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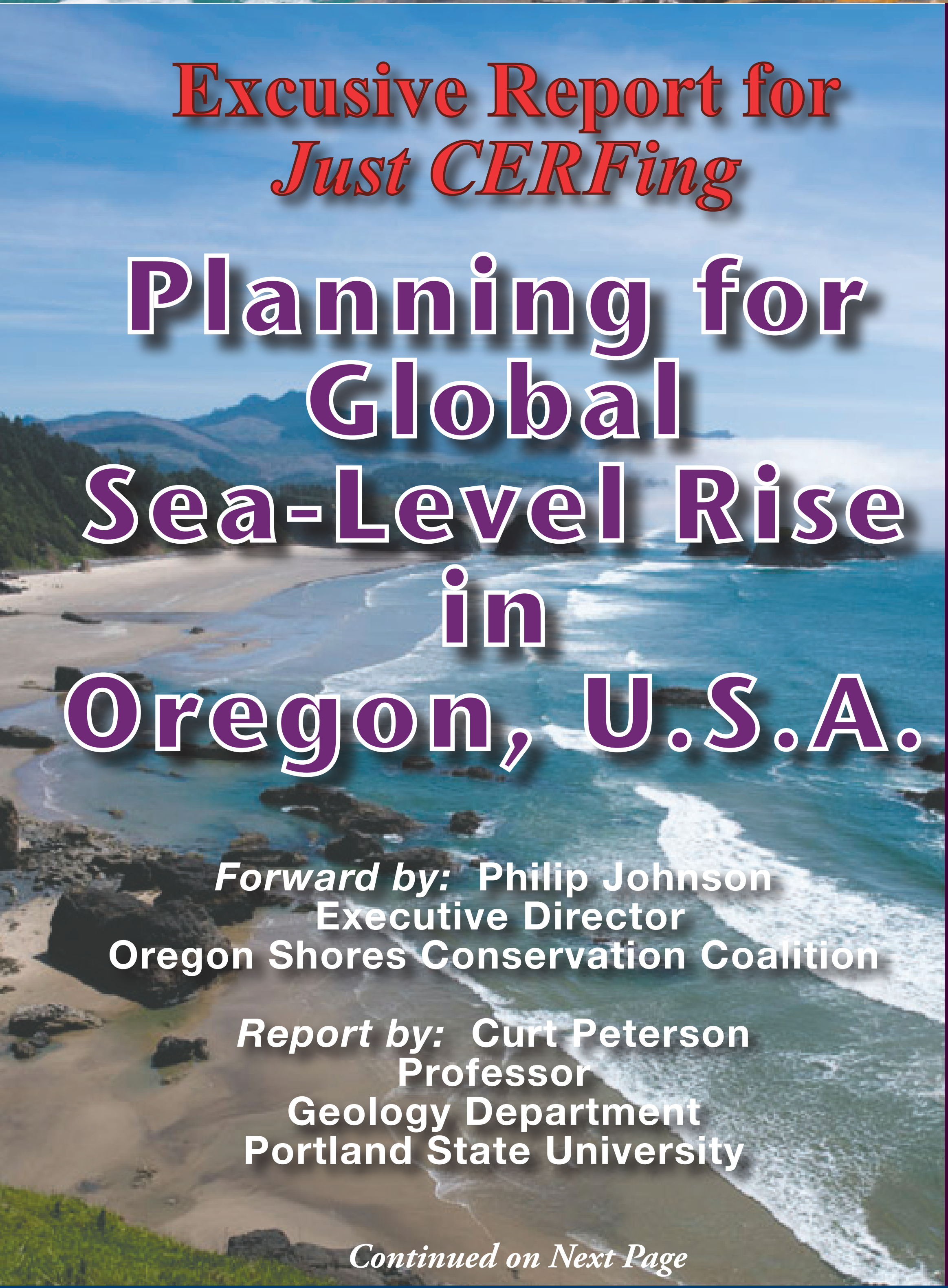

Excusive Report for *Just CERFing*

Planning for Global Sea-Level Rise in Oregon, U.S.A.

