

COVER PHOTOGRAPH AND FRONT MATTER: ELWHA RIVER, WASHINGTON, U.S.A

Source: Journal of Coastal Research, 29(4)

Published By: Coastal Education and Research Foundation

URL: https://doi.org/10.2112/1551-5036-29.4.fmii

BioOne Complete (complete.BioOne.org) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at <u>www.bioone.org/terms-of-use</u>.

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.



COVER PHOTOGRAPH





ELWHA RIVER, WASHINGTON, U.S.A.

The Elwha River, located on the north Olympic Peninsula approximately 100 km west of Seattle in Washington State, is the location of the largest dam removal project in the United States. Removal of two dams, Elwha Dam and Glines Canyon Dam constructed in 1912 and 1927 respectively, began in September 2011 and is nearing completion. Of the approximately 26 million m³ of sediment stored by the dams, up to 5.8 million m³ are anticipated to reach the nearshore Strait of Juan de Fuca within three years of dam removal. The rejuvenation of the sediment supply from the Elwha River to the marine environments of the Strait of Juan de Fuca is partially restoring nearshore habitats after a century of sediment starvation and coastal erosion. While removal of the Elwha dams is a world-scale ecosystem restoration event, the sediment processes of the Elwha drift cell continue to be disrupted due to shoreline armoring and are the focus of continued research and management discussion. (Photograph by Tom Roorda, Northwest Territories, Inc., caption by Anne Shaffer, Coastal Watershed Institute and David Parks, Washington Department of Natural Resources, Port Angeles, Washington, U.S.A., May 2013).

JOURNAL OF COASTAL RESEARCH

An International Forum for the Littoral Sciences

CHEF-HERAUSGEBER

BOOK REVIEW EDITOR

School of Environmental Sciences

J. Andrew G. Cooper

University of Ulster Coleraine, N. Ireland

MITHERAUSGEBER

jag.cooper@ulster.ac.uk

EDITOR-IN-CHIEF Charles W. Finkl

Coastal Education and Research Foundation, Inc. [CERF] Editorial Offices:

5130 NW 54th Street Coconut Creek, FL 33073, U.S.A.

MANAGING EDITOR

Allen Press Publishing Services

Lawrence, KS 66044, U.S.A.

tcandelaria@allenpress.com

Tracy Candelaria

810 E. 10th Street

e-mail: cfinkl@cerf-jcr.com (Editorial Office, Coconut Creek) CERF/JCR Website: http://www.CERF-JCR.org PUBLISHING MANAGER EDITORIA

Christopher Makowski CERF 5130 NW 54th Street Coconut Creek, FL 33073, U.S.A. cmakowski@cerf-jcr.com EDITORIAL ASSISTANT Barbara Russell CERF 5130 NW 54th Street Coconut Creek, FL 33073, U.S.A. barbara@cerf-jcr.com

ASSOCIATE EDITORS

Edward J. Anthony Coastal Geomorphology, Beach Morphodynamics Dunkeraue, France **Cecile Baeteman** Holocene Coastal Dynamics, Sea-Level Change Brussels, Belgium **Kenneth Banks** Coral Reef Geomorphology, Habitat Mapping Plantation, Florida **Patrick Barnard** Coastal Geomorphology Santa Cruz, California Lindino Benedet Oceanography, Modeling Florianopolis, Santa Catarina, Brazil David M. Bush Coastal Geology & Hazards Carrollton, Georgia Carrollton, Georgia Ilya V. Buynevich Coastal Geology Philadelphia, Pennsylvania Javier A. Carrió Sediment Processes, Marine Geology Valencia, Spain Paolo Ciavola Coastal Engineering, Sediment Transport Ferrara, Italy Raul Cociss Maritime & Coastal Law Maritime & Coastal Law Bucharest, Romania Bucharest, Romania Mark Crowell Coastal Zone Management, Shoreline Change McLean, Virginia Robert Dean Coastal Engineering & Processes Gainesville, Florida Omar Defoc **Omar Defeo** Sandy Beach Ecology, Invertebrates Montevideo, Uruguay **Reinhard Dieckman** Coastal Engineering & Geomorphology Arnis/Schlei, Germany J. Javier Diez Coastal Geomorphology Madrid, Spain Joseph F. Donoghue Coastal Morphology & Hazards Tallahassee, Florida Tallahassee, Florida Jean Ellis Aeolian Sediment Transport Columbia, South Carolina Michael S. Fenster Shoreline Change, Barrier Island Morphodynamics Richmond, Virginia Oscar Manuel Ferreira Storm Impacts, Beach Morphodynamics Faro, Portuga **Duncan M. FitzGerald** Sediment Transport, Numerical Modeling Boston, Massachusetts Boston, Massachuseus Chip Fletcher Coastal Geology Honolulu, Hawaii Kazimierz K, Furmańczyk Marine Cartography, Remote Sensi Szczecin, Poland

