinhua Net, 2022; Liu and others, 2016). It is critical, therefore, to restore these protected areas to a level to which elephants can safely maintain and increase their population without coming into conflict with surrounding human communities, and broadleaf forests are necessary to ensure elephant population groups can interact safely away from human interference (Chen and others, 2021).

The act of bringing ecosystems altered by human activities back to their "wild" state is a process-oriented approach to restoration seeking to build conditions that support self-sustaining, complex ecosystems that enhance both resilience and our connection to nature while opening up opportunities to take advantage of other ecosystem services (Perino and others, 2019). In the case of flood risk in urban areas where drainage infrastructure is being overwhelmed, restoring natural areas, like wetlands and rivers that have been long since built over, can help dissipate excess water by essentially "letting the water go where it wants." Approaches such as "daylighting," where subterranean rivers trapped beneath our cities are unearthed to enhance natural

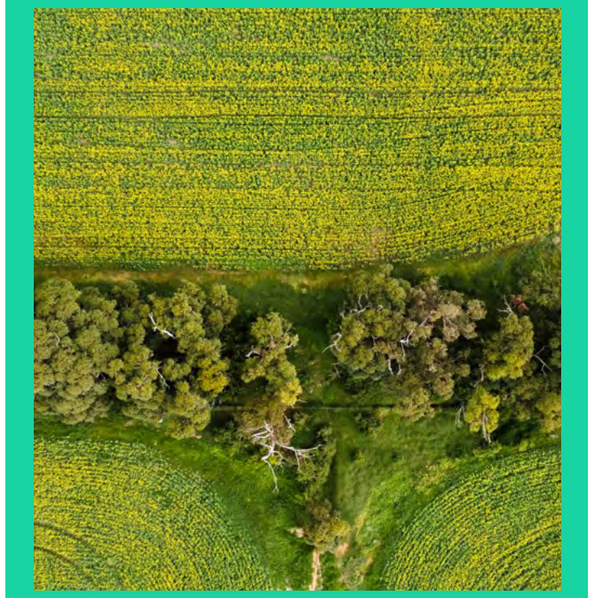
storm water flow, are being investigated in New York in the aftermath of **Hurricane Ida**; for example with Tibbets Brook in the Bronx (Cruz, 2021). While this approach provides opportunities for co-benefits such as waste management, greenways and biodiversity restoration, there are challenges that must be addressed, such as purchasing the property to be excavated as rewilding solutions often need more space and ensuring that the design of the new river is sustainable and resilient to extreme events.

As **Figure 2** shows, the different solution applications that Let nature work are not only beneficial for one type of disaster; their real value comes across when we understand how their benefits address multiple risks. Designing multifunctional landscapes, for example, not only reduces the risk of mega-fires like those that ravaged Europe during the **Mediterranean wildfires** but also the risks for human-wildlife conflict as coexistence strategies produce safer use of shared spaces (portrayed in the case of the **wandering elephants**). Adopting habitats and their natural processes through rewilding applies not only to flood risk but also wildfires. Applying a "let it burn" strategy allows for natural fire regimes to occur in forests, naturally clearing out dead underbrush that otherwise would accumulate to produce a mega-fire (Plana and others, 2016; Rott, 2018).

In terms of the drivers and root causes identified across our 10 cases for 2021/2022, by far the most effective way of reducing disaster risk by Letting nature work is via ecosystem restoration. Reviving forest ecosystems towards their natural state can be used along coastlines for coastal protection from erosion, which drives vulnerability in coastal areas, as seen in the **Lagos floods**, and storm surge or tsunamis, as triggered by the **Tonga volcano eruption**. Ecosystem restoration is also important for connecting critical habitats to mitigate human-wildlife conflict, as exemplified by the **wandering elephants** case. Healthy forest ecosystems stabilize the ground, which prevents sediment run-off that can clog vital water reservoirs, an issue that exacerbated the impacts of the **Taiwan drought**, or be swept up to create sandstorms that damage vital food crops, which contributed to the **Southern Madagascar food insecurity**. Soil stabilization is also critical for mitigating landslides, such as those that occurred in the wake of the **Haiti earthquake**. By employing management approaches that Let nature work, we can not only build resilience to multiple types of hazards but also as a bonus receive the benefits to biodiversity and physical/mental health that come along with a better relationship with nature.

Box 1:
Coyote Valley Landscape Linkage (Open Space Authority)

Coyote Valley, near San Jose in California, the United States, connects over 1 million acres of land between the Santa Cruz Mountains and the Diablo Range. Conservation and management of this area allows wildlife, such as mountain lions, western burrowing owls, and red-legged frogs, to move freely between the mountain ranges otherwise overtaken by bustling Silicon Valley.



Section 4.2.2 Innovate

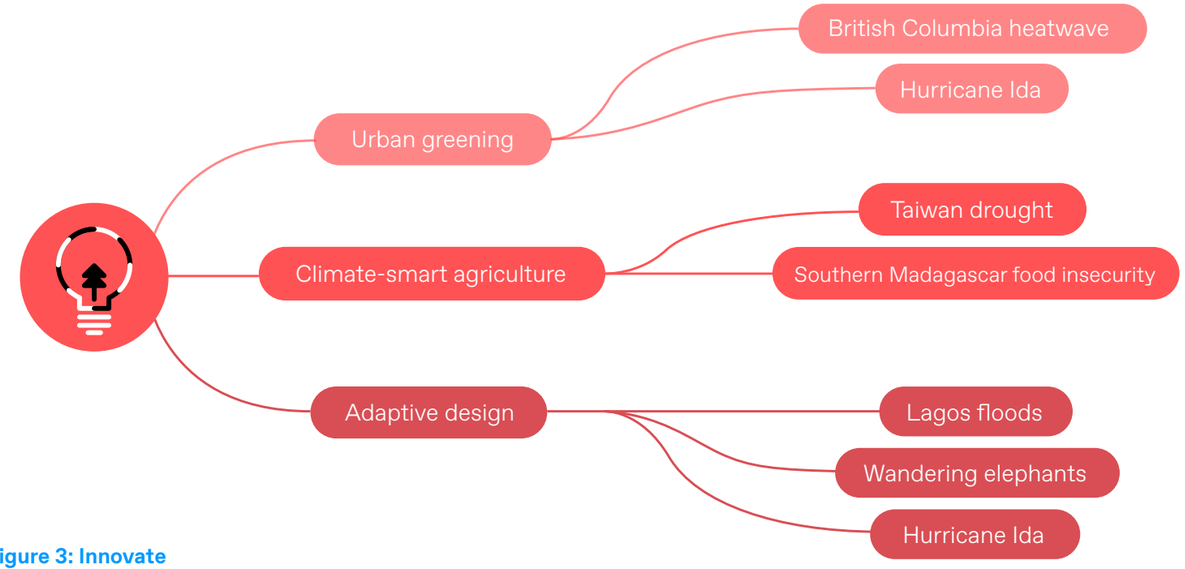


Figure 3: Innovate

As the cost of disasters continues to escalate, it is clear that traditional approaches to risk reduction and adaptation are coming up short. Innovation is required to find new ways to address the increasing intensity and frequency of hazards and the societal behaviours that increase exposure and vulnerability. We need to use what we know about the world from various sectors (architecture, agriculture, meteorology, geology, ecology, behavioural science, anthropology, economics) in intelligent ways to tackle systemic issues, maximizing benefits and minimizing trade-offs. These innovations must be sustainable, such that social or environmental impacts are avoided while opportunities for co-benefits are embedded into the design. Importantly, innovations don't have to be large, complex engineering projects or expensive technologies – they can also be simple, small-scale innovations that can make just as much of a difference. The way to find these innovations is not necessarily through brainstorming, but rather through observing with genuine curiosity the ways in which things are interconnected.

As an example of Innovate, the concept of "urban greening" intends to reincorporate nature as a significant component of the urban system. This includes things such as parks, gardens and urban forests where nature is allowed and encouraged to exist (Breuste, 2020). This system can use "green architecture," such as green walls and roofs or small dispersed parks, to help mitigate urban heat by using plants for shade, transpiration and heat absorption that could help in disasters like the **British Columbia heatwave**. In addition, green roofs not only lower urban air temperatures and mitigate the heat island effect but also absorb rainwater, provide insulation and act as habitat for urban biodiversity (Vandermeulen and others, 2011).

Alternatively, we can use what we know about the environment to alter our strategies, like adapting our farming systems to climate change in innovative ways. One way to do this is by using "climate-smart agriculture," an approach for reorienting farming practices to adapt to the new realities of climate change while securing livelihoods and ensuring practices don't further contribute greenhouse gas emissions. In **southern Madagascar**, for example, many projects encourage planting pigeon peas as they are not only drought-resistant but also provide nutritious peas to eat, while the woody stems act as a windbreak to halt erosion and can be sold as kindling (van der Perre, 2022). With the conversion or reorientation of some practices, communities may lose acquired knowledge about traditional crops (e.g., diseases, plant development, crop requirements, etc.) as well as some cultural values (e.g., food preparation, festivities, celebrations and ancestral significance). Care should be taken that these side effects of the conversion are managed and do not lead to maladaptive outcomes.

Innovative design for more sustainable and resilient infrastructure is another way we can literally build sustainability into our lives and therefore reduce our risk to future disasters. This requires transformative thinking about how we define the places we live in as we cannot solve today's challenges with yesterday's tools. For example, Lagos, like many coastal megacities in the world, is slowly sinking as a result of coastal and groundwater extraction while the sea level rises so that the city is experiencing increasingly severe flooding events (Adelekan, 2016). One adaptive approach to addressing the ever-increasing threat of inundation is the development of floating architecture for cases such as the **Lagos floods**. Projects currently being implemented in cities around the world are investigating different types of building materials and architectural strategies to deal with the challenges of flooding and sea level rise stemming from population pressure and climate change (**see Box 2**). As is common with innovative approaches, however, key barriers to be overcome include a lack of knowledge and experience in planning and construction of floating developments, as well as for those that need to regulate them. Legislation governing the sector needs to be developed, further supported by scientific research on integration with existing infrastructure, while accounting for any social or environmental impacts.

As **Figure 3** shows, innovation as a solution applies to many other cases. For example, urban greening can mitigate heat events as seen in **British Columbia** and can also help manage flood events like those experienced in the context of **Hurricane Ida**, by plant roots helping the soil to absorb more water. Drought-resistant crops are not only relevant for **southern Madagascar** but also for **Taiwan**. In the latter case, either replacing rice crops with less water-intensive and locally well-adapted alternatives or using different irrigation strategies would have helped reduce water usage. Employing the use of beehive fences to keep **elephants** out of agricultural lands and deploying small trawls or rigid traps as **vaquita**-safe fishing methods fit alongside the floating architecture in **Lagos** as a part of adaptive design. Innovation means using new ideas and challenging established norms to adapt to our changing conditions in intelligent and interconnected ways.

Box 2:
Adaptive design: OCEANIX Busan (UN Habitat)

A prototype floating city planned in Busan, Republic of Korea, the design of this system of floating modular neighbourhoods seeks to address the issue of coastal cities under threat from rising seas, intense storm activity and resulting coastal and riverine flooding by creating an adaptable, self-sustaining habitat for up to 12,000 people with potential for future expansion.