Forward by: Philip Johnson
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PLANNING FOR GLOBAL SEA-LEVEL RISE IN OREGON, USA

Forward by:
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The Oregon Shores Conservation Coalition's "Coastal Climate Change Adaptation Project" is under development as an experiment in grassroots organizing for adaptive planning for expected climate change impacts. Oregon Shores is a regional conservation group with a 40-year history of working to protect marine, shoreline, estuarine and other coastal habitats. The organization's board and staff came to recognize that the likely effects of climate change—rising sea-levels, more intensive storm surges, increased erosion, lower-river flooding, among others—would affect every aspect of the group's work. Consequently, a new program, the Climate Action Program, was created to address the need for long-range adaptive planning to preserve the resilience of communities, both human and natural. Oregon Shores' premise in developing the Coastal Climate Change Adaptation Project is that for adaptive planning to be meaningful, broad community acceptance and support are necessary. The project is thus designed as a grassroots effort, with the aim of developing broad support before any proposal should be submitted to local governments.

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IMPACTS OF PREDICTED GLOBAL SEA-LEVEL RISE ON OREGON BEACHES AND TIDELANDS

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INTRODUCTION

Two background sections on the expected impacts from predicted sea-level rise on the Oregon coast were prepared for Oregon Shores Conservation Coalition's 'Coastal Climate Change Adaptation Project' (see Forward above). The two sections are developed for broad distribution to coastal residents, community leaders, government

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agencies, and other interested parties. The two non-technical sections use geometric or gradient change approaches to illustrate potential impacts of shoreline retreat and tideland submergence under conditions of accelerated global sea-level rise, as predicted for the next century or two. The Oregon coast contains unusual geologic records of prehistoric beach erosion and tidal wetland submergence from both cyclic

