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The Role of Science and Technology in Addressing Systemic Risks

The era of hazard-by-hazard risk reduction is over. In our increasingly complex interconnected world, risk has become systemic, challenging single-hazard approaches, and governance mechanisms of established disaster risk management institutions. We need to reflect on the systemic nature of risk in how we deal with it. Systemic understanding of risk goes far beyond previous notions and concerns. It requires a more sophisticated approach as well as innovative analytical methods at the forefront that prioritize complex causality, uncertainty, and non-linearity. We need to improve our understanding of anthropogenic systems in nature. We must identify related signals and correlations to better prepare, anticipate, and adapt. Accordingly, we must continue developing and testing the tools and approaches needed for systemic risks.

Systemic risks can be characterized by five major properties:

1. high complexity;
2. transboundary and global in nature;
3. random relationships between trigger and effects;
4. non-linear and include tipping points and science struggles to identify these tipping points in advance;
5. and often underestimated in public policy arenas and public perception due to uncertainties of point of occurrence and extent of damage [1].

COVID 19: A Systemic Risk

Current health crisis stress tests our ability to cooperate, learn and adapt in the face of deep uncertainties and rising risks, which are of course systemic in nature, that is when a hazard leads not only to negative effects in parts of the system but also threatens the entire system. With its cascading and devastating effects, the impact of COVID-19 reflects the inter-connectedness of risk, highlighting the urgent need for a concerted global effort to accelerate risk reduction efforts. It calls for an important reflection on the necessary contributions of the scientific community and the technological developments to enhance comprehensive risk management. Accordingly, we have a great opportunity for future reflection and to better organize ourselves in our approach to risk with a higher level of sophistication and integration.

New Innovations on Systemic Risks

Successful risk management depends on a scientific understanding of risk factors and drivers, and on their behaviour, as well as on the ways in which disasters are expressed and materialize in society. Social and natural sciences, alongside technology and innovation, will provide verifiable knowledge and evidence-based answers to help understand causal factors underlying risk. Additionally, observation and experimentation, explanation of principles and causes, the formulation and verification of hypotheses, the use of adapted methodologies for this purpose, and the systematization of knowledge, will help create efficient disaster risk management policies.

The global science community must come to terms with the need for a new understanding of the dynamic nature of systemic risks, new structures to govern complex risks, and develop new adaptive systems and tools for risk-informed decision-making that allows human societies to live with uncertainty. There is a need for addressing the complexity and non-linear nature of systemic risks entailing a holistic approach to hazard identification, risk assessment, and risk management. Successful risk management depends on a scientific understanding of risk factors and drivers, and on their behaviour, as well as on the ways in which disasters are expressed and materialize in society.

Social and natural sciences, alongside technology and innovation, will provide verifiable knowledge and evidence-based answers to help understand causal factors underlying risk. For example, with reference to early warning advancements, the 2004 Indian Ocean tsunami was a turning point for early warning systems and their mechanisms, and the Indian Ocean Tsunami Early Warning system was initiated with the participation of diverse stakeholder groups. However, for multi-hazards, the cross-boundary early warning remains a challenge for many different reasons. Further, early warning for slow-onset disasters (e.g. drought) has always been a challenge and the scenario of linking rapid onset, slow onset and other types of hazards needs much research and scientific backing.

Science and Technology input will add great value to [2]:

- Unpacking and revealing characteristics of vulnerability, exposure, and managing systemic risks
- Understanding the systemic nature of risk must drive innovation and systems-based solutions across all societies. For example applying a systemic risk lens in analysis, potential thematic areas for detailed examination include the relationships between human and environmental health conditions, employment and economic shifts, ecosystem services, physical and social infrastructure, and education services

- Risk-informed decision making in the context of uncertainty
- Managing systemic risks recognising that many decision-makers balk at the complexity of understanding systemic risks and the challenge of developing systems-based approaches to address multidimensional challenges in contexts of uncertainty, there is a need to offer an exploration of effective and emergent approaches to managing systemic risks to sustainable and resilient societies and ecosystems

There is also a need to re-configure risk governance. Governance of natural hazards needs to pay close attention to the interactions between human-induced, biological, and natural hazards. Inclusive governance of systemic risks can improve disaster risk governance.