Section 4.2.3 Work together

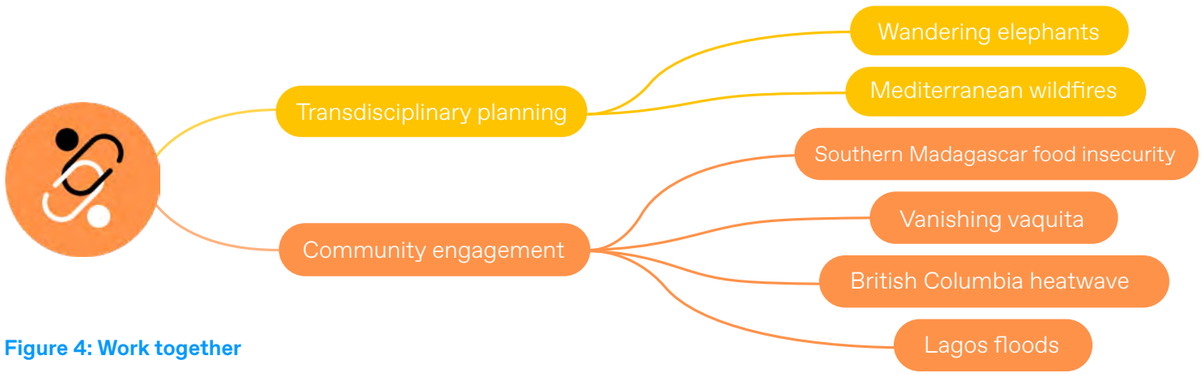


Figure 4: Work together

Addressing the interconnected nature of disaster risk involves a holistic approach that factors in the interconnected nature of different social and environmental elements working together. Too often, however, administrative and political boundaries discourage effective collaboration between sectors and institutions, making policies for managing disasters unclear when clarity saves lives. Collaborative planning enhances available knowledge, resources and inclusion. Of particular importance is the need to engage the most vulnerable members of society, for whom adaptation plans are the most critical. Engagement and co-development are important factors that improve the effectiveness of adaptation planning in at-risk communities, as in the case of the **Lagos floods** (Olajide and others, 2018).

Creating and implementing these sorts of plans requires foresight and input across disciplines. For example, strict enforcement of the legal protection of **elephants** in China was very successful in increasing the elephant population; in one nature reserve, the number of elephants nearly doubled from 1976 to 2016 (Li and others, 2018). However, at the same time, the elephant range suffered around 15 per cent overall forest loss, and the parts of the forest suitable for elephants decreased in size by 90 per cent (Campos-Arceiz and others, 2021). This resulted in the carrying capacity of the landscape becoming overwhelmed and unable to support the population (Chen and others, 2021). Therefore, a more holistic conservation strategy is needed to both increase elephant populations and ensure that their habitat can accommodate them accordingly. Therefore, working together with local community members such as farmers is key as the solution doesn't only involve conservation, but also management interventions to enable the creation of appropriate areas, such as open forests for elephants to feed. This requires controlled human disturbances and interventions in the forest by local farmers.

When asking why, if solutions to societal challenges are being developed, are we still unable to make drastic progress in areas like climate change, sustainable development, biodiversity conservation and disaster risk, we can't undervalue two important aspects of governance that hinder our ability to enforce laws and regulations that could reduce risk: lack of capacity and lack of political will. One approach becoming increasingly more important in a globalized world is the formation or strengthening of multilateral partnerships, which are particularly relevant when problems (and therefore necessary solutions) span borders and regions, such as in IUU fishing or transboundary droughts. Such partnerships can be useful in building capacity for greater enforcement of environmental regulations through the sharing of knowledge, technology and finances (Upadhyay and Mishra, 2020). This can be challenging in such cases as that of the **vaquita** however, when political and cultural issues of sovereignty limit the effectiveness of international cooperation, particularly on the ground, and can in some cases increase the level of conflict around resource management (Larson, 2002). In such cases, building collaborative management approaches between the local stakeholders, in this case the local fishermen, and the governing bodies responsible for managing their activities is key. The disenfranchisement of local communities is a major cause of environmental crimes, but including their experiences and perspectives in suggested solutions could be the only way to effectively protect threatened species (Chapsos and others, 2019).

As shown in **Figure 4**, Working together was a critical solution for multiple cases. Transdisciplinary planning applies to both a holistic **elephant** conservation strategy and collaborative governance in the **Mediterranean wildfires** by coordinating between the fire and forestry departments. Community engagement was particularly important not only for the conservation of the **vaquita** but also for addressing the problem of solid waste management in **Lagos** that clogs waterways and contributes to widespread flooding. This also applies to building community networks, such as implementing a neighbourhood safety net programme in **British Columbia** where citizens can check in on each other and in terms of women's economic empowerment in **southern Madagascar**. Working together and building community is crucial for reducing risk because we have so much to learn from each other, and integrating multiple perspectives helps everyone see the whole, interconnected picture. Giving all parts of society a stake in the solution is also critical for widespread buy-in and handling trade-offs that could impede success.

Box 3:
Multilateral partnership: Blue Resilience Project (UNDP)

As part of the Blue Justice initiative to build capacity for combating transnational crime in fisheries around the world, the Blue Resilience Project facilitates cooperation among agencies, such as fisheries, tax, labour and police, in developing countries to more effectively address fisheries crime.

Section 4.3 Other solutions

The following solution categories were evenly distributed across our 10 cases (4/10), with the exception of Boost early warning (3/10). Though they were not the most common solution categories, they are integral to consider when addressing the multifaceted nature of disasters and are a necessary part of solution packages (see **Chapter 4.4**) as, for example, using only a strategy for Letting nature work without Planning for risks or Boosting early warning will likely contribute to further impacts and trade-offs along the way.

Section 4.3.1 Secure livelihoods

While solutions to build the resilience of infrastructure and institutions are being developed and implemented, people living in disaster-prone areas with limited financial means may already be coping with the impacts of recent disasters or struggling to build resilience to the next one. In our interconnected world, reducing the vulnerability of society to disasters means ensuring that plans and policies are in place that can provide a safety net for people when disasters hit their homes and livelihoods, both in the aftermath of a disaster and to build resilience before one arrives, a part of what is known as social protection.

Governments can also help support their citizens through subsidies or grants to either improve their living spaces to be more resilient to a hazard or facilitate relocation to a less risk-prone area. For example, many of the fatalities from Hurricane Ida occurred in basement apartments. The city government of New York passed the Basement Apartment Conversion Pilot Program (BACPP) in 2019 to provide low, no-interest or forgivable loans to help low- and middle-income residents to convert their basements into safer dwellings that can be legally registered as apartments specifically to address those risks. Unfortunately, this programme was stripped of funding during pandemic-related budget cuts (Abraham, 2021). In the aftermath of Hurricane Sandy, a federally-funded home buyout programme was introduced to allow residents to sell their homes and relocate to less hazardous areas, reducing the number of households at risk from storms and flooding (Binder and Greer, 2016). However, there are several trade-offs to this solution, notably issues of social cohesion and mental health (Binder and others, 2019). In the United States, efforts have also been made to relocate indigenous communities affected by sea level rise and erosion in Louisiana and Alaska (Kumasaka and others, 2021).

Relocations of entire communities can be successful when livelihoods are recreated and there is consensus among the affected people concerning the need to relocate in its form and timing, as shown in Fiji (McMichael and others, 2019).

Another way of Securing livelihoods that can help reduce or transfer risk and increase resilience is the provision or subsidization of insurance schemes. Climate risk insurance can help protect farmers; micro-, small- and medium-sized enterprises; and homeowners from climate shocks. Climate risk insurance transfers the risk of a disaster from individuals and communities to insurance companies or the public sector. The use of parametric, or index-based, triggers allow insurance products to pay out very quickly following an extreme weather event without the need for costly and time-intensive claims adjustment processes. For example, in the case of the **Southern Madagascar food insecurity**, the government, in cooperation with WFP, have been implementing projects under a microinsurance scheme that aims to increase financial inclusion and support value chain development, linking to market access activities, with participants receiving “post-harvest Loss trainings.” As a complement, risk reduction and climate adaptation activities have been introduced by the projects in order to increase farmers’ adaptative capacity, including by investing in agroecology techniques or improving access to short-cycled crops to lower food insecurity (WFP, 2022). Climate risk insurance can also be purchased by governments, allowing them to quickly repair infrastructure or scale out social protection payments following a disaster. Such programmes work best if they are integrated into a wider adaptive social protection scheme helping to build resilience in light of climate and disaster risk. This approach, known as adaptive social protection, was discussed in detail in the **2020/2021 IDR report**.

Section 4.3.2 Consume sustainably

In an interconnected world, what we consume and how we consume it has wide-ranging impacts that affect our resilience to disasters and the resilience of people far away along obscure, complex global value chains. Excessive demand for products that require particular materials creates environmental and social pressure in areas where the materials are sourced. This pressure can increase disaster risk, yet is challenging to manage as the lure of profits incentivizes a lack of regulation and transparency at the supply chain's source. Next to appropriate regulations and transparency schemes for supply chains, one way to ease this pressure of global demand is to shift the linear economy toward a circular economy (CE) by reducing, alternatively reusing, recycling and recovering materials system-wide. This means in production, distribution and consumption processes from micro (products, companies, consumers) to macro (regional, national, global) levels, to accomplish sustainable development while benefiting the environment, economy and social equity (Kirchherr and others, 2017).

The most desirable way of reducing the impact of consumption is by reducing the consumption itself. Reuse of the materials we are already using for second and third lives after their first (intended) use rather than continually extracting more is at the heart of the transition away from single use-based consumption patterns to seeing the products we use as a resource in and of themselves, as well as finding innovative ways to capitalize on that opportunity. Another strategy for reducing the pressure our demand puts on the environment is via recycling required resources. For example, in the case of the **Taiwan drought**, the semiconductor industry in that region is incredibly water intensive, whereby a typical manufacturing facility can use between 2 and 4 million gallons per day (Baskaran, 2017). The previously mentioned TMSC has plans to reclaim and recycle industrial wastewater both for use back within the facility and for discharge as grey water to be used for other non-potable uses, allowing for more water resources to be made available for other uses and reducing vulnerability to future water crises (Hou and others, 2020).

Suitable alternatives need to be found to replace materials that have become unsustainable to obtain due to excessive demand or destructive practices. With increasing populations and development around the world, demand for resources in many sectors is increasing considerably, challenging efforts to promote sustainability and increasing disaster risk (see **Global demand pressures**). The global demand for sand fueled by booming urbanization and infrastructure development requires a multifaceted approach to reduce the environmental and social impacts stemming from often unsustainable mining practices on land and sea, including finding alternative building materials as a way to relieve the demand pressure. Alternatives are being developed from biomaterials made from mushrooms or straw (Alemu and others, 2022), while redesigning our approach to building can allow us to build out of other materials, such as wood (which must be sourced sustainably to avoid transferring risks to new areas). There are multiple ways to Consume sustainably to reduce demand however, and with the global sand mining problem, reuse and recycling options are also being investigated for building sustainably; for example, from working with materials sourced through "urban mining," whereby building materials are recycled from deconstructed buildings, or designing buildings to be deconstructed in the first place in order to maximize the future use of their materials.

Section 4.3.3 Strengthen governance

Many of these solutions are only possible given adequate organizational power to organize and implement them. In many of our cases, the institutions that would typically be responsible for dealing with specific problems were not able to do so. Some agencies don't have the resources or willpower to enact adequate risk governance; other times, it's a matter of coordination and organizational capacity. In society, we transfer risk responsibility to these organizations. Therefore, strengthening institutions themselves is critical for preparing for and responding to disasters.

