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Discussion of Hansen, J.M.; Aagaard, T., and Kuijpers, A., 2015. Sea-Level Forcing by Synchronization of 56- and 74-Year Oscillations with the Moon's Nodal Tide on the Northwest European Shelf (Eastern North Sea to Central Baltic Sea). *Journal of Coastal Research*, 31(5), 1041–1056.

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In This Issue:

CERF Regional Vice Presidents

Discussion of Hansen, J.M.; Aagaard, T., and Kuijpers, A., 2015. Sea-Level Forcing by Synchronization of 56- and 74-Year Oscillations with the Moon's Nodal Tide on the Northwest European Shelf. *Journal of Coastal Research*, 31(5), 1041-1056.

Reply to Schmith, T.; Thejll, P., and Nielsen, J.W., 2016. Discussion of Hansen, J.M.; Aagaard, T., and Kuijpers, A., 2015. *Journal of Coastal Research*, 31(5), 1041-1056.

Message from Nobuo Mimura, President of Ibaraki University

35th International Geological Congress

Wave Climate, Storminess, and Northern Hemisphere Teleconnection Patterns Influences: The Outer Bristol Channel, South Wales, U.K.

Coastal Research Library Announcement

Encyclopedia of Estuaries

Behavioral Release Condition Score of Bull and Bonnethead Sharks as a Coarse Indicator of Stress

Physical and Biological Alterations Following Dredging in Two Beach Nourishment Borrow Areas in South Carolina's Coastal Zone

CCS Newsletter Announcement

Assessing the Resilience of Coastal Systems: A Probabilistic Approach

Membership Options

CERF Website

Publish Your Photos

CERF Board of Directors

JCR Editorial Board

CERF Lifetime Members

CERF Patron Members

New CERF Members 2015-2016

Current CERF Members

JCR Outside Reviewers 2015

JCR Current Issue, Cover Photo

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Coastal Education and Research Foundation *[CERF]* is pleased to announce our newly appointed Regional Vice Presidents (RVP), who throughout the international scientific community continue to provide outstanding representation of our coastal research society. Please join us in honoring the following individuals for their tremendous service and support of CERF and the JCR.

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Vic Semeniuk, Ph.D.
Andrew D. Short, Ph.D.

CERF RVP (Southeast Asia)

Nobuo Mimura, D.Eng.

Nobuo Mimura, D.Eng., is currently serving as the President of Ibaraki University. His academic areas of expertise are global environmental engineering, coastal engineering, and adaptation policy to climate change. Dr. Mimura has also been a member of the advisory committees for Ministry of Foreign Affairs, Ministry of Infrastructure, Land and Transportation, Ministry of the Environment and Ministry of Education, Culture, Sports, and Science and Technology.

CERF RVP (North America)

James R. Houston, Ph.D.

Jim Houston, Ph.D., is Director Emeritus of the U.S. Army Engineer Research and Development Center (ERDC), which includes all the research and development laboratories of the Corps of Engineers. He managed one of the most diverse research organizations in the world – seven laboratories at four geographical sites, with over 2,000 employees and an annual program budget of $1.3 billion. Dr. Houston has published over 130 technical reports and papers and has received several honors and awards including three Presidential Rank Awards and the National Beach Advocacy Award.

Vic Klemas, Ph.D.

Vic Klemas, Ph.D., is Professor Emeritus in the University of Delaware's College of Earth, Ocean, and Environment. He directed UD's Applied Ocean Science Program from 1981-98, and he has co-directed UD's Center for Remote Sensing for more than 30 years. Dr. Klemas has served on six scientific committees of the National Research Council and received a number of awards, including, in November 2010, the Science Prize of the Republic of Lithuania. The honor recognized his lifetime achievements in applying remote sensing and other advanced techniques to study coastal ecosystems.

Orrin H. Pilkey, Jr., Ph.D.

Orrin H. Pilkey, Ph.D., is a James B. Duke Professor Emeritus of Geology within the Division of Earth and Ocean Sciences and Director Emeritus of the Program for the Study of Developed Shorelines (PSDS) in the Nicholas School of the Environment and Earth Sciences at Duke University. Since 1965, Dr. Pilkey has been at Duke University with one-year breaks with the Department of Marine Science at the University of Puerto Rico, Mayaquez, and with the U.S. Geological Survey in Woods Hole, Massachusetts. His research career started with the study of shoreline/continental shelf sedimentation, progressed to the deep sea with emphasis on abyssal plain sediments, and back to the nearshore with emphasis on coastal management. Dr. Pilkey has published more than 250 technical publications and has authored, coauthored, or edited 39 books.

Continued on Next Page

CERF RVP (South America)

Omar Defeo, D.Sc.

Omar Defeo, D.Sc., is a professor in the Marine Science Unit at the Universidad de la República in Uruguay. He is also among a select group of ecologists worldwide working on sandy beach ecosystems and how they are threatened by climate change. For the past 15 years, Prof. Defeo has also been involved in artisanal shellfisheries, ecology, and conservation of coastal marine invertebrate biodiversity research in Latin America, primarily in Mexico and Chile.

CERF RVP (Western Europe)

Carlos Pereira da Silva, Ph.D.

Carlos Pereira da Silva, Ph.D., is the Director of e-GEO within the Research Centre for Geography and Regional Planning at the Universidade Nova de Lisboa, Portugal. Dr. Pereira da Silva's research interests are mainly focused on coastal zone management, with specific emphasis in beach management, public participation studies, and carrying capacity. A long time supporter of CERF and the JCR, in April 2009, he served as the local Chair and Co-organizer of the 10th International Coastal Symposium (ICS) that took place in Lisbon, Portugal.

Michael Phillips, Ph.D.

Professor Mike R. Phillips (BSc, PGCE, MSc, PhD, MIEnvSc, FRGS) serves as Pro Vice-Chancellor of Research, Innovation, Enterprise, and Commercialization at the University of Wales Trinity Saint David (Swansea Metropolian). Professor Phillips research expertise includes coastal processes, morphological change and adaptation to climate change and sea-level rise. Consultancy includes beach replenishment issues and developing techniques to monitor underwater sediment movement to inform beach management. He is widely published and recently organized a session on Coastal Tourism and Climate Change at UNESCO Headquarters in Paris as part of his role as a member of the Climate Change Working Group of the UNEP Global Forum on Oceans, Coasts, and Islands.

Marcel J.F. Stive, Ph.D.

Until 2010, Marcel Stive, Ph.D., was Scientific Director of the Water Research Centre Delft, which is now embedded in the Delft Research Initiative Environment. He currently holds the positions of: Chair of Coastal Engineering in the Section of Hydraulic Engineering and Department Head of Hydraulic Engineering at Delft University of Technology. Dr. Stive was recently appointed Knight in the Order of the Dutch Lion in theatre the Rijswijkse Schouwburg in Rijswijk. He was presented with this award for his outstanding record as a top researcher, much consulted expert, distinguished engineer, and inspiring teacher.

CERF RVP (Eastern Europe)

Kazimierz K. Furmańczyk, D.Sc.

Kaz Furmańczyk, D.Sc., is currently Full Professor at the University of Szczecin and the Head of the Remote Sensing and Marine Cartography Unit at the Institute of Marine and Coastal Sciences. Author and co-author of over 100 scientific publications including books (2) and chapters, journal articles, abstracts, and conference papers. Contributions are mainly in the disciplines of remote sensing, coastal sciences, hydrology, and oceanography. In May 2011, he served as the local Chair and Co-organizer of the 11th International Coastal Symposium (ICS) that took place in Szczecin, Poland.

CERF RVP (Oceania)

Charles Lemckert, Ph.D.

Charles Lemckert, Ph.D., is the Head of Discipline of Civil Engineering at Griffith University's School of Engineering. He has active research interests in the fields of physical limnology, coastal systems, environmental monitoring techniques, environmental fluid dynamics, coastal zone management, and engineering education. Along with his postgraduate students and research partners, Dr. Lemckert is undertaking research studies on water treatment pond design (for recycling purposes), the dynamics of drinking water reservoirs, the study of whale migration in southeast Queensland waters, and ocean mixing dynamics. In 2007, he served as the local Chair and Co-organizer of the 9th International Coastal Symposium (ICS) along the Gold Coast of Australia.

Vic Semeniuk, Ph.D.

Vic Semeniuk, Ph.D., is a natural history research scientist, specialising in coastal, estuarine and wetland environments, and mangrove and tidal flat environments. He has 45 years experience in scientific research in Australia, Europe, Canada, the USA, Ireland, the United Kingdom, and South Africa. Dr. Semeniuk is currently the Director of the Research & Development Firm, the V & C Semeniuk Research Group, and has over 130 publications in refereed scientific journals. He also has a proactive interest in conservation and coastal management, and has published multiple scientific works directly and indirectly leading to this objective.

Andrew D. Short, Ph.D.

Andy Short, Ph.D., served as the Director of the Coastal Studies Unit at The University of Sydney and has been the National Coordinator of the Australian Beach Safety and Management Program in cooperation with Surf Life Saving Australia. Dr. Short is mainly interested in the processes and morphology of coastal systems. His present research focuses on the beach and barrier systems of Australia, as it relates to the morphodynamics of representative systems in variable wave and tide environments, and in the nature, hazards, and usage of all Australia beach systems.

Discussion of Hansen, J.M.; Aagaard, T., and Kuijpers, A., 2015. Sea-Level Forcing by Synchronization of 56- and 74-Year Oscillations with the Moon's Nodal Tide on the Northwest European Shelf (Eastern North Sea to Central Baltic Sea). *Journal of Coastal Research*, 31(5), 1041–1056.

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ABSTRACT

We criticize important aspects of the analysis presented in Hansen, Aagaard, and Kuijpers (2015) (hereafter "HAK") and thereby cast doubt on their conclusions. HAK claim that 18.6-year variations in sea level are supported by tidal theory, but this is not the case; therefore, the existence of such variations must be explicitly shown. We calculated the amplitude spectrum of the annual sea level by harmonic analysis and found no significant peaks at the periods claimed by HAK. Next, we used results given by HAK to reconstruct their decomposition and formed the residuals by subtracting the decomposition from the original data. We found that the variability near 18.6 years is present in the residuals, showing that the decomposition by HAK does not describe this variability. This motivated us to redo HAK's analysis, and we found a seven times lower amplitude for the 18.6-year periodicity than claimed by HAK. Finally, we discuss HAK's mode selection criteria, based on correlation coefficients of trending series, and find them invalid. Therefore, we performed a significance test based on a Monte Carlo technique and conclude that none of the modes identified by HAK are statistically significant.

ADDITIONAL INDEX WORDS: *Lunar nodal, spectral peak, residual, significance, sea-level rise.*

INTRODUCTION

Hansen, Aagaard, and Kuijpers (2015) (hereafter "HAK") present an analysis of annual mean sea level from the northwest European shelf in terms of the lunar nodal tide and its subharmonics. They combine 26 tide gauge records, corrected for glacio-isostatic adjustment (GIA), to form a common curve of annual average sea levels representing the region. We take the results from this work as given and proceed with analysis of the provided annual sea-level series (Hansen, personal communication).

HAK state that there must be an 18.6-year oscillation in the sea level due to the lunar nodal oscillation. Motivated by this, they apply a sine regression technique to identify the 18.6-year, and other, oscillatory components in addition to a long term trend. It is this analytical part of HAK's work that we find flawed: HAK has misunderstood tidal theory and there are statistical errors as well as an unnecessarily complex decomposition method.

In what follows, we describe each of our points of criticism in detail, each of which are independent, *i.e.* they do not assume the validity of any of the other points.

 Continued on Next Page

EXISTENCE OF THE 18.6-YEAR PERIODICITY IN ANNUAL SEA LEVEL

A pivotal point in the argumentation of HAK is the existence of a predominant 18.6-year periodicity in sea level due to the Moon's nodal tide. However, the astronomical tide forcing anticipates an 18.6-year periodicity in the tidal range (*e.g.*, Parker, 2007) or, in other words, a modulation of the tidal constituents, which causes no net transport of water, meaning no sea-level signal. This does not preclude the existence of an 18.6-year signal in the sea level regionally, as showed by Baart *et al.* (2012), but implies that the presence of the 18.6-year signal in the sea level must be explicitly demonstrated in each individual case.

We therefore performed a harmonic analysis of the observed, GIA-corrected, annual sea-level data from the eastern North Sea to the central Baltic given in HAK (their Figure 2, lower panel, thin black curve). The resulting amplitude spectrum, calculated by the successive fitting of sine curves to the observed sea-level data, after removal of the linear trend is shown in Figure 1.

The spectrum does not show any outstanding amplitude near 18.6 years, nor at the other periodicities identified in the analysis by HAK, which are all marked on the plot. This casts severe doubt on focusing on exactly these periods as HAK do.

EXAMINING THE DECOMPOSITION GIVEN IN HAK

Examination of the residuals, here being the original annual sea-level series minus its decomposition, is good practice in any statistical decomposition of a time series (*e.g.*, von Storch and Zwiers, 1999). We therefore calculated the residuals by using the original data and the decomposition parameters (period, amplitude, and culmination) given in HAK (their Table 2b). The decomposition is shown in the upper panel of Figure 2. Inspecting this reveals no convincing correspondence between the original series and the decomposition apart from the trend.

To investigate this in more detail, we calculated the residuals, shown in the middle panel of Figure 2, and their autocorrelation function (ACF) shown in the lower panel of Figure 2.

We note that the ACF of the residuals appears cyclic with large positive values near 18.6 years and multiples of this value and large negative values in between. This means that the statistical decomposition in periodic components by HAK has not properly described any variability near 18.6 years. Therefore, we do not believe that the parameters (period, amplitude, and culmination) given by HAK (Table 2b) refer to a harmonic decomposition of the original annual sea-level series.

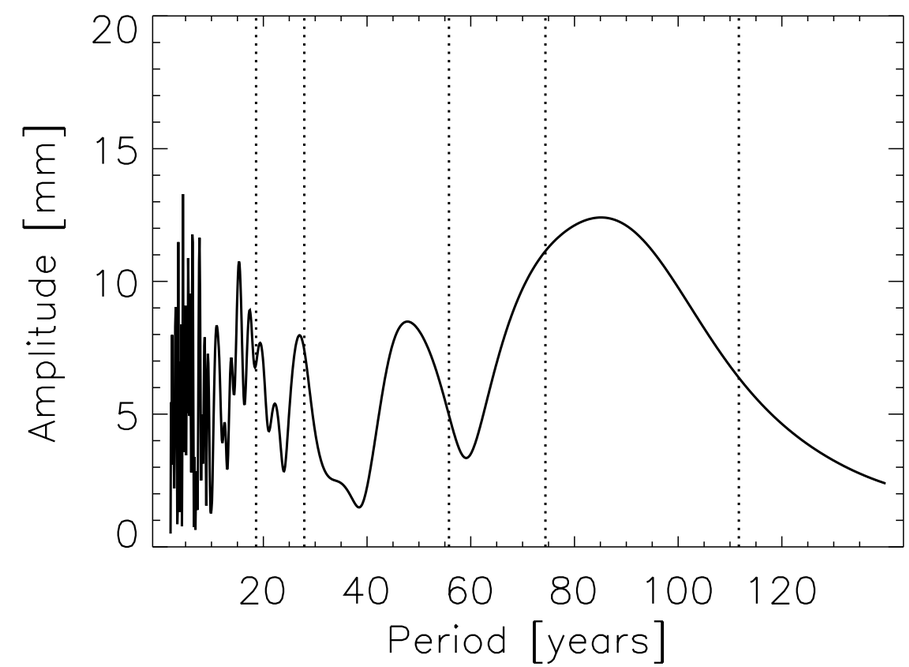

Figure 1. Amplitude spectrum of annual sea-level data from HAK, calculated by successive sine curve fitting on the linear detrended data. Vertical dotted lines indicate periods identified in HAK's analysis.

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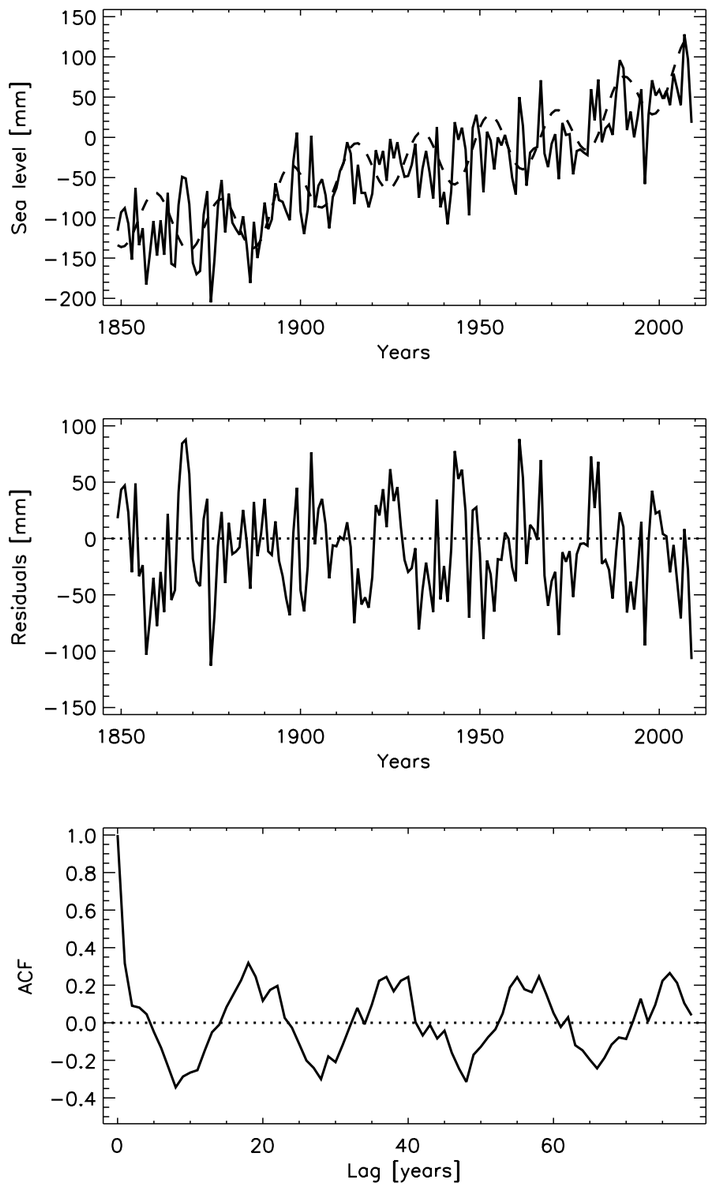

Figure 2. The decomposition given in HAK. Upper panel: Observed annual sea level, with decomposition as dashed line. Middle panel: Residuals equal observed annual sea-level data minus decomposition. Lower panel: Auto-correlation function of the residuals.

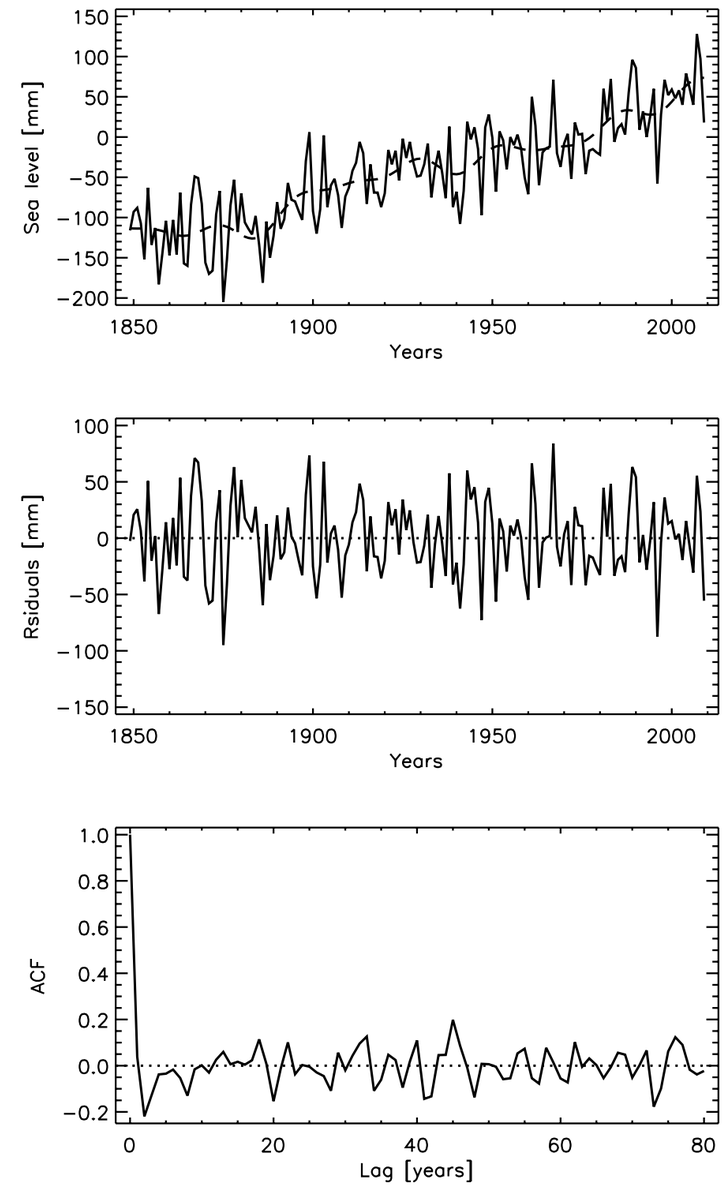

Figure 3. The decomposition estimated in this paper. Upper panel: Observed annual sea level, with decomposition as dashed line. Middle panel: Residuals equal observed annual sea-level data minus decomposition. Lower panel: Autocorrelation function of the residuals.

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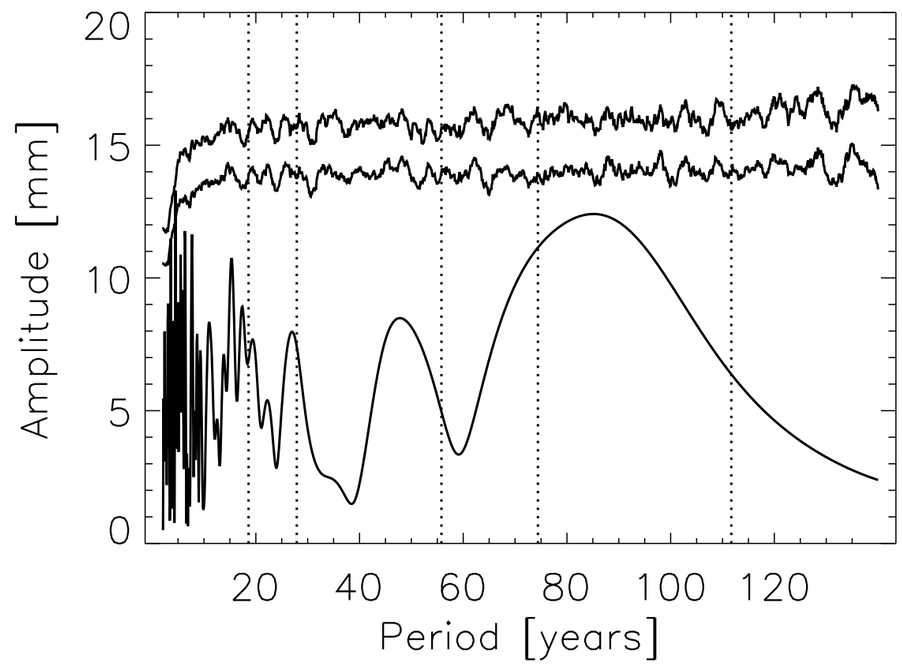

Figure 4. Selected upper percentiles (95% and 99%) of null hypothesis amplitudes as a function of period. See text for details. Also shown is the result of the harmonic analysis from Figure 1.

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Reply to Schmith, T.; Thejll, P., and Nielsen, J.W., 2016. Discussion of Hansen, J.M.; Aagaard, T., and Kuijpers, A., 2015. Sea-Level Forcing by Synchronization of 56- and 74-Year Oscillations with the Moon's Nodal Tide on the Northwest European Shelf (Eastern North Sea to Central Baltic Sea). *Journal of Coastal Research*, 31(5), 1041–1056.

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For the convenience of the readers, our basic results are shown in Figure 1. We identified five individual oscillations (upper panel), including a sea-level amplitude of 70 mm (top–bottom [t-b] of the 18.6-year oscillation caused by the lunar nodal oscillation (LNO), whereas Schmith, Thejll, and Nielsen, with their method, found other spectra and found that the amplitude effect of the LNO would be only on the order of 10 mm [t-b] (*i.e.* one-seventh of what we found). These differences are neither strange nor inexplicable but are caused by the two fundamentally different methods (see section below).

Such identification of oscillators and general trends over 160 years would be of great importance for distinguishing long-term, natural developments from possible, more recent anthropogenic sea-level changes. However, we found that a possible candidate for such anthropogenic development, *i.e.* the large sea-level rise after 1970, is completely contained by the found small residuals, long-term oscillators, and general trend. Thus, we found that there is (yet) no observable sea-level effect of anthropogenic global warming in the world's best recorded region.

KNOWN SEA-LEVEL EFFECTS OF THE LUNAR NODAL OSCILLATION

Schmith, Thejll, and Nielsen generally found agreement—within uncertainties—with our identified parameters (shown in their Table 1), but with the important exception that the sea-level amplitude of the 18.6-year oscillation is maximally one-seventh (*i.e.* around 10 mm) of our finding (70 mm; t-b). This is important, because the amplitude of the 18.6-year oscillation, in our opinion, is larger than any other oscillation of the system.

However, such small amplitudes of the 18.6-year LNO as suggested by Schmith, Thejll, and Nielsen are strongly contrasting both theoretical and observed amplitudes of the 18.6-year oscillation. It is generally agreed that the theoretical, mean amplitude is around 40–50 mm [t-b] if the globe was completely covered with one ocean (cf. Baart *et al.*, 2012) and that the amplitudes are largest at high latitudes and smallest near the equator. At North Sea–Baltic Sea latitudes, the theoretical amplitude should be on the order of 30–40 mm (t-b; *cf.* Woodworth, 2012). For Stockholm at the outskirt of our test area, Wróblewski (2001) calculated a theoretical equilibrium amplitude of 14.4 mm [t-b].