Improving Links between Science and Decision-Making on Systemic Risks

The DRR community has traditionally focused much of its effort on assessing risks and providing data, information, and knowledge on the risk that is as accurate as possible. However, and despite advances in the availability and accuracy of risk-related data, models, and prediction tools - risk-informed decision-making remains the exception and not the rule. There need to be efforts in order to better integrate science and technology into policy instruments that can address systemic risks:

- Promote scientific research that contributes to the development of evidence-based public policies so that policy decisions are based on evidence. This requires clear mandates and means for data collection, data management, and data updating

- Foster dialogue between representatives of the scientific-technological community and public policy decision-makers.
- Importance of creating knowledge that is reflective of the "truth on the ground" and directly benefits local communities [3]

The essence of this is that communities and stakeholders need to be involved from the initial design period of the research, often called ''co-design,'' and that needs to be linked to implementation, which also needs to be ''co-delivery.'' This should be the future ''new normal'' of disaster research and the application of science and technology in DRR. Engage key stakeholders, including the private sector to take part in the design, planning, and implementation of recovery efforts, promoting an interdisciplinary, multidimensional, and multisectoral approach.

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Interns' Contributions

Ecosystem-based Disaster Risk Reduction (Eco-DRR)

Not all storms need to turn into disasters

By: Rochelle Scharenguivel - IUCN Intern Volunteer

INTRODUCTION

Disasters are increasing worldwide, and the population growth rates and climate change act as threat amplifiers to exacerbate the situation in many regions of the world. Disasters are often considered social constructs: they are largely determined by how society manages its environment, the vulnerabilities present, and its capacity to face adversity as well as the availability of resources for recovery.

Disaster Risk Management (DRM) has mainly been reactive rather than preventive, engineering-focused rather than based on planning and the use of natural landscape to prevent disaster risks. In fact, the Asia-Pacific Disaster Report 2019 argued that environmental degradation increases risks and that one of the strongest defences against disasters is a healthy ecosystem

KEY TERMS:

- Disaster is "a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society using its own resources" [UNISDR]
- Eco-DRR is the sustainable management, conservation, and restoration of ecosystems to reduce disaster risk by mitigating hazards and increasing livelihood resilience
- It is part of Nature-based Solutions (NbS), an umbrella term for all natural management approaches that provide for human well-being as well as biodiversity benefits

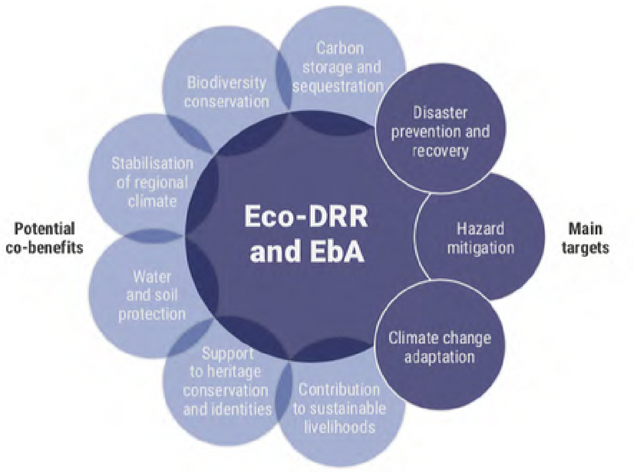
Disaster Response Units during the Japan earthquake and tsunami, 2011 (Left) and Haiti earthquake, 2010 (Right). Credits: Left [Talia Frankel, American Red Cross], Right [Tatsuya Sugiyama, Japanese Red Cross]

Why is Eco-DRR a Viable Option?

Disasters cause massive damage to the environment, while degraded environments exacerbate disaster impacts. Well managed ecosystems will protect populations from hazards as cost-effectively as engineered structures, especially when combined with preparedness measures.