Gary B. Griggs Coastal Engineering & Hazards Santa Cruz, California **Pramod Hanamgond** Pramod Hanam Coastal Geomorphology Sedimentology Belgaum, India Hans Hanson Coastal Protection, Numerical Modeling Lund, Sweden Simon Haslett Paleoceanography, Coastal Evolution Wales, United Kingdom **Michael Hilton** Dune Geomorphology & Ecology Dunedin, New Zealand Carl H. Hobbs, III Coastal Geology, Sand Mining Gloucester Point, Virginia James R. Houston Sea-Level Change, Coastal Hydrodynamics Vicksburg, Mississippi Wenrui Huang Coastal Hydrodynamics & Hazards Tallahassee, Florida Tallahassee, Florida **Michael G. Hughes** Coastal Morphodynamics, Shelf Processes Canberra, ACT, Australia **Federico I. Isla** Sea-Level Change, Remote Sensing Mar Del Plata, Argentina Derek W.T. Jackson Aeolian Sediment Transport, Beach Morphodynamics Coleraine, Northern Ireland Nancy L. Jackson Coastal Geomorphology Newark, New Jersey Markes E. Johnson Paleoshores, Coastal Sand Dunes Williamstown, Massachusetts Timothy R. Keen Waves & Circulation, Numerical Modeling Stennis Space Center, Mississippi **Dieter H. Kelletat** Coastal Geomorphology, Sea-Level Change Essen/Cologne, Germany Joseph T. Kelley Sea-Level Change, Salt Marsh Ecogeomorphology Orono Maine Syed Khalil Coastal Geology & Geophysics Baton Rouge, Louisiana **Jack Kindinger** Oceanography, Coastal Resource Management St. Petersburg, Florida Antonio H.F. Klein Coastal Morphodynamics & Hazards Florianópolis, Santa Catarina, Brazil Vic Klemas . Remote Sensing, Global Environmental Change Newark, Delaware Nobuhisa Kobayashi Coastal Engineering Newark, Delaware

Vladimir N. Kosmynin Coral Reefs, Coastal Ecology Tallahassee, Florida Joseph L. Kowalski Estuarine Plant Ecology Edinburg, Texas Eanburg, Texas **Michael J. Lace** Coastal Landforms & Processes West Branch, Iowa **Stephen P. Leatherman** Barrier Islands, Beach Erosion Miami, Florida **Charles Lemckert** Environmental Fluid Dynamics Queensland, Australia **Ioannis Liritzis** Geophysical Proxy Data Rhodes, Greece Jeffrey H. List Shoreline Change Processes Woods Hole, Massachusetts Michel M. de Mahiques Sediment Processes Sediment Processe São Paulo, Brazil **Christopher Makowski** Coastal Benthic Ecology, Marine Ecosystem Monitoring Coconut Creek, Florida Coastal & Ocenographic Engineering Gainesville, Florida Nobuo Mimura Global Environmental Engineering Ibaraki, Japan **Robert Nicholls** Global Climate Change, Sea-Level Change Southampton, United Kingdom Karl F. Nordstrom Coastal Geomorphology & Dune Processes New Brunswick, New Jersey Julian Orford Gravel Beaches, Storm Events Belfast, Northern Ireland, UK Phil D. Osborne Sediment Dynamics, Beach Morphodynamics Shoreline, Washington Hugh Parker Airborne Lidar Bathymetry Adelaide, South Australia, Australia Charitha B. Pattiaratchi Physical Oceanography Crawley, Western Australia, Australia Carlos Pereira da Silva Castal Zone Management Lisbon, Portugal Michael Phillips Coastal Geomorphology Swansea, Wales, United Kingdom Orrin H. Pilkey, Jr. Coastal Geology Durham, North Carolina Durham, North Carolina Paolo A. Pirazzoli Sea-Level Changes Paris, France Nobert P. Psuty Constit Communication Coastal Geomorphology New Brunswick, New Jersey **Ulrich Radtke** Coastal Geomorphology Duisburg-Essen, Germany