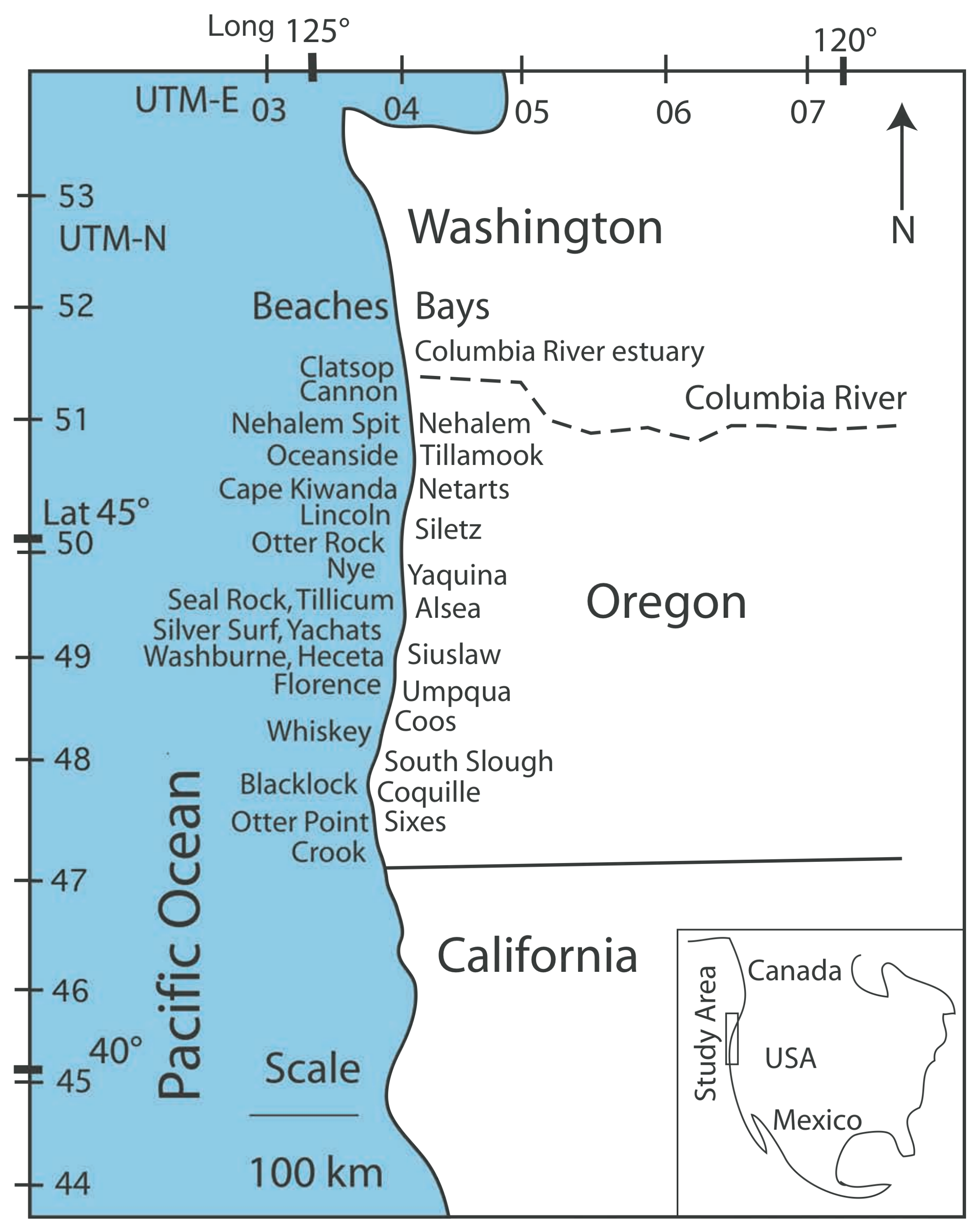

Figure 1. Map of Oregon coastline with positions of beaches and estuaries named in the background sections.

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Global Sea-level Rise on Oregon Beaches

Future global sea-level rise of 1-2 meters (3-6 feet), predicted to occur during the next century or two (Pfeffer *et al.*, 2008; Vermeer and Rahmstorf, 2009), will impact Oregon beaches through beach sand erosion and sea cliff retreat. Some of the most susceptible beaches in Oregon are showing evidence of the initial impacts of renewed beach erosion after several thousand years of relative stability (Hart and Peterson, 2007) (Figure 2). Some of the beach sand loss might be attributed to changes in storm wave direction (Peterson *et al.*, 1990), height, and/or frequency (Ruggiero *et al.*, 2010), but the long-term sand loss to the continental shelf and other submerging sand sinks will eventually impact all of Oregon's sandy coastlines.

Figure 2. Eroding beach with exposed tilted bedrock strata in the exposed wave cut platform (photo background). Site is located south of Ona Beach, Oregon. A prehistoric dune ramp 10-15 m thick at this location has washed away leaving beach cobble and a thin layer of beach sand (< 1.0 m thick) over the wave cut platform (bedrock). Photo was taken June 24, 2002. In May 2012 no sand was present above the wave cut platform in the area located landward of tilted bedrock strata. See Figure 1 for location of Ona Beach, Oregon.

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The onset of net sand loss is apparent at many Oregon beaches where "mystery tree stumps" are being exposed by episodic erosion, after having been buried by beach sand for several thousand years (Figure 3). From north to south, some of these beaches are those at Arch Cape, Cape Lookout, Neskowin, Beverly Beach, Seal Rock, and Nesika Beach (Hart and Peterson, 2002). The most recent exposures of the mysterious stumps were documented following strong El Niños in 1983 and 1998 (Hart and Peterson, 2007). Stumps from some beach platforms located north of Yachats, Newport, Neskowin, Cape Lookout, and Arch Cape are now exposed during most winter periods of large storm surf. The regular seasonal exposure of the surf zone stumps and the wave-cut beach platforms in which they are rooted demonstrates the shallow depths of beach sand along much of the Oregon coast.

Figure 3. Mystery surf zone tree stumps at Neskowin, Oregon (photo date winter 1988). Stumps are radiocarbon dated at 2-4 ka demonstrating protective burial under beach sand until recent times. By 2007 the stumps were largely eroded away.

