C. S. 'Buzz' Holling, 6 December 1930 – 16 August 2019

The ecologist C. S. Holling was a visionary of change in nature and society.

C. S. 'Buzz' Holling combined science, art and environmental problem solving to inspire his colleagues and create new ways of thinking about ecological change. He expanded and deepened our understanding of how management could create ecological surprise. Through his research, collaboration and institution building he was a visionary of change in nature and society and central in the rise of resilience thinking[1].

Buzz Holling grew up in the boreal forests of Ontario, where his childhood fascination with insects grew into a passion for science. He had an early impact on ecology, as during his PhD research he developed the first mathematical theory of predation[2]. Following this work, Holling was a pioneer in applying systems approaches to behavioural and population ecology. This work led to his influential paper[3] that introduced 'resilience' — the capacity for an ecosystem to cope with disturbance while maintaining its identity.

Holling and colleagues at the University of British Columbia perceived that ecosystem management required understanding social–ecological systems, or interactive feedback systems of nature and people. They began a series of Resource Science Workshops that engaged social and natural scientists, practitioners and local people in regional planning for environmental change[4]. Their early explorations of social–ecological landscape change in British Columbia's Gulf Islands expanded into a process of participatory workshops and simulation modelling for regional environmental management known as *Adaptive Environmental Assessment and Management*[5]. This edited volume presented the work of renowned leaders of adaptive management, which explicitly uses management actions as opportunities to learn the behaviour of the ecosystem interacting with the people who use it. It is an early example of transdisciplinary research, and adaptive management has an ongoing international impact by promoting experimental and learning-oriented approaches to ecosystem management.

Buzz Holling's work on ecosystem management led him to develop new social–ecological theories. Holling identified a common dynamical pathway of human interventions in ecosystems that he represented as an adaptive cycle of growth, development, collapse and renewal[6] (Fig. 1). Holling's early work on spruce budworm outbreaks in eastern Canada showed that logging combined with spraying of insecticides intensified insect outbreaks rather than controlling them. Based on this surprise and years of experience with adaptive management, Holling focused on how initially successful human modification of ecosystems could erode the resilience of social–ecological systems. He recognized that resilient management requires continual 'safe-to-fail' experiments, disturbance and learning. Resilient systems 'stay in the game' by exploring and learning to avoid ever-shifting harmful boundaries. These ideas inspired a diverse body of research by Holling and collaborators that has continued to have wide influence within sustainability science[7].

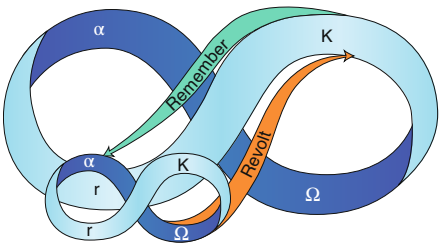

Fig. 1 | Nested adaptive cycles showing the connections among processes at larger or slower scales and smaller or faster scales. At each scale, an adaptive cycle begins with renewal (r) of system organization, eventually leading to limitation of development (K), followed by collapse to a disordered phase (Ω) that gives way to a time of creative exploration (α), culminating in a new phase of renewal. Cross-scale interactions are 'revolt', whereby collapse of the smaller-faster cycle at the right time can trigger collapse of the larger-slower cycle, and 'remember', whereby the growth phase of the larger-slower cycle influences the creative exploration of the smaller-faster cycle. Adapted from ref. [7], Island Press.

Along with research papers, Holling created new ways for people to work together. Workshops designed by Holling often stimulated new ideas. He combined rigorous interdisciplinary planning sessions with walks, field trips, art, food, warmth and humour. Many friendships and productive collaborations were formed across traditional boundaries among disciplines and between research and practice. In his time as a board member of the Beijer Institute of Ecological Economics and the Santa Fe Institute, he promoted new approaches to social–ecological systems grounded in complexity theory and real-world practice. From those experiences, he also founded the Resilience Network and then the Resilience Alliance to provide an interdisciplinary space for researchers to develop new concepts[8]. Recognizing that social–ecological research lacked an academic outlet, in 1998 Holling became the founding editor of *Conservation Ecology*, one of the first online open-access journals. This journal was renamed *Ecology and Society* (https://www.ecologyandsociety.org/) and became a major journal for research that connects social and ecological perspectives. Finally, Buzz Holling was keen to enable others, especially young scholars, to develop and test new ideas. This support was formalized in the Resilience Alliance Young Scholars network, which provided key networks for many current mid-career social–ecological researchers.

Buzz Holling received a wide range of international awards for his work. He was a Fellow of the Royal Society of Canada and a foreign Fellow of the Royal Swedish

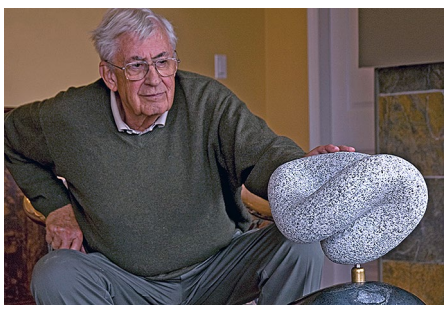

Fig. 2 | Buzz Holling with the sculpture Trajectory of Resilience (2008) by his friend Lee Gass. The sculpture is made of granite and basalt from Quadra Island near Buzz's last home. See https://leegass.com/buzz-holling/ for the full story of the sculpture. Image courtesy of Lee Gass.

Academy of Sciences. The Ecological Society of America recognized his early work on predation with the Mercer Award and his career accomplishments with the Eminent Ecologist Award. His international awards included the Austrian Cross of Honour for Science and Art, the Kenneth E. Boulding Memorial Award and the Volvo Environment Prize. He was made an Officer of the Order of Canada "for his pioneering contributions to the field of ecology, notably for his work on ecosystem dynamics, resilience theory, and ecological economics." An annotated list of his major contributions to science is presented in the Supplementary Information.

Holling received BS and MSc degrees from the University of Toronto in 1952 and a PhD from the University of British Columbia (UBC) in 1957. After receiving his PhD, he worked at the Canadian Department of Forestry in Sault Ste. Marie and Victoria. He moved to UBC in 1967 to become professor of zoology and subsequently director at the Institute of Resource Ecology. He spent 1973–1974 at the International Institute of Applied Systems Analysis (IIASA) in Austria and later served as its director from 1981–1984. He then continued his career as the first Eminent Scholar, Arthur R. Marshall Jr. Chair in Ecological Sciences in the Department of Zoology at the University of Florida. Following his retirement in 1999, he moved to Nanaimo, British Columbia, on Vancouver Island with his beloved wife Ilse to be closer to family, including three children and many grandchildren. There he continued to mentor younger scientists; advising scientific, environmental and government organizations; and creating sculptures inspired by his love of nature and by the complexity of social–ecological change (Fig. 2). ❒

Stephen R. Carpenter[1*] and Garry D. Peterson[2]

[1]*Center for Limnology, University of Wisconsin, Madison, WI, USA.* [2]*Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden.*

**e-mail: steve.carpenter@wisc.edu*

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