However, when turning from theory to measurements Woodworth, Shaw, and Blackmann (1991) found real amplitudes between 88 and 402 mm [t-b] in 13 records around the British Isles corresponding to a mean amplitude of 211 mm [t-b], whereas Yndestad, Turrell, and Ozhigin (2008) found by wavelet analysis an amplitude of 80–90 mm at Aberdeen (84 mm in Woodworth, Shaw, and Blackmann, 1991). In the long Stockholm curve, Yndestad, Turrell,

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and Ozhigin (2008) found dominant imprints of the 18-, 55-, and 75-year oscillations, as we did. In a satellite-based study of the Pacific, Cherniawsky *et al.* (2010) found real amplitudes of 30–70 mm [t-b], *i.e.* 1.5 to 3.5 times higher than Pacific theoretical amplitudes.

Thus, where real amplitudes have been studied, they are considerably larger than anticipated theoretical amplitudes. If the 18.6-year oscillation's amplitude would be only around 10 mm in the North Sea and Baltic region as suggested by Schmith, Thejll, and Nielsen, it would be highly surprising and in contrast to theoretical models, as well as in contrast to the empirical study by Woodworth, Shaw, and Blackmann (1991) of the British Isles, the studies of Yndestad (2006) and Yndestad, Turrell, and Ozhigin (2008) of the North Atlantic region, and the study by Baart *et al.* (2012) of the Dutch North Sea coast.

Our finding of an amplitude of 70 mm [t-b] is within the center range of other empirical findings of the region; Schmith, Thejll, and Nielsen's proposal is not. Figure 2 shows the annual mean residuals we found for identification of the dominant 18.6-year oscillation.

KNOWN GENERAL SEA-LEVEL RISE

Identification of a linear or polynomial general sea-level rise over the 160-year record is not a general anticipation, but another result, of the method we applied for least residual sine regression iteration. We have shown that the smallest residuals are produced at a general sea-level rise of 1.16 mm/y if no synchronization of the oscillations is anticipated, and 1.18 mm/y if the oscillations are completely synchronized to rational factors of the 18.6-year LNO. The method's finding of these two parametric values is completely independent of anything else than being an integral part of our least residual regression method. The identified general sea-level trend in the range of 1.1 to 1.2 mm/y is within the center range of what has been found in most other studies of the region (referred to and discussed in Hansen, Aagaard, and Binderup, 2012; Hansen, Aagaard, and Kuijpers, 2015). Consequently, we consider our method's capability to reproduce empirically found trends to support strongly the reliability of our method.

OTHER SPECIFIC COMMENTS

In the beginning of the abstract, Schmith, Thejll, and Nielsen say that we have claimed that our theory is supported by tidal theory. This is not true. We have not written about tidal theory, but about classical wave theory as described in textbooks on wavelets and superposition (*e.g.*, Hubbard, 1996) and on entrainment of waves (frequency and amplitude locking) as reviewed by, *e.g.*, Pikovsky and Rosenblum (2007). Thus, as should be expected from classical wave theory, we discovered that our findings show synchronization to rational factors of the oscillations' period lengths and locking to rational rates of the oscillations' amplitudes (see also Hansen, 2015).

Schmith, Thejll, and Nielsen claim that our method is unnecessarily complicated and that the many iterations are "inviting accumulation of round-off errors," which may explain our different results. This is not true, because each individual iteration applies the original sea-level data set and do not apply any calculations thereof or recalculated figures. Every iteration performs a modulation of the original data set around the oscillation parameters found by the previous iteration, such that still smaller residuals will occur. This leads to a still more precisely determined set of oscillation parameters, which in the next iteration is modulated on the original data set. This procedure is continued until smaller residuals will not occur by modulation of the original data set around the oscillation parameters found by the previous iteration. Thus, accumulation of round-off errors is not possible.

Schmith, Thejll, and Nielsen claim that our results cannot be reproduced. This is not strange, but a consequence of the fact that they did not apply our method as we did and explained in our detailed method section as well as in several letters.

Schmith, Thejll, and Nielsen have not redone our time-consuming iteration procedure but, instead, applied a surrogate method, which they erroneously believe simulates our method. As explained in the next section, our method differs fundamentally from Schmith, Thejll, and Nielsen's method and the statistical limitations adhered to it. Our method and basic idea attempt to identify a theoretical curve by identification of the smallest possible number of

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harmonic oscillations (and a general polynomial or linear trend) that in coherence will produce the smallest possible residuals (*i.e.* difference between the observed and the sum-curve of all identified elements).

This is a crucial point, and the two methods are not comparable when more than one oscillation characterizes an oscillatory system.

FUNDAMENTAL METHODOLOGICAL DIFFERENCES

In the present discussion, the readers should primarily be aware that they witness two fundamentally different approaches to reconstruction of sea levels (and any other kind of superpositioned, harmonic oscillations). The method applied by Schmith, Thejll, and Nielsen basically claims—within broad limits of statistical uncertainty—that the parameters of *singular* sea-level oscillations can initially be identified from continuous time series by harmonic amplitude spectrum analysis. In contrast, our method (as described in great detail in Hansen, Aagaard, and Kuijpers, 2015) claims that the parameters of a truly harmonic oscillation cannot be identified without determination of all superimposed sea-level oscillations and general trends. Thus, our method differs from the often applied spectral analysis method of, *e.g.*, Schmith, Thejll, and Nielsen, which will only be roughly able to identify a fraction of the oscillations searched for and mostly those of clearly different periods, as well as relatively large *quasi-oscillations* formed by superposition of two or more harmonic oscillations.

Because such more directly observable quasi-oscillations are composed by superposition of two or more individual oscillations of different period lengths, the underlying individual oscillations cannot be distinguished by spectral analysis unless the available time series is many times longer than the period lengths of the longest underlying oscillations.

In the present context this means, *e.g.*, that the 85-year peak found in the spectrum shown in Schmith, Thejll, and Nielsen's figure 1 is a *quasi-oscillation* produced by superposition of "our" 55.8- and 74.4-year harmonic oscillations, which quasi-oscillation will peak every *ca*. 80 to 90 years (*cf.* Hansen, Aagaard, and Kuijpers, 2015, figure 4). The exact period and amplitude of the quasi-oscillation will depend on the actual, exact phases of the two superimposed, harmonic oscillations. If, for instance, these two oscillations were the longest of the system, separation by traditional spectral analysis of the 55.8-and 74.4-year oscillations would require a continuous time series of 220 to 300 years (dependent on the two oscillators' phase distribution in the represented time series) to obtain complete separation of the two oscillators, whereas our method is independent of the phases of oscillations shorter than the represented time series and would therefore only require a continuous time series as long as the longest oscillation (75 y in this example).

By our method of l*east residual sine regression iteration* we wished to find a way to decompose more directly observable quasi-oscillations into their underlying components (Figure 1, upper panel). Thus, we found it is possible to identify five oscillators that constitute an *ensemble* of significant harmonic oscillations plus one general trend, which in coherence will produce very small residuals (*i.e.* root mean square = 2.5 mm) and great similarity (correlation=0.997) with the observed sea-level changes (Figure 1, lower panel)

As stated by Schmith, Thejll, and Nielsen, neither they nor we "know of any parametric approach to correctly evaluate confidence levels with trending and cyclic data." This implies that although the reconstructed or theoretical sea-level curve *correlates* extremely well with the observed curve, the general lack in statistical science of methods and possibilities for calculating realistic *confidence levels* of cyclic data superimposed on a general trend can neither strengthen nor weaken any theory on such matters.

The Monte Carlo simulation applied by Schmith, Thejll, and Nielsen relies on surrogate data and neglects our basic principle that the individual oscillators' residuals must be individually and iteratively regressed in the oscillations' order of significance (amplitude). This means that the result of every iteration must be surveyed continuously and that the order of successive regressions must be changed when the advance of iterations shows change in the oscillations' order of significance. Such built-in surveillance is neither present in Schmith, Thejll, and Nielsen's Monte Carlo simulations nor in their amplitude spectrum analyses and may explain their misleading results.

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We wish to add these observations illustrating the capacity of our method: (1) Smaller residuals cannot be produced by adding a sixth oscillation in the period interval of 18.6 to 160 years. (2) Larger residuals are produced by individual removal of one of the five oscillations followed by modulation of the remaining four oscillators or by further modulation of the ultimately identified parameters of the five oscillations.(3) Second- and third-order polynomial modulations with accelerations above 0.0004 mm/y2 of the general trend of 1.18 mm/y would also produce larger residuals. (4) Because the oscillations are iteratively modulated in their successively identified order of significance (amplitude) and individually in the order of period, amplitude, and phase, the reconstruct-ed curve in Figure 1 (lower panel) cannot be produced by a different ensemble of oscillators (number of oscillators and different oscillation parameters) without producing larger residuals. (5) Our method is not able to (i) propose oscillations smaller than the smallest parametrically identified oscillator (*i.e.* 8mm,t-b),(ii) distinguish general trendsfrompossible oscillators that are longer than the available time series (*i.e.* 160 y), (iii) propose parametric changes over time of a general trend beyond the repetition period of entrained oscillators (*i.e.* 223 y).

CONCLUSION

We conclude that the above facts strongly support our hypothesis. The general lack in statistical science of methods for calculating realistic *confidence levels* of cyclic data super-imposed on a general trend can neither strengthen nor weaken any such hypothesis.

However, our method produces results that are in concordance with empirical findings in all other studies of the region's 18.6-year oscillation. Our method identifies a regional general sea-level rise by 1.16–1.18 mm/y corresponding to the center range of 1.1–1.2 mm/y in other studies of the region. Also, our colleagues' finding of a large 85-year peak strongly supports our finding of quasi-oscillatory peaks every 80–90 years formed by superposition of "our" 55.8- and 74.4-year oscillations. We have shown that the identified oscillations and general trend reproduce the observed sea levels extremely well (correlation 0.997). We also have shown that backward prolongation of the five oscillations will reproduce the large preinstrumental peaks (culminating ca. AD 1790 and *ca.* AD 1850) originally found by Hansen, Aagaard, and Binderup (2012) in the region's salt marsh shorelines. Moreover, it has been shown that a 19-year cycle is present in these salt marsh shorelines in a 500-year record (AD 1150–1652) of coastal salt production (Hansen, 2010). When, furthermore, the three largest oscillations have identified plausible physical causes (sea-level effects of the LNO, North Atlantic Oscillation, and Atlantic Multidecadal Oscillation), we see no theoretical or empirical reasons for compromising our hypothesis.

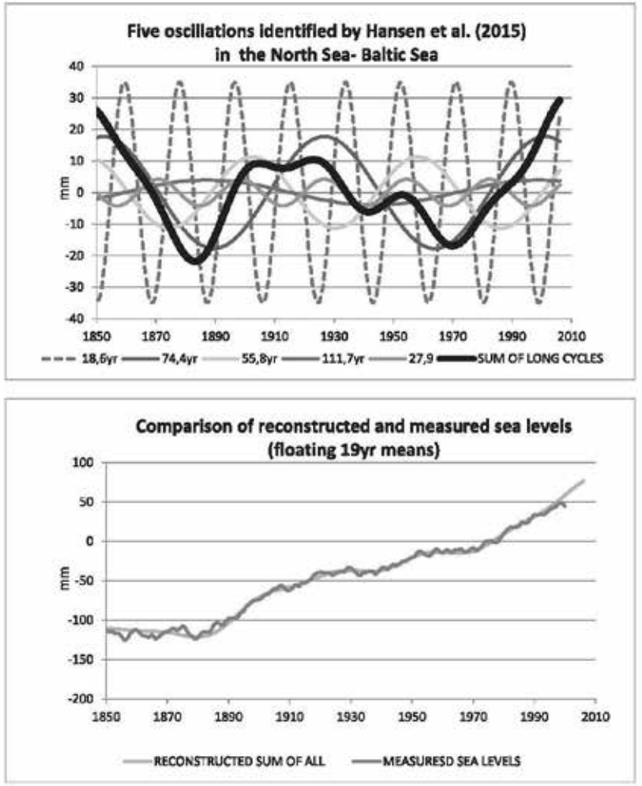

Figure 1. Upper panel: The five harmonic oscillations identified by Hansen *et al.*, 2015. Solid black curve shows the directly observable quasi-oscillations in normally applied 19-y mean curves detrended for the 18.6-year oscillation, *i.e.* the sum of the 74-, 56-, 111-, and 28-year oscillations. Lower panel: Comparison of sea-level curve as found by addition of the five found harmonic oscillations and general sea-level rise. Nineteen-year floating mean of annual means.

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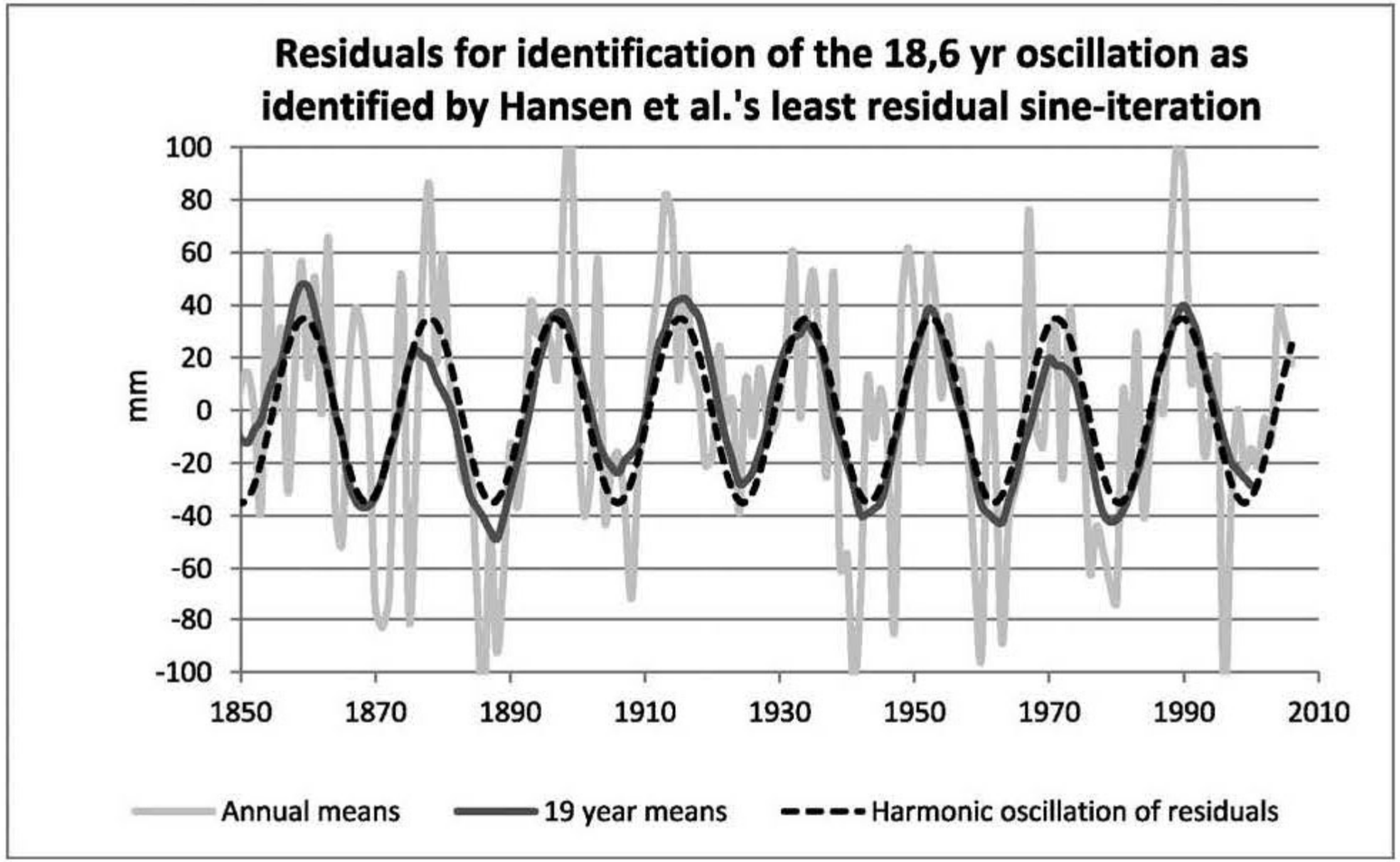

Figure 2. Residuals left for identification of the 18.6-y oscillation according to our least residual sine regression iteration method for the lowest possible number of oscillators (five) that in coherence can produce the lowest possible root mean square residual of the theoretically reconstructed and the observed sea-level curves.

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Nobuo Mimura, President of Ibaraki University and CERF Regional Vice President, delivers a powerful message on the status of his educational institution.

Welcome to Ibaraki University! In this message, I would like to describe Ibaraki University as it stands today and its objectives for the future.

Ibaraki University has a 65-year history dating back to May 1949, when it started out as a national university under Japan's new educational system. It was formed through the integration of the former educational system's Mito High School, Ibaraki Normal School, Ibaraki National School for Youth and Taga Technical College. Today, the university has developed into a mid-size national university with five undergraduate colleges and four graduate schools. There are approximately 8,400 students studying at the university.

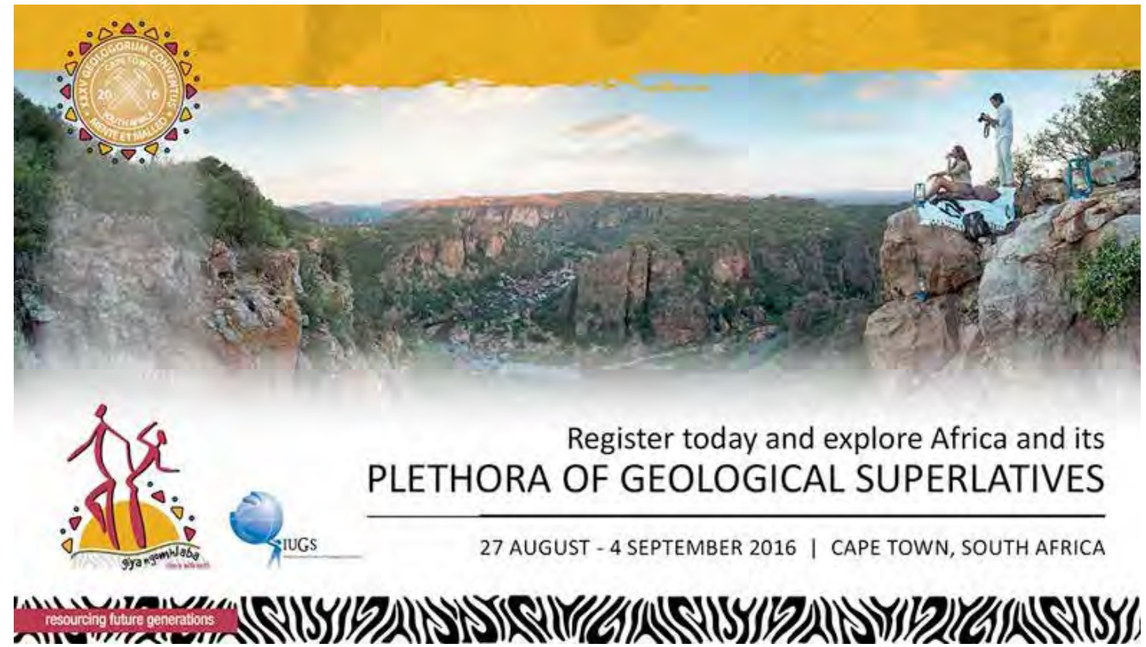
Ibaraki University has consistently aimed to develop outstanding human resources through teaching and research. In our modern age, the world is being rapidly transformed by ongoing globalization. In Japan, we face pressing issues such as a shrinking population and the aging of society, as well as disaster readiness and environmental problems. In our fast-changing society, I believe that it is crucial for Ibaraki University's students to continue growing even after graduation, and thereby succeed in their endeavors. To this end, Ibaraki University emphasizes "active learning," which is focused on developing practical knowledge and skills, and a liberal arts education that fosters an expansive perspective. In doing so, we are working to reform education (*i.e.* shift the quality of education) from "teaching" to "active learning." Going further, we are developing a diverse learning environment that supports the growth of our students by upgrading and expanding international exchange student programs, where students study abroad at universities in Asia and Western countries, along with short-term training programs.

Another feature of Ibaraki University is that we are firmly rooted in the local region and are helping to build sustainable regional communities. To date, we have built up an extensive track record in such areas as joint research with local corporations, environmental preservation and natural energy development, disaster readiness, and support for the town development initiatives of local governments. In fact, we have just initiated a project to make the university a new regional center of knowledge, with the launch in April 2014 of the Social Collaboration Center. Looking ahead, we intend to advance an even broader range of activities to expand our circle of collaboration with Ibaraki Prefecture, municipalities, corporations, civic groups and others. On the research front, Ibaraki University has produced significant achievements in many different areas, notably material sciences, atomic sciences , climate change issues, biofuel, environmental improvement of Lake Kasumigaura, and support for recovery from earthquake and radiation disasters. We seek to create distinctive fields by further strengthening our advanced research activities, as we strive to make Ibaraki University's research achievements widely known across Japan and the rest of the world.

Universities are vital organs of society that are crucial to building a sustainable regional society. They not only serve as institutes of higher education, but also help to advance research and solve a variety of issues facing the region. Keeping this firmly in mind, Ibaraki University will practice open management in order to contribute to the development of society through teaching, research, regional collaboration and internationalization. I hope that this will increase your understanding of Ibaraki University, and I look forward to your continued support.

Nobuo Mimura, D.Eng.
President, Ibaraki University
Ibaraki Prefecture 310-0056, Japan

35TH INTERNATIONAL GEOLOGICAL CONGRESS
27 AUGUST - 4 SEPTEMBER 2016 | CAPE TOWN, SOUTH AFRICA

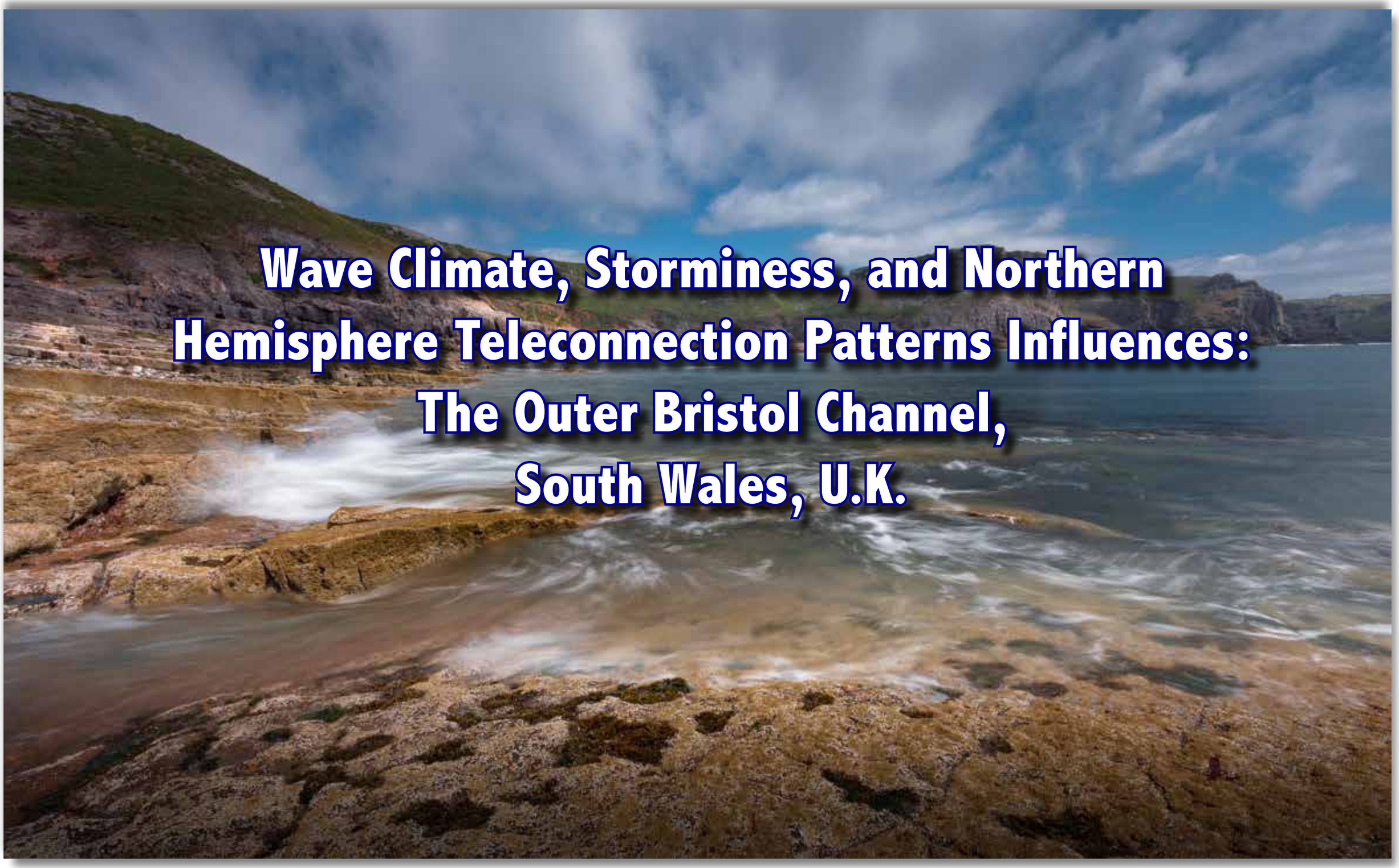


Special session on Coastal Tectonic and Sea-Level Change, with conveners: Said MAOUCHE (said.maouche@gmail.com), Christophe MORHANGE (morhange@cerege.fr), and Stathis STIROS (stiros@upatras.gr)

Session description:

The change of the sea level is due to variation in the volume of water in the oceans or, alternatively, a change in the shape of oceans basins. In several cases, the sea level variation can be observed due to the coastal tectonic activity. This kind of isostatic change takes place only in areas with crustal deformation (*i.e.*, with subsidence or uplift) and sometimes after large earthquakes or a volcanic activity. The sea or lake shorelines may be raised or lowered suddenly and relatively to the regional water level by coastal tectonics. In many active geological domains, observations with measurements and isotopic dating of Quaternary marine terraces provide some constraints on the long-term tectonic activity. Uplift or subsidence rate that may reach 1 to 10 mm/yr can be compared and corrected with respect to the sea level fluctuations. In this session, we seek contributions covering the field of coastal tectonics and sea level change using paleoclimatic, geological, geomorphological, archaeological, historical and instrumental data. A particular interest will be devoted to new methods that include total station, LIDAR and remote sensing measurements, isotopic dating and modeling of coastal deposits and deformation. Young researchers are particularly encouraged to present their results and discuss the latest advances and progress in this issue.