In some cases, strengthening institutions means making sure there is actually an institution in place that takes responsibility for certain disaster preparation and response. In **British Columbia**, for example, there was no single department or agency that was responsible for coordinating a response to the heatwave, unlike for flooding and wildfires (Keith and others, 2021). Occasionally, there is a need for coordination among government ministries to prepare for or respond to a disaster. In many **Mediterranean** countries, such as Algeria and Greece, the forestry and fire departments are separate entities, often meaning efforts to prevent forest fires become tangled in bureaucracy between departments (Bouandel, 2021; Clapp, 2021). Coordination between authorities could help build risk maps and synthesize prevention efforts across multiple disciplines.

Section 4.3.4 Plan for risks

Hazards wreak particular havoc when they impact infrastructure, such as roads, buildings and communication systems, which are critical, particularly in times of disaster. Our built environment should be designed with an awareness of the potential risks it may be exposed to, ideally incorporating resilience to these risks from their inception. This involves the actual physical building materials, the designs from which they are built and how they are spatially distributed across the landscape.

In terms of physical building materials, they must be adapted to the risk landscape. In **Haiti**, for example, upgrading to concrete buildings is seen to be more modern, drier and safer, representing a step up the socioeconomic ladder. However, much of the concrete is poorly prepared, containing mud and smooth sand, and is often unreinforced (Audefroy, 2011; Hausler, 2010). The more traditional wattle and daub or wooden structures are not only more resistant to earthquakes but also made with lighter materials that are less deadly in the event of collapse, as well as having the added benefit of utilizing local materials (Audefroy, 2011). It should be noted, however, that wood is much more expensive than concrete in Haiti, so there is an obvious financial barrier to overcome in creating more resilient housing.

Especially for infrastructure that we rely on for essential services, we need to design a planned redundancy into our system so they don't go offline, as the communication infrastructure did in **Tonga** after the volcano eruption. Implementing a more diversified communication infrastructure, such as using satellite-based systems, can help ensure uninterrupted service when people need it most (Dominey-Howes, 2022). Our relationship with the landscape must also be risk-informed; as mentioned in the Let nature work solution section, hazards such as fires and floods should be given room to "go where they want," meaning that humans should ideally also be kept out of harm's way. One way to do this is to ensure that there is a buffer zone between where the hazard is expected and where people will be. In the **Mediterranean**, agricultural fields and grazing lands used to serve as "fire-resisting zones" around villages that ensured wildfires couldn't spread into towns (Bergmeier and others, 2021).

Section 4.3.5 Boost early warning

Despite our best efforts to prevent disasters, storms still form, fires still burn and volcanoes still erupt. Awareness of an oncoming disaster is key to preparation and response efforts that can make all the difference to the impacts experienced when extreme events strike. Though we can do our best with the solutions mentioned above, people should be made aware of the risks they might be exposed to. Early warning systems should be optimized to provide timely, relevant and transparent information to those who may be in harm's way. Currently, one in three people around the world are still not adequately covered by early warning systems, showcasing the need for improving risk information and timely alerts as a top priority (World Meteorological Organization (WMO), 2022). Efforts to boost early warnings are already in place: United Nations is pushing countries to ensure that every citizen worldwide is protected by early warning systems within the next five years. This ambitious target will see the WMO spearhead new action to ensure people can benefit from forecasting and act timely in order to reduce disaster risk (United Nations (UN), 2022). Ideally, information distributed should not only be an alert that a hazard is impending but also provide advice and resources to make sure those who receive the message can make the most informed decisions.

One of the biggest barriers in early warning is to make sure the information actually reaches the relevant people. Mobile applications can be particularly useful for people living in remote areas, or for real-time forecasting abilities. For example, in the context of the **Lagos floods**, the Flood Mobile App in Nigeria aims to use data from the Nigeria Hydrological Service Agency to help authorities monitor daily flood risks. One potential drawback of this mobile application is that it isn't designed for use by the civilian population, with smartphone use often isolated to younger generations or those living in cities. Therefore, this approach should also be combined with other methods of early warning to increase its effectiveness (Johnson, 2021).

Satellite remote sensing techniques are increasingly being investigated for integration into disaster risk management, providing close to real-time data on the generation of floods, fires, landslides, hurricanes and volcanic activity, among other hazards, with the aim of identifying potential at-risk areas so that people can be warned ahead of time (Poursanidis and Chrysoulakis, 2017). In the case of volcano activity, there are roughly 1,500 potentially active volcanoes worldwide; however, only around 50 per cent of them are monitored from the ground (Simmon, 2019). The **Tonga volcano eruption** was a wake-up call for the need to better understand submarine volcanoes which, while often remote, can deliver impacts from a powerful eruption around the world (see **section 3.1.2**). Pacific island states could use satellite technology to bridge the gap in monitoring, identifying the precursors of eruptions early, such as smoke or changes in ocean colour or surface temperature (Blackett, 2022). However, like Tonga, many of these islands are still in need of strengthening international cooperation to develop an integrated, remote-sensing monitoring effort in order to enhance volcano risk management and associated tsunami alerts (Pultarova, 2022). This showcases the need for combining Boosting early warning with Working together as a collaborative planning effort that enhances knowledge-sharing beyond borders (Tupper, 2022) (see **section 4.2.3**).

Section 4.4 Implementing solutions

Section 4.4.1 Solutions packages

With the solution themes described above, we created "solution packages" for each of the 10 cases, designed with the understanding that the plans and policies we call "solutions" should not be thought of as a silver bullet. Rather, they are only pieces of a puzzle that must be fit together with other elements to make a positive difference. A disaster is not one-dimensional – it is created through multiple layers, societal processes and practices that have come together in the "perfect storm" (Oliver-Smith and others, 2016). The problems a disaster brings to the surface need to be addressed from multiple angles, getting at the roots of the problem to fix the system that created the disaster in the first place while also having interventions in place to save lives and livelihoods (such as early warning) as well as measures to boost recovery once a disaster is expected or recorded, such as forecast-based finance, climate and disaster risk insurance, and social protection. For this reason, we use the concept of solution packages for each disaster that showcase solutions which can complement each other to address some of the most pressing issues each of the 10 disasters highlighted (shown in **Figure 5**). More information on these solution packages can be found in the individual disaster technical reports.

These solution packages should integrate solutions targeting social, economic, governmental and environmental aspects, as all of these systems are interconnected and influence each other. For example, some of the main issues associated with the **Mediterranean wildfires** were the separation of the fire and forestry departments, dead vegetation that accumulated as fuel for forest fires and increasing exposure of people and assets at the wildland-urban interface due to settlement expansion and land-use changes. As demonstrated earlier in Figure 1, the combination of all of these factors created the perfect storm for these raging wildfires to cause so much damage across the Mediterranean basin. Therefore, solutions to prevent this problem from occurring again should ideally address each of these problems in a multilayered approach. By Working Together and Strengthening Governance, we can better coordinate between fire and forestry departments to create a transdisciplinary approach for forest management and wildfire response. Additionally, Letting Nature Work and Working Together can help create strategies to clear out flammable material from forests, using prescribed burning or grazing animals with guidance from stakeholders such as fire crews or pastoralists. Lastly, by Planning for Risks, we can promote fire-safe development and reduce the risk of exposure by diversifying the landscape, creating natural firebreaks that prevent flames from reaching homes and businesses. None of these solutions would be sufficient if implemented in a singular way. However, integrating solutions into packaged approaches can help to take advantage of co-benefits of each solution that help promote and enhance the others or address barriers to effectiveness inherent to local contexts (see **table 5**).

As per the solutions framework presented in the **2020/2021 IDR Report**, the preferred solutions included in the solution packages are those that can address multiple societal challenges while minimizing trade-offs (i.e., win-win-win). Single solutions implemented in departmental silos must undergo a transformative shift to more integrated, interconnected approaches. Because all sectors are inextricably linked, developing integrated solutions also means that the process is not just for scientists and politicians. Integration also applies to the people using the solutions: We need to engage engineers, designers and artists, together with researchers from different fields and politicians from across the political spectrum, but most importantly, the people on the ground who will be implementing and benefiting from these solutions. Such approaches are currently being developed (see **Box 4**) but are yet to be mainstreamed.

Figure 5: Solution packages

Box 4:
Example: integrated solutions

R4 Rural Resilience Initiative – World Food Programme (WFP)

To better manage climate risk in food-insecure areas prone to recurring extreme weather events (such as persistent drought in southern Madagascar), WFP's R4 initiative is an integrated climate risk management approach that aims to help communities build resilience by combining four risk management strategies:

- Reducing the risk of climate-related shocks through nature-based solutions and improved agricultural practices
- Transferring the risk of catastrophic events to private insurance markets
- Enabling better risk retention of households and communities through the promotion of group savings and integration with social protection systems
- Promoting prudent risk taking through financial education, livelihood diversification and easier access to credit to enable better investments

The benefits of index insurance products are greatly enhanced through combining mutually reinforcing components, such as nature-based risk reduction measures, improved farming practices and better access to climate and financial services. In addition to providing financial protection from potentially catastrophic events, insurance can unlock access to formal financial services, stimulating investments in more resilient and diversified livelihoods. In 2021, R4 reached over 395,000 households with insurance in 14 countries in Africa, Asia, and Latin America and the Caribbean, benefiting 1.8 million people.

Section 4.4.2 Barriers and trade-offs

Identifying trade-offs, or the negative consequences that may arise from implementing a solution, did not disqualify a solution from being considered for inclusion in this report. Trade-offs are inherent in such an interconnected system, so they are essential to highlight and address if a solution is implemented. Trade-offs could be environmental, as in the case of the heatwave in **British Columbia**: increasing access to air conditioning produces greenhouse gas emissions, and urban greening can result in increased water (Keith and others, 2021). If these trade-offs aren't addressed, it could lead to maladaptation, whereby the solution actually worsens the original conditions. There may also be social trade-offs; for example, creating habitat corridors or protected areas for the **wandering elephants** may involve the people living in or using those areas to lose access (Shaffer and others, 2019). Identifying trade-offs is vital for engaging people who may be harmed by certain actions, or even act to hinder them, in finding suitable compromise where the interests of all stakeholders are considered. With funding gaps and access to available resources as significant limiting factors in implementing promising solutions being developed worldwide, it is critical to thoroughly assess the potential for adverse outcomes and wasted investments. Far too often, development approaches favour environmental destruction for short-term gains. For solutions to be sustainable, they should ideally be designed to maximize long-term, multipurpose benefits rather than maximizing short-term performance on single indicators.

Though a solution may look good on paper and those implementing it may have the best intentions, those plans and intentions are irrelevant if the consequences end up doing harm or reinforcing environmental or social injustices (Solomonian and Di Ruggiero, 2021). For example, creating habitat corridors or expanding nature preserves for elephants or other species can potentially remove local populations from lands they live on or have become accustomed to using. Safeguards must be put in place to ensure all possible measures are taken to avoid harm to people or environments with an equitable distribution of benefits and trade-offs. To accomplish this, stakeholder engagement must be inclusive, transparent and honest (see: **4.2.3: Work together**). Including diverse perspectives, especially from the most marginalized, is necessary to limit or prevent social or environmental injustices from occurring. This can be seen very clearly in the case of **Haiti**, whereby centuries of colonialism, slavery, foreign occupation, dictatorships, military interventions and disaster capitalism created a context of extreme vulnerability for Haitians who struggle to have a voice in designing their own futures. However, there are solutions already on the ground in Haiti that merely need recognition and support, such as the Commission to Search for a Haitian Solution to the Crisis, representing unions, farmers' cooperatives, human rights organizations, Voodoo groups and churches dedicated to "work towards a peaceful resolution of the current political and institutional crisis" (Forum Société Civile Haïtienne, 2021; Clesca, 2021). Prioritizing the agency of stakeholders is key in this respect, particularly when agency has been undermined.