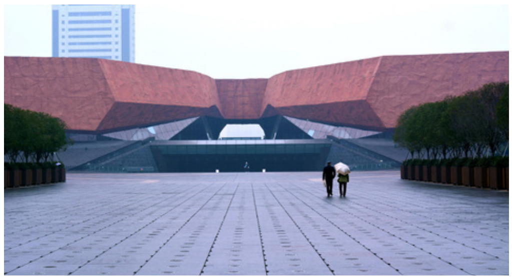
Well-managed ecosystems provide protective services among other functions that, if recognized, can be integrated into comprehensive risk management planning and risk reduction actions. Their benefits include:

- acting as natural infrastructure
- reducing physical exposure to many hazards and,
- increasing socio-economic resilience of people and communities



Because of these multiple system-wide benefits, Eco-DRR/NbS is considered to provide effective, cost-efficient, and 'no-regret' or 'low-regret' solutions for reducing disaster risk and building resilience.

In addition, hybrid infrastructure, such as a combination of grey and green infrastructure has proven to be very effective. For example, the Sponge City initiative, launched in 2016 in 16 cities across China uses green infrastructure such as permeable pavements, green rooftops, rain gardens, etc. to capture and regulate excess water year-round. It has been estimated that the Southern China floods in 2020 were not as damaging as it was in the 1998 floods was because of the investments made in nature-based solutions. Therefore, when integrated into socio-economic planning, NbS serve the dual purpose of enhancing disaster and climate resilience while providing basic services. Thus a unique opportunity presents itself where future-proofing new infrastructure and choosing green options will pay huge dividends to ensure a resilient future.



Permeable pavements in China
Source: smartcitylab.com

Types of Ecosystems and their Benefits

ECOSYSTEM	REGULATING SERVICES - HAZARD MITIGATION
Mountain forests and other vegetation on hillsides	Protects against erosion and increase slope stability by binding soil together, preventing landslides Protect against rockfall and stabilise snow reducing the risk of avalanches Reduces risk of floods by increasing infiltration of rainfall
Wetlands and flood plains	Control floods in coastal areas, inland river basins and mountain areas subject to glacial melt Stores water and releases it slowly, reducing the speed and volume of runoff Reduces the height and speed of storm surges and tidal waves
Coastal ecosystems, such as mangroves, saltmarshes, coral reeds, barrier islands, and sand dunes	Protecting against hurricanes, storm surges. flooding and other coastal hazards Coral reefs and coastal wetlands absorb (low magnitude) wave energy, reduces wave heights and reduce erosion from storms and high tides. Buffer against saltwater intrusion and adapt to (slow) sea-level rise by trapping sediment and organic matter Non-porous natural barriers dissipate wave energy and act as barriers against waves, currents, storm surges and tsunamis
Drylands	Retain moisture to ameliorate the effects of drought and control desertification Shelterbelts, greenbelts etc act as barriers against wind erosion and sand storms

[Source: UNDRR (2020)]

Case Studies

Ecosystem management for resilience through NbS is embedded in many global frameworks and is implemented in different geographical regions and ecozones for a range of hazards.

European Alps

Mountain forests have a long history of being managed for protection against avalanches and rockfall. The state provides considerable financial incentives to manage forests for hazard protection (Wehrli and Dorren, 2013)

Japan's coast

During the 2011 tsunami, coastal vegetation provided some protection by catching large debris (such as boats). As a result, the Japanese government is expanding the national park system along Japan's coast with strict land use guidelines (Onishi and Ishiwatari, 2012, UNEP and CNRD, 2014)

Niger: DRR and CCA

Sustainable dryland management in Burkina Faso/ Niger showcases innovations on traditional soil and water conservation and agroforestry techniques to increase food production and rehabilitate degraded lands (UNEP and CNRD, 2014)

Case Study: Sri Lanka

Anthropogenic climate change does not solely refer to changes in globally averaged surface temperatures, but also includes changes in atmospheric circulation, in the size and patterns of natural climate variations as well as local weather. El Niño and La Niña regional variations are expected to become more extreme in a warming climate (royalsociety.org, 2020).