35th IGC web page: http://www.35igc.org
Abstract submission: http://www.35igc.org/Verso/211/Submit-an-Abstract



Wave Climate, Storminess, and Northern Hemisphere Teleconnection Patterns Influences: The Outer Bristol Channel, South Wales, U.K.

Wave Climate, Storminess, and Northern Hemisphere Teleconnection Patterns Influences: The Outer Bristol Channel, South Wales, U.K.

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ABSTRACT

This paper investigates potential climate-change impacts on the Outer Bristol Channel (Wales, U.K.) by analysing a 15-year wave-buoy dataset (1998–2013) to characterise wave climate and storms. The research showed that the increasing storminess experienced during the latter half of the 20th century did not, as expected, continue into the first decades of the 21st century; however, the wave climate showed clear cyclic variation in average monthly significant wave height (H_s), with low values occurring between May and August (H_s < 1.4 m, H_{smax} < 6 m) and a minimum in August (H_s = 1.3 m, H_{smax} = 5.2 m). Monthly mean wave power was 27.4 kwm^{-1}, with a maximum of 951 kwm^{-1} during December. The 267 storm events were recorded during the assessment period. Storm-severity distribution presented a log-normal trend, with weak and moderate events making up 73% of the record (125 and 69 events, respectively); significant (18%), severe (4%), and extreme (6%) storms resulting in 73 events that are more destructive made up the remainder of the record. Fifty-five percent of the monthly averaged wave variations, wave power, and storminess indices are linked to several teleconnection patterns, the most relevant being the Arctic Oscillation, with 23.45%, the North Atlantic Oscillation, with 20.65%, and the East Atlantic with 10.9%. This kind of characterization is essential for design considerations to any proposed developments within the Bristol Channel that affect the coastal zone, *e.g.*, the proposed design of the Swansea Bay Tidal Lagoon, which is capable of generating over 542,000 MWhyr^{-1} of renewable energy.

ADDITIONAL INDEX WORDS: *Storms, wave power, North Atlantic Oscillation (NAO), Arctic Oscillation (AO), East Atlantic Oscillation (EA), Wales.*

INTRODUCTION

There is a growing globally acknowledged urgency to develop adaptation and mitigation measures to cope with future climate-change impacts on coastlines (Ng *et al.*, 2015). In addition to this, climate change is expected to influence storm effects in terms of frequency, trajectory, and intensity (IPCC, 2007). This issue becomes more important because of their related impacts on coastal areas, human settlements, and associated activities. Research on climate-change effects along the coastal zone has been almost entirely focused on the impact of sea-level rise as a result of global warming (Phillips and Crisp, 2010; Rangel-Buitrago and Anfuso, 2011a, 2013). Wind speed and their directional components that in turn influence wave height are linked to changes in large-

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scale atmospheric patterns, such as the North Atlantic Oscillations (NAOs) and Southern Oscillations (Hurrell, 1996); however, less attention has been given to wave climate and storm understanding and trends.

In recent years, there has been a rise in extreme wave height influenced by increasing storm intensity and occurrence (Allan and Komar, 2000; Bacon and Carter, 1991; Dupuis, Michel, and Sottolichio, 2006; Komar and Allan, 2008; Soomere, 2008). Increasing storm intensity and occurrence not only reduce coastal defence effectiveness, but they also have an effect on low-lying areas adjacent to the coast, resulting in more frequent, extensive, and damaging floods (Ballinger and Stojanovic, 2010). The elevated concentration of important natural and socio-economic assets within littoral zones raises concern about potential damage associated with rising wave heights and accelerating storm-trend intensity (Costa, Tekken, and Kropp, 2009), and coastal areas constantly change in response to these external environmental factors (Phillips, 2008).

Governments impose increasing pressure to develop environment-friendly energy (Vanucchi and Cappietti, 2011), and tidal energy sources have the potential to contribute large amounts of renewable energy (Duckers, 1994). In this context, the Bristol Channel has been chosen as a suitable location for the generation of renewable energy, achieved by utilising one of the world's highest tidal ranges (Hashemi *et al.*, 2008). Such wave-power generation is reliable and predictable, a key consideration for managing the future electricity supply in the U.K. (Thomas, Phillips, and Lock, 2015). Indeed, permission for planning has recently been granted a start date for the construction and operation of a tidal lagoon with the goal of generating renewable energy, the first of its type in the world, achieved by utilising Swansea Bay's high tidal range to generate over 542,000 $MWhyr^{-1}$. The strong winds and tidal components in the Bristol Channel/Severn Estuary, however, can potentially cause devastating impacts, such as flooding and wave erosion, when coupled with rising sea-level trends. Although dependent on location, these effects may be further exacerbated by observed increasing frequency that has occurred since the 1960s of severe storms within southern parts of the U.K. (Allan, Tett, and Alexander, 2009; Phillips and Crisp, 2010; Phillips, Ress, and Thomas, 2013). Variations observed in wind speed and direction associated with changes in high-pressure systems, related with teleconnection patterns, have the potential to generate energetic storms and the associated surge wave heights. Wave heights equal to or higher than 3.4 m in the Channel increases the coastal erosion risk (Rayner and Parker, 2010). These predictions need to be incorporated in the design when consideration is given to the location of any renewable energy developments.

Consequently, this paper establishes storm (*i.e.* climate, extremes, and potential energy) and climatic (*i.e.*NAO *interalia*) parameter trends that characterise the outer Bristol Channel wave potential. This was achieved by analysing wave-buoy data over a 15-year period (1998–2013), recorded at the western extremity of the Bristol Channel (Wales). The related information obtained within this study constitutes the first step toward the creation of any coastal response action concerning the impacts of storms and protection of economic coastal activities that can be used to support the design of coastal structures such as the proposed tidal lagoon in Swansea Bay.

Study Area

The Bristol Channel/Severn Estuary constitutes a large body of partially enclosed tidal water in SW Britain (Uncles, 2010; Figure 1) and is exposed to winds and waves from the prevailing SW direction (SBCEG, 1999). Tides are semidiurnal and are attributable to the funnelling effect of the Bristol Channel/Severn Estuary; the tidal range in the area is the second largest in the world (16.4 m). Innerchannel tidal current speeds generally exceed 1.5 m s^{-1} on spring tides and 0.75 m s^{-1} on neap tides, meaning sections of water can move up to 25 km during a flood or ebb tide. Locally generated waves, which give rise to the largest wave heights at Newport, are uncorrelated with high water levels. This is opposite to the Outer Bristol Channel where swell waves from the west give rise to the largest wave heights; these are correlated to high water levels (Rogers *et al.*, 2010). Subdominant winds from a south toward easterly direction are quite frequent, however, and can have damaging effects on coastal infrastructure (Phillips, 2008). Phillips and Williams (2007) showed that an increasing trend of easterly winds caused infrastructure damage along the Penarth coastline, and Thomas *et al.* (2011a,b) showed that despite a limited

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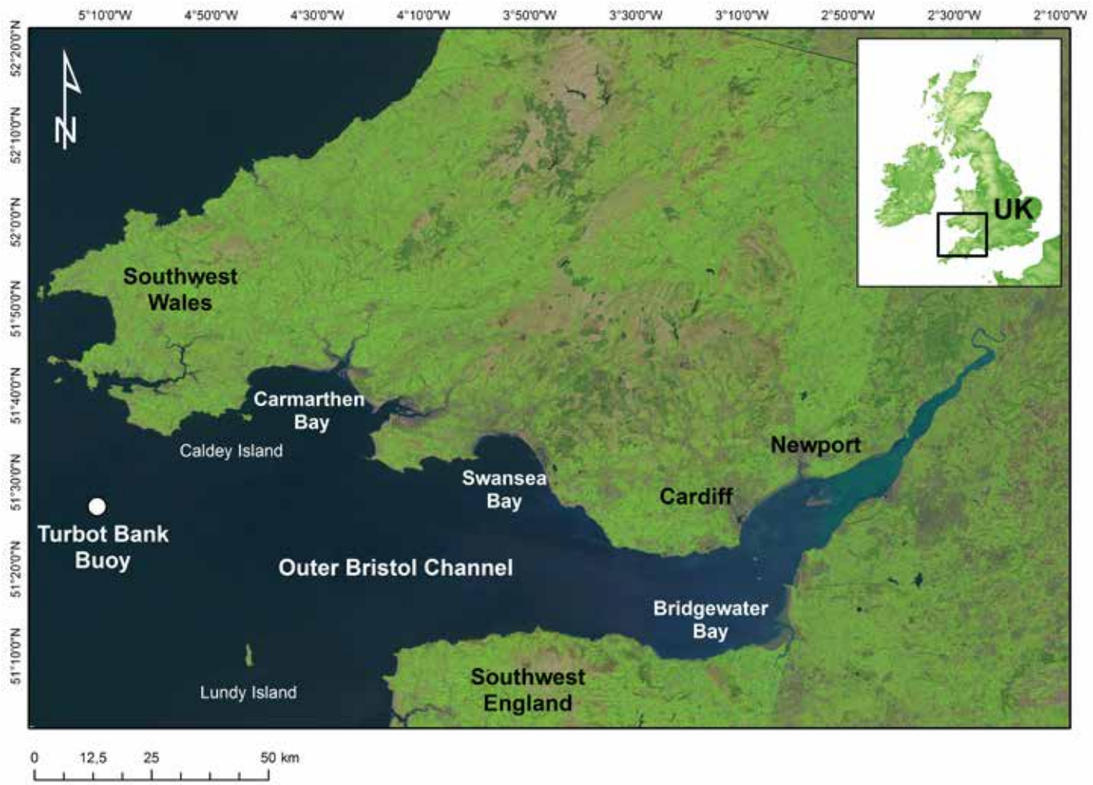

Figure 1. Study area locality and the turbot bank buoy position.

fetch, SE regimes reversed the general south toward north longshore drift, aided somewhat by the influences of refraction and diffraction around offshore islands sediment. The chief forcing factors are relative sea level, tidal regime, windiness, and the incidence of storms (Allen and Duffy, 1998).

Tides and strong winds alongside north Atlantic swells contribute to a high-energy wave environment (Allan, Tett, and Alexander, 2009). Dominant and prevailing SW winds expose the Bristol Channel to unrefracted North Atlantic waves and guarantee significant wave action within these macrotidal 7.5-m spring-tidal range waters (Phillips and Crisp, 2010). South to westerly waves of *ca.* 1.4-m height and a 5.2-second period that were recorded offshore dominate, although storm waves *ca.*9 m with periods >8.5 seconds are not uncommon (Thomas, Phillips, and Williams, 2010). Regional gale-record statistics showed that 71% of gale-generated waves emanated from the south toward the west (180°–270°), 90% of wave periods ranged between 5 seconds and 9 seconds, and 70% of gale waves generated by 22 kn winds ranged between 2 m and 4 m. The highest waves (6 m–8 m) emanated from a NW direction (270°–330°) comprised just 1.3% of the record, while 80% of gale waves up to 5 m emanated between 180°–330° (Thomas, Phillips, and Lock, 2015).

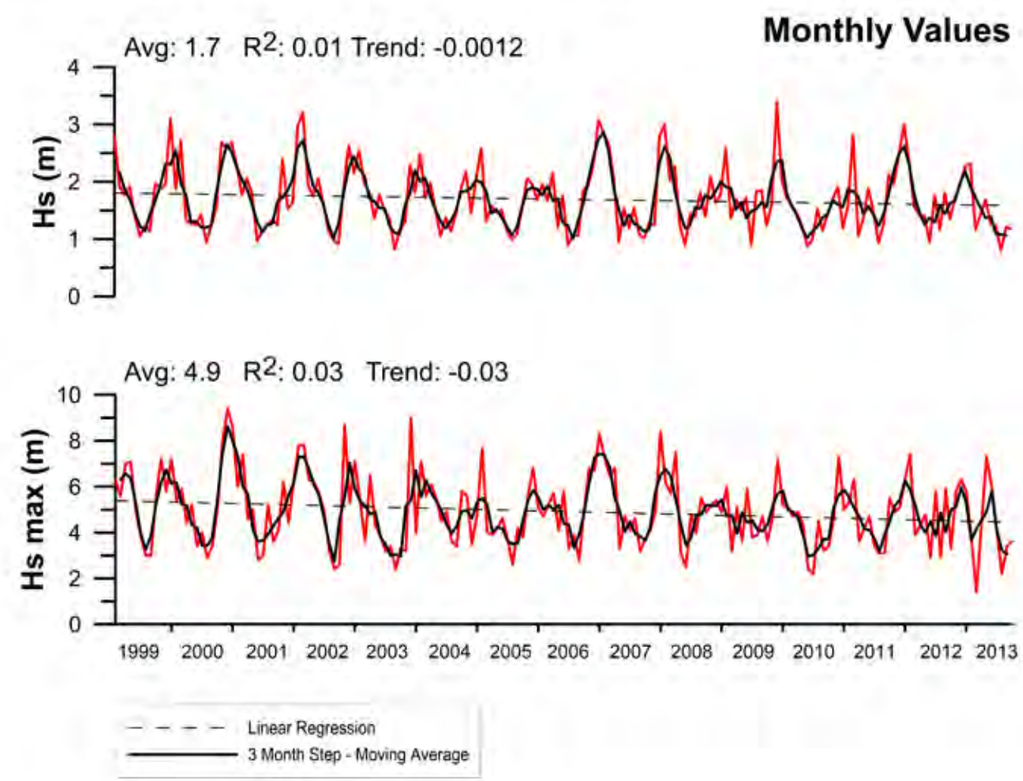

Figure 2. Monthly average values of significant wave height (H_s) and maximum wave height (H_{smax}).

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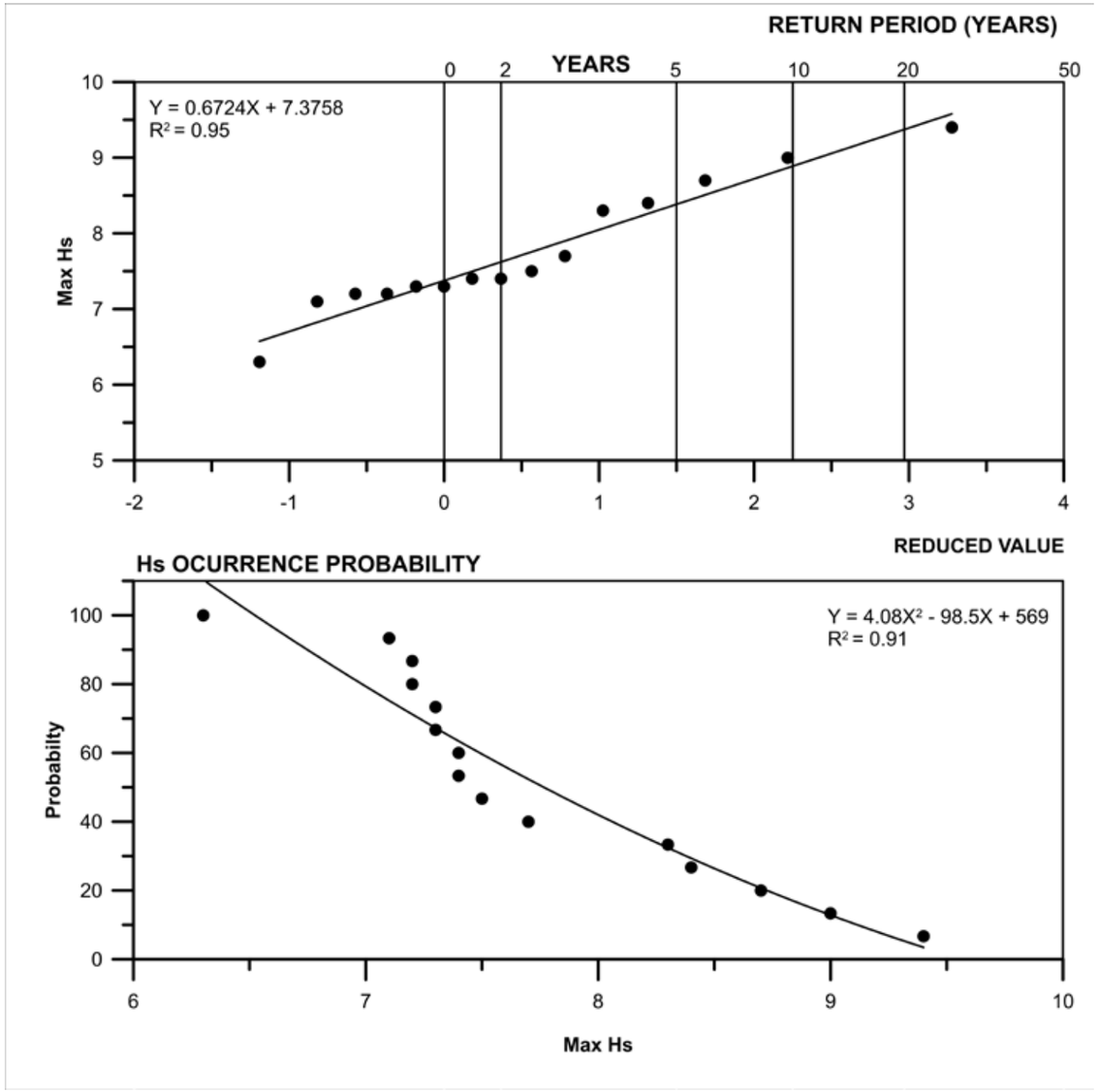

Figure 3. Wave recurrence and probability. Annual maximum significative wave height plotted *vs.* the reduced value from the Gumbel distribution using the Gringorten Plotting position, and wave occurrence probability plotted *vs.* the annual maximum wave height value.

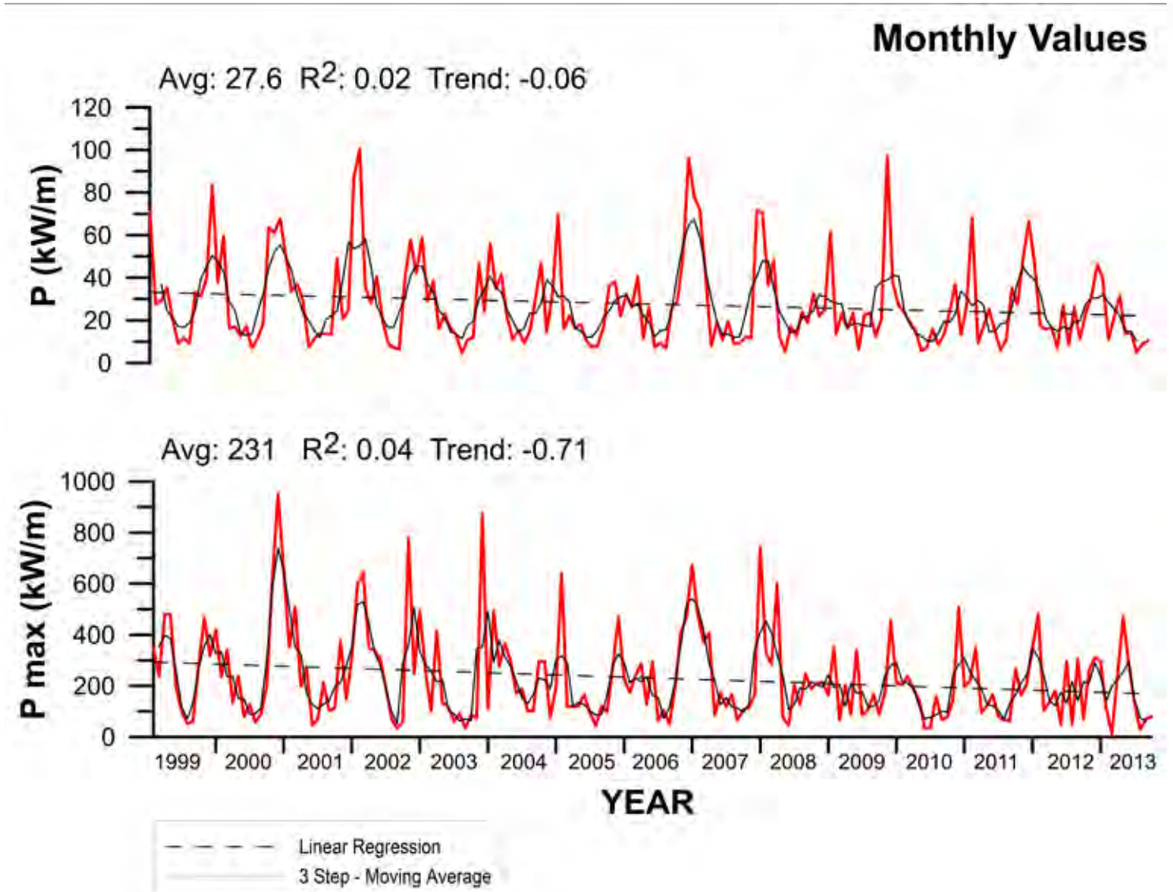

Figure 4. Monthly average values of wave power and maximum wave power.

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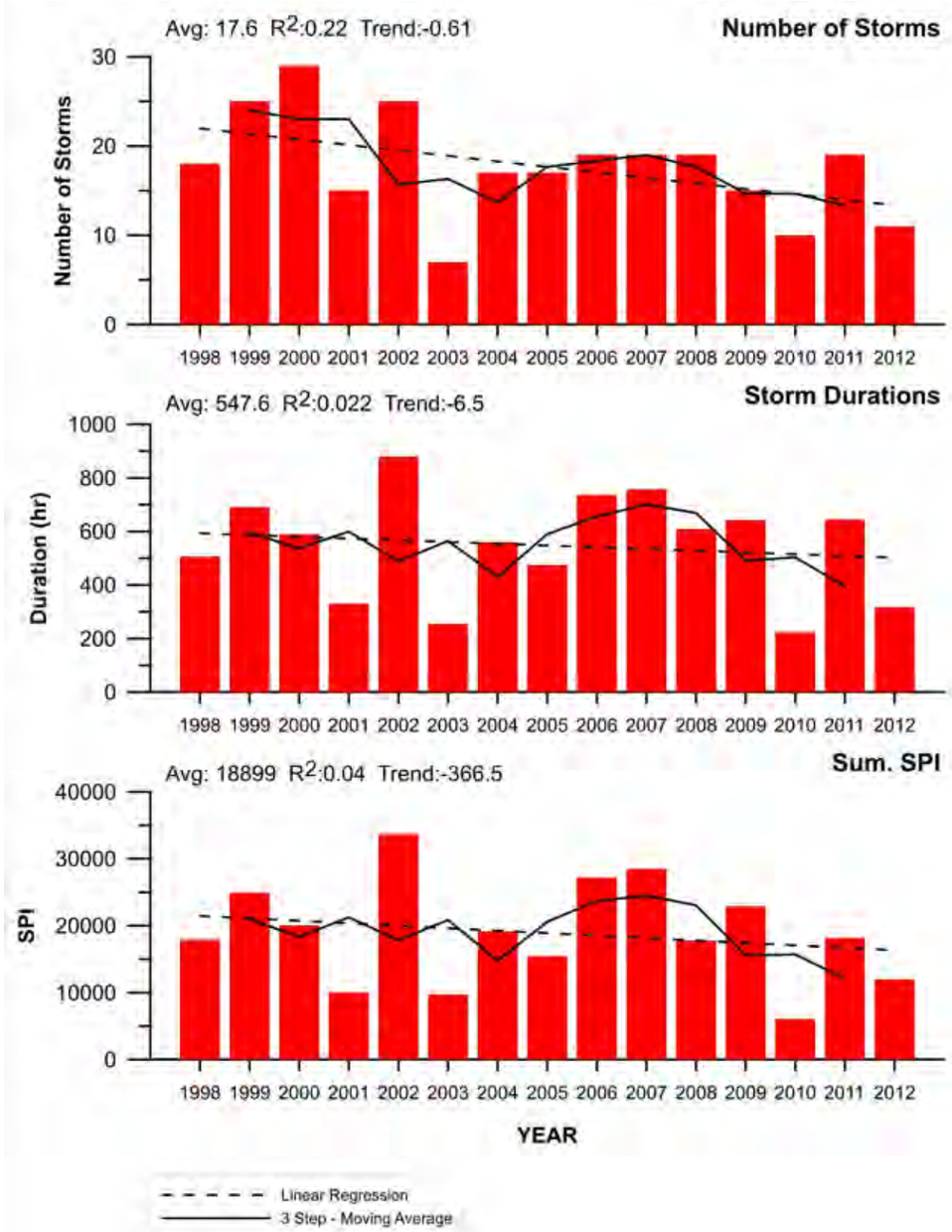

Figure 5. Distribution of the number of storms, duration, and sum of storm power per year with their respective linear regression and the 3-year moving average. Average values (Avg), eoot mean square (r^2), and trends also presented.

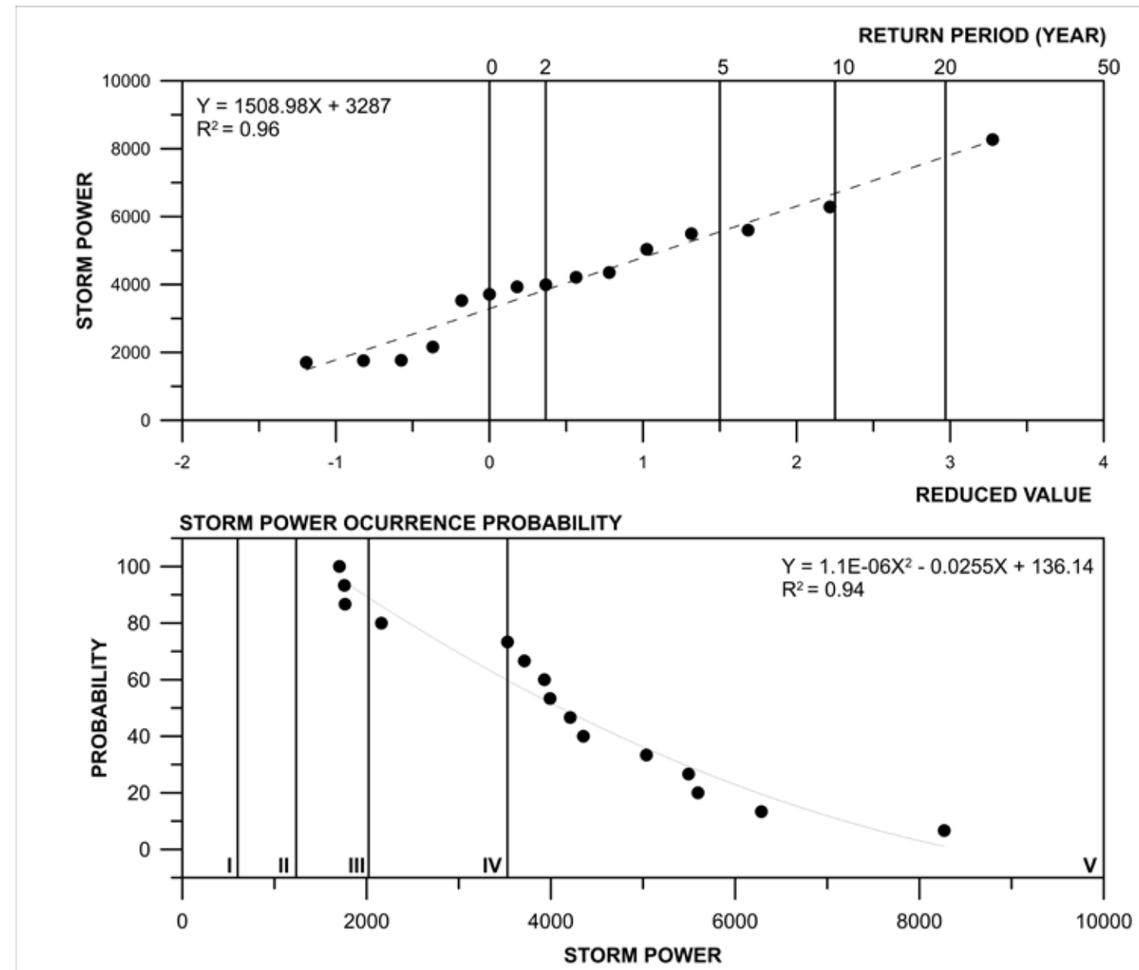

Figure 6. Storm recurrence and probability for the different storm classes in the study area. Annual maximum storm power plotted *vs.* the reduced value from the Gumbel distribution using the Gringorten plotting position, and storm occurrence probability plotted *vs.* the annual maximum storm power.