COMITÉ DE REDACTION

Elijah W. Ramsey, III Coastal Image Processing Lafayette, Louisiana Richard C. Raynie Wetland/Marsh Restoration, Coastal Erosion Baton Rouge, Louisiana Kirt Rusenko Sea Turtles, Dune Restoration Boca Raton, Florida Boca Raton, Florida **Douglas J. Sherman** Coastal Hydrodynamics & Sedimentation College Station, Texas **Andrew D. Short** Coastal Geomorphology, Beach Morphodynamics Sudnay Nay, South Wales, Aus. Sydney, New South Wales, Australia Pravi Shrestha Coastal Engineering Irvine, California Alejandro J. Souza Coastal & Sediment Processes Liverpool, United Kingdom Tom Spencer Tom Spencer Biogeomorphology, Wetland Morphodynamics Cambridge, United Kingdom Marcel Stive Coastal Hydrodynamics, Sediment Dynamics Delft, The Netherlands Vallam Sundar Coastal Engineering Chennai, India Adam D. Switzer Adam D. Switzer Coastal Hazards, Sea-Level Change NTU, Singapore E. Robert Thieler E. Robert Thieler Marine Geology Woods Hole, Massachusetts Frank Van Der Meulen Coastal Zone Management, Climate Change Delft, The Netherlands Ian J. Walker Coastal Dunes, Sediment Transport Victoria, British Columbia, Canada Ping Wang Beach Morphodynamics, Sediment Transport Tampa, Florida Tampa, Florida Allan Williams Coastal Geology Swansea, Wales, United Kingdom Swansea, Wales, United Kin Harry F. Williams Hurricane Sedimentation, Paleotempestology Denton, Texas **Colin D. Woodroffe** Coastal Geomorphology, Sea-Level Change Wollongong, Australia Donald Young Coastal Plant Ecology Richmond, Virginia Robert S. Young Coastal Processes & Management Cullowhee, North Carolina

Postage paid at Coconut Creek, FL, and additional mailing offices. POSTMASTER: Send address changes to Journal of Coastal Research, Allen Press Association Management, P.O. Box 1897, Lawrence, KS 66044.

© 2013 The Coastal Education & Research Foundation [CERF].

Solution State State

RÉDACTEUR-EN-CHEF

THE COASTAL EDUCATION AND RESEARCH FOUNDATION

5130 NW 54th Street

Coconut Creek, FL 33073, U.S.A.

Officers of the Foundation

Founded in 1983 by: Charles W. Finkl, Sr., Charles W. Finkl, Jnr., Rhodes W. Fairbridge, and Maurice L. Schwartz

President & Executive Director Charles W. Finkl	r: Assi	ior Vice President & istant Director: nristopher Makowski
Vice President:	Secretary:	Executive Assistant:
Syed Khalil	Heather M. Vollmer	Barbara Russell

Board of Directors (Trustees)

J. Andrew G. Cooper	Victor Klemas	Elijah W. Ramsey, III
Robert Dean	Charles Lemckert	Maurice L. Schwartz
Charles W. Finkl	Christopher	Andrew D. Short
Gary B. Griggs	Makowski	Daniel J. Stanley
James R. Houston	Michael Phillips	Marcel Stive
Robert Huff	Orrin H. Pilkey, Jr.	Allan Williams
Joseph T. Kelley	Norbert P. Psuty	

Lifetime Members

Yong-Sik Cho Charles Lemckert Ya Ping Wang

Patron Members

Luis Antonio Buenfil-Lopez Georges Chapalain Nicholas K. Coch	Carl H. Hobbs, III Timothy W. Kana Bedoor Adel Mohammad	Giovanni Randazzo Harley Winer Robert S. Young
Mark Crowell	Norbert P. Psuty	

The Coastal Education and Research Foundation [CERF] is a nonprofit society dedicated to the advancement of the coastal sciences. The Foundation is devoted to the multi-disciplinary study of the complex problems of the coastal zone. The purpose of CERF is to help translate and interpret coastal issues for the public and to assist professional research and public information programs. The Foundation specifically supports and encourages field and laboratory studies on a local, national, and international basis. Through the medium of scientific publications, television, and radio CERF brings accurate information to the public and coastal specialists on all aspects of coastal issues in an effort to maintain or improve the quality of shoreline resources.

Because CERF is concerned with broad environmental issues, our efforts concentrate on significant problems such as maintenance of good quality (potable) water with adequate supply, and hazards associated with potential beach erosion, flooding, and susceptibility of developed shorelines to storm surge and wave attack. By focusing attention on these potential man-made and natural hazards, it is hoped that our research efforts will help others improve the quality of life in diverse coastal areas. CERF thus aims to stimulate awareness of coastal (marine and freshwater shorelines) land and water problems; initiate and foster research and innovation to promote long-term coastal productivity; establish an educational forum for the debate of contentious coastal issues; and develop new principles and approaches for enlightened coastal management, and encourage their adoption and use.