Sri Lanka has experienced severe shifts in its seasonal rainfall patterns that have been accompanied by an increase in flood and drought in the past decade thus directly impacting the rural food security and incomes. While the country's wet zone reliably receives an abundance of rainfall, the intermediate and dry zones receive little to none rainfall for long periods of time.

The Dry Zone, considered the agricultural heartland, uses numerous semi-rained reservoirs and diversions referred to as tank cascade systems. This ancient tank irrigation technology optimises the use of scarce water resources and produces a plethora of positive externalities. By recycling and reusing water, it will impact the microclimate by creating cooler habitats and enhance biodiversity and agrobiodiversity. Moreover, given that the activities and maintenance of the tank systems are implemented through community participatory methodologies, it enhances social cohesion, creates employment opportunities and reduces rural-urban migration, which in turn will reduce poverty and help develop rural communities.

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Slow Onset Disasters

Changes in Mosquitoes with Increased Temperatures

By: Nashmoon Sheena - IUCN Intern Volunteer

Source: Ishara S. Kodikara—AFP/Getty Images, Times Magazine 2017

INTRODUCTION

- With rapid increases in temperatures, pest populations can either decrease or increase. This depends on the species.
- For mosquitoes, with increased temperatures, the number of eggs increases while the time to lay eggs and the incubation period is shortened.
- With increased temperatures, the overall lifespan of the mosquito decreases because it spends less time in each of the immature stages of its life cycle.

TEMPERATURE RELATED CHANGES

- In some vertebrates hosts, the arthropod borne viruses can replicate at temperatures ranging from 37°C up to 44°C, while in their ectotherm vectors it varies on the ambient temperature (as low as 15°C)
- Lipids, nucleic acids, protein structures and functions are altered with temperature changes, so it is highly likely that the properties of virions and their interactions with cellular components during replication are also modified.
- It has been shown that ligand binding affinity and catalytic rate are the key targets during temperature adaptation. Ligand affinity decreases during cold adaptation so that rapid catalysis can take place.
- Thermodynamic models suggest that at lower temperatures, increased cell binding may compensate for lower replications kinetic rates.
- Some dengue virus serotypes can undergo a temperature-dependent conformational change from a 'smooth' form at lower temperatures to a 'bumpy' form at temperatures when approaching around 37°C.
- Alphaviruses are found to enter mammalian cells through a temperature-dependent mechanism. At temperatures that inhibit virus receptor-mediated endocytosis, viral genomes enter directly at the cell membrane.
- Furthermore, silent mutations (mutations without amino acid sequence changes) occur which makes the RNA virus adapt at higher temperatures.
- The temperature could also increase the risk of arthropod-borne viruses by altering evolution, selection, and transmission.

EFFECTS ON GENE EXPRESSION & IMMUNITY

- To maintain fitness in response to stressors such as temperature organisms extensively use the regulation of gene expression to adapt their phenotypes.
- *Ae. aegypti* adult mosquitoes showed a gene alteration when reared at different temperatures. The altered genes were involved in expressing various aspects of

mosquito biology like blood-meal digestion, ROS metabolism, and mosquito innate immunity.

- Mosquito immunity consists of powerful protection in symbiotic, entomopathogenic, and mosquito-borne pathogen infections.
  To be able to defend against pathogens, mosquitoes activate several immune-signaling pathways.
- Temperature affects the functions of mosquito immunity. Larvae that have undergone thermal stress show effects on adult gene expression as well.
- According to studies, RNAi is the most significant antiviral immune response in mosquitoes. The triggering of RNAi pathways can be destabilized when mosquitoes are reared at cooler temperatures (18°C)
- The impairment of immune barriers can greatly affect mosquito interaction with symbionts, entomopathogenic organisms, and mosquito-borne organisms, and mosquito-borne pathogens but also the interactions of the latter together.
- The subtle balance between the effects of temperatures on mosquito antiviral immune responses and virus replication likely conditions the outcome of virus transmission.