Many of the wide beaches that are readily apparent during summer low tide conditions actually represent very thin layers of sand (1-2 m in thickness) above gravel or

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sedimentary rocks (Peterson *et al*., 1991; Peterson *et al*., 1994). The wide summer beaches shown in many scenic photographs of Cannon Beach, Agate Beach, Port Orford, and Gold Beach, among others, will not exist when the remaining thin layer of beach sand is permanently lost from the beach face within the next century or two. Historically, the Oregon beaches were thought to be in dynamic seasonal equilibrium, as summarized by Fox and Davis (1978). This theory proposed that offshore and northward transport of beach sand during winter months was balanced by onshore and southward transport of sand during summer months. However, longer-term records of sand supply to many Oregon beaches do not support the equilibrium theories. For example, alongshore net littoral drift is indicated by dune sand accumulations at the northern ends of littoral cells in northern Oregon and at the southern ends of littoral cells in southern Oregon (Peterson *et al*., 2009). The episodic export of sand from one littoral cell to another might account for long-term loss of sand from some of these cells including Lincoln City, Neskowin, and Arch Cape in north-

Figure 4. Sea cliff near Seal Rock, Oregon, showing Holocene dune sand (top 3-4 m of sea cliff) above forest soil (black layer) at top of Pleistocene dune sand (light shaded strata) above uplifted Pleistocene wave cut platform (dark bedrock). The modern beach platform was likely cut at 4-7 ka (ka is thousand years). The Holocene dune ramp is younger than the underling forest soil, which is dated at about 3 ka. The late Holocene dune ramp that reached the terrace top has eroded away during the last 2 ka, re–exposing the middle to late Holocene sea cliff.

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ern Oregon and Gold Beach and Brookings in southern Oregon.

Observations from some littoral cells in central Oregon focus on areas that do not experience any n*et al*ongshore littoral drift, yet they show long-term loss of beach sand. In addition to the mystery stumps that are being exposed along some of these beaches, such as Newport and Bandon, the large sand dune ramps that backed up against the sea cliffs in those beaches have been largely eroded away (Figure 4) (Hart and Peterson, 2007). The broader list of eroded prehistoric sand ramps includes exposed sea cliffs at Oceanside, Cape Lookout, Cape Kiwanda, Lincoln Beach, Nye Beach, Yaquina Point, Seal Rock, Waldport, Tilicum, Silver Surf, Yachats, Washburne, Heceta Head, Whiskey Run, Bandon, Blacklock Point, Nesika, Otter Point, and Crook Point (Hart and Peterson, 2007).

The wide-scale planting of European dune grass has caused historic foredune accretion in some Oregon beaches (Reckendorf *et al.*, 1998). However, the artificially produced foredune accretion presents a false impression of long-term beach stability. The foredunes have not continued to accrete seaward at either Coos Bay or Florence since their development several decades ago. In some localities, including Port Orford, Ona Beach, and Neskowin, the artificially accreted foredunes are undergoing modern erosion.

With the important exception of the Clatsop Plains, and a few other beaches located near large rivers, most of the Oregon's beach sand originated from onshore transport of continental shelf sand (Clemens and Komar, 1988). That onshore transport of sand peaked during the middle Holocene transgression five to eight thousand years ago (Peterson *et al.*, 2007). During the last several thousand years of minimal sea-level rise of 1.0 meter per thousand years (Darienzo *et al.*, 1994), the ocean waves