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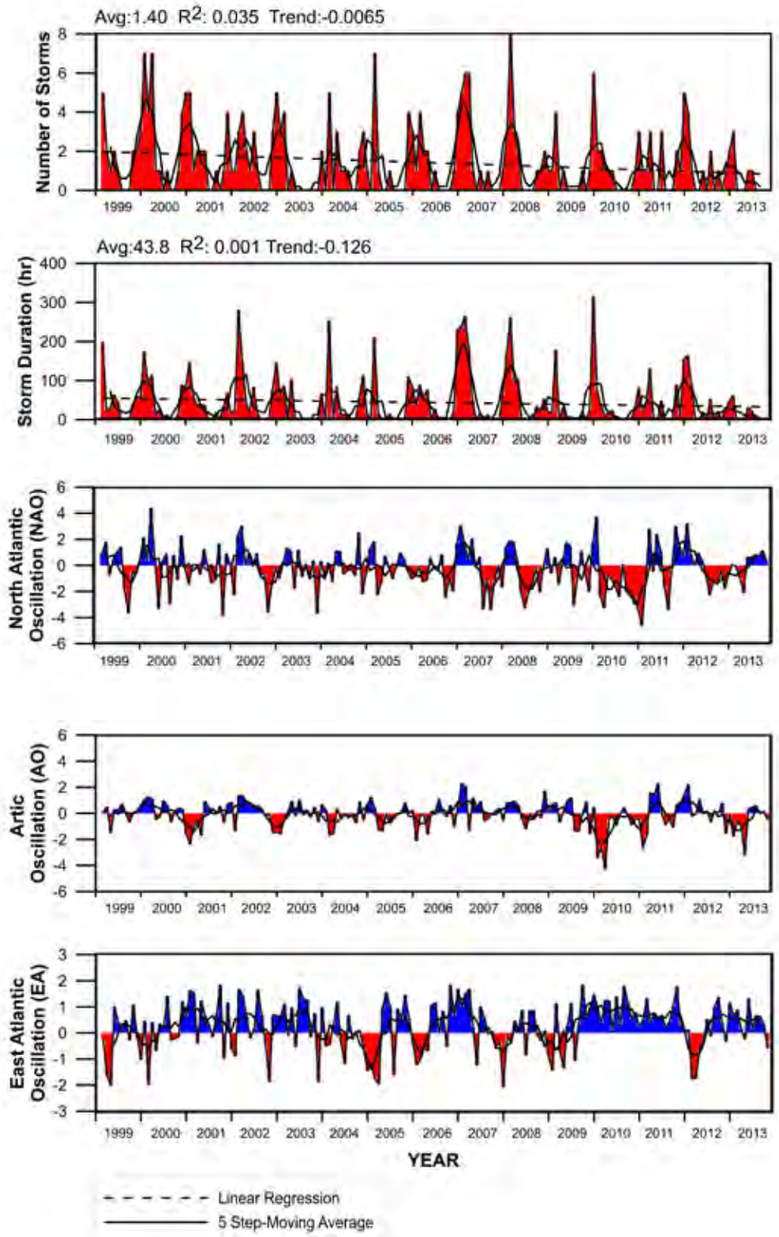

Figure 7. Monthly values of number of storms, storm durations, North Atlantic Oscillation (NAO), Arctic Oscillation (AO), and East Atlantic (EA) Oscillation.

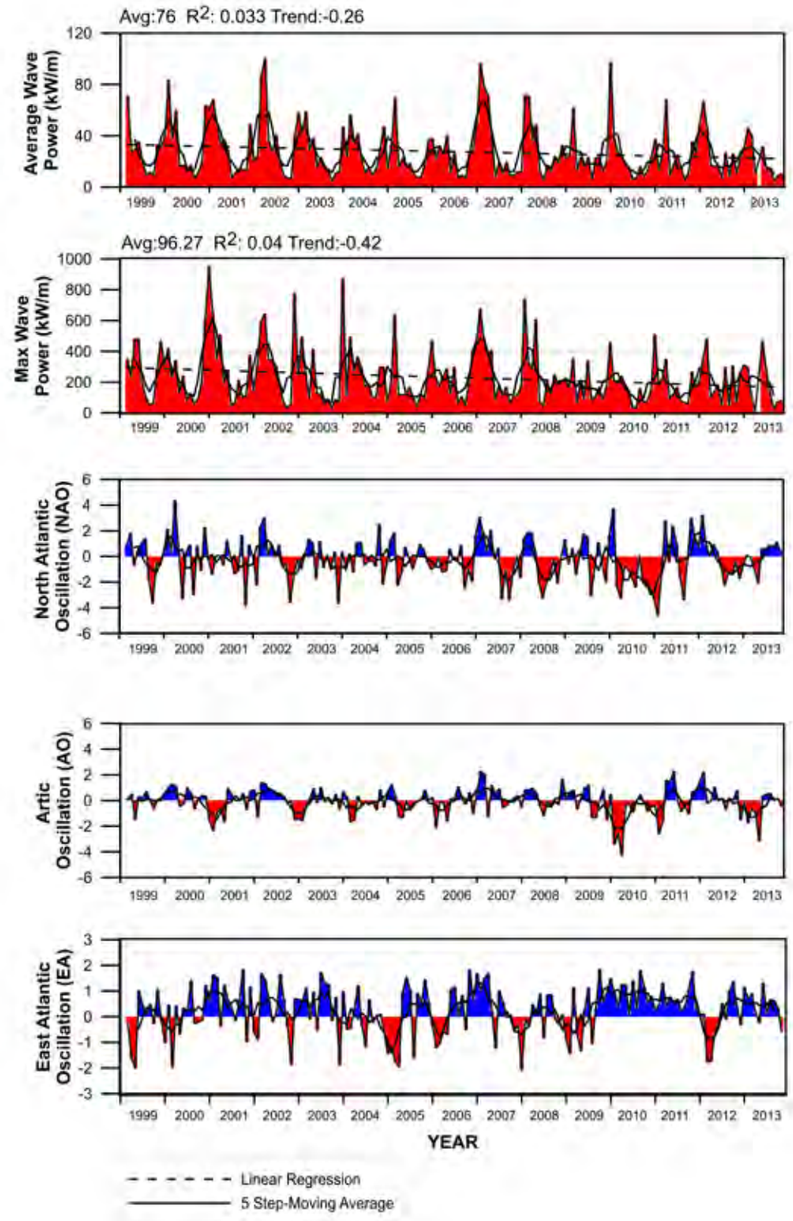

Figure 8. Monthly values average wave power and maximum wave power, North Atlantic Oscillation (NAO), Arctic Oscillation (AO), and East Atlantic (EA) Oscillation.

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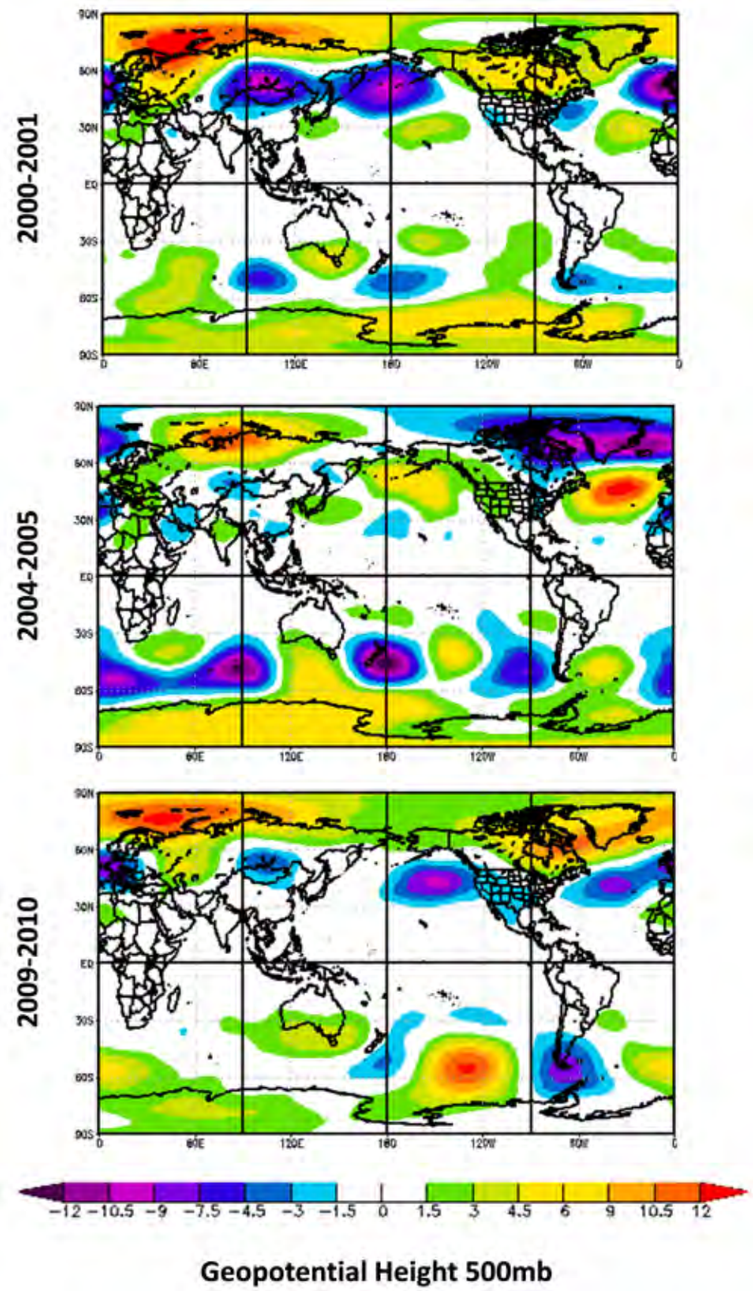

Figure 9. Geopotential height anomalies at 500 mb during 2000–01, 2004–05, and 2009–10 (from NCEP-NCAR reanalysis; National Weather Service Climate Prediction Center, 2015a). Extreme conditions and coldest conditions were recorded during aforementioned periods.

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Commission on Coastal Systems
Commission sur les Systèmes Côtiers

newsletter

Union Géographique Internationale
International Geographical Union
No. 74 - January 2016
Norbert P. Psuty, Co-Editor
Margarita Stancheva, Co-Editor

Objectives: The Commission on Coastal Systems encourages the study of coastal systems throughout the world. The Commission sponsors and supports activities leading to the exchange of information regarding coastal systems among our members and throughout the IGU at large. The focus of attention is on interactive systems, both human and physical, and the areas of inquiry include issues such as sea-level rise, land-use changes, estuarine resources, coastal tourism and shoreline development, coastal recreation, and coastal zone management. The Commission will make concerted efforts to emphasize issues of Global Change. Copies of our Newsletter and announcements are on our website: http://www.igu-ccs.org/

Message from the Chair

I would like to wish all members of the Commission on Coastal Systems, and other coastal enthusiasts reading this Newsletter, a successful 2016. The CCS has continued to foster interest and support for coastal research activities and the exchange of ideas through 2015. I have much appreciated the support of steering committee members, but particularly the excellent co-ordination that Norb Psuty continues to bring as Secretary with his tireless dedication to communication and production of this Newsletter.

2016 is a Congress year. The 33rd International Geographical Congress will be held in Beijing in August. I am very pleased that Zhongyuan Chen and Yongqiang Zong are convening a coastal session, sponsored by CCS jointly with IGBP/LOICZ, at this important meeting. I encourage those with a focus on coasts to participate (abstracts close very shortly). The Congress also marks the time when IGU reconsiders its Commissions. I am re-assured by the enthusiasm that has been communicated to me, and I believe we can promote a strong case for the continuation and revitalisation of CCS.

2016 has been designated the International Year of Global Understanding. This exciting initiative is described below in this Newsletter; it promotes cross-disciplinary integration between the sciences and the social sciences and humanities. The coast is an excellent place to develop this greater understanding, and the many threats that are already impacting our coasts will require development of environmental and socio-economic sustainability policies. I believe that we have already taken many of these into consideration in the past, but new initiatives such as this, together with other international programs, such as Future Earth, provide a framework for greater co-operation.

I hope that you will continue to participate in CCS. I would be pleased to hear from coastal scientists with new ideas for how we can promote the Commission and how we can communicate more widely across disciplines and internationally to ensure that the world's coasts are sustainably managed. Please enjoy this Newsletter, and contribute information and reports for inclusion in future editions. I wish to express my thanks to Norb for his editing of these newsletters, and to also thank Margarita Stancheva who has assisted in the editing of this newsletter. We also welcome Paul Rooney to the steering committee. We hope members of the Commission on Coastal Systems will continue to contribute to the promotion of knowledge and exchange of ideas through meetings such as those listed below, and by setting up other initiatives in the name of the CCS!

COLIN WOODROFFE

MEETINGS WITH COASTAL INTEREST

MARCH 6-11, 2016. 14th INTERNATIONAL COASTAL SYMPOSIUM (ICS) 2016. SYDNEY, AUSTRALIA

The 14th International Coastal Symposium (ICS) will be hosted by the Geocoastal Research Group, School of Geosciences at the University of Sydney, under the auspices of the Coastal Education and Research Foundation (CERF) and the *Journal of Coastal Research* (JCR).

The ICS brings together delegates from all over the world to collaborate and discuss the most current coastal research studies and projects. The proceedings of the conference, published as peer-reviewed special issue of papers in the *Journal of Coastal Research*, represent an invaluable resource for coastal scientists, engineers and managers.

- The meeting will consist of a number of sessions on **coastal science comprising geomorphology, geology, ecology, biology, coastal engineering and coastal management including planning and policy**.
- Keynote speakers will include international leaders in coastal science and engineering with special attention to highlighting Australian expertise.
- Fieldtrips will be organised to showcase local knowledge and study cases, including trips to the Great Barrier Reef and to the coast of NSW.

The call for abstracts has closed.
Visit the website: **http://ics2016.org/**

APRIL 20-23, 2016. 34th ANNUAL CONFERENCE 'GEOGRAPHY OF SEAS AND COASTS' (AMK). GERMANY

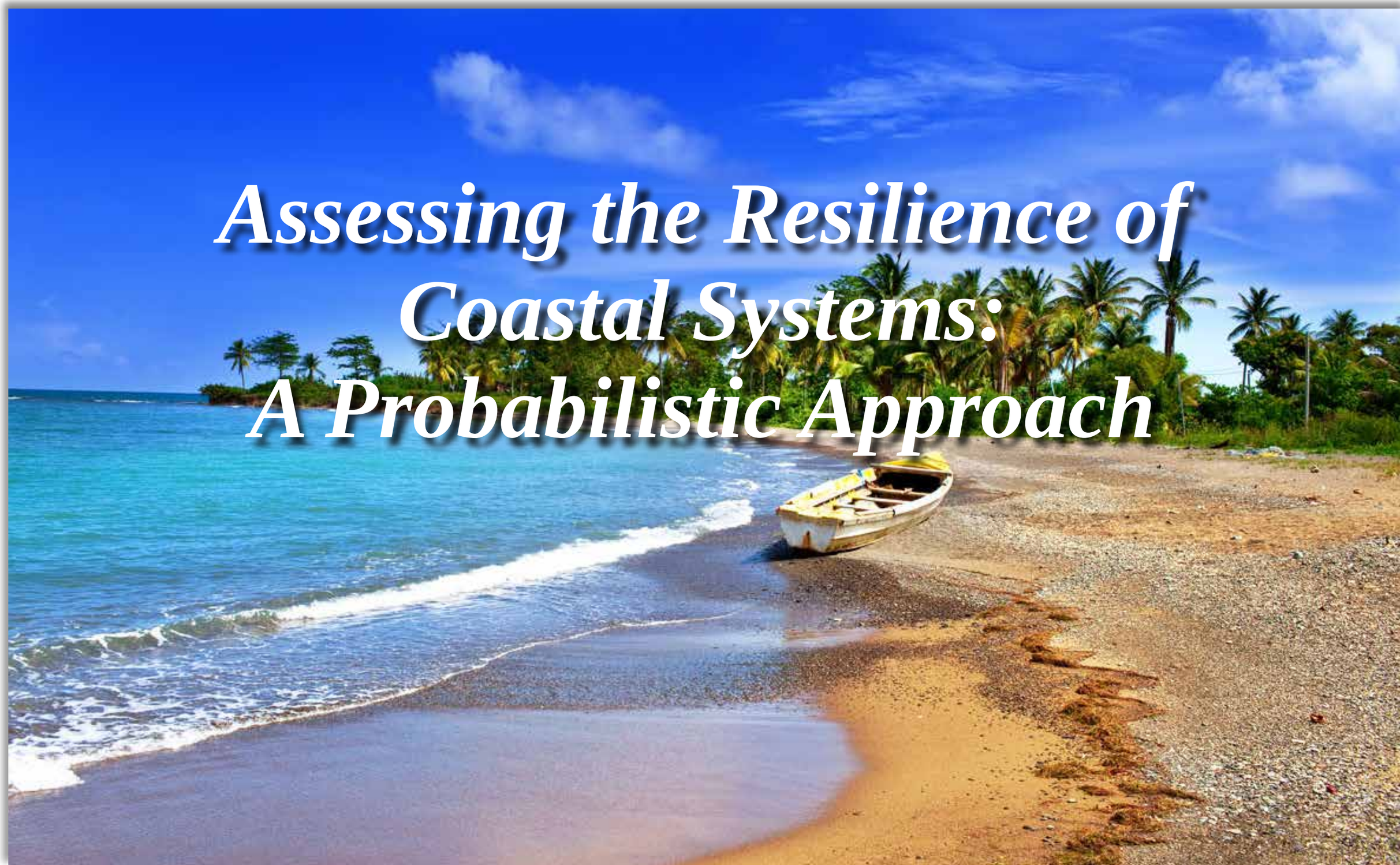
The Conference will take place on 20-23 April 2016, in Warnemünde, Germany.
Conference website: http://www.baltcoast.net/AMK.html

The AMK allows for a wide spectrum of coastal and marine geography topics, including:

- Coastal zone management
- Marine spatial planning and Geographic Information Systems (GIS)
- Resource management and aquaculture
- Coastal protection and risk management
- Ecosystem services and indicators
- Marine debris and water quality

Abstract submission deadline: 01 March 2016. Contact e-mail: amk2016@eucc-d.de.

Assessing the Resilience of Coastal Systems: A Probabilistic Approach



Assessing the Resilience of Coastal Systems: A Probabilistic Approach

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ABSTRACT

Resilience is the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions. Methods and tools to quantify resilience are needed to provide actionable intelligence to plan, design, construct, and manage coastal systems. This paper describes how a probabilistic measure of resilience can be assessed for a coastal community using a Bayesian network. The measure of resilience is the joint probability of meeting two management objectives, one with respect to the level of system performance and the other with respect to the length of time required to restore system performance. This paper describes a pilot study to demonstrate the approach in Jamaica Bay, New York, a dense, urban, residential community located on the southern coast of Long Island. Results of the pilot study illustrate how practical information can be developed to support decisions about managing coastal systems. The pilot study provides insights into data and information requirements; the advantages, challenges, and limitations of the approach; and the feasibility of implementing this approach for operations. This approach to resilience assessment is well suited for coastal planning contexts because it explicitly incorporates information about uncertainty in the severity of coastal storm events, as well as uncertainty in how the system will perform when exposed to storm loads. The method challenges the community to establish explicit objectives for coastal resilience, identifies what data are needed to monitor progress toward objectives, and provides a platform from which to explore how those objectives might be achieved in practice.

ADDITIONAL INDEX WORDS: *Bayesian network, infrastructure networks, risk assessment, engineering resilience, community resilience, natural hazards, extreme events, lifelines, Jamaica Bay.*

INTRODUCTION

Resilience is the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions. How to improve the resilience of coastal communities to coastal storm events has become the focus of a national conversation (NRC, 2012, 2014; Rosati, Touzinsky, and Lillycrop, 2015). The problem is exacerbated by sea-level rise and increasing populations and their associated infrastructure on the coast, which tend to increase the severity of consequences associated with coastal storm events (NOAA, 2013a; Williams, 2013). The aim of this research is to supply coastal practitioners with methods and tools to assess resil-ience so that decisions about how to manage resilience are well informed. Resilience assessment provides actionable intelligence about the ability of a system to retain and recover functional performance following an adverse event. Resilience management is the practice of planning and preparing for adverse events, monitoring and tracking performance, implementing maintenance and recovery plans, and adapting a system to achieve the desired level of resilience.

Definitions of resilience abound (Zhou *et al.*, 2009). Nuances aside, most em-

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phasize the concepts of system function and recovery following an adverse event. At the 2005 World Conference on Disaster Reduction, the United Nations Office for Disaster Risk Reduction (UNISDR) defined resilience as "the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure" (2005). A National Research Council (NRC) report subsequently defined resilience as "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events" (2012). The U.S. Army Corps of Engineers (USACE) definition—"the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions"—is consistent with these definitions (Rosati, Touzinsky, and Lillycrop, 2015).

Some authors have concluded that most of the literature on resilience is conceptual, theoretical, or too impractical for operational use in managing real systems (Alderson, Brown, and Carlyle, 2015; Gay and Sinha, 2013). A number of rating tools, metrics, and indicators are available for community resilience assessment. Examples include the Baseline Resilience Index for Communities (Cutter, Burton, and Emrich, 2010) and the Coastal Resilience Index SeaGrant (Sempier *et al.*, 2015). Chang *et al.* (2014) and McDaniels *et al.* (2015) have developed structured qualitative frameworks for characterizing system resilience and identifying priorities to mitigate potential losses in the functional performance of infrastructure systems. These efforts are useful because they help create self-awareness, identify potential shortcomings, and set priorities for remedial action to improve resilience. Few authors have suggested truly quantitative measures of disaster resilience. Bruneau *et al.* (2003) introduced the concept of the "resilience triangle" and proposed that resilience could be measured in terms of the loss in quality of performance integrated over the recovery period. This is illustrated in Figure 1a, which shows a system operating at nominal performance level q_0 until a disturbance occurs at time t_D, when performance degrades to q. A disturbance is a transient excursion of forces acting on a system that jeopardizes its function because those forces are outside the range for which thatt system was designed to operate (Schultz, McKay, and Hales, 2012). After forces acting on the system have returned to normal, system performance recovers from level q to level q_0 by some recovery trajectory. The resilience triangle measures the loss in performance between t_D and recovery at time t.The performance loss L is calculated: $L = \int^{t}_{tp}[q_0 - Q(t)]dt$ (Bruneau *et al.*, 2003). The function $Q(t)$ can take different forms (Cimellaro, Reinhorn, and Bruneau, 2010). Three possible patterns of recovery are illustrated in Figure 1a: (a) concave, (b) linear, and (c) convex. Greater loss is associated with patterns of recovery that follow a concave function than with those that follow a convex function. This approach has been further developed using variations on this measure of loss in studies of health care facilities (Bruneau and Reinhorn, 2007; Cimellaro, Reinhorn, and Bruneau, 2010), bridge networks (Bocchini and Frangopol, 2011; Bocchini *et al.*, 2014), and natural gas distribution networks (Cimellaro, Villa, and Bruneau, 2015). One feature of this approach is that an accurate characterization of the loss requires knowledge of the recovery trajectory, which can be a challenge.

Using the resilience triangle as a point of departure, Chang and Shinozuka (2004) proposed a probabilistic measure of resilience that avoids the need to specify the shape of the recovery trajectory. This is illustrated in Figure 1b, which shows the quality of functional performance Q on the y-axis and time T on the x-axis. Here, Q and T are random variables because they describe system performance and recovery following a future storm event. Performance and recovery are uncertain because they cannot be observed before the event. Before a disturbance that occurs at time t_D, the functional performance of the system is at a nominal predisturbance level, q_0. The effect of the disturbance is to cause the functional performance of the system to degrade to a minimum level, q, following the event. The ability of the system to maintain its functional performance is called robustness. The recovery period r follows the disturbance event until the predisturbance nominal level of performance is recovered at time t. The speed with which the system recovers its predisturbance level of functional performance is rapidity. The system is resilient, R=A, if the minimum level of functional performance q is no less than that prescribed by system managers, q^*_s, and the time needed to recover the nominal level of performance, $r = t - t_D$,

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is no greater than that prescribed by system managers, r^*_s. These two limit state criteria, q^* and r^*, are the resilience management objectives for the system and they vary with severity of the disturbance event. The measure of resilience proposed by Chang and Shinozuka (2004) is the probability that both limit state criteria are met given the severity s of an event: $p(A|s)=p(q \geq q^*_s \cup r \leq r^*_s)$. The probabilistic measure of resilience is straightforward conceptually, but it can be a challenge to assess in practice. Schultz, McKay, and Hales (2012) explored how this probabilistic measure of resilience could be applied to integrated coastal systems, focusing on mission functions of the USACE. This paper builds on that work by demonstrating how the probabilistic measure of resilience can be assessed for a dense, urban, coastal community focusing on infrastructure systems.