Additionally, we looked at possible solutions for any barriers to implementation, or factors that may have prevented such a solution from being implemented in the first place. These were often educational and perceptive barriers, such as teaching farmers how to use precision irrigation systems or shifting to cultivating less water-intensive crops in **Taiwan** (Hale, 2021). There could also be financial or political barriers, such as the cost and controversy of building additional communication infrastructure for **Tonga** (Watson, 2021) or the challenge of implementing solutions requiring government administration in regions where political instability is the norm (Birenbaum, 2021; Fatton, 2021). Such barriers were noted for each solution, and help inform the necessary enabling conditions for different solutions and hence their current viability.

Section 4.4.3 Enabling conditions

Like a plant that needs a specific mixture of soil conditions, rainfall and sunlight to grow, solutions also require a nurturing and enabling environment. Although these disastrous events are interconnected, each situation is context-specific, so understanding local conditions is critical for understanding and overcoming any potential barrier or identifying the preconditions for success, or the enabling conditions. Priorities should be made for local community inclusion to better understand critical and yet often overlooked cultural and historical contexts. Understanding people's cultural production of risk and how they perceive and respond to risks is a key part of addressing the reasons that people are affected by disasters and why they do or do not take certain actions to minimize their impact (Bankoff and others, 2015). Integrating local cultural knowledge and context as part of co-producing solutions is a recommendation that appears over and over in studies on implementing strategies for reducing disaster risk to enhance their effectiveness and is being called for by local communities (Kuruppu and Willie, 2015; Chapsos and others, 2019).

A participatory approach at every stage of the planning and implementation process can thus establish trust and transparency, which is so important and yet so often mishandled in the solutions space (see **4.2.3 Work together**). Accessibility of solutions is another key condition, as no matter how good a solution is, it must be usable on the ground. For example, giving smallholder farmers access to formal markets and aid in places like **southern Madagascar** must go along with ensuring that roads and transport are in place that allow for the most vulnerable to access areas of delivery, while insurance solutions meant for building resilience after disasters strike must be affordable for the target demographic. Cultivating enabling conditions is often a question of political priorities; therefore, concerted efforts are needed to both strengthen institutional capacity (see **4.3.3 Strengthen governance**) and encourage sustainable development approaches.

> "It's the little things citizens do. That's what will make the difference."
>
> – Wangari Maathai

Section 4.5 Change the system

Key concepts for solutions, when applied in context-specific ways, cut across various types of disasters. By designing our solutions well, we are not only surviving but thriving, and encouraging the world we live in to do the same. Importantly, designing solutions well means understanding the systemic nature of risk and being willing to reframe the way we view our place in the world in order to address the root causes and systemic structures that create risk and reinforce vulnerabilities. We must place ourselves as part of a set of interconnected systems where our actions and our voices matter.

First, the interconnectivity of the drivers and root causes of disasters identified in this report show that we must strengthen our institutions and hold them accountable for enforcing the laws and policies to protect people and nature. We need to establish the political will necessary to recognize that disasters do not just happen but are created by systemic problems that must be addressed. We should work together across different parts of society to create a safe, sustainable and nurturing environment for ourselves and for the future. Additionally, the way we produce and consume products and services have taken us to a place where our environment and societies stand on a knife's edge, nearly tipping to the point of collapse.

Our interactions with the environment should be based on sustainability: in that we do not take more than we need and that the materials and services we use for everyday life can be replenished without harmful trade-offs. Shifting our current economy from linear (where a product is made, bought, used and discarded) to circular (where a product is made, bought, used, reused, repaired, repurposed and recycled) has begun in many parts of the world but needs to be drastically scaled up. Changing this system is often not seen as "cost-effective" only because the external costs and damage from the linear waste system are not accounted for in the cost of the product and are instead pushed off on the most vulnerable parts of society and the environment.

To make the circular system work, we must begin to value and account for the social and environmental costs of our actions. Lastly, we must address systemic inequalities that produce vulnerability. As with disasters, inequality doesn't just happen but is the tip of an iceberg created through a long historical process. Recognizing the systemic nature of inequality in its various forms is a critical step to dismantling the systems that reinforce and perpetuate the disproportionate impacts of disasters on the most disadvantaged members of society.

> "Progress is impossible without change, and those who cannot change their minds cannot change anything."
>
> – George Bernard Shaw

Chapter 5

Conclusion

In 2021/2022, once more, the world witnessed a large number of disasters. The 10 disasters analysed in this report were selected as representatives of larger trends and emerging risks in the fabric of our globalized world. Based on forensic analyses of the interconnectivity among these seemingly unconnected cases, this report identifies individual solutions and solution packages that target the causes behind risks to people and nature around the world or innovate to change paradigms that allow systemic vulnerabilities to develop.

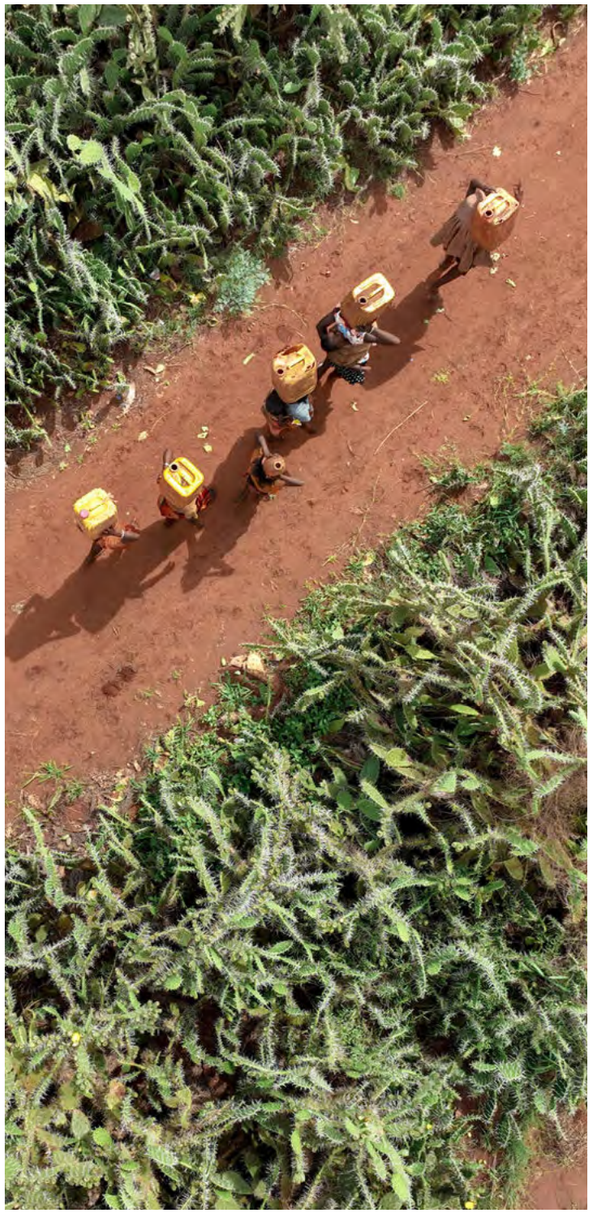
Section 5.1 Findings in a nutshell

Disasters and global challenges share key drivers and root causes.

Disasters occurring across the planet often share the same underlying drivers. Key shared drivers among the 10 cases included atmospheric warming, deforestation, increasing urbanization in areas exposed to hazards and vulnerable infrastructure that is unprepared to deal with the increasing challenges driven by climate change. Though the drivers were similar, the consequences manifest differently for each event. For example, deforestation contributed to the devastating landslides during the **Haiti earthquake**, as well as to the formation of sandstorms in **southern Madagascar** and the reduction in capacity of water infrastructure in **Taiwan** before the drought hit.

Each of these drivers was influenced by causes rooted in various systems and structures, such as our economic or political systems. Insufficient risk governance, Undervaluing environmental costs, Inequality of development and livelihood opportunities, Global demand pressures and Human-induced greenhouse gas emissions were identified as key root causes behind multiple disasters investigated in this report that reinforced persisting vulnerabilities, contributed to hazard formation and increased risk in the lead-up to disasters. For example, inequality of development and livelihood opportunities is a primary cause behind the migration of people to cities, usually to cheaper areas with higher exposure to hazards and/or less regulated housing (as seen in the **Lagos floods** and **Hurricane Ida**). When disaster strikes, this inequality also puts people in vulnerable positions with few options to cope or adapt. Both the cases of the earthquake in **Haiti** and the food crisis in **southern Madagascar** highlight how vulnerabilities of populations and inequalities have built up historically over centuries.

No disasters manifest from a single root cause but rather from a combination of root causes, which are themselves interlinked. Many of them can be traced back to a collective mindset and moral framework that underpins economic growth at all costs with little consideration for the impacts on the environment. As we better understand the interconnectivity among the root causes of disasters, we can use it to our advantage to find better solutions.



Integrated solutions must be tailored to address context-specific causes of vulnerability.

The analyses also show that most disasters are preventable if we implement the right solutions to address the interconnected causes of disasters in combination with measures to help save lives and livelihoods when a hazard strikes, as well as supporting recovery in the aftermath. Although the 10 cases we analysed are fundamentally different, the possible solutions to the problems they brought to the surface are similar. Key solution categories across all event types included approaches to Let nature work for mutual benefit, and Innovations for disaster and climate resilience, as well as approaches supporting more cooperation and Working together. For example, innovations help us to avoid addressing problems with the same tools that got us into vulnerable situations in the first place. We have to rethink our ways of addressing risk and adapt to changing conditions by using new ideas and challenging established norms. Examples include the use of adaptive design such as floating cities to live with recurrent flooding (**Lagos floods**), bioacoustic fences to prevent damage from wildlife (**wandering elephants**), and the use of sustainable fishing gear to prevent over-exploitation and species extinction (**vanishing vaquita**).

To better address the interconnected nature of risk, solution packages must be implemented that are designed to be used in combination to address different elements of disaster risks with the most vulnerable in mind. These packages should be set up by combining measures that get at the roots of the problem with those that help to save lives and livelihoods and support recovery in the aftermath of disasters. An example for a solution package to address the looming extinction of the **vaquita** is to apply more collaborative resource management by involving local fisher communities, to implement more sustainable fishing methods while also raising awareness for sustainable consumption and enforcing regulations to prevent harmful overfishing and illegal trade. In this way, we can better address barriers and trade-offs that often hamper solutions when they are implemented in isolation.

Any solution package needs to have a special focus on the most vulnerable. Examples include encouraging the establishment of neighbourhood safety nets in **British Columbia**, where neighbours would check in with each other and especially with those most vulnerable in case of a heatwave. Children under the age of five, for example, are especially vulnerable to the impacts of food insecurity as seen in **southern Madagascar**, and need special focus to avoid long-lasting impacts such as weak immune systems and, thus, susceptibility to infections and illnesses, stunting and delayed motor and cognitive development.