CERF is associated with the Department of Geosciences at Florida Atlantic University (FAU) in Boca Raton, Florida, and one of the main editorial offices for the *Journal of Coastal Research* (JCR) is located at the University. This partnership provides a basis for cooperative investigation, in private and public sectors, of biophysical resources found in open and naturally protected coastal regions, estuaries, large inland bodies of water bounded by shorelines, wetlands, and other coastal environments. Multidisciplinary studies at FAU's Department of Geosciences brings together experts from various fields in remote sensing, geographic information science, spatial ecology, environmental studies, marine biology, coastal geology, geography, and coastal engineering. \Box CERF MEMBERSHIP \Box

Members are individuals that support the aims of the foundation through personal and group efforts or by donations. Memberships are available in different categories with privileges.

Subscription information is available online at www.cerf-jcr.org. Subscriptions office: Allen Press, Inc., P.O. Box 1897, Lawrence, KS 66044, U.S.A. CERF@allenpress.com

Editor-in-Chief

Charles W. Finkl Ph.D., CSci, CMarSci, FIMarEST, CPGS, CPSSc, PWS

Dr. Charles W. Finkl is President and Executive Director of the Coastal Education & Research Foundation [CERF], publisher of the JCR. Charlie, a founding editor of the Journal of Coastal Research, has served as Editor-in-Chief for the past 27 years. He is a Research Professor in the Department of Geosciences at Florida Atlantic University in Boca Raton, Florida. He received his Bachelor and Master of Science degrees from Oregon State University and the Ph.D. from the University of Western Australia. He is a member of more than 20 professional societies and has published more than 200 professional papers, books, and reports. He is a Chartered Marine Scientist (CMarSci) [Institute of Marine Engineering, Science and Technology], Certified Professional Geological Scientist (CPGS) [American Institute of Professional Geologists (AIPG),], Certified Professional Soil Scientist (CPSSc) [American Registry of Certified Professionals in Agronomy, Crops, and Soils], and a Professional Wetland Scientist (PWS) [Society of Wetland Scientists]. Charlie has field experience in parts of the USA, Caribbean area, Brazil, Honduras, Russia, South Africa, Western Europe, Australasia, and South Pacific islands. He is also the Series Editor of the Encyclopedia of Earth Sciences Series that is published by Springer (Germany). There are more than twentyeight volumes in the Series and about twenty-five are available online. Charlie also serves on the Editorial Board of the International Journal of Environmental Studies (Routledge) and is an occasional peer reviewer for many other professional journals.

Charlie has interests and expertise in the general areas of surficial geology, coastal and marine geomorphology (including coastal classification), coastal/marine biophysical environments, exploration geochemistry, soils and weathering (regolith geology), coastal zone management and engineering applications or impacts on natural systems (including erosion control and shore protection), coastal hydrology including submarine freshwater and mineralized seeps, subaerial and marine structural geology, natural hazard mitigation in coastal zones, marine environments and coastal wetland protection and restoration, and remote sensing (*e.g.* land cover classification in coastal wetlands, advection-diffusion turbidity plumes in coastal waters, delineation of bottom types and sand resources), effluent disposal and pollution of wetlands and estuaries, water resources mapping and conservation, time series studies of wetland hydroperiod and soil moisture.

CERF Foundation Meetings International Coastal Symposiums (ICS)

The International Coastal Symposium (ICS) was originally set up by Per Bruun (deceased) and Charlie Finkl as the official meeting of the Coastal Education & Research Foundation (CERF), with the first meeting being held in Hilton Head, South Carolina, in 1993. After the repeated success of these meetings, CERF moved the ICS to the international scene holding these conferences in conjunction with local sponsors in Australia, Brazil, Iceland, New Zealand, Northern Ireland, Poland and Portugal. The ICS brings together delegates from all over the world to collaborate and discuss the most current coastal research studies and projects. The ICS 2014, which is scheduled to be held from April 13–17 in Durban, South Africa, will be a grand celebration of CERF and the JCR, marking the 30th Anniversary for both. For more information, please visit www.cerf.jcr.org.