This demonstration uses a Bayesian network to calculate the probabilistic resilience measure. Bayesian networks are directed acyclic graphs (DAGs) designed for probabilistic reasoning about a system of interest (Pearl, 1988). The Bayesian network provides a convenient way to represent the dependencies among infrastructure components, the uncertainty in the response of infrastructure components to coastal storm loads, and the influence of management actions on functional performance of the system. Bayesian networks have previously been used to model the reliability of networked infrastructure systems (Bensi, Der Kiureghian, and Straub, 2013; Langseth and Portinale, 2005; Mahadevan, Zhang, and Smith, 2001; Straub and Der Kiureghian, 2010a, b; Wilson and Huzurbazar, 2007). Other authors have described the benefits and the challenges of using Bayesian networks to model infrastructure systems (Langseth, 2008; Medina-Oliva *et al.*, 2009). In this application, the Bayesian network provides value in terms of its ability to represent dependencies among infrastructure components, integrate the outputs of storm simulation models, and facilitate reasoning about what effect management actions might have on the probabilistic resilience measure.

The study site is Jamaica Bay, New York, and the focus is on four community functions that are relevant to the USACE mission. These are life safety, housing, utilities, and transpor-tation. The Bayesian network provides a platform upon which to assess the resilience benefits of proposed actions to mitigate coastal storm risks, including wetlands restoration, beach nourishment, and evacuation policies. The aim of the pilot study is to demonstrate the method; identify data requirements; evaluate advantages, challenges, and limitations; and assess the feasibility of using this approach to support coastal risk management. Therefore, numerical results of this pilot study should be considered illustrative. Results illustrate how practical information can be gleaned from this approach to resilience assessment to support decisions about coastal resilience design, monitoring, assessment, management, and adaptation.

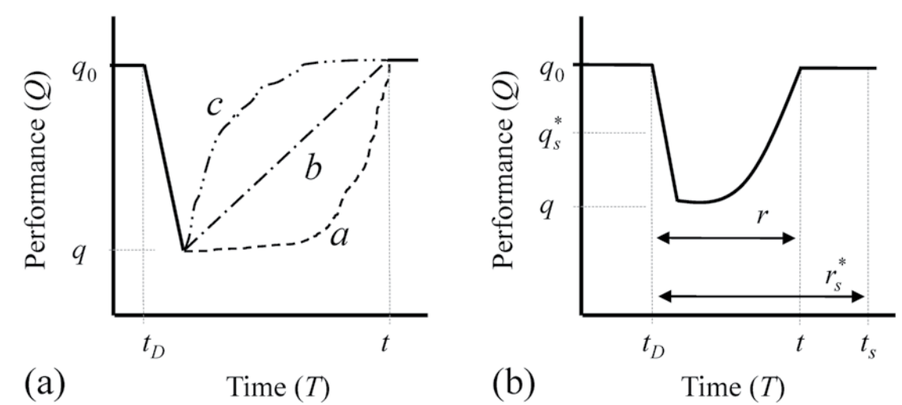

Figure 1. Conceptual diagram of resilience. (a) Functional performance degradation and recovery by one of three possible trajectories. Greater loss is associated with patterns of recovery that follow a concave function than with those that follow a convex function. (b) Limit state criteria q^*_s and r^*_s, which are the resilience management objectives for robustness and rapidity.

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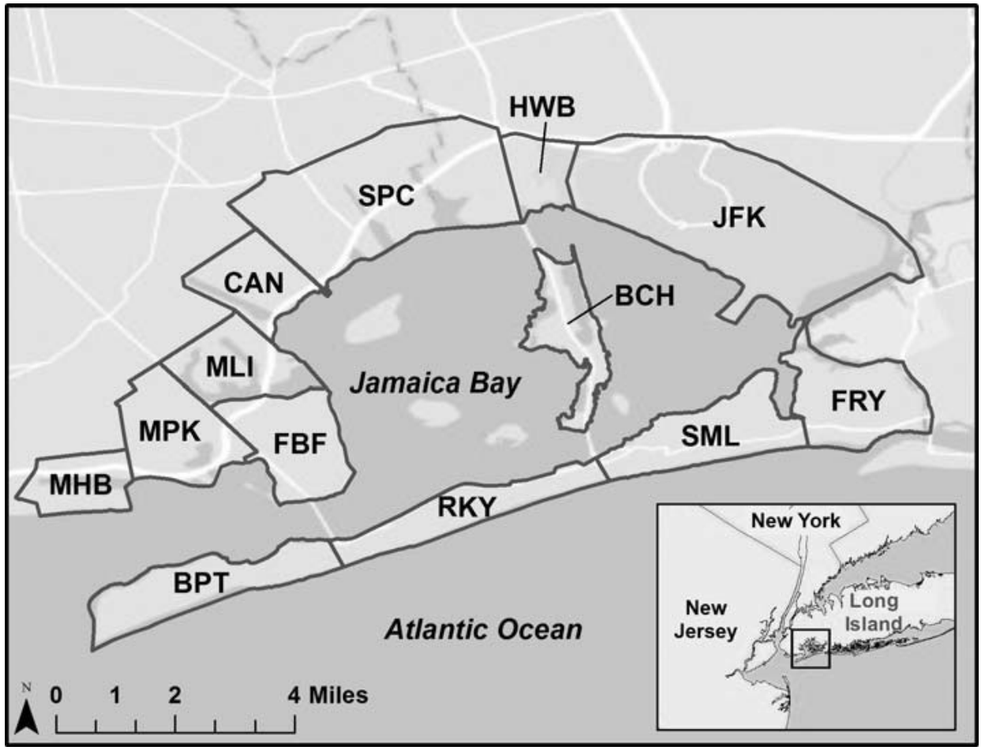

Figure 2. Map of the Jamaica Bay study area. The figure shows the location of the 13 planning units. See Table 1 for an explanation of planning unit abbreviations.

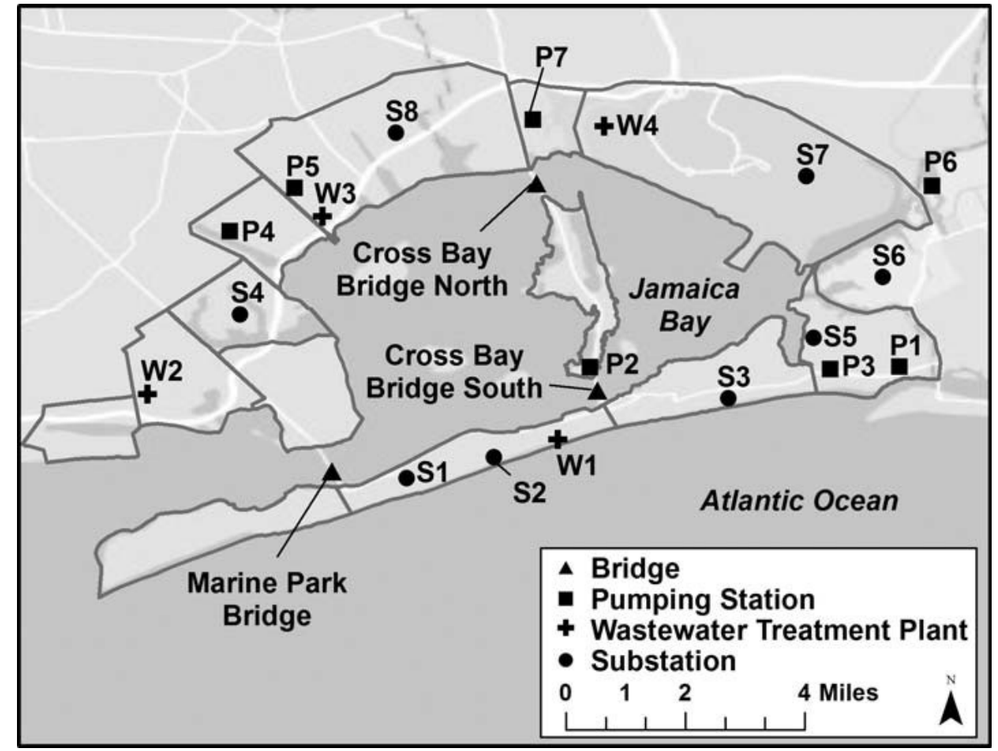

Figure 3. Map of infrastructure component locations. The figures shows where bridges, area electric substations (S), wastewater pumps (P), and wastewater treatment plants (W) are located.

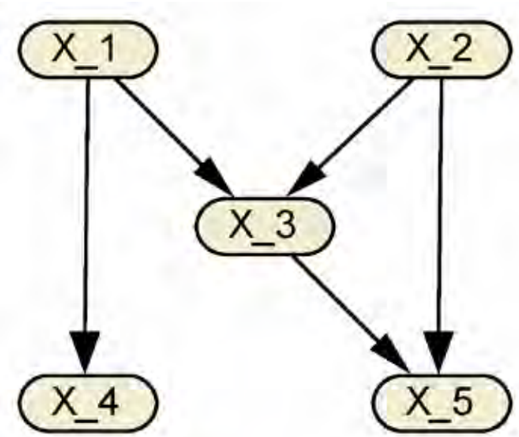

Figure 4. A DAG. The figure shows a graphical model that describes causal relationships among five random variables. The variables are represented by nodes, and the directed edges between nodes signify the influence of one variable (the parent) on another variable (the child) in the direction of the edge.

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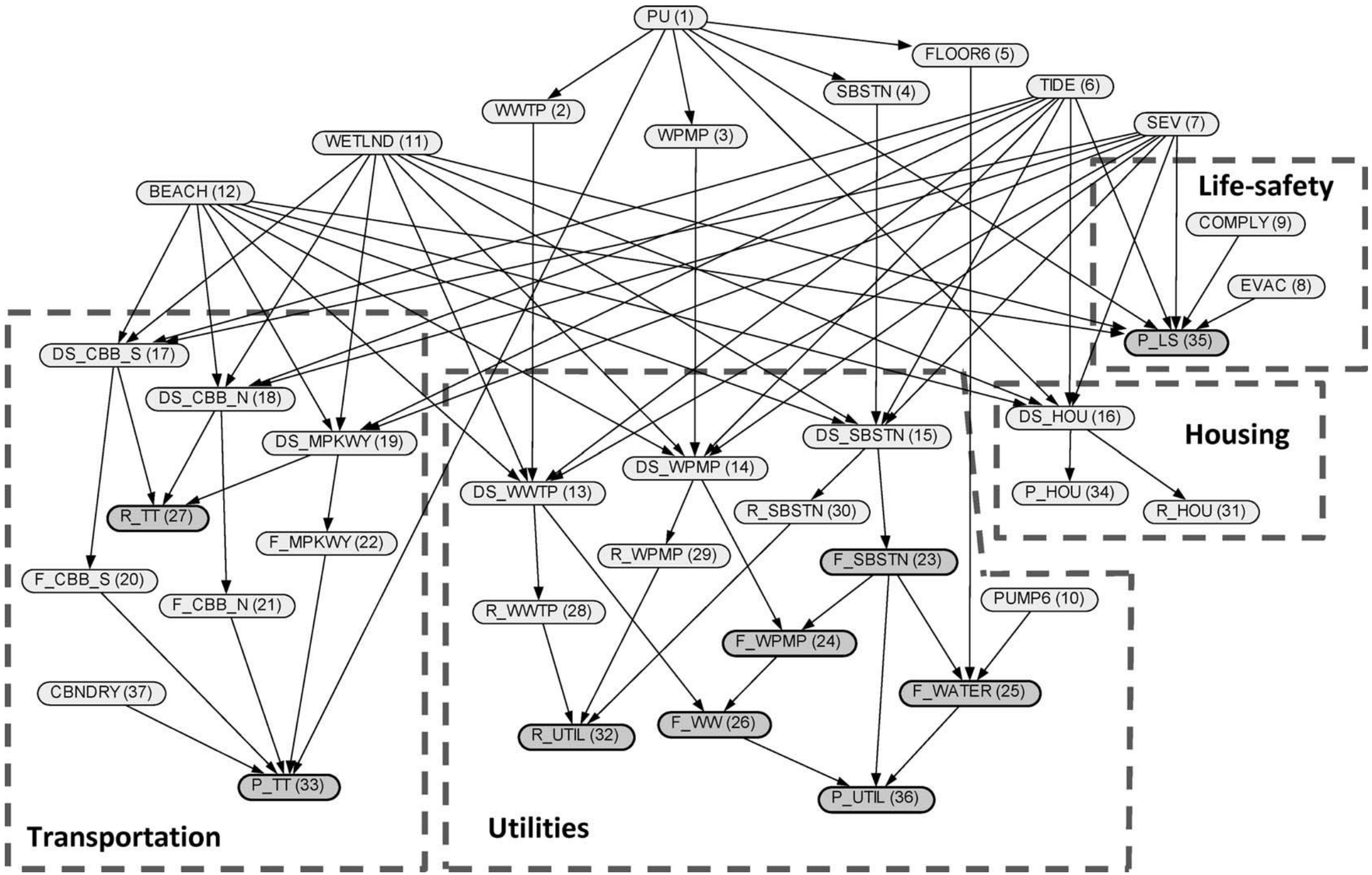

Figure 5. Bayesian network for resilience assessment in Jamaica Bay. Each node represents a random variable that influences resilience in the Jamaica Bay area, and edges between nodes show which variables have direct influence on other variables. The dashed lines denote the boundaries of subgraphs for functional performance objectives as described in the text.

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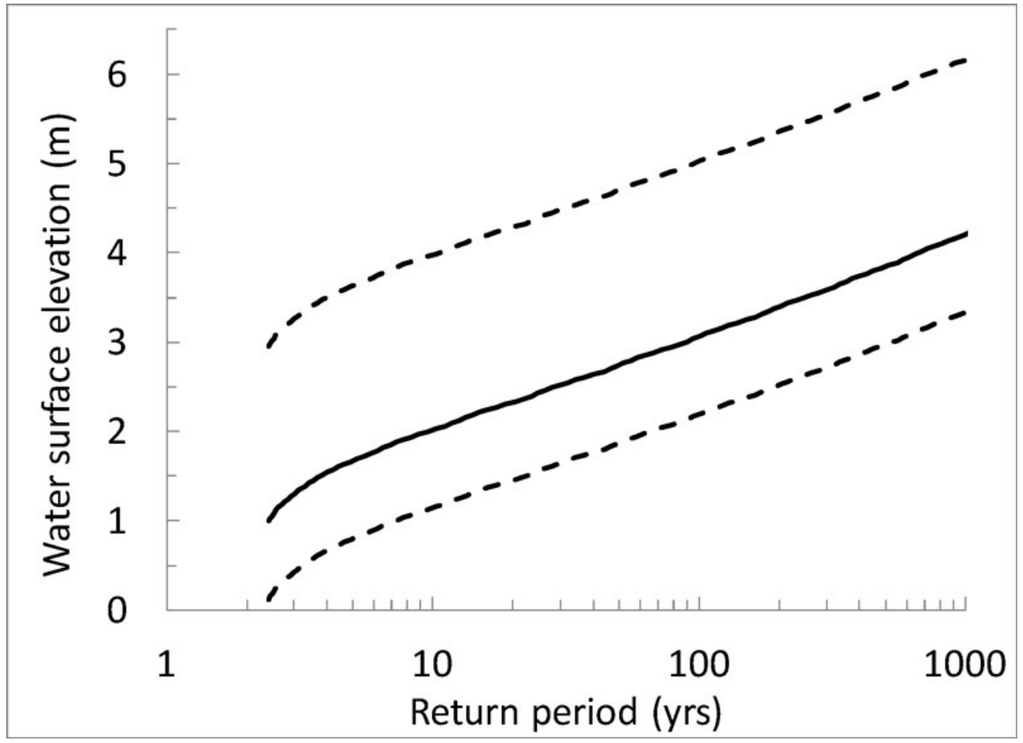

Figure 6. Storm surge return period curve at the Marine Park Bridge. Water surface elevations are relative to NAVD88. The return period curve is used to estimate 250-, 500-, and 1000-year storm surge elevations. Upper and lower dashed lines show the potential effect of high and low tide on water surface elevation, respectively.

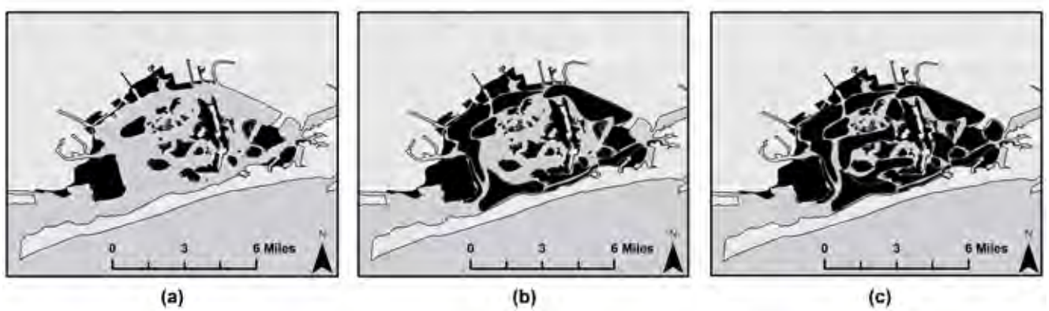

Figure 7. Three wetland alternatives in Jamaica Bay: status quo (a), moderate (b), and extensive (c). The figure shows how the existing configuration of wetland areas in the status quo scenario was modified to represent moderate and extensive wetland restoration scenarios.

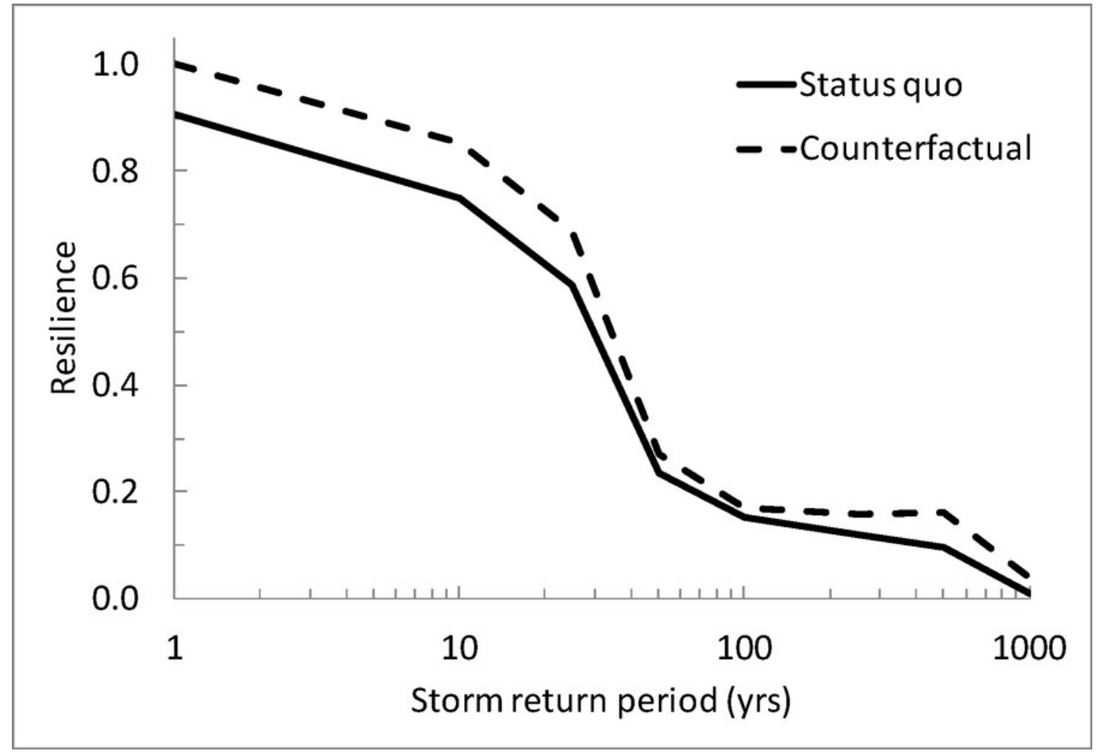

Figure 8. Resilience of the status quo and counterfactual scenarios. The figure shows that the counterfactual scenario increases resilience in Jamaica Bay relative to the status quo scenario.

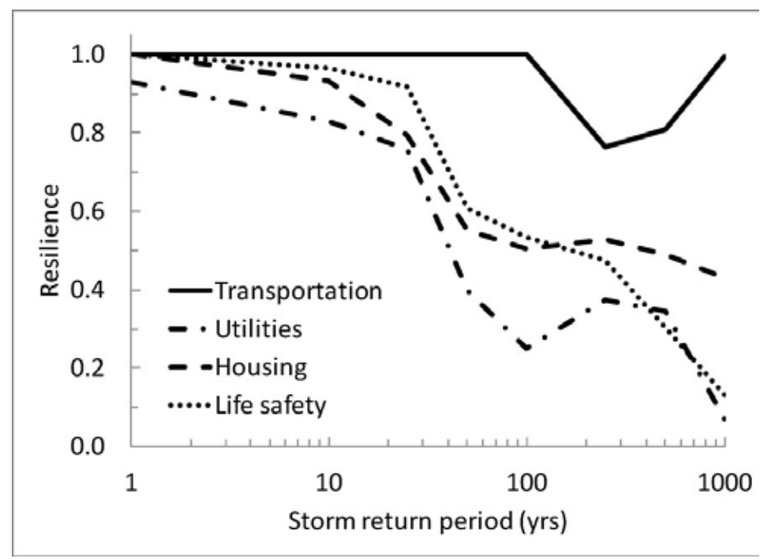

Figure 9. Resilience of the status quo scenario with respect to individual functional performance objectives. The figure shows that resilience under the status quo scenario varies for each functional performance objective. Resilience is highest for the transportation performance objective and lowest for the utility performance objective.

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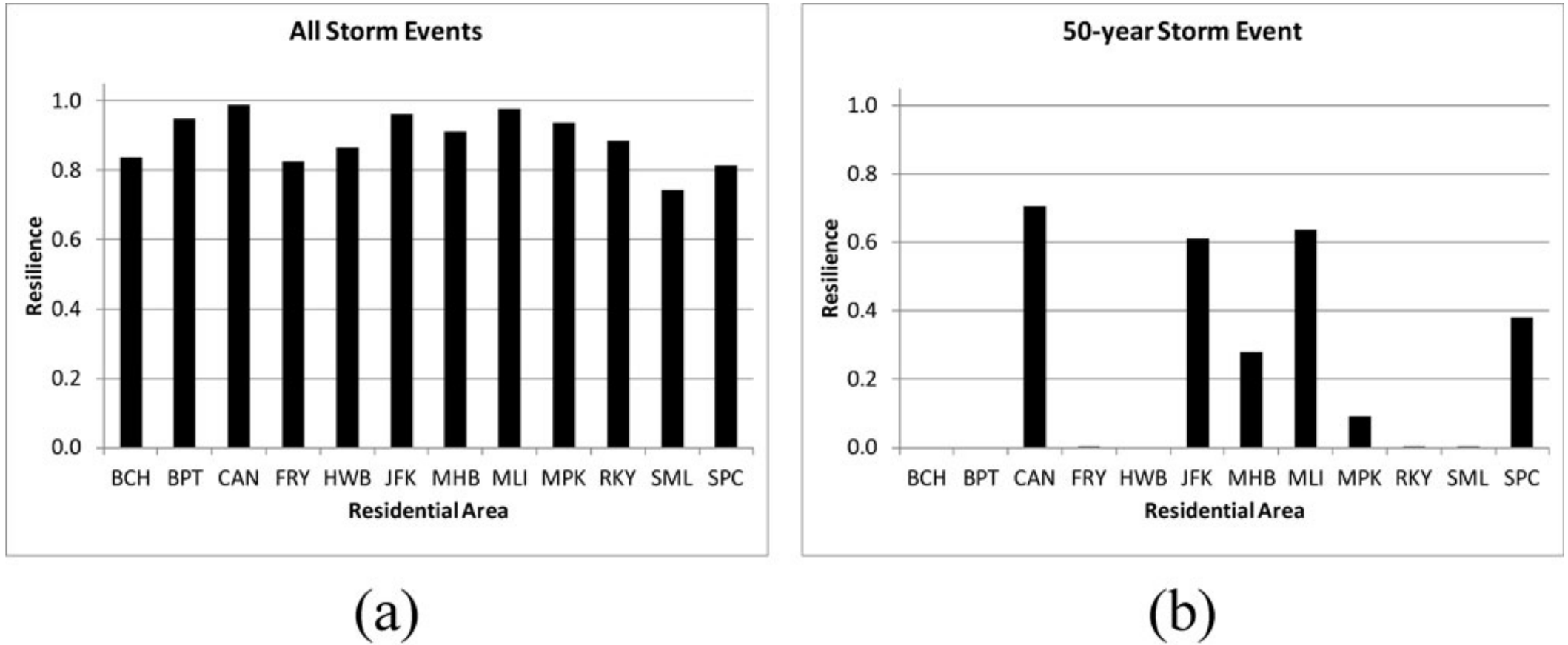

Figure 10. Status quo resilience by planning unit. (a) Resilience of each planning unit is relatively high under the status quo scenario when calculated for all potential storm events. (b) Resilience of each planning unit is lower when calculated for a 50-year storm event.

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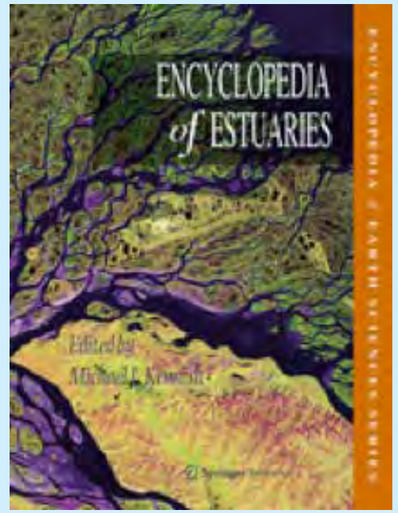

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Behavioral Release Condition Score of Bull and Bonnethead Sharks as a Coarse Indicator of Stress

Behavioral Release Condition Score of Bull and Bonnethead Sharks as a Coarse Indicator of Stress

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ABSTRACT

Capture and handling stress can induce acidosis and sometimes mortality in sharks. To approximate physiological condition after capture, fisheries researchers may use a behavioral health assessment at release. The goal of this study was to assess the efficacy of the behavioral release condition score (BRCS) in estimating the physiological stress response. The score was tested against changes in acid-base, blood gas, and metabolite analytes (pH, partial pressure of CO_2, and lactate) and factors known to influence those analytes (species, capture and handling time, and water temperature) among wild-caught bull (*Carcharhinus leucas*) and bonnethead (*Sphyrna tiburo*) sharks. After gill net capture, sharks were processed for tagging, morphometrics, and blood sampling. Blood was sampled immediately before release. At release, a BRCS was assigned as good, fair, poor, or moribund. BRCS was modeled as a response to changes in blood analytes and putative stressors using ordinal logistic regression (OLR). Effects of significant main factors were further explored graphically and in chi-square tests or (multivariate) analyses of variance (MANOVAs/ANOVAs). Linear discriminant analyses with cross-validation were used to assess the ability of those factors to discriminate among BRCS on a case-by-case basis. The OLR models suggest that BRCS responds in species-specific ways to all three blood analytes and putative stressors. However, the broad overlaps in ranges of these parameters among BRCS lend prediction of BRCS by either of these two sets of predictors to be challenging to utilize. Given the coarse relationship of BRCS to acid–base status in these species, further investigation of this and other behavioral assessment methods is recommended.