Section 5.2

Recommendations

As climate change and its impacts are increasingly being felt today, the challenges for disaster risk reduction will only grow in the future and will combine with the impacts of loss of nature and vanishing biodiversity. While hazard intensity and frequency are expected to increase, we simply cannot afford to delay the implementation of the solutions we have at hand, and we can't miss the opportunity for more innovation and creativity. We need to act now and embrace solutions. Some of these will be inconvenient as they call for the implementation of transformative change in a just way and imply a redistribution of resources among generations (**Lagos floods**), countries (**Haiti earthquake**) and groups with different vulnerabilities (**Hurricane Ida**), or request the inclusion of stakeholders who are rarely heard (**vanishing vaquita**). The implementation of some well-known solutions was so far unsuccessful (banning illegal fishing) or still have to overcome implementation barriers (upgrading water management infrastructure in **Taiwan**). Other solutions are yet beyond our current imagination, and thus we need to direct our attention and resources to embrace innovation for disaster risk reduction and allow for experimentation. Innovation is needed to drive cultural changes in the way we live and in a way that can reduce our impact on the people and ecosystems around us, as well as adapting to the changing conditions coming with a changing climate and biodiversity loss.

Section 5.3 What can we all contribute

Although the largest influence on risk and, therefore, the largest responsibility lies with large-scale industry and policy, as well as a need for structural change, a whole of society approach is needed. Individual action and changes in thinking are the foundation of social learning and mind shifts that can enable collective action. This way, individual change and system-level change are interconnected. When viewed in isolation, an individual action presents a very minor change, but when viewed as a part of a larger whole, our collective actions can create lasting, meaningful and positive change, and this "butterfly effect" can start with you. The solution categories detailed above can also be thought of in terms of personal actions. Here are some examples:

- **Let nature work:** Whether you have a farm or a windowsill, you can give spaces back to nature that allow us to coexist with our environment. Whether carefully designing a garden for particular species or letting green spaces grow wild, you can help support native species and important links in the biodiversity chain, like pollinators (e.g. bees and butterflies), to do the jobs we rely so heavily on. Citizens can work together to install and maintain gardens in public areas. These can also be decorated with artwork to not only improve the air quality in the neighbourhood but also support mental health, recreation and inspiration for culture, as well as creating a sense of place for neighbours, building an engaged community. These spaces could also grow food, providing produce to local communities.

- **Consume sustainably:** Find out what you can about where the products you buy come from, and how they address issues of sustainability. Buying locally when possible and choosing more sustainable alternatives can help reduce the negative impacts of our consumption system, especially if you are in a privileged position to do so – your purchase has the power to make those options more widely accessible for everyone. Additionally, rethink the way you use products and materials, prioritizing reducing, reusing, repurposing and recycling to play your part in decreasing the demand for materials being extracted around the world.

- **Strengthen governance:** Political will to act on issues of environmental, social and climate justice is one of the major roadblocks to protecting society from disasters. We must strengthen our institutions at all levels and hold them accountable for enforcing the laws and policies being implemented to protect people and nature. Voting and advocating for action on sustainable development, rather than economic growth at all costs, will help to build long-term resilience of society as a whole, rather than erode it for short-term economic gain.

- **Work together:** Becoming engaged in your community through volunteering or simply exchanging knowledge and resources with neighbours to aid actions for sustainability or what to do in the case of extreme weather events can be a way to build capacity at the local level. Communities can also mobilize to organize events in collaboration with local small businesses to spread the concept of sustainability.

- **Secure livelihoods:** There are several ways you can secure your livelihoods or help others to do so. Join or lead the maintenance, repair and rehabilitation of infrastructure in your community or participate in reforestation and protection of water bodies to make them more resilient to extreme events. Support the work of local farmers and small businesses as a way to alleviate economic vulnerability. Encourage savings and financing mechanisms, such as savings groups, revolving funds and cooperatives, or learn about the insurance options available and what they cover in terms of disaster impact.

For many people with limited resources, the priority is doing what is necessary to survive day to day, rather than actions on climate change and disaster risk reduction even though in the longer term these things are linked to daily survival. Therefore, those of us in the privileged position to act and change the system have a moral obligation to do so. This is often a challenging step to take and involves acknowledging a connection to the causes of disasters around the world. However, until we do, any solutions centred around behavioural change in vulnerable areas will be hopelessly out of touch. The good news is that the solutions are there. We only need to make the choice to act and use them well.

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Works cited

Abnett, Kate (2021). Mediterranean has become a 'wildfire hotspot', EU scientists say, 4 August. Available at https://www.reuters.com/business/environment/mediterranean-has-become-wildfire-hotspot-eu-scientists-say-2021-08-04/

Abraham, Roshan (2021). NYC Funded a Pilot to Make Basement Apartments Safer, But Then It Went Off Track, 13 October. Available at https://nextcity.org/urbanist-news/nyc-funded-pilot-to-make-basement-apartments-safer-but-then-went-off-track

Adelekan, Ibidun O. (2016). Flood risk management in the coastal city of Lagos, Nigeria. *Journal of Flood Risk Management*, vol. 9, No. 3, pp. 255–64. DOI: 10.1111/jfr3.12179

Agnew, David, and others (2009). Estimating the Worldwide Extent of Illegal Fishing. *PLOS ONE*, vol. 4, No. 2, art. e4570. 1-8. DOI: 10.1371/journal.pone.0004570

Aguirre-Ochoa, Jerjes, and Mario Gómez (2021). Debilidad institucional y experiencia anticrimen en México. *URVIO: Revista Latinoamericana de Estudios de Seguridad*, No. 29, pp. 45–57. DOI: 10.17141/urvio.29.2021.4407

Al-Olaimy, Tariq (2020). Why nature is the most important stakeholder of the coming decade, 7 January. Available at https://www.weforum.org/agenda/2020/01/why-nature-will-be-the-most-important-stakeholder-in-the-coming-decade/

Alemu, Digafe, Mesfin Tafesse and Ajoy K. Mondal (2022). Mycelium-Based Composite: The Future Sustainable Biomaterial. *International Journal of Biomaterials*, vol. 2022, art. 8401528. pp. 1–12. DOI: 10.1155/2022/8401528

Audefroy, Joel (2011). Haiti: post-earthquake lessons learned from traditional construction. *Environment and Urbanization*, vol. 23, No. 2, pp. 447–62. DOI: 10.1177/0956247811418736

Austen, Ian (2021). Sifting Through Mud, Flooded Canadians Fear Next Disaster. *The New York Times*, 29 November. Available at https://www.nytimes.com/2021/11/29/world/canada/british-columbia-floods-storm.html

Aviso, Kathleen B., and others (2021). Taiwan Drought was a Microcosm of Climate Change Adaptation Challenges in Complex Island Economies. *Process Integration and Optimization for Sustainability*, vol. 5, No. 3, pp. 317–18. DOI: 10.1007/s41660-021-00188-1

Bagaipo, Jorge, and Emily Janoch (2021). How the Earthquake in Haiti Affected Access to COVID-19 Vaccine, 16 November. Available at https://www.care.org/news-and-stories/health/how-the-earthquake-in-haiti-affected-access-to-covid19-vaccine/

Bankoff, Greg, and others (2015). Exploring the links between cultures and disasters. In *Cultures and Disasters: Understanding Cultural Framings in Disaster Risk Reduction*. Krüger, Fred, and others, eds., Taylor and Francis. Hoboken. DOI: 10.4324/9781315797809-1

Baskaran, Aiswarya (2017). Waste Not, Want Not – Water Use in the Semiconductor Industry, 22 March. Available at https://www.sustainalytics.com/esg-research/resource/investors-esg-blog/waste-not-want-not-water-use-in-the-semiconductor-industry

Bergmeier, Erwin, and others (2021). 'Back to the Future'—Oak wood-pasture for wildfire prevention in the Mediterranean. Plant Sociology, vol. 58, No. 2, pp. 41–48. DOI: 10.3897/pls2021582/04

Bernd, Würsig, and others (2021). Vaquita: beleaguered porpoise of the Gulf of California, México. *THERYA*, vol. 12, No. 2, p. 187. Available at https://www.revistas-conacyt.unam.mx/therya/index.php/therya/article/view/1109

Berry, Alex (2021). Taiwan drought could threaten global supply of electronic chips, 19 May. Available at https://www.dw.com/en/taiwan-drought-could-threaten-global-supply-of-electronic-chips/a-57579184

Binder, Sherri, and Alex Greer (2016). The Devil Is in the Details: Linking Home Buyout Policy, Practice, and Experience After Hurricane Sandy. *Politics and Governance*, vol. 4, No. 4, pp. 97–106. DOI: 10.17645/pag.v4i4.738

Binder, Sherri, and others (2019). Home buyouts and household recovery: neighborhood differences three years after Hurricane Sandy. *Environmental Hazards*, vol. 18, No. 2, pp. 127–45. DOI: 10.1080/17477891.2018.1511404

Birenbaum, Gabby (2021). To rebuild, Haiti needs a break from neocolonialism, 18 August. Available at https://www.vox.com/22629569/haiti-earthquake-tropical-storm-grace-neocolonialism-rebuilding

Blackett, Matthew (2022). Underwater volcanoes: how ocean colour changes can signal an imminent eruption, 21 January. Available at https://theconversation.com/underwater-volcanoes-how-ocean-colour-changes-can-signal-an-imminent-eruption-175408

Boiselet, Aurelien (2021). Haiti Earthquake in 2021: Could it have been anticipated?, 8 October. Available at https://www.climate.axa/articles/haiti-earthquake-in-2021-could-it-have-been-anticipated

Bouandel, Youcef (2021). Why did wildfires claim so many lives in Algeria?, 20 August. Available at https://www.aljazeera.com/opinions/2021/8/20/why-did-wildfires-claim-so-many-lives-in-algeria

Works cited

Bratu, Andreea, and others (2022). The 2021 Western North American heat dome increased climate change anxiety among British Columbians: Results from a natural experiment. *The Journal of Climate Change and Health*, vol. 6, art. 100116. pp. 1–6. DOI: 10.1016/j.joclim.2022.100116

Breuste, Jürgen (2020). The Green City: General Concept. In *Making Green Cities*. Breuste, Jürgen, and others, eds., Springer International Publishing. Cham. DOI: 10.1007/978-3-030-37716-8_1

Brownell, Robert, and others (2019). Bycatch in gillnet fisheries threatens Critically Endangered small cetaceans and other aquatic megafauna. *Endangered Species Research*, vol. 40, pp. 285–96. DOI: 10.3354/esr00994

Caglayan, Ceyda, and Ezgi Erkoyun (2021). Turkey's wildfires hit hopes for tourism rebound, 6 August. Available at https://www.reuters.com/world/middle-east/turkeys-wildfires-hit-hopes-tourism-rebound-2021-08-06/

Campos-Arceiz, Ahimsa, and others (2021). The return of the elephants: How two groups of dispersing elephants attracted the attention of billions and what can we learn from their behavior. *Conservation Letters*, vol. 14, No. 6, DOI: 10.1111/conl.12836

Caplan, Brian (2021). Social construction of risk: a postcolonial retrospective longitudinal analysis of Haiti's 2010 earthquake. Working Paper, No. 210. Available at https://www.ucl.ac.uk/bartlett/development/publications/2021/nov/dpu-working-paper-no-210

Cardoso, Pedro, and others (2021). Scientists' warning to humanity on illegal or unsustainable wildlife trade. *Biological Conservation*, vol. 263, art. 109341. pp. 1–9. DOI: 10.1016/j.biocon.2021.109341

