Encyclopedia of Earth Sciences Series

ENCYCLOPEDIA OF SNOW, ICE AND GLACIERS

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Vijay P. Singh holds the Caroline and W. N. Lehrer Distinguished Chair in Water Engineering, and is also Professor of Biological and Agricultural Engineering, and Civil and Environmental Engineering at Texas A & M University. He has authored 16 text and reference books, edited 49 books, authored 72 book chapters, and published more than 550 refereed journal articles, 320 conference proceedings papers and 70 technical reports. He is Editor-in-Chief of the Water Science and Technology Book Series of Springer, the ASCE Journal of Hydrologic Engineering, and Water Science and Engineering. He has received more than 60 national and international awards and numerous honors, including the ASCE’s Arid Lands Hydraulic Engineering Award; Distinguished Research Master Award from Louisiana State University; ASCE’s Ven Te Chow Award; AIH’s Ray K. Linsley Award; Hon. Ph.D. from University of Basilicata, Italy; and Hon. Diplomate from American Academy of Water Resources Engineers. He is a fellow of ASCE, AWRA, IE, IAH, ISAE, and IWRS. He is a member/fellow of 10 international science and engineering academies. His research interests include surface and groundwater hydrology, hydraulic engineering, irrigation engineering, and mathematical and stochastic modeling.

Pratap Singh has over 30 years experience in snow and glacier hydrology with an emphasis on modeling of snow and glacier melt runoff. He developed a snow melt model (SNOWMOD), which has been applied for streamflow simulation for snow- and glacier-fed rivers. He has published over 100 technical papers in international/national journals and co-authored with Professor V.P. Singh a book on Snow and Glacier Hydrology, published by Kluwer Academic Publishers, The Netherlands. He is Associate Editor for the Hydrological Sciences Journal, Wallingford, UK.

Umesh K. Haritashya is a faculty member in the Department of Geology at the University of Dayton, where he teaches courses in glacial geology, geomorphology and remote sensing. He has extensive experience of working on many mountain regions around the world. His research interests include debris cover glacier characterization, glacier dynamics, contribution of glaciers to sea level rise, impact of climate change on mountain glaciers, and glacier hydrology. He is also associated with NASA’s GLIMS project and is an editorial board member of the Journal of Hydrologic Engineering, the Open Hydrology Journal, and Himalayan Geology.

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Aims of the Series
The Encyclopedia of Earth Sciences Series provides comprehensive and authoritative coverage of all the main areas in the Earth Sciences. Each volume comprises a focused and carefully chosen collection of contributions from leading names in the subject, with copious illustrations and reference lists. These books represent one of the world’s leading resources for the Earth Sciences community. Previous volumes are being updated and new works published so that the volumes will continue to be essential reading for all professional earth scientists, geologists, geophysicists, climatologists, and oceanographers as well as for teachers and students. See the dustjacket of this volume for a current list of titles in the Encyclopedia of Earth Sciences Series. Go to http://www.springerlink.com/reference-works/ to visit the “Earth Sciences Series” online.

About the Series Editor
Professor Charles W. Finkl has edited and/or contributed to more than eight volumes in the Encyclopedia of Earth Sciences Series. For the past 25 years he has been the Executive Director of the Coastal Education & Research Foundation and Editor-in-Chief of the international Journal of Coastal Research. In addition to these duties, he is Research Professor at Florida Atlantic University in Boca Raton, Florida, USA. He is a graduate of the University of Western Australia (Perth) and previously worked for a wholly owned Australian subsidiary of the International Nickel Company of Canada (INCO). During his career, he acquired field experience in Australia; the Caribbean; South America; SW Pacific islands; southern Africa; Western Europe; and the Pacific Northwest, Midwest, and Southeast USA.

Founding Series Editor
Professor Rhodes W. Fairbridge (deceased) has edited more than 24 Encyclopedias in the Earth Sciences Series. During his career he has worked as a petroleum geologist in the Middle East, been a WW II intelligence officer in the SW Pacific and led expeditions to the Sahara, Arctic Canada, Arctic Scandinavia, Brazil and New Guinea. He was Emeritus Professor of Geology at Columbia University and was affiliated with the Goddard Institute for Space Studies.
Definition

White-winged Diuca Finch (*Diuca speculifera*) is a bird species that uses glaciers in the High Andes for both roosting and nesting.

Many birds are well adapted to environments seasonally dominated by snow or sea ice, but excepting penguins, birds are not generally associated with glaciers. Even flying over mountain glaciers and ice caps can be hazardous to birds, subjecting them to low oxygen pressure, low temperatures, and harsh environmental conditions such as snowstorms; mortality has been documented from glaciers in Alaska, USA and Yukon Territory, Canada (Krajick, 2002), Greenland (Pfeffer W. T., 2009, personal communication), the Himalaya (Thompson L. G., 2007, personal communication), and on Kilimanjaro (Hardy D. R., 2008, unpublished data).

Conditions on glaciers are usually not well suited for nesting in particular, being cold, actively changing through accumulation and ablation, and at times wet. Until recently the ornithological literature contained only one detailed account of nesting on a glacier, the unusual circumstance where glaciers advancing into Alaska’s Prince William Sound overran a Black-legged Kittiwake (*Rissa tridactyla*) colony (Irons, 1988). Previously used nest sites became unavailable and 77 kittiwake nests were constructed on the glacier face; all failed.

One bird species is exceptional, roosting at night within glaciers and perennially nesting on glaciers. This is the White-winged Diuca Finch (*Diuca speculifera* hereafter WWDF), found above 4,500 m elevation in the High Andes of Perú, western Bolivia, and northern Chile (Fjeldså and Krabbe, 1990). Their association with glaciers was first noted at Chacaltaya (5,200 m) near La Paz Bolivia, gathering for the night inside a crevasse (Niethammer, 1953), and Johnson (1967) provides a second-hand report — also from Chacaltaya – of the species nesting in a generalized “ice cave” at 5,300 m. Hardy and Hardy (2008) documented roosting and numerous glacier nests of WWDF in the Cordillera Vilcanota of southern Perú. Nests were found primarily on the near-vertical, retreating glacier margin of the Quelecaya Ice Cap, at elevations up to 5,300 m, over several consecutive years. Observed nests were both in situ on the ice and recently fallen. Supporting evidence, including WWDF eggs and feathers within glacier nests, remains on the ice of WWDF victimized by predation, as well as active WWDF in the area. Glacier nesting by WWDF occurs at Quelecaya Ice Cap despite subfreezing air temperature throughout the year, with extreme night-time radiational cooling whenever cloud cover is low. Furthermore, WWDF is among the highest-elevation nesting bird species of the Western Hemisphere.

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**GLACIER CAVE**

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Caves formed completely in ice are termed as glacier caves and are also very often called ice caves. Glacier caves almost always form from flowing water entering the glacier through cracks or crevasses, which are then enlarged over time, both by erosion and melting. Glacier caves serve as conduits for water through glaciers. Glacier caves are rarely extensive, and may come and go as glaciers recede. Glacier caves are very dynamic and change from year to year. Large glacier cave systems have disappeared as glaciers melt and retreat. The Paradise Glacier Cave system on Mt. Rainier was at one time several