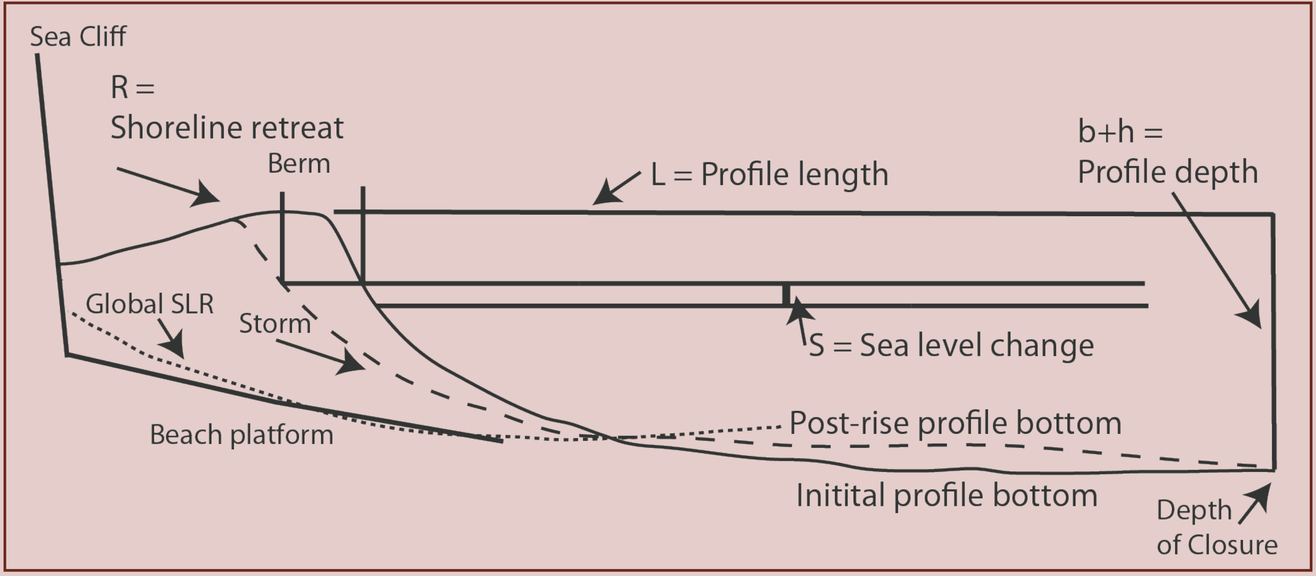

Figure 5. Bruun's relation showing the short term response to a minor change in sea-level from a storm event versus the long term response to a major sustained change in sea-level from global sea-level rise (SLR). Figure modified from Bruun

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pushed ashore the remaining shelf sand that was within their reach of water depth, known as "wave base." There are no significant sources of new sand other than eroding sea cliffs that are now available to supply the beaches of the central Oregon coast. The predicted increase of sea-level rise (1-2 meters) from ongoing global warming (Vermeer and Rahmstorf, 2009) will effectively raise the depth of wave base and thus allow eroding beach sand to backfill the deepening inner continental shelf (Bruun, 1962). This reversal of net across-shore sand supply from early transgressive onshore transport to post high-stand offshore transport has already been reported from some of the world's most susceptible shorelines, such as in the Netherlands. The submergence of estuarine tidal flats in some of Oregon's bays will provide a smaller sink for eroding beach sand. Longshore transport of beach sand will temporarily benefit downdrift beaches at the expense of updrift beaches in some littoral cells (Peterson *et al.*, 2009). However, the lack of new sand supply, under a regional condition of rapidly rising sea-level (1-2 meters in the next century or two), will ultimately impact all of the Oregon beaches.