Temperature & its Potential to Influence Arthropod-borne Virus Transmissions

Concepts in medical entomology

- The transmission of an arthropod-borne virus by a mosquito is controlled by both intrinsic (microbiota, mosquito, and virus genetic) and extrinsic (temperature) factors.
- The idea of vector competence is integrated into a broader one that is vectorial capacity- which is an epidemiological measure of the transmissibility of an infectious agent by a particular vector species/population.
- The mosquito survival rate and extrinsic incubation period (EIP) are said to be the most important variables that affect the vectorial capacity. The EIP is the time needed between the ingestion of a virus and the ability to transmit it. As the EIP increases the vectorial capacity decreases- so the more likely the virus will be transmitted before the vector dies.

Effects of temperature on vectorial capacity

- Temperature can affect the following parameter of the vectorial capacity:
  1. The mosquito density- relies on temperature-sensitive traits like gonotrophic cycles, and developmental time, which decides contact rates between hosts and vectors.
  2. The biting rate- it requires an active host-seeking behaviour which includes temperature-sensitive parameters. Highly anthropophilic and active mosquitoes are prone to transmit human pathogens and ensure their propagation.
  3. Mosquito survival- higher temperatures increases the time during which infected females serve as vectors.
  4. Vectorcompetence and EIP- they result from a complex combination of many intrinsic factors such as virus dynamics, virus, and vector genetic, vector physiological traits, microbiota, and immunity. So, vector competence and EIP depend a lot on temperature. Temperature can either increase or decrease the potential of arthropod-borne viruses as it affects major components of vectorial capacity.

Temperature-Dependent Factors that Influence Mosquito-borne Virus Transmission

- EIP is often used as an index of vector competence. So higher temperatures are associated with a lower EIP and enhanced vector competence in many virus-vector pairings.
- With increases in temperature virus replications rates also, mostly, increase. Since dissemination and transmission is proportional to the viral load, a lower temperature would be less advantageous for the transmission of arthropod-borne viruses.
- However, there are certain exceptions to this. The Cx. Tarsalis mosquitoes were found to be less competent for the Western Equine Encephalitis Virus (WEEV) at 32°C than at lower temperatures. Similarly, in *Ae. aegypti* infected with the Dengue Virus and with *Ae. albopictus* infected with the Chikungunya Virus, higher infection, and transmission rates were detected at lower temperatures.
- The issue of conflicting evidence arises from the fact that disparate effects of temperature affect the virus replication and vector immune responses in each virus-combination.
- Thermal exposure undergone during larval development can have effects on mosquito susceptibility to virus infections.
- During a study, it was found that the immature stages of *Ae. albopictus* reared at lower temperatures showed decreased viral dissemination when orally infected with dengue-1 virus. However, conflicting results were found with the chikungunya virus and the dengue-2 virus, where it was seen that the susceptibility to infection increased at lower temperatures. This difference could be because the interaction between the virus and the vector was controlled by factors other than temperature. Certain traits in mosquitoes, such as the adult body size, changes with the rearing temperature of immature stages. Large females are said to absorb twice the volume of blood than smaller females. This would mean that the volume of viral matter ingested by the larger female will also increase.
- When exposed to cooler temperatures at immature stages, *Ae. albopictus* grew into larger adults with increased susceptibility to the chikungunya virus. However, smaller *Ae. aegypti* and *Ae. albopictus* were more likely to become infected and disseminate the dengue-2 virus than its larger counterparts.
- It is thought that vertical transmission of viruses takes place from the females to their offspring. This is the reason why the virus persists in nature during unfavorable periods for horizontal transmission.