Ceballos, Gerardo, Paul Ehrlich and Peter Raven (2020). Vertebrates on the brink as indicators of biological annihilation and the sixth mass extinction. *Proceedings of the National Academy of Sciences*, vol. 117, No. 24, pp. 13596–602. DOI: 10.1073/pnas.1922686117

Challender, Daniel W., and Douglas C. MacMillan (2014). Poaching is more than an Enforcement Problem. *Conservation Letters*, vol. 7, No. 5, pp. 484–94. DOI: 10.1111/conl.12082

Chapsos, Ioannis, Juliette Koning and Math Noortmann (2019). Involving local fishing communities in policy making: Addressing Illegal fishing in Indonesia. *Marine Policy*, vol. 109, art. 103708. pp. 1–9. DOI: 10.1016/j.marpol.2019.103708

Charles, Jean M. (2021). The Cost of Regime Survival: Political Instability, Underdevelopment, and (Un)natural Disasters in Haiti Before the 2010 Earthquake. *Journal of Black Studies*, vol. 52, No. 5, pp. 465–81. DOI: 10.1177/00219347211012619

Chen, Ying, and others (2021). Anthropogenic pressures increase extinction risk of an isolated Asian elephant (Elephas maximus) population in southwestern China, as revealed by a combination of molecular- and landscape-scale approaches. *Integrative Zoology*, pp. 1–17. DOI: 10.1111/1749-4877.12534

Clapp, Alexander (2021). The Fires in Greece Are a Terrifying Warning. *The New York Times*, 27 August. Available at https://www.nytimes.com/2021/08/27/opinion/greece-fires-climate-change.html

Clesca, Monique (2021). My Group Can Save Haiti. Biden Is Standing in Our Way. *The New York Times*, 1 December. Available at https://www.nytimes.com/2021/12/01/opinion/haiti-commission-government.html

Colantoni, Andrea, and others (2020). Sustainable Land Management, Wildfire Risk and the Role of Grazing in Mediterranean Urban-Rural Interfaces: A Regional Approach from Greece. *Land*, vol. 9, No. 1, p. 21. DOI: 10.3390/land9010021

Copernicus (2021). Wildfires wreaked havoc in 2021, CAMS tracked their impact, 1 November. Available at https://atmosphere.copernicus.eu/wildfires-wreaked-havoc-2021-cams-tracked-their-impact

Cruz, David (2021). How Extreme Flooding Of This Bronx Highway Could Have Been Avoided, 23 September. Available at https://gothamist.com/news/how-extreme-flooding-bronx-highway-could-have-been-avoided

Desrosiers, Katherine (2019). 5 Facts About Malnutrition in Madagascar, 27 June. Available at https://borgenproject.org/malnutrition-in-madagascar/

Disease Control Priorities Project (2007). Natural disasters: Coping with the Health Impact, July 2007. Available at https://www.eird.org/isdr-biblio/PDF/Natural%20disasters%20coping.pdf

Dominey-Howes, Dale (2022). The Tonga volcanic eruption has revealed the vulnerabilities in our global telecommunication system, 17 January. Available at https://theconversation.com/the-tonga-volcanic-eruption-has-revealed-the-vulnerabilities-in-our-global-telecommunication-system-175048

Duane, Andrea, and others (2019). Adapting prescribed burns to future climate change in Mediterranean landscapes. *The Science of the total environment*, vol. 677, pp. 68–83. DOI: 10.1016/j.scitotenv.2019.04.348

Faliarivola, Manoa, Marc Lanteigne and Velomahanina Razakamaharavo (2022). The forgotten, cascading crisis in Madagascar, 18 January. Available at https://africanarguments.org/2022/01/the-forgotten-cascading-crisis-in-madagascar/

Faranda, Davide, and others (2022). A climate-change attribution retrospective of some impactful weather extremes of 2021. *Weather and Climate Dynamics Discussions*, pp. 1–37. DOI: 10.5194/wcd-2022-9

Fatton, Robert (2021). Will Haitians get the chance to determine their future — without foreign intervention? *The Washington Post*, 23 July. Available at https://www.washingtonpost.com/politics/2021/07/23/will-haitians-get-chance-determine-their-future-without-foreign-interference/

Forum Société Civile Haïtienne (2021). Commission for Haitian Solution to the Crisis, 12 May. Available at https://www.haitiwatch.org/home/commissionforhaitiansolution

Glaser, Sarah M., Paige M. Roberts and Kaija J. Hurlburt (2019). Foreign Illegal, Unreported, and Unregulated Fishing in Somali Waters Perpetuates Conflict. *Frontiers in Marine Science*, vol. 6, art. 704. pp. 1–14. DOI: 10.3389/fmars.2019.00704

Goldmann, Emily, and Sandro Galea (2014). Mental health consequences of disasters. *Annual review of Public Health*, vol. 35, pp. 169–83. DOI: 10.1146/annurev-publhealth-032013-182435

Guo, Jessie, Daniel Kubli and Patrick Saner (2021). The economics of climate change: No action not an option. Available at https://www.swissre.com/dam/jcr:e73ee7c3-7f83-4c17-a2b8-8ef23a8d3312/swiss-re-institute-expertise-publication-economics-of-climate-change.pdf

Hale, Erin (2021). Taiwan faces water wake-up call as climate change intensifies, 20 August. Available at https://www.aljazeera.com/news/2021/8/20/taiwan-water-woes

Halkos, George, and Eleni-Christina Gkampoura (2021). Where do we stand on the 17 Sustainable Development Goals? An overview on progress. *Economic Analysis and Policy*, vol. 70, pp. 94–122. DOI: 10.1016/j.eap.2021.02.001

Hänke, Hendrik (2016). Livelihoods on the edge: farming household income, food security and resilience in southwestern Madagascar. PhD dissertation, Georg-August-Universität Göttingen. Available at https://d-nb.info/1103233858/34

Hausler, Elizabeth (2010). Building Earthquake-Resistant Houses in Haiti: The Homeowner-Driven Model. *Innovations: Technology, Governance, Globalization*, vol. 5, No. 4, pp. 91–115. DOI: 10.1162/INOV_a_00047

Healy, Timothy (2018). The Deep South: Constraints and opportunities for the population of southern Madagascar towards a sustainable policy of effective responses to recurring droughts/emergencies. Washington D.C. World Bank. Available at https://documents1.worldbank.org/curated/en/587761530803052116/pdf/127982-WP-REVISED-deep-south-V27-07-2018-web.pdf

Hoegh-Guldberg, Ove, and John F. Bruno (2010). The Impact of Climate Change on the World's Marine Ecosystems. *Science*, vol. 328, No. 5985, pp. 1523–28. DOI: 10.1126/science.1189930

Hou, Howard, M.L Lee and D.W. Sun (2020). TSMC Fulfills Green Manufacturing by Supporting the Establishment of First Private-owned Reclaimed Water Plant in Taiwan, 5 March. Available at https://esg.tsmc.com/en/update/greenManufacturing/caseStudy/32/index.html

Intergovernmental Panel on Climate Change (2022). Summary for Policymakers. In *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. Pörtner, Hans-O, and others, eds., Cambridge University Press. Cambridge, United Kingdom. Available at https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services. IPBES secretariat. Bonn. DOI: 10.5281/zenodo.3553579

International Federation of Red Cross and Red Crescent Societies (2022). Tonga: Red Cross tackles triple disaster - COVID-19, volcanic fallout, tsunami, 14 April. Available at https://www.ifrc.org/press-release/tonga-red-cross-tackles-triple-disaster-covid-19-volcanic-fallout-tsunami

Islam, S.N., and John Winkel (2017). *Climate Change and Social Inequality*. Working Paper No. 152, 17 October. Available at https://www.un.org/esa/desa/papers/2017/wp152_2017.pdf

Janzen, Daniel H. (2001). Latent Extinction — the Living Dead. *Encyclopedia of Biodiversity*, vol. 3, pp. 689–99. DOI: 10.1016/b0-12-226865-2/00173-5

Johnson, Ayodele (2021). How Africa's largest city is staying afloat, 22 January. Available at https://www.bbc.com/future/article/20210121-lagos-nigeria-how-africas-largest-city-is-staying-afloat

Keith, Ladd, and others (2021). Deploy heat officers, policies and metrics. *Nature*, vol. 598, pp. 29–31. DOI: 10.1038/d41586-021-02677-2

Kirchherr, Julian, Denise Reike and Marko Hekkert (2017). Conceptualizing the circular economy: An analysis of 114 definitions.

Works cited

Resources, Conservation and Recycling, vol. 127, pp. 221–32. DOI: 10.1016/j.resconrec.2017.09.005

Kleinhans, Jan-Peter, and Julia Hess (2021). Understanding the global chip shortages: Why and how the semiconductor value chain was disrupted. Policy Brief, 16 November. Available at https://www.stiftung-nv.de/de/publikation/understanding-global-chip-shortages

Kumasaka, Osamu, and others (2021). Planning for resettlement: building partnerships for, by, and with Indigenous peoples. *GeoJournal*, pp. 1–21. DOI: 10.1007/s10708-021-10518-y

Kuruppu, Natasha, and Reenate Willie (2015). Barriers to reducing climate enhanced disaster risks in Least Developed Country-Small Islands through anticipatory adaptation. *Weather and Climate Extremes*, vol. 7, pp. 72–83. DOI: 10.1016/j.wace.2014.06.001

LaFortune, Rachel, and others (2021). Canada: Disastrous Impact of Extreme Heat, 5 October. Available at https://www.hrw.org/news/2021/10/05/canada-disastrous-impact-extreme-heat

Li, Wenwen, and others (2018). Human-elephant conflict in Xishuangbanna Prefecture, China: Distribution, diffusion, and mitigation. *Global Ecology and Conservation*, vol. 16, e00462, 1-13. DOI: 10.1016/j.gecco.2018.e00462

Liu, Peng, and others (2016). Habitat evaluation for Asian elephants (Elephas maximus) in Lincang: Conservation planning for an extremely small population of elephants in China. *Biological Conservation*, vol. 198, pp. 113–21. DOI: 10.1016/j.biocon.2016.04.005

Lourens, Marine (2022). 'The people of Tonga are tough': Tonga battling Covid outbreak three months after volcanic eruption, 15 April. Available at https://www.stuff.co.nz/world/south-pacific/128337849/the-people-of-tonga-are-tough-tonga-battling-covid-outbreak-three-months-after-volcanic-eruption

Ma, Shuangmei, Congwen Zhu and Juan Liu (2020). Combined Impacts of Warm Central Equatorial Pacific Sea Surface Temperatures and Anthropogenic Warming on the 2019 Severe Drought in East China. Advances in *Atmospheric Sciences*, vol. 37, No. 11, pp. 1149–63. DOI: 10.1007/s00376-020-0077-8

Mejia, Martin (2022). The Tonga volcano caused an oil spill on Peru's coast. Fishermen are protesting, 19 January. Available at https://www.npr.org/2022/01/19/1074089271/peru-tonga-oil-spill-volcano

Migdal, Alex (2021). More than a billion seashore animals may have cooked to death in B.C. heat wave, says UBC researcher, 5 July. Available at https://www.cbc.ca/news/canada/british-columbia/intertidal-animals-ubc-research-1.6090774