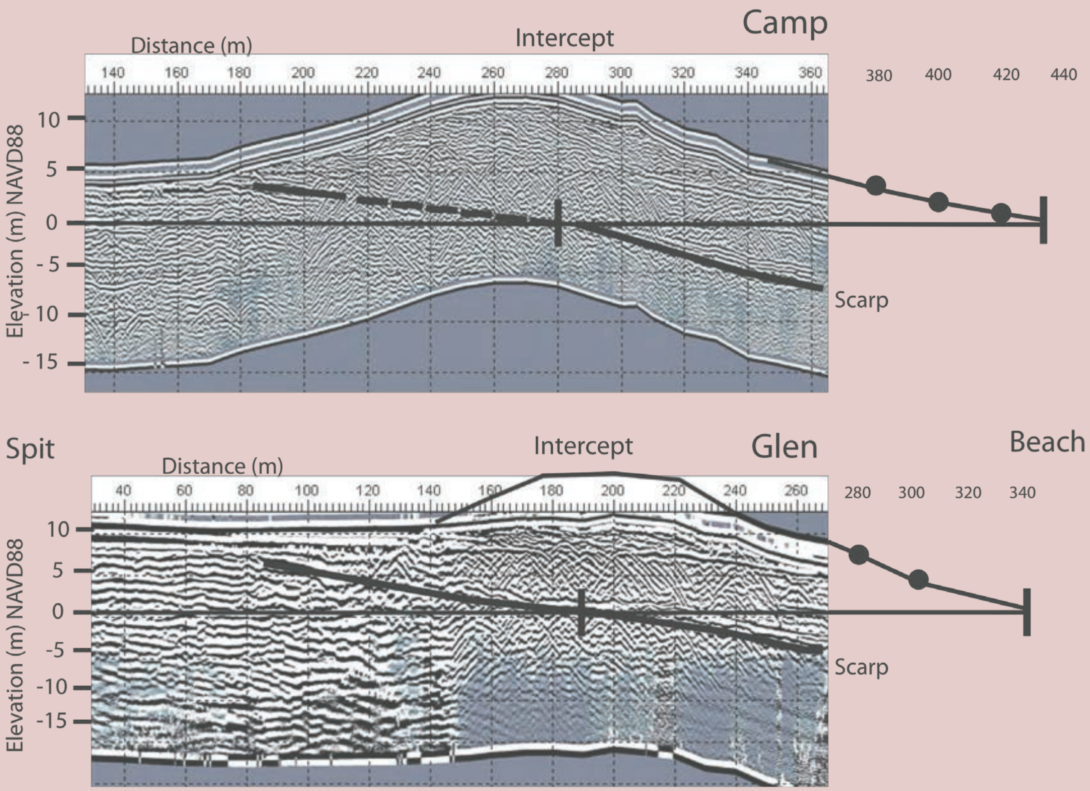

Figure 6. Ground penetrating radar profiles at Nehalem spit, Oregon showing erosional retreat scarps 130 m in length (black sloping lines) produced from coastal subsidence (1.5 m) that accompanied the last Cascadia earthquake at AD 1700 (Peterson *et al.*, 2010).

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There are different methods of predicting the shoreline retreat that will occur from global sea-level rise along the Oregon coast. Probably the simplest methods are based on lateral shifts of equilibrium across-shore profiles, i.e., assumptions that the current shape, slope, and annual sand replenishment cycle of a beach (its "equilibrium profile") will be maintained and this whole system will simply move inland as the sea-level rises. The "Bruun rule" equates beach shoreline retreat distance to a landward shift of the equilibrium profile (Figure 5), based on the rise of relative sea-level (Bruun, 1988).

Figure 7. Eroded beach face at Cove Beach, Oregon, showing beach cobble above a wave cut platform (bedrock not exposed in this photo). The lack of beach sand represents shoreline conditions that probably existed in mid-early Holocene time during periods of rapid sea-level rise. Similar conditions are expected to prevail during the next century or two of rapid sea-level rise (1-2 m) as predicted to occur from global warming.

Calculated ratios of retreat distance to sea-level rise range from 100:1 or 200:1 for

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sand-bottomed beaches in the northern Oregon coast (Peterson *et al.*, 2000). A sea-level rise of 1-2 meters could therefore be expected to yield 100-200 meters (~300-600 feet) of beach retreat. Such retreat distances in Oregon are confirmed by evidence from coseismic subsidence events following the last Cascadia great earthquake in AD 1700 (Figure 6). In some locales, during the earthquake the land surface at the coast dropped 1 to 2 meters, causing widespread beach erosion in southern Washington and northernmost Oregon (Meyers *et al.*, 1996).

Most of Oregon's beaches are narrower than the potential retreat distances that are calculated for predicted sea-level rise of 1-2 m during the next century or two. Most Oregon beaches lack sufficient sand buffers to accommodate 100 meters of beach retreat without exposing sea cliffs and associated wave-cut platforms or flat areas of rock that extend seaward from the foot of the sea cliffs, to wave attack. Steeply sloped wave-cut platforms provide cliffs with more protection against sea-level rise than do gently sloped ("low gradient") wave-cut platforms. An equilibrium profile method can be used to estimate the retreat of wave-cut platforms and sea cliffs that are cut into weak Pleistocene strata, layers of cliff that are common along the coast. A 1.5 meter

Figure 8. Tidal marsh in South Slough, Coos Bay, Oregon. Brackish tidal marsh grows at 0.5-1.5 m above mean sea-level.

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rise in sea-level is estimated to result in 30 to 60 meters (90-180 feet) of landward shifts of representative sea cliffs that are cut into weakly cemented sand or mudstone strata, based on the present wave cut platform gradients of 3.0 and 1.5, respectively. Such low gradient platform slopes have been measured in Cannon Beach, Lincoln City, Otter Rock, Newport, Yachats, Whisky Run, and Garrison Beach, among other locations (Peterson *et al.*, 1994).