ADDITIONAL INDEX WORDS: *Acidosis, behavior, blood gas, capture, handling, shark.*

INTRODUCTION

Understanding the connection between capture and handling, stress response, and morbidity and mortality of sharks after release is valuable for developing best conservation practices for these important apex predators. Sharks are sensitive to acute capture and handling stress, which can result in physiological acidosis in the blood and tissues and can lead to death in some cases (Cliff and Thurman, 1984; Hyatt *et al.*, 2012; Skomal and Mandelman, 2012). This presents significant challenges in commercial fisheries, in catch-and-release recreational fishing, to scientists studying sharks in the wild and in human care, and to veterinarians caring for sharks in public aquaria.

Sharks have a low capacity for aerobic metabolism compared with higher vertebrates and quickly shift to anaerobic metabolism when caught or handled (Brill *et al.*, 2008; Cliff and Thurman, 1984; Hoffmayer and Parsons, 2001; Mandelman and Skomal, 2009; Manire *et al.*, 2001). Sharks will naturally use anaerobic muscle activity for short bursts of speed, such as in hunting or predator evasion, but response to prolonged capture and handling stress can exac-

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erbate anaerobic metabolism, often leading to exhaustion. The adaptive components of the stress response are mediated endocrinologically via the secretion of catecholamines and glucocorticoid hormones, often considered as indices of a primary stress response (Sumpter, 1997). Together, these hormones cause a suite of changes in the physiology of the animal, considered as secondary stress indices. These include changes in the matrix of osmotic, acid–base, blood gas, and biochemical components of the blood (McDonald and Milligan, 1997). Tertiary stress indices include measures such as behavioral changes (Schreck, Olla, and Davis, 1997), and depression in growth, weight gain, fecundity, and survival of offspring (Pankhurst and Van Der Kraak, 1997). This homeostatic disruption can result in a decrease in blood pH secondary to an overreliance on glycolysis beyond a steady state, with excessive production of protons (H^+). In response, lactate production increases under these cellular conditions to prevent pyruvate accumulation and supply the nicotinamide adenine dinucleotide (oxidized) need-ed for glycolysis. Increased lactate production coincides with cellular acidosis and is a good indirect marker for cellular metabolic conditions that induce metabolic acidosis (Cliff and Thurman, 1984; Hoffmayer and Parsons, 2001; Holeton and Heisler, 1983; Mandelman and Skomal, 2009; Manire *et al.*, 2001; Robergs, Ghiasvand, and Parker, 2004; Skomal and Mandelman, 2012).

In addition, many sharks are obligate ram ventilators. In times of capture stress or entanglement in a net, their ventilation is depressed or even stopped, leading to an increase in carbon dioxide in the blood (partial pressure of CO_2 [pCO_2]), which can depress the blood pH further, thus producing a respiratory acidosis (Mandelman and Skomal, 2009; Skomal and Mandelman, 2012). Sharks that fight and are unable to swim are more severely affected, with a mixed metabolic and respiratory acidosis (Mandelman and Farrington, 2007a,b; Mandelman and Skomal, 2009; Manire *et al.*, 2001). There is still debate about whether this is a major contributing factor to the high rates of mortality some sharks experience after capture and handling (Frick, Walker, and Reina, 2012; Mandelman and Skomal, 2009; Wood, Turner, and Graham, 1983). The change in blood gases, acid–base balance, and biochemistry is a secondary stress response in sharks and can be used as a relative correlate to overall physiological condition (Skomal and Mandelman, 2012). Measurement of blood gas, acid–base status, and biochemical analytes, collectively re-ferred to as blood gas analysis for simplicity, includes pH, partial pressure of oxygen (pO_2), pCO_2, bicarbonate (HCO^-_3), and lactate concentrations ([lac]). Blood gas analysis has become the standard for assessing the physiological stress response in shark fisheries research and veterinary medicine (Gallagher *et al.*, 2010; Hadfield, Whitaker, and Clayton, 2007). This is a benchmark because of the well-understood mechanisms previously described, and also due to the lack of commercially available assays for the primary stress hormone in sharks,1a-hydroxycorticosterone (Nunez and Trant, 1999). Although there are many physiological indicators of stress in animals, blood gas analysis is one of the better tools, as it has been extensively studied in sharks.

Predicting postrelease mortality or survival to improve fisheries management strategies has been the topic of numerous studies (*e.g.*, Campana, Joyce, and Manning, 2009; Carruthers, Schneider, and Neilson, 2009; Cooke *et al.*, 2008; Frick, Reina, and Walker, 2010; Frick, Walker, and Reina, 2010; Gallagher *et al.*, 2014; Hueter and Manire, 1994; Hueter *et al.*, 2006; Mandelman and Farrington, 2007a,b; Manire *et al.*, 2001; Moyes *et al.*, 2006; Musyl *et al.*, 2009; Renshaw *et al.*, 2012; Sepulveda *et al.*, 2015; Skomal, 2007). Many of the above researchers recommend the development of better predictive models on the basis of physiological consequences of capture and handling stress to estimate postrelease delayed mortality. Before predictive models for mortality can be established, a better understanding of how stress physiology relates to behavioral, physiological, and biochemical indices is warranted. The evaluation of behavior postcapture and handling and how it may relate to physiological changes can be a starting point to build upon. Some scientists have invoked the scoring of swimming behavior upon release after a stressful event as a behavioral method of assessing condition (Afonso and Hazin, 2014; Hueter and Manire, 1994; Hueter *et al.*, 2006; Manire *et al.*, 2001). The behavioral release condition score (BRCS) is usually given as good, fair, poor, or moribund; or a related scheme. One premise behind the BRCS is that it may relate to severity of acidosis developed during capture and handling stress. It is hypothesized that

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if a shark becomes overwhelmed by stress and develops acidosis, then the shark's swimming behavior could be affected upon release. As an example, a presumed minimally stressed shark with no evidence of acidosis would likely be released with a BRCS of good, whereas a highly stressed shark with severe acidosis would be released with a BRCS of poor, or even moribund. However, the BRCS of a shark as a correlate of its physiological condition has not been validated. Corresponding changes in blood gas analysis to the BRCS would help validate the use of BRCS to estimate the stress response to capture and handling. This method holds merit in ecological risk assessments, veterinary care, and husbandry of sharks, where evaluating behavioral condition would be easier, less expensive, and less invasive than blood gas analysis or other physiological diagnostics.

The objective of this study was to assess the reliability of BRCS to (1) correspond with blood gas analysis analytes of pH, pCO_2, and [lac] in assessing the severity of the secondary stress response of wild bull *(Carcharhinus leucas)* and bonnethead (*Sphyrna tiburo*) sharks to capture and handling, and (2) respond to factors known to affect the acid–base status, such as species, capture and handling time (Hyatt *et al.*, 2012), and temperature (Heisler, Neumann, and Holeton, 1980).

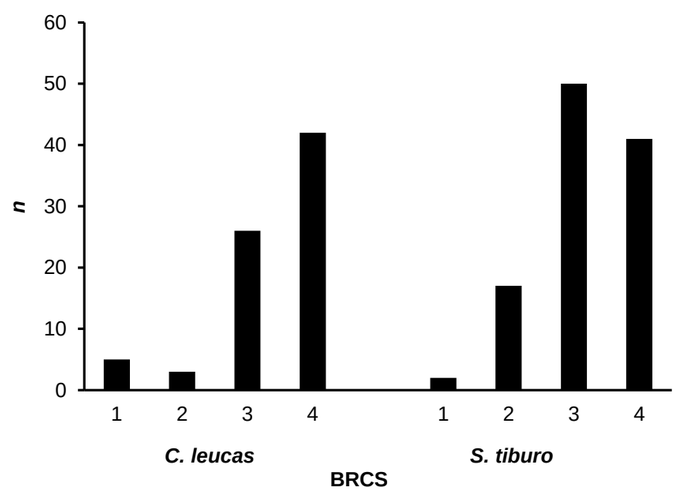

Figure 1. Histogram of BRCS among captured and handled *C. leucas* and *S. tiburo*.

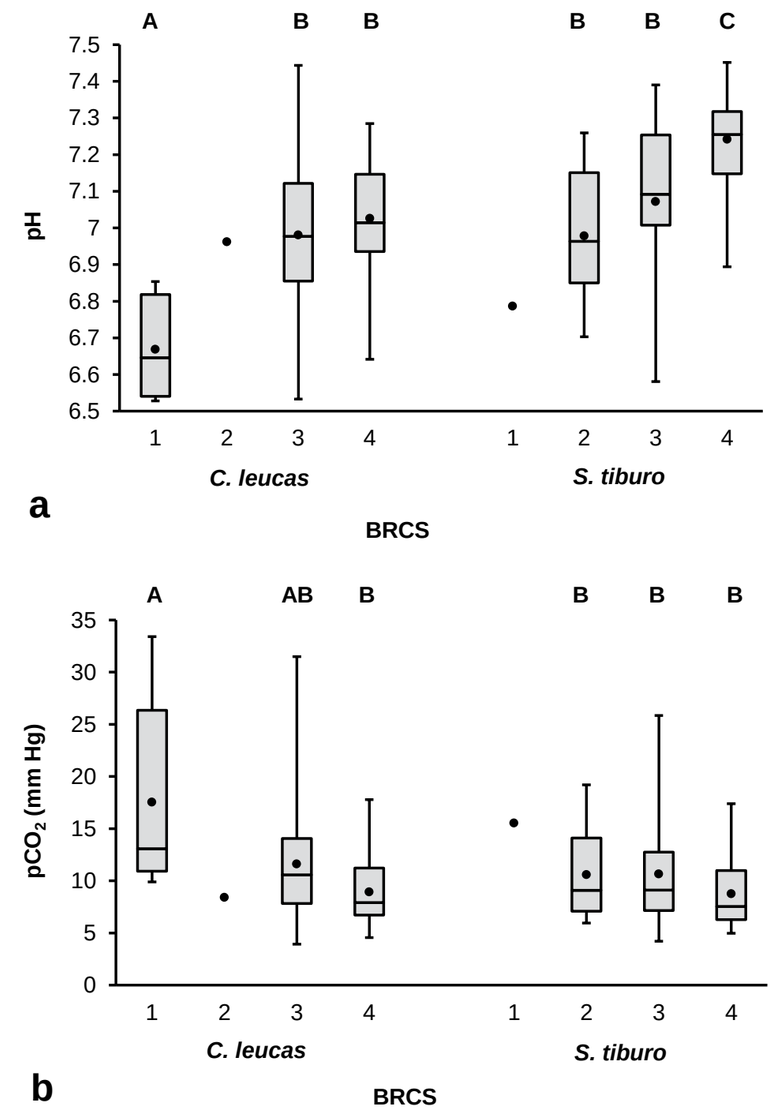

Figure 2. Box plots of blood gas analysis parameters among BRCS for *C. leucas* and *S. tiburo*. Some BRCS did not contain sufficient sample sizes to construct box plots; means are only represented in those categories (as closed circles). Means that do not share a letter above box plots are significantly different as determined by ANOVA and Tukey's test. (a) pH (temperature corrected). (b) pCO_2 (temperature corrected). (c) [lac].

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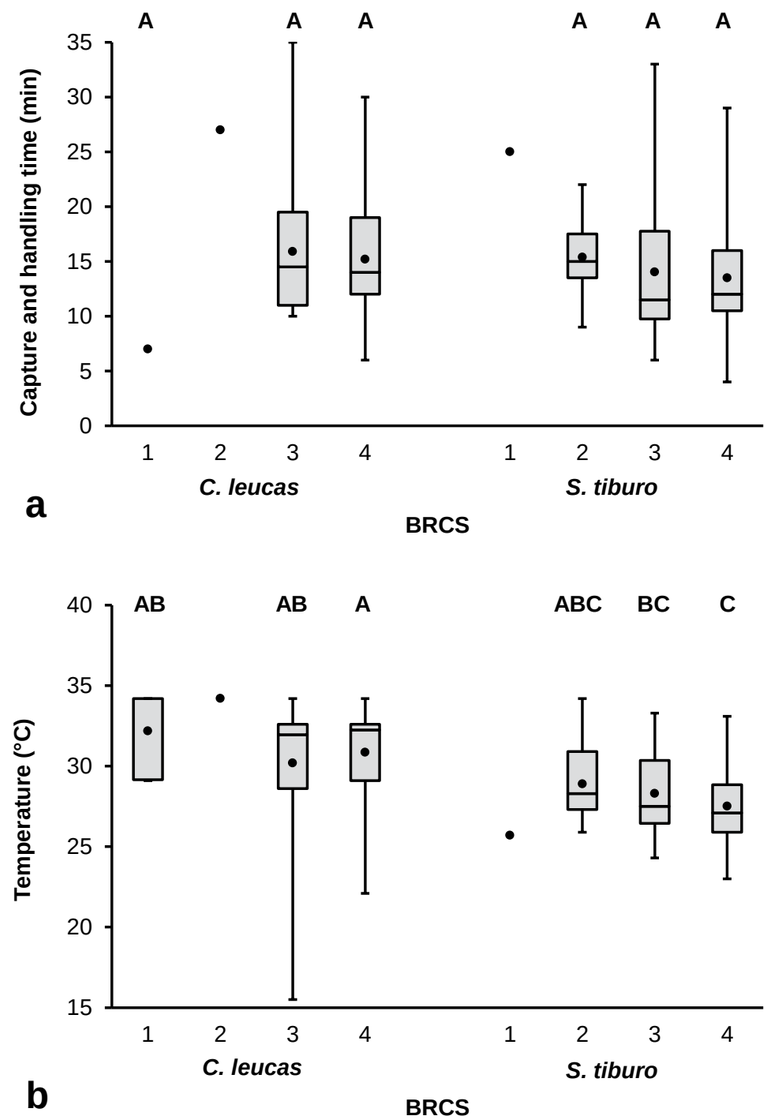

Figure 3. Box plots of putative stressors among BRCS for *C. leucas* and *S. tiburo*. Some BRCS did not contain sufficient sample sizes to construct box plots; means are only represented in those categories (as closed circles). Means that do not share a letter above box plots are significantly different as determined by ANOVA and Tukey's test. (a) Capture and handling time. (b) Temperature.

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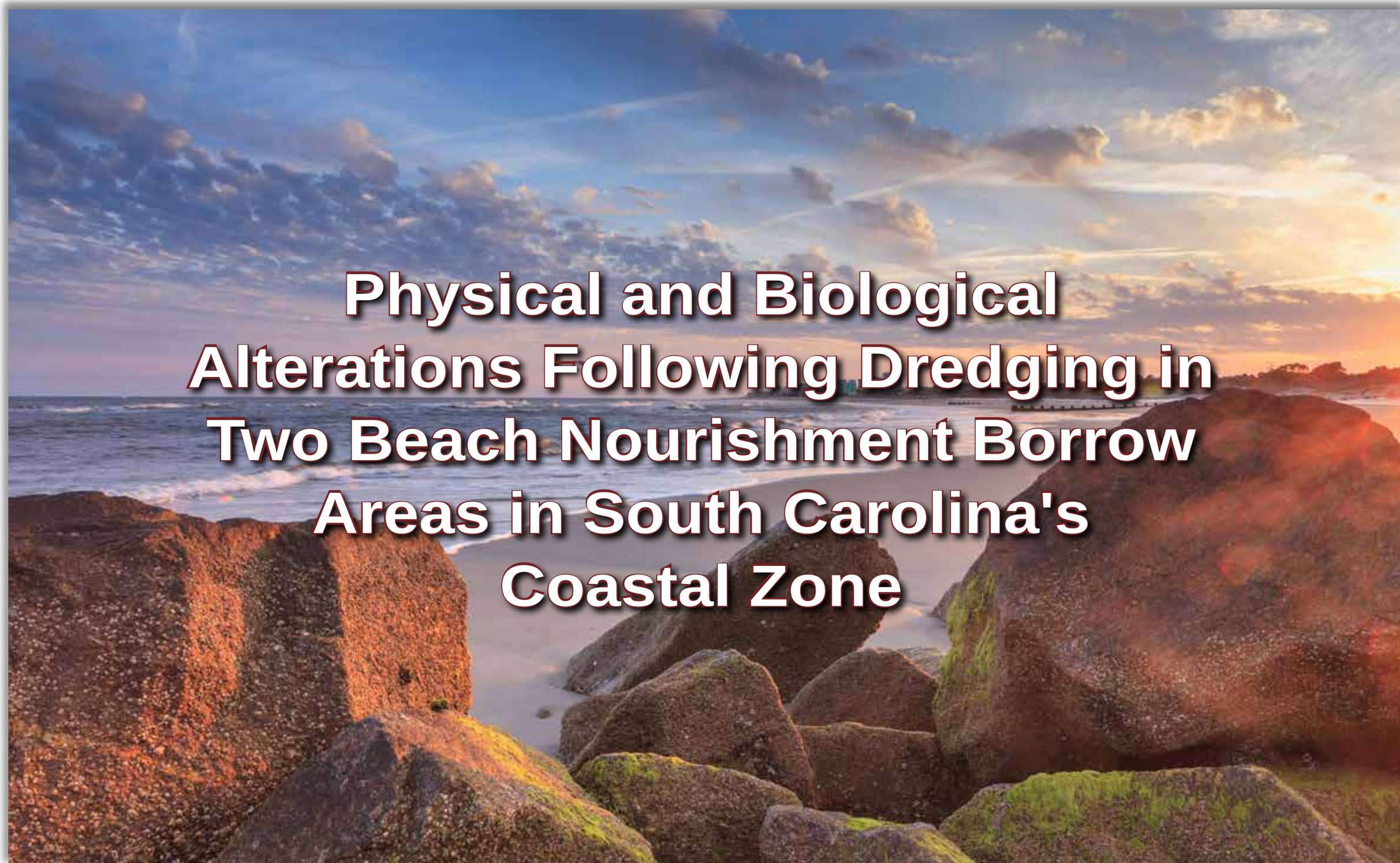

Physical and Biological Alterations Following Dredging in Two Beach Nourishment Borrow Areas in South Carolina's Coastal Zone

Physical and Biological Alterations Following Dredging in Two Beach Nourishment Borrow Areas in South Carolina's Coastal Zone

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ABSTRACT

Dredging of nearshore subtidal sand deposits as a source for beach fill is a common practice in the SE United States, but the long-term effects of this practice on benthic environments are not well documented. Two borrow areas used to nourish the shoreface of Folly Beach, South Carolina, in 2005 (borrow area A) and 2007 (borrow area B) were sampled for sediment characteristics (silt and clay, calcium carbonate, total organic matter content, and sand phi size) and macrobenthic infaunal community composition using a before–after, control–impact design over periods of 8 and 6 years postdredging, respectively. Following dredging, surficial sediment characteristics within both borrow pits shifted toward finer materials and showed little evidence of recovering 8 and 6 years after impact. Changes in the benthic community occurred with respect to faunal density, number of species, and changes in composition at the species level, largely reflecting recolonization by opportunistic taxa within the disturbed seafloor. Benthic community changes consisted largely of the loss of species associated with coarser sands and shell and recolonization by species associated with finer sands and silt and clay. The similar responses of two nearby borrow areas dredged 2 years apart may be partly because of their location and the depth they were dredged below the seafloor. Borrow site location and the depth at which sediments are mined below grade may be important considerations for improving the sustainable reuse of limited sand resources in many areas and avoiding long-term changes in benthic infaunal community composition.

ADDITIONAL INDEX WORDS: *Renourishment, disturbance, benthic community, sediment.*

INTRODUCTION

Beach nourishment represents a widely used and rapidly expanding strategy for countering erosion worldwide (Finkl, Benedet, and Campbell, 2006; Hanson, 2003; Valverde, Trembanis, and Pilkey, 1999). This process involves removing beach-compatible material from a "borrow" area and placing that material onto the eroding shoreface, in essence replacing lost sand and adding to the littoral sediment budget (NRC, 1995). The sediment required for nourishment projects commonly originates from dredging of nearshore subtidal sand deposits. Dredging of these environments often causes immediate and persistent changes in the volume and composition of sediment and in local biological communities (Foden, Rogers, and Jones, 2009; ICES, 2001; Newell, Seiderer, and Hitchcock, 1998; Wilber *et al.*, 2009).

The rate of sediment refilling of dredged pits can be highly variable and depends on numerous factors, including proximity to mobile sediment sources and wave and current energy (Desprez, 2000; Foden, Rogers, and Jones, 2009; van der Veer, Bergman, and Beukema, 1985; Van Dolah *et al.*, 1998). In many places, dredge pits may be expected to refill with material similar to that removed or that surrounding the pit (Byrnes *et al.*, 2004a, b; Simonini *et al.*, 2007; van Dalfsen *et al.*, 2000). However, sediment char-

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acteristics within the dredge pit can also diverge from those present before dredging. Dredging sometimes uncovers buried sediment layers, resulting in at least short-term shifts in surface sediment characteristics (Kenny and Rees, 1996), while in others highly mobile clay, silt, and/or finer sands settle into the pit (Fraser, Hutchings, and Williamson, 2006; Graca, Burska, and Matuszewska, 2004; van Dalfsen *et al.*, 2000; van der Veer, Bergman, and Beukema, 1985). In some cases, fine material accumulated in a dredge pit may be capped by a layer of sand, potentially affecting the sustainable reuse of the area for future nourishment projects and leading to dredging of previously undisturbed seafloor (Van Dolah *et al.*, 1998).

Dredging removes surficial sediments and associated fauna, which can result in the benthic invertebrate community structure changing significantly following dredging (Naqvi and Pullen, 1982; Newell, Seiderer, and Hitchcock, 1998). Recovery of benthic community characteristics to predredge conditions may occur within 1 year when dredging depths are limited, the dredged area is small, sediment and current conditions are minimally modified, and/or ridges of undisturbed sediment provide sources of recruits to disturbed dredged furrows (Jutte *et al.*, 2001a; Newell *et al.*, 2004; Posey and Alphin, 2002). Longer-term recolonization (recovery) rates vary significantly, however, and likely depend strongly upon the recovery of native substrate and hydrodynamic regimes (Desprez, 2000; Foden, Rogers, and Jones, 2009; Newell, Seiderer, and Hitchcock, 1998). Depending on the environment and the nature of the dredging impact, biological recovery may not occur for many years (Cooper *et al.*, 2007; Fraser, Hutchings, and Williamson, 2006; Kenny and Rees, 1996; Palmer, Montagna, and Nairn, 2008).

The purpose of this study was to determine the effects and recovery of sediment characteristics and invertebrate communities following dredging in two borrow areas used to nourish Folly Beach, South Carolina, in 2005 and 2007. The timing of these projects provided a unique opportunity to examine the responses of two spatially discrete borrow areas located in close proximity but dredged 2 years apart. In addition, the study included post-dredge monitoring in the borrow areas and a nearby unaffected reference area over a period longer than most similar studies previously conducted in the coastal zone of the United States (NRC, 1995; Wilber *et al.*, 2009).

Folly Island, a barrier island within Charleston County, South Carolina, includes approximately 8.4 km of Atlantic shoreface (Figure 1). The island supports a population of about 2000 residents and a healthy tourist industry largely dependent upon beach access. Folly Island is located about 14 km south of Charleston, South Carolina, a largely urbanized area surrounding the Charleston Harbor estuary. The island is bounded by tidal inlets to the NE and SW, both of which are ebb-tidal deltas typical of South Carolina's mesotidal, mixed-energy coast (Kana *et al.*, 2013; Levine *et al.*, 2009). The nearshore environment off Folly Beach is relatively shallow and covered by thin sand deposits, and only a few areas have sufficient sand volume for mining using a pipeline dredge (U.S. Army Corps of Engineers, or USACE, unpublished data). Net wave energy is to the south and is modulated by the mean tidal range of 1.6 m (1.9 m during spring tides; Weathers and Voulgaris, 2013). Current and sediment flow in the area is generally toward the SW, including ebb tidal sediment plumes from the Charleston Harbor estuary (Blanton, Amft, and Tisue, 1997; Levine *et al.*, 2009). Dominant wind direction changes during the four seasons of the year and typically alternates in the longshore direction from SW to NE (Xu *et al.*, 2014).

Because of erosion, the Atlantic shoreface (Folly Beach) of Folly Island was nourished in 1993 using material dredged from the Folly River, a tidal waterway located behind the island. Ongoing erosion, combined with an active hurricane season in 2004, required another nourishment effort in 2005. This renourishment project included dredging approximately 1.5 million m^3 of sediment from a nearshore borrow area (designated "borrow area A") between May and October 2005 and placing it on approximately 8.0 km of Folly Beach. Near the halfway point of that project's completion, Hurricane Ophelia and Tropical Depression Tammy contributed to the loss of approximately 360,000 m^3 of material from the completed NE end of the project, 50% of the material placed. As a result, an additional emergency nourishment project was performed between April and July 2007. This project dredged 371,000 m^3 of sand from another borrow area (designated "borrow area B") and placed it along a 3.2-km

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stretch of beach (Figure 1). Both borrow areas were located approximately 5.3 km from shore in an 8- to 12-m depth. Because of the relatively shallow bottom depths and wave action, the water column was well mixed (based on water quality measures collected during sampling). Sands were mined using a hydraulic cutter head pipeline dredge, which excavated the borrow pits to depths of 2 to 3.5 m dependent on sand availability over other substratum not suitable for beach nourishment (USACE, unpublished data). Only a portion of each borrow area was mined in this project (Figure 1).