JOURNAL OF COASTAL RESEARCH

An International Forum for the Littoral Sciences



Supporting Scientific Organizations

- AZTI Tecnalia [Pasaia, Spain; www.azti.es/]
- Coastal and Hydraulics Laboratory (CHL), US Army Corps of Engineers[®] [Vicksburg, Mississippi, U.S.A.; http://chl.erdc.usace.army.mil/]
- Coastal and Marine Geology Program (CMGP), U.S. Geologic Survey (USGS) [Reston, Virginia, U.S.A.; http://marine.usgs.gov/]
- Coastal Research Laboratory (CRL), University of South Florida [Tampa, Florida, U.S.A.; http://crl.usf.edu/]
- Commission on Coastal System (CCS), International Geographical Union (IGU) [http://www.igu-ccs.org/]
- Consorzio Nazionale Interuniversitario per le Scienze del Mare (Co.N.I.S.Ma.) [Rome, Italy; www.conisma.it/]
- Deltares Institute [Delft, The Netherlands; http://www.deltares.nl/en/coast-sea]
- Department of Geosciences, Florida Atlantic University (FAU) [Boca Raton, Florida, U.S.A.; http://www.geosciences.fau.edu/]
- e-Geo Center for Geographical and Regional Planning Studies [Lisbon, Portugal; http://e-geo.fcsh.unl.pt/]
- Institute of Marine and Coastal Sciences (IMCS), Rutgers University [New Brunswick, New Jersey, U.S.A.; http://marine.rutgers.edu/main/]
- Louisiana Coastal Protection & Restoration Authority (CPRA) [Baton Rouge, Louisiana, U.S.A.; www.coastal. louisiana.gov/]
- Royal Belgian Institute of Natural Sciences: Management Unit of the North Sea Mathematical Models (**MUMM**). [Brussels, Belgium; www.mumm.ac.be/]

Aims and Scope of the Journal

Journal of Coastal Research, an International Forum for the Littoral Sciences, is dedicated to all aspects of coastal research. These include geology, biology, geomorphology (physical geography), climate, littoral oceanography, hydrography, coastal hydraulics, environmental (resource) management, engineering, and remote sensing. Although each field functions effectively within its own purview, the cross-disciplinary nature of coastal studies requires familiarity with other fields as well. Hence, the scope of topics is necessarily broad in order to address the complexity of coastal biophysical and socio-economic interactions. Because of the wide range of interrelated topics, the journal invites original contributions and manuscripts dealing with theory, methodology, techniques, and field or applied topic studies on interdisciplinary coastal issues.

The journal encourages the dissemination of knowledge and understanding of the coastal zone by promoting cooperation and communication between specialists in different disciplines. Natural scientists, for example, are encouraged to collaborate with professionals in other fields to prepare contributions relating to the coastal zone that foster increased appreciation of coastal environments and processes. By means of this journal, with its scholarly and professional papers, systematic review articles, book and symposia reviews, communications and news, and special topical issues, an international forum for the development of integrated coastal research is provided.

Advertising, Editorial, and Subscription Information

Advertising and Editorial Office: All advertising and editorial correspondence should be sent to Dr. Charles W. Finkl, Editor-in-Chief, *Journal of Coastal Research*, 5130 NW 54th Street, Coconut Creek, FL 33073, U.S.A. PHONE: 828-333-2300. E-MAIL: cfinkl@cerf-jcr.com.

Subscription Information: The *Journal of Coastal Research* is a bimonthly publication. Calendar-year (2013) print and online subscription prices for the JCR are: \$115.00 for US CERF members / \$125.00 for International CERF members (\$95.00 for online only), and \$519.00 for US institutions / \$541.00 for International institutions (\$437.00 for online only). Additional surface charges may apply to subscribers located outside of the USA. For additional membership and subscription forms and information, please go to www.CERF-JCR.org. To obtain a membership or subscription form by mail, please send request to *Journal of Coastal Research*, P.O. Box 7065, Lawrence, KS 66044. Back Issues and Special Issues of the JCR, when available, can be directly purchased at www.CERF-JCR.org.

The Journal of Coastal Research is currently surveyed in Applied Science & Technology Abstracts; Applied Science & Technology Index (H.W. Wilson); Aquatic Sciences & Fisheries Abstracts; BIOBASE; Biological Abstracts; BIOSIS Previews (Thomson); CAB International Abstracts (CABI); CSA Civil Engineering Abstracts (ProQuest); Current Awareness in Biological Sciences (Elsevier); Current Contents/Agriculture, Biology, & Environmental Sciences (Thomson); Ecology Abstracts (ProQuest); Environmental Sciences & Pollution Management; GeoAbstracts [Geographical Abstracts: Physical Geography; Ecological Abstracts; Geological Abstracts; GEOBASE] (Elsevier); GeoRef; Meteorological & Geoastrophysical Abstracts (ProQuest); Oceanic Abstracts (ProQuest); Oceanographic Literature Review (Elsevier); Physical Sciences Digest (CSA, Ebsco); Pollution Abstracts (ProQuest); Referativnyi Zhurnal; Science Citation Index; SciSearch (Thomson); SCOPUS; Water Resources Abstracts (Bethesda); Zoological Record (Thomson).