Figure 9. Mud flats in South Slough, Coos Bay, Oregon. Tidal flats are developed at below 0.5 m mean tidal level. Global sea-level rise of 1-2 in the next century will submerge existing tidal marshes, converting them to mud flats.

These geometric methods do not provide rates of shoreline retreat, or how quickly the shoreline will move landward, but only the long-term response to a prolonged change of sea-level. Nevertheless, the estimates provided above demonstrate the potential for widespread loss of existing sandy beaches (> 80 %) and destabilization of sea cliffs (> 50 %) along the Oregon coastline in response to predicted sea-level rise of 1-2 meters during the next century, or two (Figure 7).

Impacts of Predicted Global Sea-Level Rise on Oregon Tidelands

Future global sea-level rise of 1–2 meters (3–6 feet), predicted to occur during the next century or two (Pleffer *et al.*, 2008; Vermeer and Rahmstorf, 2009), will impact Oregon tidelands through increased flooding and salinity intrusion (Figure 1). Estuary tidelands in Oregon range from freshwater spruce bogs growing 2 meters (6 feet)

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above mean (average) sea-level to freshwater-brackish marsh (1–2 meters above mean sea-level) (Figure 8) to brackish-marine marsh (0–1 meters above mean sea-level) to mud and sand tidal flats below mean sea-level (Figure 9). These tidelands, also known as tidal wetlands, provide unique conditions for biological productivity and habitat in Oregon estuaries.

Figure 10. Current extent of natural or non-diked tidal marsh (yellow lines) in Tillamook Bay, Oregon. Rapid sea-level rise will submerge these natural bay shoreline wetlands, but new tidal marsh will not develop in most of the preexisting floodplains, due to extensive dike and tidal gate restrictions of tidal flow. The remaining natural salt marsh in Tillamook Bay will be largely eliminated by global sea-level rise of 1-2 m in the next century.

During the last several decades much work in Oregon has gone into the restoration and protection of these valuable coastal wetlands (PNCERS: Oregon Sea Grant, 2003). Additional submergence of the tidal wetlands by 1–2 meters (3–6 feet) of

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sea-level rise will kill the lowest spruce bogs, bury the salt marshes under mud, and erode some tidal channel banks (Peterson *et al.*, 2000). The higher sea-levels will also increase winter flooding in upper estuarine reaches, impacting dikes, tide gates, roads, and combined sewer outfalls (Barnett, 1997).