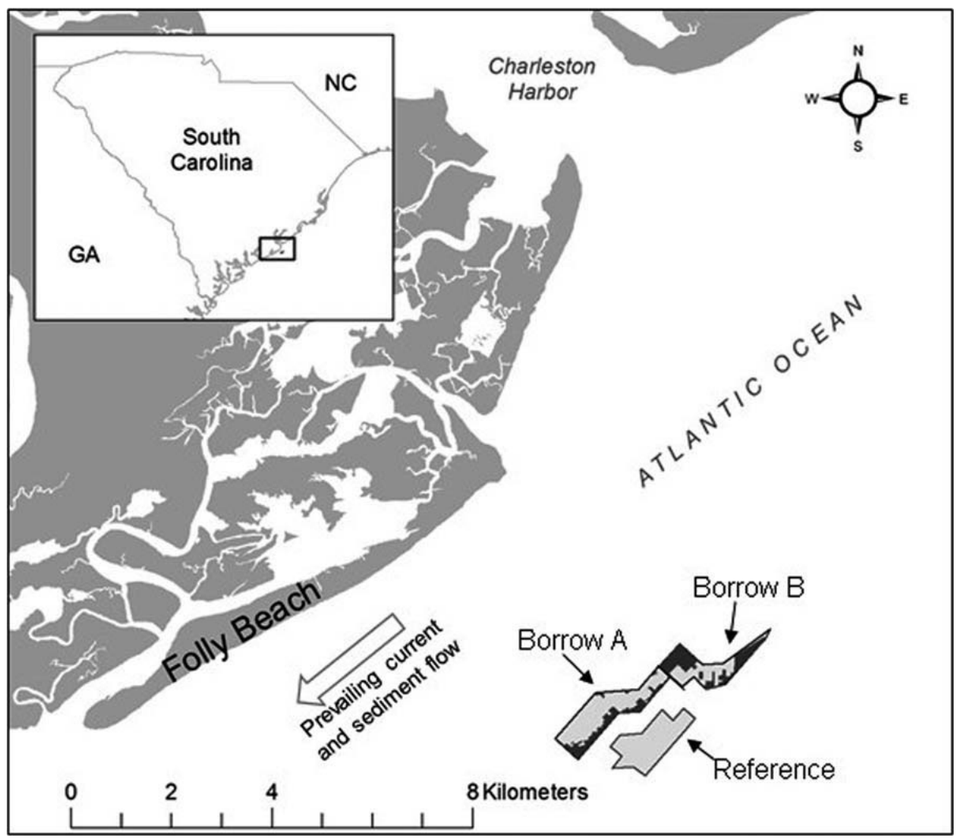

Figure 1. Map of Folly Beach, South Carolina, showing locations of the borrow areas (A and B) used to renourish Folly Beach in 2005 and 2007 and the reference area used for both renourishments. The outline of each borrow area shows the original proposed area, with black shading representing portions not mined for sand.

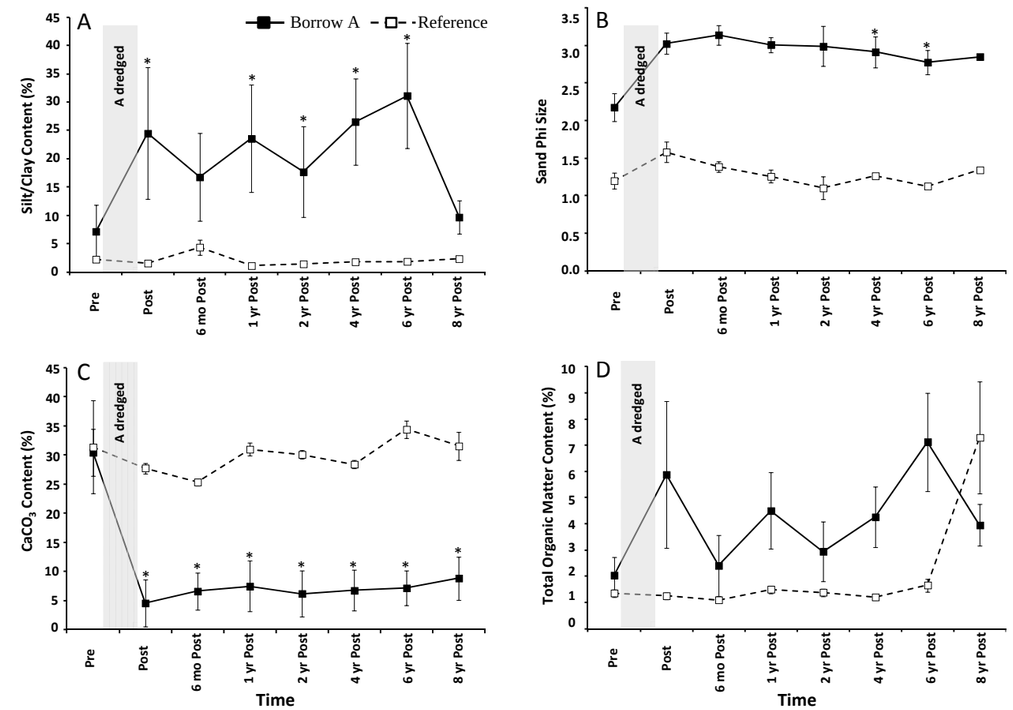

Figure 2. Average values (±SE) for the sediment characteristics (A) percent silt and clay, (B) mean sand phi size, (C) percent $CaCO_3$, and (D) percent TOM through time at borrow area A and the reference area. Asterisks indicate postdredging periods during which the change in observed sediment characteristics at the borrow area was significantly different from the change observed at the reference area when compared to predredging time *–p <0.05.

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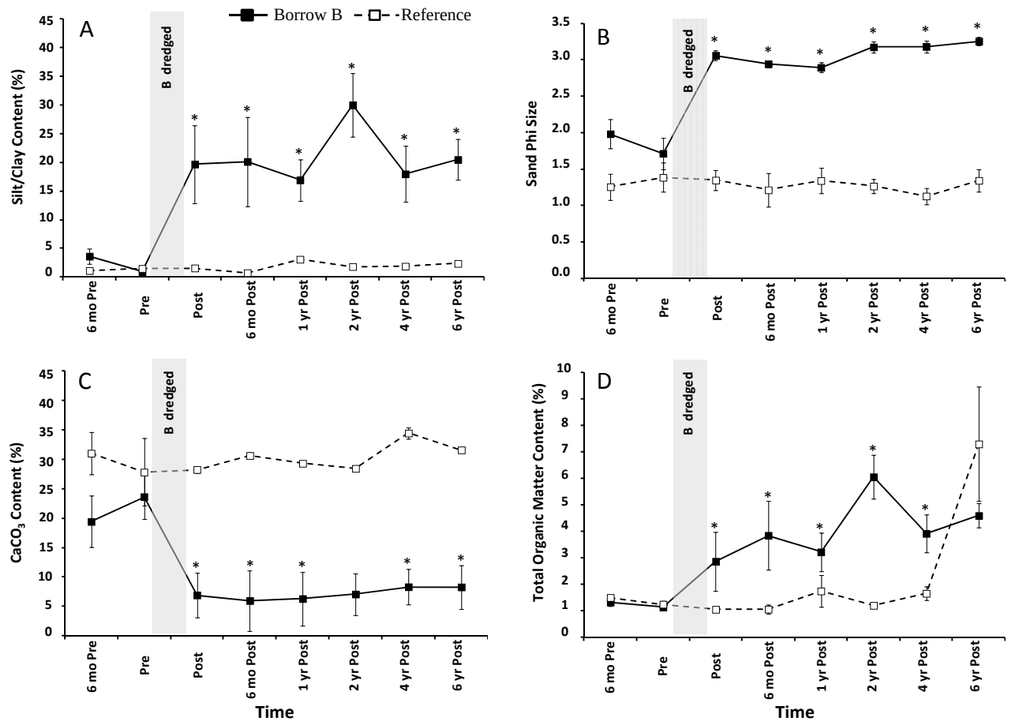

Figure 3. Average values (±SE) for the sediment characteristics (A) percent silt and clay, (B) mean sand phi size, (C) percent $CaCO_3$, and (D) percent TOM through time at borrow area B and the reference area. Asterisks indicate postdredging periods during which the change observed sediment characteristics at the borrow area was significantly different from the change observed at the reference area when compared to predredging time *p <0.05.

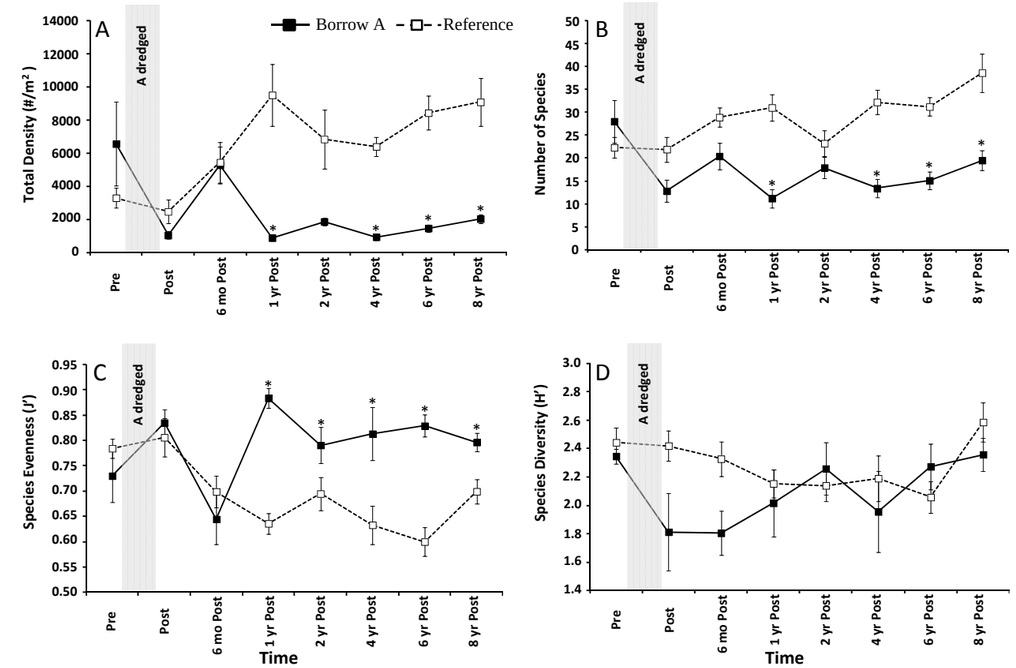

Figure 4. Average values (±SE) for the broad community indices (A) total infauna density, (B) species richness, (C) species evenness, and (D) species diversity through time at borrow area A and the reference area. Asterisks indicate postdredging periods during which the change observed in community indices atthe borrow area was significantly different from the change observed at the reference area when compared to predredging time *p <0.05.

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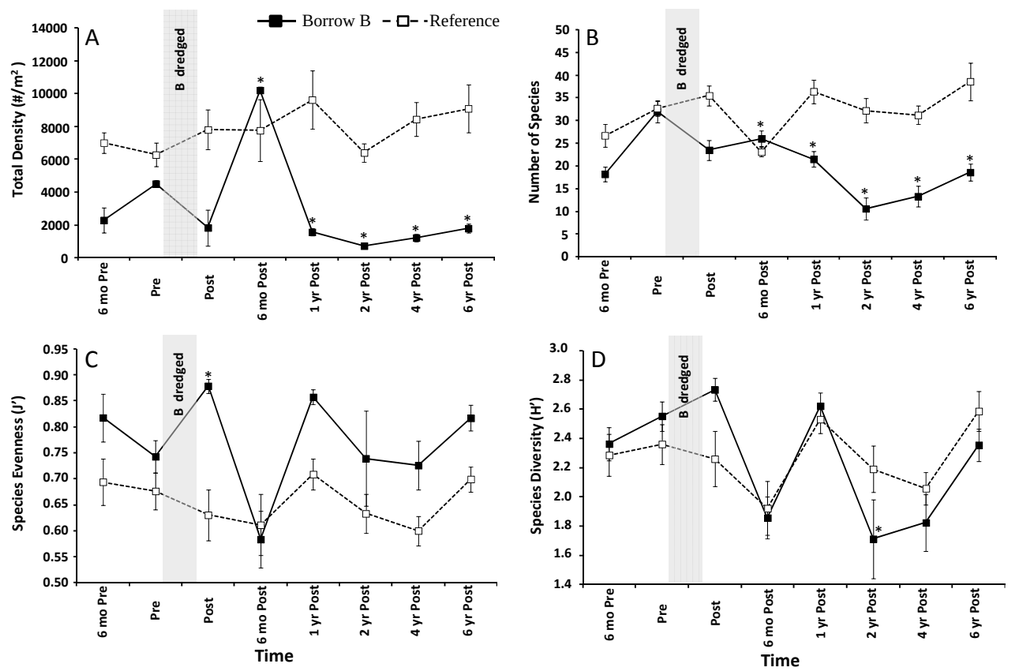

Figure 5. Average values (±SE) for the broad community indices (A) total infauna density, (B) species richness, (C) species evenness, and (D) species diversity through time at borrow area B and the reference area. Asterisks indicate post-dredging periods during which the change observed in community indices at the borrow area was significantly different from the change observed at the reference area when compared to predredging time *p <0.05.

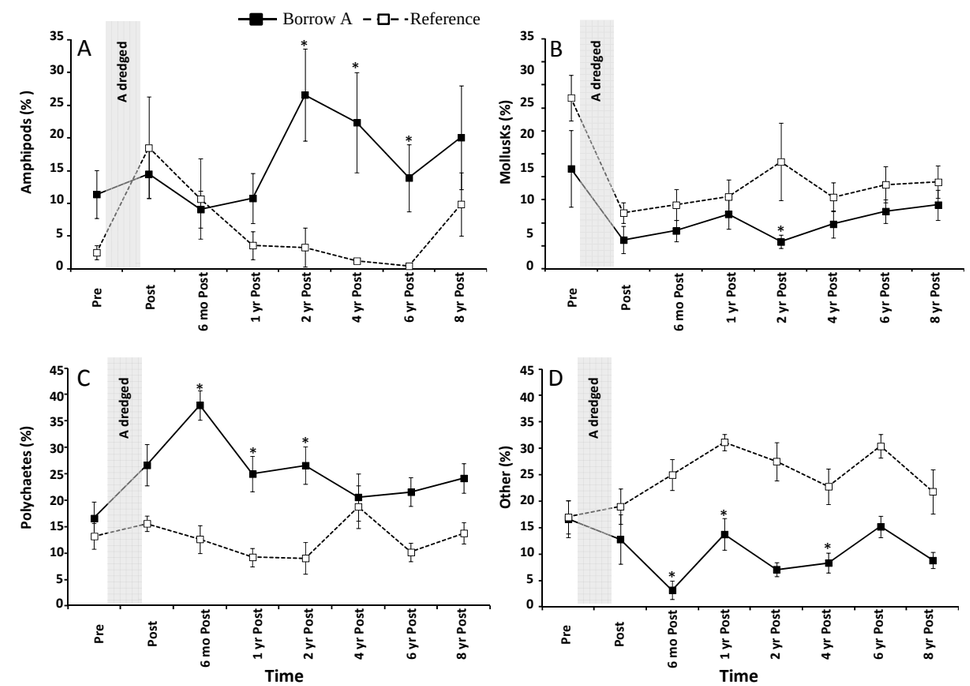

Figure 6. Average values (±SE) for higher taxonomic group composition (A) percent amphipods, (B) percent mollusks, (C) percent polychaetes, and (D) percent other taxa through time at borrow area A and the reference area. Asterisks indicate post-dredging periods during which the change observed in higher taxonomic groups at the borrow area was significantly different from the change observed at the reference area when compared to predredging time *p <0.05.

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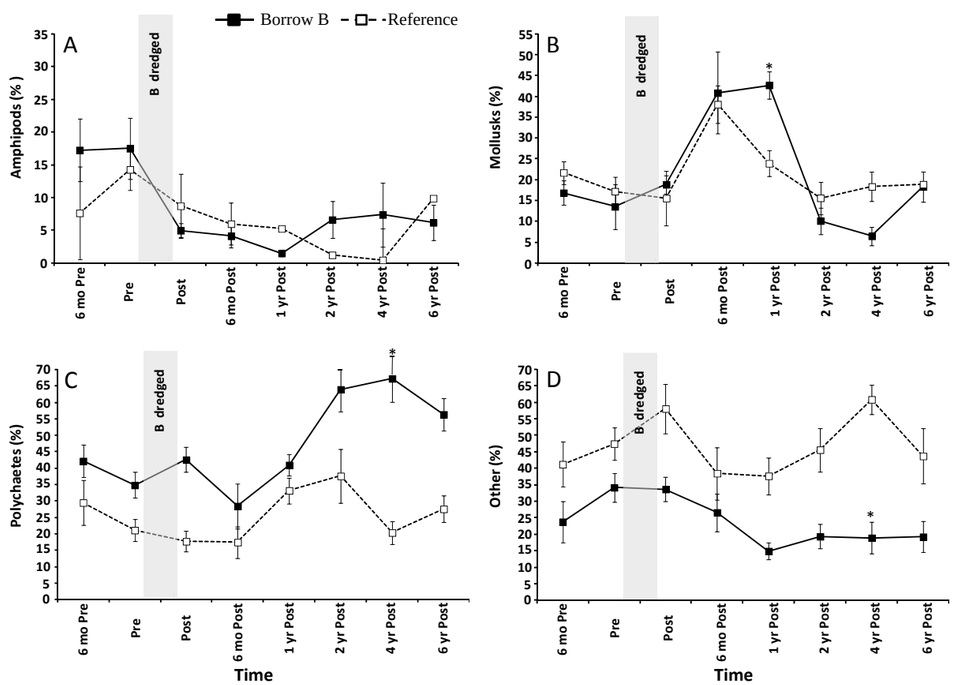

Figure 7. Average values (±SE) for higher taxonomic group composition (A) percent amphipods, (B) percent mollusks, (C) percent polychaetes, and (D) percent other taxa through time at borrow area B and the reference area. Asterisks indicate postdredging periods during which the change observed in higher taxonomic groups at the borrow area was significantly different from the change observed at the reference area when compared to predredging time *p<0.05.

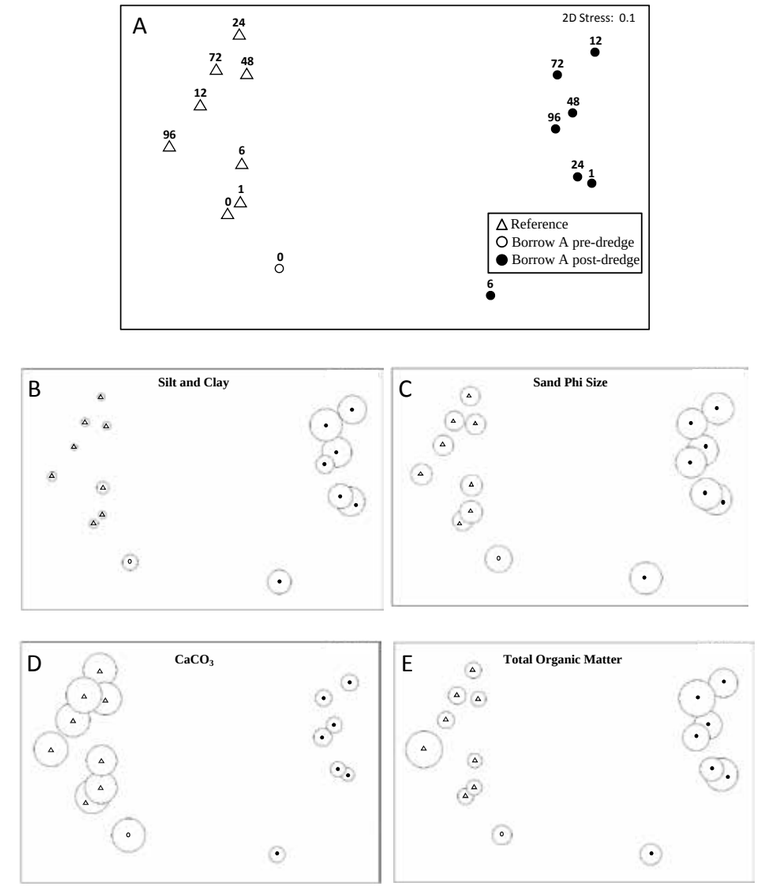

Figure 8. Nonmetric MDS ordination plot of the infaunal community (A) averaged at borrow area A and the reference area during each sampling period. Triangles =reference area, open circles = borrow area A during the predredging period, solid circles = borrow area A during the postdredging periods; nonmetric MDS bubble plots showing the relationship between differences in benthic community structure (averaged by area and period) and sediment characteristics (B) percent silt and clay content, (C) mean phi size, (D) percent $CaCO_3$, and (E) percent TOM. The size of the bubble indicates the relative level of the sediment characteristic (larger circle = larger value of the sediment characteristic). Positions of points on the graph are based on ordination of the species matrix and are identical to (A). Numbers in (A) correspond to the number of months pre- or postdredging, with 0 = predredge period.

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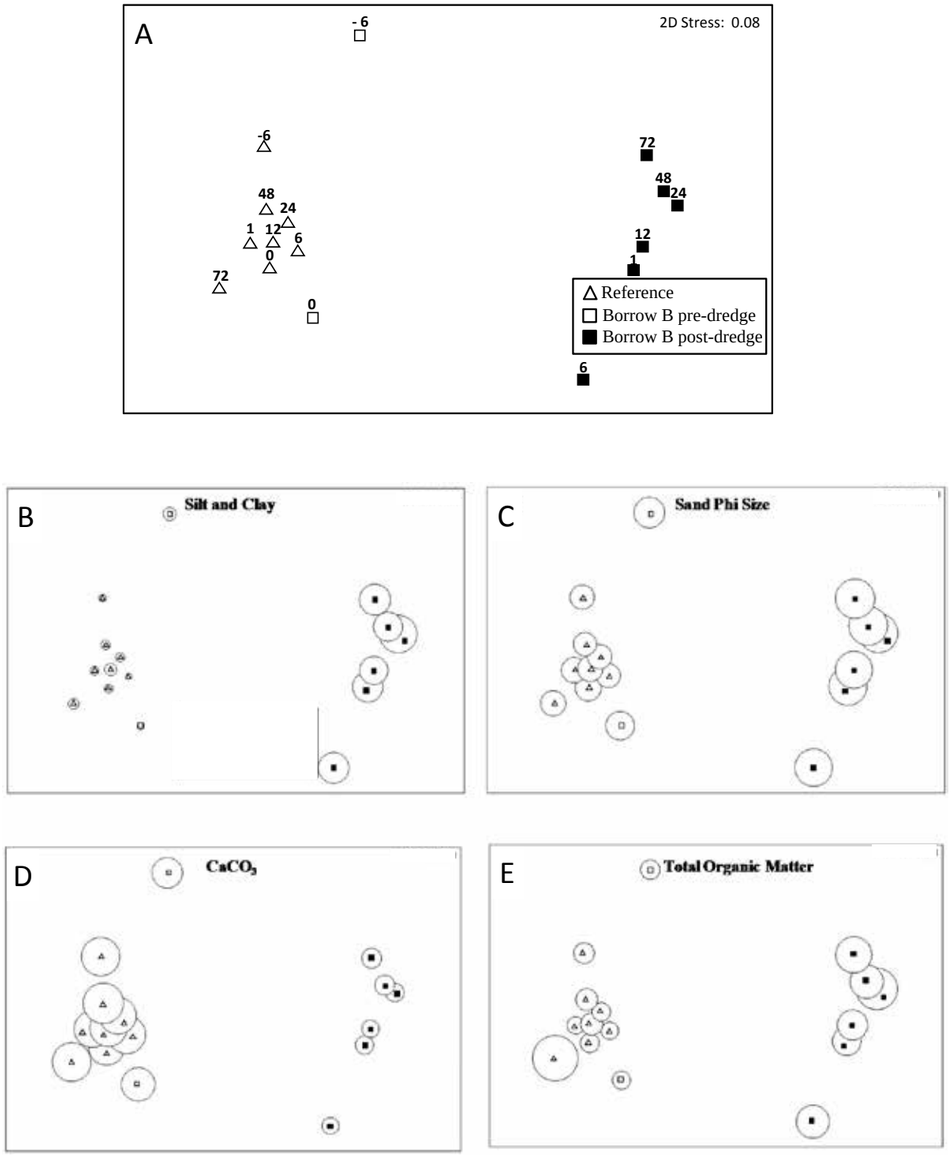

Figure 9. Nonmetric MDS ordination plot of the infaunal community (A) averaged at borrow area B and the reference area during each sampling period. Triangles = reference area, open squares=borrow area B during predredging periods, solid squares=borrow area B during postdredging periods; nonmetric MDS bubble plots showing the relationship between differences in benthic community structure (averaged by area and period) and sediment characteristics (B) percent silt and clay content, (C) mean phi size, (D) percent $CaCO_3$, and (E) percent TOM. The size of the bubble indicates the relative level of the sediment characteristic (larger circle= larger value of the sediment characteristic). Positions of points on the graph are based on ordination of the species matrix and are identical to (A). Numbers in (A) correspond to the number of months pre- or postdredging, with 0 = predredge period.