- Since mosquitoes are mobile and tend to move quite often between habitats, to stay within an optimal temperature, they are not quite exposed to large temperature variations.
- Microclimates found in urban lands, such as houses, tend to have higher and more stable temperatures than outdoor environments. This allows vector survival and transmission survival to persist despite adverse meteorological conditions.
- Moreover, urbanization alters the climate within cities forming warmer spots, which lead to a rise in temperature compared to the vegetated areas outside the city.
- Temperature is one of the most significant abiotic factors that affect both the vectors and the pathogens they transmit.
- There is a clear gap in information about how temperatures influence virus evolution and phenotypes. This could help understand arthropod-borne virus epidemics much better. It would also be important to find out how mosquito microbiota and immune functions impacted in viral transmission respond to temperature.
- Neglected arboviruses are expected to become increasingly important, with temperature as a determinant factor of emergence.
- It is also vital to investigate anthropophilic factors when looking at the spread of mosquito-borne diseases. Factors like human behavior, movement, and land use in relation to climate change are also potential areas to explore.

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International Symposium on Multi-Hazard Early Warning and Disaster Risk Reduction to Support Implementation of Sendai Framework for Disaster Risk Reduction 2015-2030

The international symposium on Multi-Hazard Early Warning and Disaster Risk Reduction 2020 (MHEW DRR 2020) held on 14th, 15th, and 16th of December 2020 at the BMICH, Colombo witnessed the participation of thirty-two national, regional, and international agencies responsible for tackling disaster risk in Sri Lanka.

It brought together over 2,500 participants from the Sri Lankan government, private sector, non-governmental organizations, and higher educational institutions on to one common platform. The event was jointly organized by the Disaster Management Centre (DMC), the University of Huddersfield in the UK, the Asian Disaster Preparedness Centre and the University of Moratuwa.

The Symposium included a combination of four keynote addresses and five-panel discussions that involved leading national and international policymakers and scientists. These were complemented by twenty technical sessions where 157 detailed scientific, policy and practical applications were presented and shared. The participants examined how research, science, and technology could be used to support the efforts of the implementation of the Sendai Framework for Disaster Risk Reduction towards 2030 (SFDRR).

Commenting on the successful conclusion of this three-day event, the Director-General of Disaster Management Centre Major General (Retd) Sudantha Ranasinghe said, "This international symposium was conducted at a very critical time amidst a global crisis which is still searching for a permanent solution for the COVID-19 global pandemic. The crisis has taught the world a lesson and it is time we harmonize with the environment and hold Mother Nature supreme. The world continues its life but has put humans in cages". Conference book can be freely accessed via this link: http://cabaret.buildresilience.org/2020_Symposium/img/outputs/BookIndesignV2.pdf

The culmination of the symposium is the "Colombo Declaration" where Sri Lankan Government, along with stakeholders such as the private sector, and higher education sector have committed to work together in order to improve multi-hazard early warning and reduce disaster risk. The declaration expresses deep concern at the growing frequency and intensity of extreme weather and climate-related challenges and the continuing impact of disasters, resulting in an unacceptable loss of human lives and livelihoods, displacement of people, and environmental and economic damages in Sri Lanka and across the world.

The Declaration was inspired by the UN Sendai Framework for Disaster Risk Reduction, agreed by UN member states in 2015. It includes a strong call for higher education and science to support the understanding of disaster risk and promote risk-informed decisions and risk-sensitive planning from the local to global levels. The goal is to strengthen the evidence-base in support of the implementation of the new framework.[1]
The Colombo Declaration can be accessed at http://cabaret.buildresilience.org/2020_Symposium/

Fifty-seven scientific contributions from the conference will also be published in a peer-reviewed book, titled: "Multi-Hazard Early Warning and Disaster Risks" [Amaratunga, D., Haigh, R., & Dias N. (Ed.)] to be published by Springer Nature in 2021.

Photo: Major General (Retd) Sudantha Ranasinghe (middle), Director General, Disaster Management Centre, Sri Lanka handing the Colombo Declaration to Major General (Retd) G.D.H. Kamal Gunaratne, State Secretary of Ministry of National Security, Home Affairs and Disaster Management, Sri Lanka (left)