Möller, Tessa, and others (2022). From volcanic eruptions to tropical cyclones - adaptation and disaster risk reduction are still a question of finance for small islands, 8 February. Available at https://climateanalytics.org/blog/2022/adaptation-and-disaster-risk-reduction-are-still-a-question-of-finance-for-small-islands/

National Bureu of Statistics (2021). Nigerian Capital Importation: Q4 2021, 2021. Available at https://nigerianstat.gov.ng/elibrary/read/1241154

Olajide, Oluwafemi A., Muyiwa E. Agunbiade and Hakeem B. Bishi (2018). The realities of Lagos urban development vision on livelihoods of the urban poor. *Journal of Urban Management*, vol. 7, No. 1, pp. 21–31. DOI: 10.1016/j.jum.2018.03.001

Olanrewaju, Caroline C., and others (2019). Impacts of flood disasters in Nigeria: A critical evaluation of health implications and management. *Jamba*, vol. 11, No. 1, p. 557. DOI: 10.4102/jamba.v11i1.557

Oliver-Smith, Anthony, and others (2016). Forensic investigations of disasters (FORIN): A conceptual framework and guide to research. IRDR FORIN, No. 2. Beijing. Available at https://www.irdrinternational.org/uploads/files/2020/08/n0EpdIvgoGZuwbrhioKRFLQiw5XlLfF1vIDE7tEB/FORIN-2-29022016.pdf

Pallathadka, Arun, and others (2022). Urban flood risk and green infrastructure: Who is exposed to risk and who benefits from investment? A case study of three U.S. Cities. *Landscape and Urban Planning*, vol. 223, No. 104417, pp. 1–14. DOI: 10.1016/j.landurbplan.2022.104417

Peduzzi, Pascal (2014). Sand, rarer than one thinks. Environmental Development, vol. 11, pp. 208–18. DOI: 10.1016/j.envdev.2014.04.001
Perino, Andrea, and others (2019). Rewilding complex ecosystems. *Science*, vol. 364, No. 6438, pp. 1–8. DOI: 10.1126/science.aav5570

Philip, Sjoukje Y., and others (2021). Rapid attribution analysis of the extraordinary heatwave on the Pacific Coast of the US and Canada June 2021. *Earth System Dynamics*, pp. 1–34. DOI: 10.5194/esd-2021-90

Plana, E., and others (2016). Fire and forest fires in the Mediterranean; a relationship story between forest and society. Five myths and realities to learn more. Available at http://efirecom.ctfc.cat/docs/revistaefirecom_en.pdf

Poursanidis, Dimitris, and Nektarios Chrysoulakis (2017). Remote Sensing, natural hazards and the contribution of ESA Sentinels missions. *Remote Sensing Applications: Society and Environment*, vol. 6, pp. 25–38. DOI: 10.1016/j.rsase.2017.02.001

Pressly, Linda (2021). 'Cocaine of the sea' threatens critically endangered vaquita, 13 May. Available at https://www.bbc.com/news/world-latin-america-57070814

Public-Planet Partnerships (2022). Home. Available at https://www.publicplanetpartnerships.com/

Pultarova, Tereza (2022). How satellites have revolutionized the study of volcanoes, 22 February. Available at https://www.space.com/how-satellites-revolutionized-study-of-volcanoes

Ralaingita, Maixent I., and others (2022). The Kere of Madagascar: a qualitative exploration of community experiences and perspectives. *Ecology and Society*, vol. 27, No. 1, art. 42. pp. 1–17. DOI: 10.5751/ES-12975-270142

Randrup, Claudia (2010). Evaluating the Effects of Colonialism on Deforestation in Madagascar: A Social and Environmental History. BA Thesis, Oberlin College. Available at https://digitalcommons.oberlin.edu/honors/390/

Reidy, Susan (2021). Drought relief measures to impact Taiwan's rice production, 14 June. Available at https://www.world-grain.com/articles/15418-drought-relief-measures-to-impact-taiwans-rice-production

Ritchie, Hannah, and Max Roser (2018). Urbanization. Available at https://ourworldindata.org/urbanization

Roberts, Michelle (2022). Tonga tsunami: Health warnings over toxic volcanic ash and sulphur, 19 January. Available at https://www.bbc.com/news/health-60036369

Rott, Nathan (2018). Fire Ecologists Say More Fires Should Be Left To Burn. So Why Aren't They?, 27 September. Available at https://www.npr.org/2018/09/27/649649316/fire-ecologists-say-more-fires-should-be-left-to-burn-so-why-arent-they

Schoolov, Katie (2021). Inside TSMC, the Taiwanese chipmaking giant that's building a new plant in Phoenix, 16 October. Available at https://www.cnbc.com/2021/10/16/tsmc-taiwanese-chipmaker-ramping-production-to-end-chip-shortage.html

Selig, Elizabeth R., and others (2022). Revealing global risks of labor abuse and illegal, unreported, and unregulated fishing. *Nature Communications*, vol. 13, art. 1612. DOI: 10.1038/s41467-022-28916-2

Seto, Karen C., Burak Güneralp and Lucy R. Hutyra (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences*, vol. 109, No. 40, pp. 16083–88. DOI: 10.1073/pnas.1211658109

Shaffer, L. J., and others (2019). Human-Elephant Conflict: A Review of Current Management Strategies and Future Directions. *Frontiers in Ecology and Evolution*, vol. 6, art. 235. DOI: 10.3389/fevo.2018.00235

Siddiqui, Faareha, and others (2020). The Intertwined Relationship Between Malnutrition and Poverty. *Frontiers in Public Health*, vol. 8, art. 453. DOI: 10.3389/fpubh.2020.00453

Simmon, Robert (2019). How Satellite Imagery Can Help Predict Volcanic Eruptions, 31 July. Available at https://www.planet.com/pulse/how-satellite-imagery-can-help-predict-volcanic-eruptions/

Solomonian, Leslie, and Erica Di Ruggiero (2021). The critical intersection of environmental and social justice: a commentary. *Globalization and health*, vol. 17, art. 30. DOI: 10.1186/s12992-021-00686-4

Stokstad, Erik (2020). Global efforts to protect biodiversity fall short. *Science*, vol. 369, No. 6510, p. 1418. DOI: 10.1126/science.369.6510.1418

Swain, Frank (2021). The wonder material we all need but is running out, 9 March. Available at https://www.bbc.com/future/article/20210308-rubber-the-wonder-material-we-are-running-out-of

Taj, Mitra (2022). Who Is Responsible for the 27-Mile Oil Spill in Peru? *The New York Times*, 3 February. Available at https://www.nytimes.com/2022/02/03/world/americas/peru-oil-spill.html?smid=url-share

Thompson, Vikki (2021). Canada's flood havoc after summer heatwave shows how climate disasters combine to do extra damage, 19 November. Available at https://theconversation.com/canadas-flood-havoc-after-summer-heatwave-shows-how-climate-disasters-combine-to-do-extra-damage-172187

TRAFFIC (2008). What's Driving the Wildlife Trade? A Review of Expert Opinion on Economic and Social Drivers of the Wildlife Trade and Trade Control Efforts in Cambodia, Indonesia, Lao PDR, and Vietnam. Washington D.C.: World Bank. Available at https://www.traffic.org/site/assets/files/5435/whats-driving-wildlife-trade.pdf

Tupper, Andrew (2022). Tonga's Hunga Tonga-Hunga Ha'apai eruption reinforces the value of multi-hazard early warning systems, 3 February. Available at http://naturalhazardsconsulting.com/web/index.php/2022/02/03/tongas-hunga-tonga-hunga-haapai-eruption-reinforces-the-value-of-multi-hazard-early-warning-systems/

Turvey, Samuel T., and others (2007). First human-caused extinction of a cetacean species? *Biology Letters*, vol. 3, No. 5, pp. 537–40. DOI: 10.1098/rsbl.2007.0292

Works cited

United Nations (2022). *UN weather agency to spearhead 5 year early warning plan, boosting climate action*, 23 March. Available at https://news.un.org/en/story/2022/03/1114462

United Nations Environment Programme (2019). *Environmental Rule of Law: First Global Report*. Nairobi. Available at https://stg-wedocs.unep.org/handle/20.500.11822/27279

_____ (2021). *Emissions gap report 2021: The heat is on – A world of climate promises not yet delivered*. Nairobi. Available at https://www.unep.org/resources/emissions-gap-report-2021

_____ (2022). *Sand and sustainability: 10 strategic recommendations to avert a crisis*. Geneva. Available at https://www.unep.org/resources/report/sand-and-sustainability-10-strategic-recommendations-avert-crisis

United Nations Human Settlements Programme (2018). *Lagos: City Context Report*. Nairobi. Available at https://www.globalfuturecities.org/resources/lagos-city-context-report

United Nations International Children's Emergency Fund, and World Food Program (2021). *Malnutrition among children expected to quadruple in Southern Madagascar as drought worsens, warn UNICEF and WFP*, 26 July. Available at https://www.unicef.org/press-releases/malnutrition-among-children-expected-quadruple-southern-madagascar-drought-worsens

United Nations Office for Disaster Risk Reduction (2022). *Global Assessment Report on Disaster Risk Reduction 2022: Our World at Risk - Transforming Governance for a Resilient Future*. Geneva. Available at https://www.undrr.org/gar2022-our-world-risk

United Nations University - Institute for Environment and Human Security, and United Nations Office for Disaster Risk Reduction (2022). *Rethinking risks in times of COVID-19*. Bonn. Available at http://collections.unu.edu/eserv/UNU:8833/CARICO_META_2022.pdf

van der Perre, Christophe (2022). Pigeon peas help Madagascan farmers grow food despite drought, 25 April. Available at https://www.reuters.com/business/environment/pigeon-peas-help-madagascan-farmers-grow-food-despite-drought-2022-04-25/

Vandermeulen, Valerie, and others (2011). The use of economic valuation to create public support for green infrastructure investments in urban areas. *Landscape and Urban Planning*, vol. 103, No. 2, pp. 198–206. DOI: 10.1016/j.landurbplan.2011.07.010.

Vaswani, Karishma (2022). Tonga PM counts mental health 'cost' of disasters, 15 February. Available at https://www.bbc.com/news/world-asia-60256143

Watson, Amanda H. (2021). Undersea internet cables connect Pacific islands to the world. But geopolitical tension is tugging at the wires, 19 November. Available at https://theconversation.com/undersea-internet-cables-connect-pacific-islands-to-the-world-but-geopolitical-tension-is-tugging-at-the-wires-167968

Westfall, Sammy, and Amanda Coletta (2021). Crushing heat wave in Pacific Northwest and Canada cooked shellfish alive by the millions. *The Washington Post*, 8 July. Available at https://www.washingtonpost.com/world/2021/07/08/canada-sea-creatures-boiling-to-death/

World Food Programme (2022). *2021 Climate Risk Insurance Annual Report*. Rome. Available at https://www.wfp.org/publications/2021-climate-risk-insurance-annual-report

World Meteorological Organization (2022). *World Meteorological Day 2022 - Early Warning and Early Action*. Available at https://public.wmo.int/en/resources/world-meteorological-day/world-meteorological-day-2022-early-warning-early-action

Wright, Susan (2022). Keystone species and trophic cascades. Available at https://rewildingbritain.org.uk/explore-rewilding/reintroductions-key-species/keystone-species-and-trophic-cascades

Xinhua Net (2022). Xinhua Headlines: Working to keep wandering elephants happy at forest home, 21 March. Available at https://english.news.cn/20220321/6f64354d0c024028aea513d84b2a30b6/c.html

Xu, Jianchu, R. Edward Grumbine and Philip Beckschäfer (2014). Landscape transformation through the use of ecological and socioeconomic indicators in Xishuangbanna, Southwest China, Mekong Region. *Ecological Indicators*, vol. 36, pp. 749–56. DOI: 10.1016/j.ecolind.2012.08.023

Xu, Zhenci, and others (2020). Assessing progress towards sustainable development over space and time. *Nature*, vol. 577, No. 7788, pp. 74–78. DOI: 10.1038/s41586-019-1846-3

Zhong, Raymond, and Amy Chang (2021). Drought in Taiwan Pits Chip Makers Against Farmers. *The New York Times*, 8 April. Available at https://www.nytimes.com/2021/04/08/technology/taiwan-drought-tsmc-semiconductors.html?smid=url-share

Zogib, Liza (2014). On the move - for 10000 years: Biodiversity Conservation through Transhumance and Nomadic Pastoralism in the Mediterranean. Available at https://med-ina.org/wp-content/uploads/2020/12/Transhumance-and-nomadic-pastoralism-in-the-Mediterranean-2014.pdf

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Page 7 – © ANGELOS TZORTZINIS / AFP
Local youths and volunteers gather in an open field and wait to support firefighters during a wildfire next to the village of Kamatriades, near Istiaia, northern Evia (Euboea) island on August 9, 2021.