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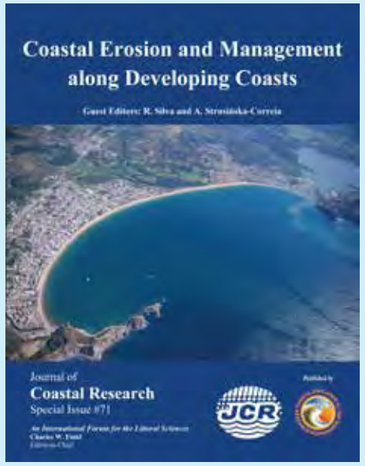

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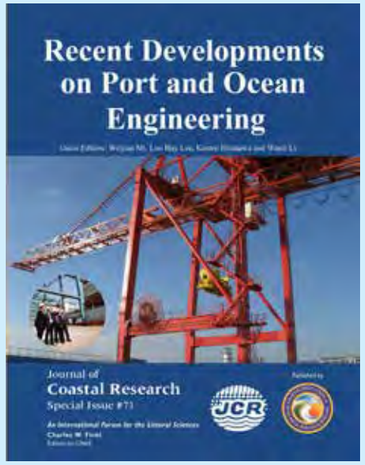

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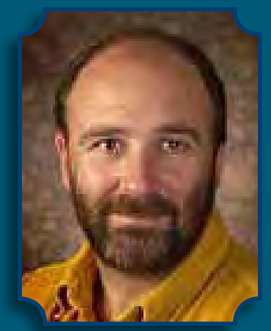

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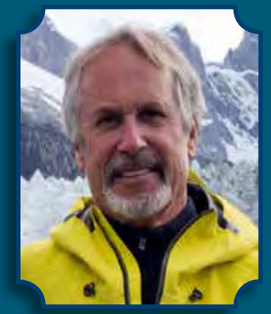

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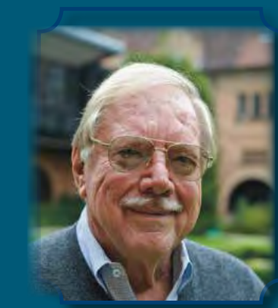

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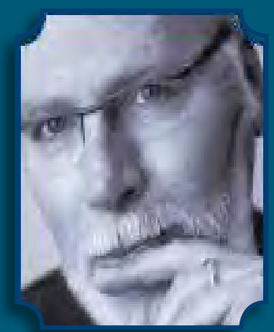

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Dr. Erik van Wellen

Dr. Frédéric Bouchette

A Special Acknowledgement To:
Associate Professor Dr. Charles Lemckert
CERF Lifetime Member

We are proud to acknowledge Associate Professor Dr. Charles Lemckert as the Coastal Education & Research Foundation's first ever Lifetime Member. Dr. Lemckert has always showed great support for CERF and the JCR, and even served as the Chair and Organizer of the 9th International Coastal Symposium (ICS) at Griffith University (Queensland, Australia) in 2007. We are honored to have Dr. Lemckert as a Lifetime Member and warmly recognize his devotion to our coastal research society.

Associate Professor Lemckert has active research interests in the fields of physical limnology, coastal systems, environmental monitoring techniques, environmental fluid dynamics, coastal zone management and engineering education. Along with his postgraduate students and research partners he is undertaking research studies on water treatment pond design (for recycling purposes), the dynamics of drinking water reservoirs, the study of whale migration in South East Queensland Waters, end ocean mixing dynamics.

He is also an active member of the CRC Polymer, where he is leading a study on the evaluation of evaporation reduction techniques.

Selected Publications:

Ali, A.; Lemckert, C.J.; Zhang, H., and Dunn, R.J.K., 2014. Sediment dynamics of a very shallow subtropical estuarine lake. Journal of Coastal Research, 30(2), 351-361.

Dunn, R.J.K.; Lemckert, C.J.; Teasdale, P.R., and Welsh, D.T., 2013. Macroinfauna Dynamics and Sediment Parameters of a Subtropical Estuarine Lake—Coombabah Lake (Southern Moreton Bay, Australia). Journal of Coastal Research, 29(6A), 156-167.

Ali, A.; Lemckert, C.J., and Dunn, R.J.K., 2010. Salt fluxes within a very shallow subtropical estuary. Journal of Coastal Research, 26(3), 436-443.

Brushett, B.A.; King, B., and Lemckert, C.J., 2011. Evaluation of met-ocean forecast data effectiveness for tracking drifters deployed during operational oil spill response in Australian waters. Journal of Coastal Research, 64, 991-994.

Lemckert, C.J.; Zier, J., and Gustafson, J., 2009. Tides in Torres Strait. Journal of Coastal Research, 56, 524-52.

For a complete list of Dr. Lemckert's publications or
his contact information, please visit:
http://www.griffith.edu.au/engineering-information-technology/griffith-school-engineering/staff/associate-professor-charles-lemckert

Continued on Next Page

A Special Acknowledgement To:

Professor Yong-Sik Cho
CERF Lifetime Member

We are proud to acknowledge Professor Yong-Sik Cho as a Lifetime Member of the Coastal Education & Research Foundation. Professor Cho, Yong-Sik received his bachelors and masters degrees from Hanyang University in February 1981 and August 1988 respectively, and his Ph.D. from the School of Civil and Environmental Engineering of Cornell University in January, 1995. The title of the thesis is "Numerical Simulations of Tsunami Propagation and Run-up" (Advisor: Professor Philip L.-F. Liu).

He had continuously worked at Cornell University as a Post-Doctoral Associate after graduation. From March of 1997, he had been employed as an Assistant Professor at the Department of Civil and Environmental Engineering at Sejong University and then moved to Hanyang University in March, 2000. From February 2003 to January 2005, he had served as the Chair of the Department of Civil and Environmental Engineering at Hanyang University. Professor Cho has served as the Director of Innovative Global Construction Leader Education Center, a government enterprises sponsored by the Ministry of Education, Science and Technology, and the Chair of Graduate Studies of the Department of Civil and Environmental Engineering since 2006.

Professor Cho has published 52 journal papers in prominent international journals registered in Science Citation Index such as Coastal Engineering, the Journal of Coastal Research, the Journal of Fluid Mechanics, the Journal of Hydraulic Research, Physics of Fluids, the Journal of Geophysical Research, the Journal of Engineering Mechanics, and Ocean Engineering. He has also published 120 papers in domestic journals and about 360 proceedings in international and domestic conferences. Professor Cho has also registered eight patents.

<u>Selected Publications:</u>

Kim, Y.-C.; Choi, M., and Cho, Y.-S., 2012. Tsunami hazard area predicted by probability distribution tendency. Journal of Coastal Research, 29(5), 1027-1038.

Cho, Y.-S., 2012. Numerical study for spreading of a pollutant material in coastal environment. Energy Sources, Part A, 34(16), 1459-1470.

Cho, Y.-S.; Kim, T.-K.; Jeong, W.-C., and Ha, T.-M., 2012. Numerical simulation of oil spill in ocean. Journal of Applied Mathematics, 2012, 1-15.

For a complete list of Professor Cho's publications or his contact information, please visit: http://civil.hanyang.ac.kr/coast/

 Continued on Next Page

A Special Acknowledgement To:

Professor Ya-Ping Wang
CERF Lifetime Member

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DEGREES AND DIPLOMA

July, 2000: Ph.D. (Marine Sediment Dynamics), Institute of Oceanology, Chinese Academy of Sciences (China)

July, 1997: M.Sc. (Coastal Geomorphology and Sedimentology), Department of Geography, Nanjing Normal University (China)

July, 1994: B.Sc. (Geomorphology and Quaternary Geology), Department of Geo-Ocean Sciences, Nanjing University (China)

RESEARCH INTERESTS

Marine Sediment Dynamics; Benthic Boundary Layer Processes; Estuarine and Coastal Morphodynamics

RESEARCH PROGRAMMES (PI)

Monitoring and Development of support system on seabed topographical changes in Pearl River Estuary and Taiwan Shoal. Ocean special funds for scientific research on public causes (No. 201105001-2). 2011-2014. RMB 1,570,000 (about USD240,000).

Simulation on the evolution and realignment of North branch, Changjiang Estuary (No. BK2010050). Jiangsu Key NSF. 2010-2012. RMB 250,000 (about USD38,000).

Physical processes near bottom boundary layer in shallow seas with strong tides and high turbid water. China NSF (No. 40876043). 2009-2011. RMB 500,000 (about USD77,000).

Study and strategy on typical marine hazards of Hainan. Comprehensive Survey and Evaluation Program of Coastal Sea, Hainan Province (No. HN908-02-05). 2008-2011. RMB 250,000 (about USD38,000).

Sediment dynamics and associated environment response in intertidal area and estuary. Program for New Century Excellent Talents in University(No. NCET-06-0446). 2007-2009. RMB 500,000 (about USD77,000).

Wave-current dynamic processes and tidal basin system evolution over tidal flats. China NSF (No. 40576040). 2006-2008. RMB 380,000 (about USD58,000).

The estuary evolution by human activity impacts and associated hazards potential analysis. Jiangsu NSF (No. BK2006131). 2006-2008. RMB 75,000 (about USD12,000).

Siltation hazard and strategy on major embayment and estuary. National Comprehensive Survey and Evaluation Program of China Coastal Ocean (No. 908-02-03-08). 2005-2009. RMB 250,000 (about USD38,000).

Physical oceanography and marine meteorological survey in Jiangsu coastal sea. National Comprehensive Survey and Evaluation Program of China Coastal Ocean (No. JS-908-01-01). 2005-2009. RMB 921,000 (about USD140,000).

SELECT PUBLICATIONS; Refereed Publications (English papers only)

Huang, H; Wang, Y.P.; Gao, S.; Chen, J.; Yang, Y., and Gao J., 2012. Extraction of morphometric bedform characteristics from profiling sonar datasets recorded in shallow coastal waters of China. China Ocean Engineering, 26(3), 469-482.

Yunling Liu, Y.; Wang, Y.P.; Li, Y.; Gao, J.; Jia, J.; Xia, X., and Gao, S., 2012. Coastal embayment long-term erosion/siltation associated with P-A relationships: A case study from Jiaozhou Bay, China. Journal of Coastal Research, 28(5), 1236-1246.

Continued on Next Page

A Special Acknowledgement To:

Professor Nicholas K. Coch, Ph.D., C.P.G

CERF Lifetime Member

We are proud to acknowledge Professor Dr. Nicholas K. Coch as a Lifetime Member of the Coastal Education & Research Foundation. Dr. Coch received his Ph.D. in 1965 from Yale University with a specialization in sedimentology and coastal geology. In 1967, he joined the faculty at Queens College of the City University of New York (CUNY). He is now a Professor of Geology in the School of Earth and Environmental Sciences at Queens College of C.U.N.Y. and a member of the Doctoral Faculty of CUNY at the Graduate Center. He has co-authored two college geology textbooks (PHYSICAL GEOLOGY) and is the author of GEOHAZARDS (Pearson). In 2008, he received the President's Award for Teaching Excellence at Queens College and the John Moss Award For Excellence in College Teaching from the National Association of Geology Teachers. His research studies since 1967 have included sedimentation on the Moon, as a Principal Investigator in NASA's Lunar Sample Study Program, and shipboard studies of continental shelf, coastal and estuarine areas in the Northeast, as well as ground and aerial studies of the effects of hurricanes on coasts and urban centers.

His recent research deals with the effects of hurricanes on coasts, urban centers and inland areas, in predicting hurricane damage and in critically analyzing our coastal management policies in a time of sea level rise. He has carried out ground and aerial studies of most recent hurricanes as well as forensic studies of older (16th-20th century) hurricanes.

He is a Fellow of the Geological Society of America and a Member of The American Meteorological Society, Society of Sedimentary Geologists, National Association of Geology

His recent research deals with the effects of hurricanes on coasts, urban centers and inland areas, in predicting hurricane damage and in critically analyzing our coastal management policies in a time of sea level rise. He has carried out ground and aerial studies of most recent hurricanes as well as forensic studies of older (16th-20th century) hurricanes.

He is a Fellow of the Geological Society of America and a Member of The American Meteorological Society, Society of Sedimentary Geologists, National Association of Geology

Teachers, American Association of Petroleum Geologists and is a Certified Professional Geologist.

Dr. Coch is an expert on Northern Hurricanes and has been a consultant to the N.Y. City Emergency Management Organization and the N.Y.S. Office of Emergency Management. He has presented hurricane seminars to emergency management and government officials in every county in southern New York as well as insurance, reinsurance and risk management groups nationwide. In 2003, he was chosen as a Sigma Xi Distinguished Lecturer for 2004-2007, and presented lectures on his research at educational and research facilities in the U.S. and Canada.

Programs including aspects of his hurricane research have aired on the CNN, PBS, Weather, Discovery, History and National Geographic Channels, and in local, national and international news programs and periodicals.

Selected Publications:

Coch, N.K., 2015. Unique vulnerability of the New York-New Jersey Metropolitan Area to Hurricane Destruction. *Journal of Coastal Research*, 31(1), 196-212.

Coch, N.K., 2013. A field course in tropical coastal geology. *Journal of Coastal Research*, 29(6A), 214-225.

Coch, N.K., 2006. The unique vulnerability of the Northeast U.S. to hurricane damage. Geologic Society of America, Abstract with programs, National G.S.A. Meeting (Philadelphia, Pennsylvania).

For a complete list of Dr. Coch's publications or his contact information, please visit:

http://www.qc.cuny.edu/Academics/Degrees/DMNS/sees/People/Pages/FacultyResearch.aspx?ItemID=23

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A Special Acknowledgement To:

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La Jolla, California, U.S.A.

We are proud to acknowledge Dr. Hany Elwany as a Lifetime Member of the Coastal Education & Research Foundation. Dr. Elwany received a B.S. degree in Engineering from Alexandria University in 1971. In 1977, he completed his Ph.D. at the University of Dundee, United Kingdom. He obtained an additional B.S. degree in Mathematics and Statistics at Alexandria University in 1980. Dr. Elwany has extensive experience with nearshore oceanography, coastal processes, coastal engineering, and estuarine dynamics. He was the principal investigator for the physical oceanographic program of one of the largest environmental studies ever conducted on the U.S. west coast (at San Onofre). He has conducted in-depth studies of Nile Delta erosion, particularly since the construction of the Aswan Dam. His experience also includes projects involving optimization, numerical modeling, structural dynamic analysis, design of offshore structures, and data analyses, simulation, and dynamic modeling of ocean and coastal conditions. As an educator, both at Liverpool and Alexandria Universities, he taught courses in dynamics, statistics, numerical analysis, computer applications, and maritime engineering.

Dr. Elwany also serves as the President of Coastal Environments, a unique multi-disciplinary oceanographic, coastal engineering, and environmental consulting firm. Coastal Environments, founded in 1988, is comprised of over 30 professional associates, all experts in their respective fields. Technical specialties include coastal and ocean engineering, engineering geology, oceanography, marine biology and geology, environmental analysis, economics, statistics, and computer programming/modeling.

For more information about Dr. Elwany and Coastal Environments, please visit:

http://coastalenvironments.com/

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We are proud to acknowledge Dr. Björn Kjerfve as a Lifetime Member of the Coastal Education & Research Foundation. He is the former Dean of the College of Geosciences and was a Professor of Oceanography at Texas A&M University, 2004-2009. While at Texas A&M, he oversaw four academic departments, the Texas Sea Grant Program, and the Integrated Ocean Drilling Program (IODP), including the 475'ocean sciences drilling vessel, D/V JOIDES Resolution. Kjerfve was previously Professor of Marine and Geological Sciences at the University of South Carolina, 1973-2004, and served as the Director of the Marine Science Program, 2000-2004. He received Ph.D., M.S., and B.A. degrees from Louisiana State University (Marine Sciences), University of Washington (Oceanography), and Georgia Southern University (Mathematics), respectively.

Professor Kjerfve's expertise is coastal and estuarine physical oceanography. He has published some 12 books and 250 scientific journal papers, book chapters, and reports; has supervised 14 Ph.D. dissertations and 24 M.S. theses, and taught more than 6,000 oceanography students. His research includes problem-solving in estuarine and coastal waters as well as climate change and has attracted $20 million in research funding for 90 projects. Dr. Kjerfve's field research has taken place along the East and Gulf coasts of the USA, the Caribbean, Brazil, Mexico, Colombia, Chile, Thailand, Malaysia, the Persian Gulf, Papua New Guinea, and Australia. Dr. Kjerfve was elected as a corresponding member of the Academia Brasileira de Ciências, the Brazilian Academy of Sciences in 2012. Dr. Kjerfve has served as the President of the World Maritime University from 2009 to 2014. He now has the great honor of serving as the fourth Chancellor of the American University of Sharjah in the UAE.

Selected Publications:

Cavalcante, G.H.; Kjerfve, B.; Bauman, A.D., and Usseglio, P., 2011. Water currents and water budget in a costal mega-structure, Palm Jumeirah Lagoon, Dubai, UAE. Journal of Coastal Research, 27(2), 384-393.

Cavalcante, G.H.; Kjerfve, B.; Knoppers, B., and Feary, D.A., 2010. Coastal currents adjacent to the Caeté Estuary, Pará Region, North Brazil. Estuarine Coastal and Shelf Science, 88(1), 84-90.

Medeiros, C. and Kjerfve, B., 2005. Longitudinal salt and sediment fluxes in a tropical estuary: Itamaracá Brazil. Journal of Coastal Research, 21(4), 751-758.

Perillo, G.M.E. and Kjerfve, B., 2005. Regional estuarine and coastal systems of the Americas: An introduction. Journal of Coastal Research, 21(4), 729-730.

For a complete list of Dr. Kjerfve's publications or his contact information, please visit: http://www.aus.edu

 Continued on Next Page

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Dr. Wei Zhang works as an associate professor of Harbor, Coastal, and Offshore Engineering in State Key Laboratory of Hydrology-Water Resources and Hydraulic Engineering, Hohai University. He focuses on the tidal current, sediment and salinity movement and transportation laws of estuaries and coasts. Dr. Zhang has published over 20 papers in recent years, including five papers indexed by SCI and EI. He took part in one Key Project of National Nature Science Foundation of China, one 95th Year Key Science and Technology Project for the Ministry of Transport, and two Science and Technology Research Projects of Guangdong Province. He has also led youth projects for the National Nature Science Foundation.

Continued on Next Page

A Special Acknowledgement To:

Charles Thibault

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Chuck Thibault is currently a Ph.D. candidate at the University of Memphis and a Geologist for EarthCon, Inc. Mr. Thibault received his M.S. from the University of Washington (Geology) and a B.S. from the University of Memphis (Geology). His research interests include coastal and environmental hydrogeology and coastal geomorphology. His current research investigates the movement of storm surge generated saline water plumes through coastal surficial aquifers. Mr. Thibault's field research has taken place along the U.S. coasts of Mississippi, Louisiana, and Washington, and on the eastern coast of Kamchatka, Russia.

For more information, please contact
Mr. Thibault at:
cthibalt@memphis.edu

 Continued on Next Page

A Special Acknowledgement To:

Erik van Wellen, Ph.D.

CERF Lifetime Member

DEME
(Dredging, Environmental & Marine Engineering)
http://www.deme-group.com/

Dr. van Wellen works as project manager for the DEME (Dredging, Environmental, & Marine Engineering) group, whose head office is based in Belgium. Graduating with a Ph.D. in coastal engineering from the University of Plymouth, his expertise lies in the fields of maritime civil engineering, operations research, and coastal processes. Dr. van Wellen has also served as Chief Technical Officer for DEME, as well as, a commercial diver and instructor for Coxside Diving & Marine Centre. His outstanding underwater photographs have graced the cover of the *Journal of Coastal Research* (JCR) more than once.

Continued on Next Page

A Special Acknowledgement To:

Frédéric Bouchette Ph.D.
CERF Lifetime Member

Associate Professor of Littoral Dynamics
Geosciences Montpellier
UMR 5243 – University of Montpellier / CNRS

Following a M.Sc. in physics and mechanics, Fred Bouchette received his Ph.D in March 2001 from the University of Montpellier, South of France. The title of the thesis is "Wave/Seabottom Interaction: The Liquefaction Process" (free translation from French; advisor: Professor M. Séguret). After his Ph.D., Fred had been employed at the University of Montpellier as an associate professor in the department of Geosciences. From 2008 to early 2011, he had moved to the Institute of mathematics and modeling of Montpellier for a three years long stay. Then, until 2012, he has been hosted as an invited professor in the METOS laboratory at the University of Oslo, Norway. He is now back to the University of Montpellier in the same department of Geosciences.

From 2002, Fred was asked to build a scientific staff on littoral hydro-morphodynamics called GLADYS (www.gladys-littoral.org). From that time, the group GLADYS has grown progressively. At now, Fred co-leads the group GLADYS, which rallies most of the scientists working on littoral hydro-morphodynamics along the French Mediterranean Coast, with distinct approaches ranging from applied mathematics to geosciences.

The scientific activity of Fred Bouchette concerns the development of concepts and methods in relation with the dynamics of shallow water environments. He studies the domain that extends from a few tens of meters of water depth at sea to the coastal watershed onshore, with a strong emphasis on the littoral area and the shoreline itself. He has worked in Spain, Taiwan, Canada, Norway, Chad, Italy, Greece, Switzerland, Tunisia, in the French Alps and in the Gulf of Lions (Mediterranean Sea). As testified by his publications, his research combines various points of view from geophysics to geology, including applied mathematics, civil engineering, quantitative geomorphology, with a strong connection to coastal archeology and the analysis of littoral hazards. Nevertheless, his heart's passion still lies with geophysics and applied mathematics.

Presently, Fred Bouchette actively works on the conceptualization of the growth of long term shoreline instabilities such as cuspates or sand spits. On that topic, his last contribution for the *Journal of Coastal Research* (JCR) is the following proceeding:

Bouchette, F.; Manna, M.; Montalvo, P.; Nutz., A.; Schuster, M., and Ghienne, J.-F., 2014. Growth of cuspate spits. *In*: Green, A. and Cooper, J.A.G. (eds.), *Proceedings from the International Coastal Symposium (ICS) 2014 (Durban, South Africa)*. *Journal of Coastal Research*, Special Issue No. 70, pp. 47-52.

Fred Bouchette has published>50 papers and short papers in international journals such as *Coastal Engineering*, *Journal of Coastal Research*, *Discrete and Discontinuous Dynamical Systems*, *Journal of Geophysical Research, Sedimentology, Continental Shelf Research*, *Quaternary Research, Ocean Engineering, Marine Geology, and Climate Research*. Most of his works were performed with and for students. He has contributed to more than 80 proceedings in international or domestic conferences. Fred Bouchette also heads the scientific development of a HPC numerical platform for coastal engineering (www.mirmidon.org).

For a complete list of publications and more information, please visit:
www.bouchette.org

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Continued on Next Page

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Continued on Next Page

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Continued on Next Page

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Continued on Next Page

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Continued on Next Page

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Continued on Next Page

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Continued on Next Page

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Continued on Next Page

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Schuerch, Mark, Germany
Seckus, Jonas, Italy
Seingier, Georges, Mexico
Sekiguchi, Hideo, Japan
Sherman, Clark, United States
Siokou-Frangou, Joanna, Greece
Song, Dehai, China
Spieler, Richard, United States
Spinoni, Jonathan, Italy
Stevenson, Duane E., United States
Stremme, Donald, United States
Sui, Jueyi, Canada
Suman, Daniel O., United States
Sun, Jian, China
Suzuki, Tomohiro, Belgium
Switzer, Adam, Singapore
Szekielda, Karl, United States
Thoe, W., United States
Thomson, Jim, United States
Underwood, Graham J.C., United Kingdom
Velo-Suárez, L., Spain
Venugopal, V., United Kingdom
Vicinanza, Diego, Italy
Vollmer, Heather, United States
Walker, Tony, Canada
Wang, David, United States
WANG, Yunwei, China
Wang, Shaohui, China
Ware, Carolyn, United States
Warrick, Richard, New Zealand
Wdowinski, Shimon, United States
Wei, Zhangping, United States
Wernand, Marcel, Netherlands
Wernette, Phil, United States
Weston, Mike, Australia
Whadams, Peter, United Kingdom
Whitehead, Jessica, United States
Wilber, Pace, United States
Wright, Grant, United Kingdom
Xiu, Peng, China
Xu, Dewei, China
Yagci, Oral, Turkey
Yang, Haiyan, China
Yilmaz, Tuluhan, Turkey
Yin, Jianjun, United States
Yin, Kedong, China
Young, Donald, United States
Zhai, Weidong, China
Zhang, Yunlin, China
Zhang, Y. Joseph, United States
Zhao, Zhongxiang, United States
Zhou, Jun, China

Current Issue Volume 32, Issue 1 (January 2016)

COVER PHOTOGRAPH:
Magdalena Channel and Agostini Sound in Tierra del Fuego, Chilean Patagonia

Magdalena Channel and Agostini Sound in Tierra del Fuego, Chilean Patagonia. Agostini Sound is a fjord in Tierra del Fuego that separates two branches of the Darwin Cordillera, part of the longest range found in the Andes. It was named after Alberto María de Agostin (1883–1960), who was an Italian missionary in Tierra del Fuego and a passionate mountaineer, explorer, geographer, ethnographer, photographer, and cinematographer. He was the first person to reach several of the peaks in the region, as well as numerous glaciers and fjords. The Cordillera contains some of the most rugged peaks in southern Chile, many covered in ice. The fjord was carved by the Aquila Glacier during the last Ice Age and is part of the Magdalena Channel, which serves as a major navigation route that connects the Strait of Magellan with the Cockburn Channel. Local wildlife includes condors, dolphins, sea lions, and penguins. (Photograph taken 30 January 2015 by Deepika Shrestha Ross and caption by Gary Griggs, University of California, Santa Cruz [UCSC], Santa Cruz, California, U.S.A.)

The Coastal Education & Research Foundation *[CERF]* graciously thanks you for your membership and involvement in our international society. We hope that you have enjoyed this latest edition of *Just CERFing*, our society's official newsletter. As mentioned previously, we encourage the worldwide communication of our members through the *Just CERFing* newsletter. If you have any news or announcements that you would like to promote, please send your request or questions directly to Dr. Charles W. Finkl at cfinkl@cerf-jcr.com CERF continues to provide our members with the most up-to-date, professional features of the society. We encourage you to please visit our Foundation's website at http://www.cerf-jcr.org to see all the new content that has been added.

Next Issue of *Just CERFing* coming March 2016.

In This Issue:

CERF Regional Vice Presidents

Discussion of Hansen, J.M.; Aagaard, T., and Kuijpers, A., 2015. Sea-Level Forcing by Synchronization of 56- and 74-Year Oscillations with the Moon's Nodal Tide on the Northwest European Shelf. *Journal of Coastal Research*, 31(5), 1041-1056.

Reply to Schmith, T.; Thejll, P., and Nielsen, J.W., 2016. Discussion of Hansen, J.M.; Aagaard, T., and Kuijpers, A., 2015. *Journal of Coastal Research*, 31(5), 1041-1056.

Message from Nobuo Mimura, President of Ibaraki University

35th International Geological Congress

Wave Climate, Storminess, and Northern Hemisphere Teleconnection Patterns Influences: The Outer Bristol Channel, South Wales, U.K.

Coastal Research Library Announcement

Encyclopedia of Estuaries

Behavioral Release Condition Score of Bull and Bonnethead Sharks as a Coarse Indicator of Stress

Physical and Biological Alterations Following Dredging in Two Beach Nourishment Borrow Areas in South Carolina's Coastal Zone

CCS Newsletter Announcement

Assessing the Resilience of Coastal Systems: A Probabilistic Approach

Membership Options

CERF Website

Publish Your Photos

CERF Board of Directors

JCR Editorial Board

CERF Lifetime Members

CERF Patron Members

New CERF Members 2015-2016

Current CERF Members

JCR Outside Reviewers 2015

JCR Current Issue, Cover Photo