Page 12 – © Don MacKinnon / AFP
The city of Vancouver, British Columbia, is seen through a haze on a scorching hot day, June 29, 2021.

Page 13 – © Kris Durlen / Shutterstock
Woman fanning herself with the restaurant menu to refresh and protect from the heatwave in Vancouver on June 27, 2021.

Page 16 – © Stanley Louis / AFP
People search through the rubble of what used to be the Manguier Hotel after the earthquake hit on August 14, 2021 in Les Cayes, southwest Haiti.

Page 17 – © Reginald LOUISSAINT JR / AFP
The Church St Anne is seen completely destroyed by the earthquake in Chardonnieres, Haiti on August 18, 2021.

Page 20 – © Branden Eastwood / AFP
Kayakers paddle down a portion of Interstate 676 after flooding from heavy rains from hurricane Ida in Philadelphia, Pennsylvania on September 2, 2021.

Page 21 – © Michael M. Santiago / GETTY IMAGES NORTH AMERICA / Getty Images via AFP
Abilio Viegas attempts to fix his flooded van on South Street on September 02, 2021 in Newark, New Jersey.

Page 24 – © Sebastian Barros Photography
Most of the sand for the concrete used in expanding Lagos comes from the bottom of Lagos Lagoon. Early every morning, men tugged out into the lagoon. They lower ladders from their boats, 13 to 16 feet down to the lagoon bed, take a deep breath, dive down to the bottom, fill a bucket of sand, then haul it up the ladder and tip it into the hull. Many of them are immigrants to the city, and came here eager to make it, a story that has drawn many Africans to this city. This photos series tells the extraordinary lengths some of these people go to make a living in this city.

Page 25 – © Kola Sulaimon / AFP
People attempt to pull out a car washed away by flood water on a street affected by floods following a heavy downpour, in Lugbe, Abuja, Nigeria, on September 13, 2021.

Page 28 –© ARIS MESSINIS / AFP
Firefighters work to put out a wildfire in Anavyssos, south of Athens, on September 9, 2020.

Page 29 –© Alexandros Michailidis / iStock by Getty Images
A Greek flag waves on a hill as flames approaching at the village of Gouves, on the island of Evia in Greece on August 8, 2021.

Page 32 – © Safidy Andrianantenaina / UNICEF
The large trees of Ambovombe grow following the direction of the Tioka wind which blows all year round. A little boy took advantage of the tree trunk to shelter himself from the attacks of the sandy wind.

Page 33 – © RIJASOLO / AFP
Children eat food supplements (Plumpy) that they have just received from the Doctors Without Borders (MSF) mobile clinic team in the village of Befeno, Commune Marovato, on September 2, 2021.

Page 36 – © Sam Yeh / AFP
This picture taken on March 16, 2021 shows an aerial view of the dry Ai Liao River bed in Taiwan's Pingtung county.

Page 37 – © REUTERS / Annabelle Chih
Boats sit at a pier on Sun Moon Lake with low water levels during an islandwide drought, in Nantou, Taiwan May 15, 2021.

Page 40 – © NOAA / UNICEF
On 15 January 2022, a satellite image captures another explosive eruption of the Hunga Tonga-Hunga Ha'apai volcano, located in the South Pacific Kingdom of Tonga.

Page 41 – © Mary Lyn FONUA / Matangi Tonga / AFP
This photo taken on January 16, 2022 shows destroyed beach resorts in the Hihifo district of Tonga's main island Tongatapu following the January 15 eruption of the nearby Hunga Tonga-Hunga Ha'apai underwater volcano.

Page 44 – © SAUL LOEB / AFP
Demonstrators with The Animal Welfare Institute hold a rally to save the vaquita, the world's smallest and most endangered porpoise, outside the Mexican Embassy in Washington, DC, on July 5, 2018.

Page 45 – © Tom Jefferson/St Andrews University/PA
Vaquita in the northern gulf of California.

Page 48 – © Molly Ferrill
A newborn elephant takes shelter beneath her mother.

Page 49 – © LAN LIANCHAO / AFPTV / YUNNAN FOREST FIRE BRIGADE / AFP
Aerial shot of resting herd of elephants which had wandered 500 kilometres north from their natural habitat, July 2021, in Yunnan, China

Page 54 – © GUILLERMO ARIAS / AFP
Fishermen prepare their nets at Campo Serena fishing camp, in the Gulf of California, near Puertecitos, 90 kilometers south of San Felipe, Baja California state, northwestern Mexico on March 9, 2018.

Page 58 – © Ed JONES / AFP
A worker unblocks drains on a street affected by floodwater in Brooklyn, New York early on September 2, 2021, as flash flooding and record-breaking rainfall brought by the remnants of Storm Ida swept through the area.

Page 61 – © Michael HANSON / AFP
A lone standup paddleboarder heads west on the Columbia River near Troutdale, Oregon on August 13, 2021 during an abnormal heat wave in the Pacific Northwest.

Page 62 – © Safidy Andrianantenaina / UNICEF
On 3 February 2022 in Ambovombe, Androy region, Madagascar, a struggling sorghum plantation during a Tiomena event.

Page 64 – © Faizal Abdul Aziz/CIFOR
Wild Elephant group in Sebokor Village Forest, this area is part of Padang Sugihan Wildlife Reserve - Sebokor.

Page 67 – © Reginald LOUISSAINT JR / AFP
A bulldozer clears the rubble of a building that collapsed in the earthquake in Brefet, a neighborhood of Les Cayes, Haiti, on August 17, 2021.

Page 68 – © Sam Yeh / AFP
This aerial photo taken on March 16, 2021 shows a truck riding along the empty Ai Liao river bed in Pingtung county, southern Taiwan.

Page 71 – © Sebastian Barros Photography
Sand miners in Lagos.

Page 73 – © Juan Haro / UNICEF
Klensly Cerger, 16, was orphaned ten years ago. His mother, due to the lack of means, sent him to an orphanage where they could take care of him. For the first time since then, he was returning home to spend the first vacation with his biological mother, but the earthquake changed all of his plans. His ankle was completely shattered and now he waits for the cast to be removed.

Page 74 – © Kathryn Elsesser / AFP
People rest at the Oregon Convention Center cooling station in Oregon, Portland on June 28, 2021, as a heatwave moves over much of the United States.

Page 77 – © ANGELOS TZORTZINIS / AFP
Local residents fight the wildfire in the village of Gouves on Evia (Euboea) island, second largest Greek island, on August 8, 2021.

Page 82 – © iStock by Getty Images
Drove view over yellowing, flowering Canola fields with tracks running thru and bordered by native Australian trees, Victoria.

Page 83 – © Abbie Trayler-Smith / Panos Pictures / Department for International Development
Meenakshi Dewan tends to maintenance work on the solar street lighting in her village of Tinginaput, India.

Page 85 – © OCEANIX/BIG-Bjarke Ingels Group
Located in calm, sheltered waters, near coastal megacities, OCEANIX City will be an adaptable, sustainable, scalable and affordable solution for human life on the ocean.

Page 87 – © Rodrigo Jardon
Maria Antonia is a fisher from San Felipe in Baja California, Mexico who wakes up every day before dawn to catch milkfish, corvina and sierrita, expecting to go back home with whatever God gives her on the day.

Page 89 – © Mary Lyn FONUA / Matangi Tonga / AFP
A woman carries a refilled gas container in the centre of the capital Nuku'alofa ahead of the country's first lockdown on February 2, 2022, after Covid-19 was detected in the previously virus-free Pacific kingdom as it struggles to recover from the deadly January 15 volcanic eruption and tsunami.

Page 90 – © Sebastian Barros Photography
Sand miners in Lagos.

Page 96 – © Safidy Andrianantenaina / UNICEF
In the photo, the vegetable garden of the women's association “DEFI” in Madagascar, Androy region, Ehavo village during the lean season 2022 and after the passage of Cyclone Batsirai.

Page 98 – © Abela Ralaivita / UNICEF
On 4 March 2022 in Bevoalavo village, Madagascar, Sanasoanandrasana, 25, carries her 2-year-old son Razafimandimby while he eats a Ready-to-use therapeutic food (RUTF).

Page 101 – © SAUL LOEB / AFP
Demonstrators with The Animal Welfare Institute hold a rally to save the vaquita, the world's smallest and most endangered porpoise, outside the Mexican Embassy in Washington, DC, on July 5, 2018.

Page 103 – © Safidy Andrianantenaina / UNICEF
On 9 February 2022, Bearivo village, Ambovombe district, of the Androy region in Madagascar, the villagers walk 14 kilometers to the Mandrare river to find water. The group of men, women, and children left the village early in the morning to be back home before sunset. They walk in the sand with 20 liters of water on their heads.

Page 105 – © Sebastian Barros Photography
Sand miners in Lagos.

Page 106 – © Axel Fassio/CIFOR
April 2021 acacia plantation near the village of Moussa, Yangambi - DRC.

References to disasters

For ease of reading and understandability, the names of the disasters in the following countries and regions have been abbreviated throughout the report:

“British Columbia heatwave” refers to a heatwave in the Province of British Columbia, Canada

“Haiti earthquake” refers to an earthquake in the Republic of Haiti

“Lagos floods” refers to flooding in Lagos State, the Federal Republic of Nigeria

“Hurricane Ida” refers to a storm that hit New York City, New York, the United States of America

“Mediterranean wildfires” refers to wildfires in the Mediterranean basin region, primarily the Republic of Italy, the Hellenic Republic, the Republic of Türkiye, the People's Democratic Republic of Algeria

“Southern Madagascar food insecurity” refers to food insecurity crises in the Grand South and Grand Southeast of the Republic of Madagascar

“Taiwan drought” refers to a drought in Taiwan Province of China

“Tonga volcano eruption” refers to the eruption of the Hunga Tonga-Hunga Ha’apai volcano in the Kingdom of Tonga

“Vanishing vaquita” refers to the critically endangered status of the vaquita in the Gulf of California, the United Mexican States

“Wandering elephants” refers to a migration of Asian elephants in Yunnan Province, the People’s Republic of China

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