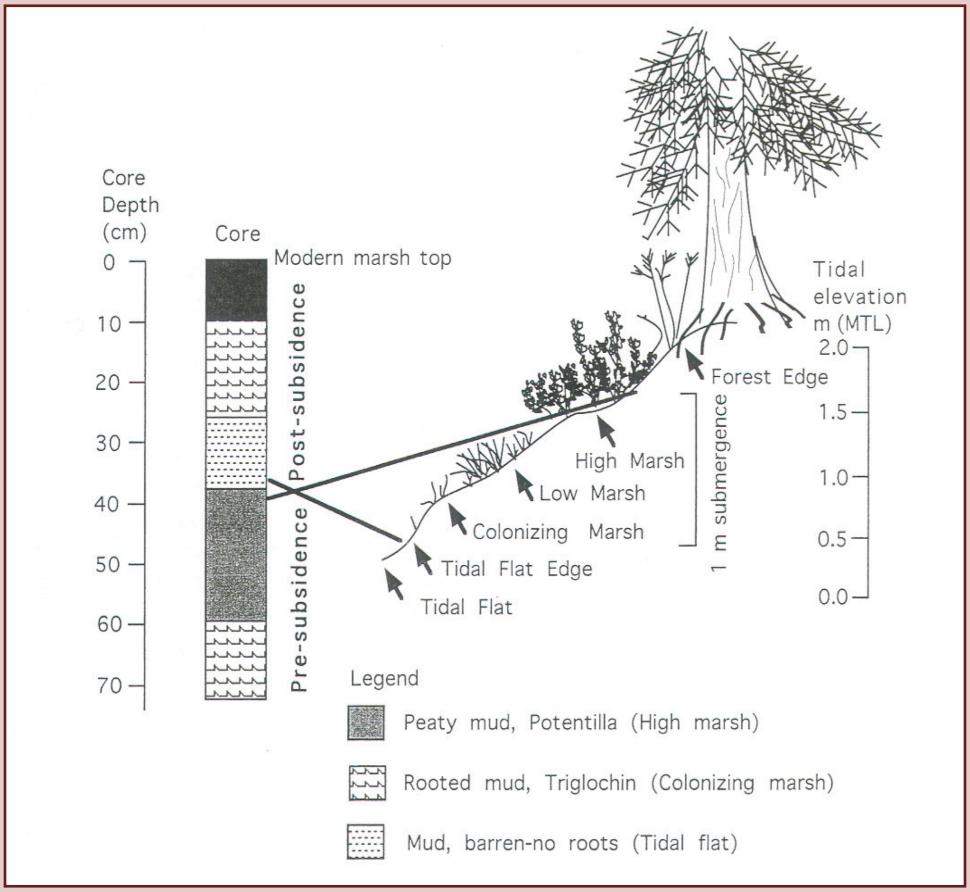

Figure 11. Vegetation zones relative to mean tidal level datum in Oregon estuaries. A rapid rise in sea-level will submerge tidal marshes. Most supratidal settings (> 2.5 m above mean tidal level) in Oregon estuaries enclosed by dikes, so they are not expected to provide refuge for the colonization of new tidal marshs following predicted global sea-level rise. Core log shows expected geologic record of peat buried by mud following abrupt sea-level rise (see Figure 12 for examples). Figure drafted from Peterson *et al.* (2000).

The long-term ecological impacts of global sea-level rise will occur in estuaries where human-built dikes have cut off the enclosed floodplains from tidal influence (Borde *et al*, 2003). The extensive dikes in the Columbia River estuary, Tillamook Bay, and Coos Bay will prohibit the creation of new spruce bogs or tidal marshes (no tidal wetland "re-colonization") under the conditions of predicted global sea-level rise (Figure 10). Shallow tidal creeks used by juvenile salmonids (PNCERS, 2003) will be lost, as well as the nutrient organic matter that is produced in tidal marshes (Ruesnick *et al.*, 2003) when the few remaining natural salt marshes are submerged by predicted sea-level rise.

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Figure 12. Episodically submerged peat horizons (dark) buried by bay mud (light) from great earthquake subsidence events (mean recurrence interval 400–500 years) in Coos Bay, Oregon. Each burial event represents about 1.0 m of rapid sea-level rise (see Figure 11 for details). Interseismic uplift and sedimentation permit the mudflat to convert back to a marsh, before the next earthquake subsidence (Barnett, 1997).

The recent geologic record of coastal wetland response to rapid submergence in Oregon and Washington is well established (Figure 11). These abrupt burials of tidal marshes by bay mud and sand have occurred repeatedly from episodic lowering of coastal land elevations by 1–2 meters (3–6 feet) during great Cascadia earthquakes (Atwater *et al.*, 1995). These “coseismic subsidence” events, reoccurring every few hundred years in Oregon (Darienzo *et al.*, 1994), provide direct analogs to the expected impacts from predicted global sea-level rise in Oregon tidelands. Earthquake-caused lowering of the shoreline in the Nehalem, Tillamook, Netarts, Siletz, and Yaquina Bays killed 80-90 % of the pre-existing tidal marshes in those bays (Barnett, 1997).

Tectonic rebound and uplift of 0.5–1.5 meters eventually permitted the prehistoric tidal mashes to recolonize the barren mudflats within a century or two (Figure 12) (Darienzo, 1991; Darienzo and Peterson, 1990). Unlike these prehistoric earthquake cycles, the predicted global sea-level rise is not expected to reverse in the foreseeable future. In the worst-case scenario a global sea-level rise of 1–2 meters could be augmented by earthquake-generated coseismic subsidence, resulting in an additional 0.5 to 1.5 meters of relative sea-level rise in Oregon following the next Cascadia megathrust rupture (Peterson *et al.*, 2000), yielding a combined submergence or relative sea-level rise of 1.5–3.5 meters.

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In addition to the submergence of tidelands the predicted global sea-level rise will also impact estuaries, small coastal creeks, and shallow beach sand aquifers by salinity intrusion. Salinity intrusion following global sea-level rise is of concern around the world, but the potential impacts in Oregon have not been widely reported.

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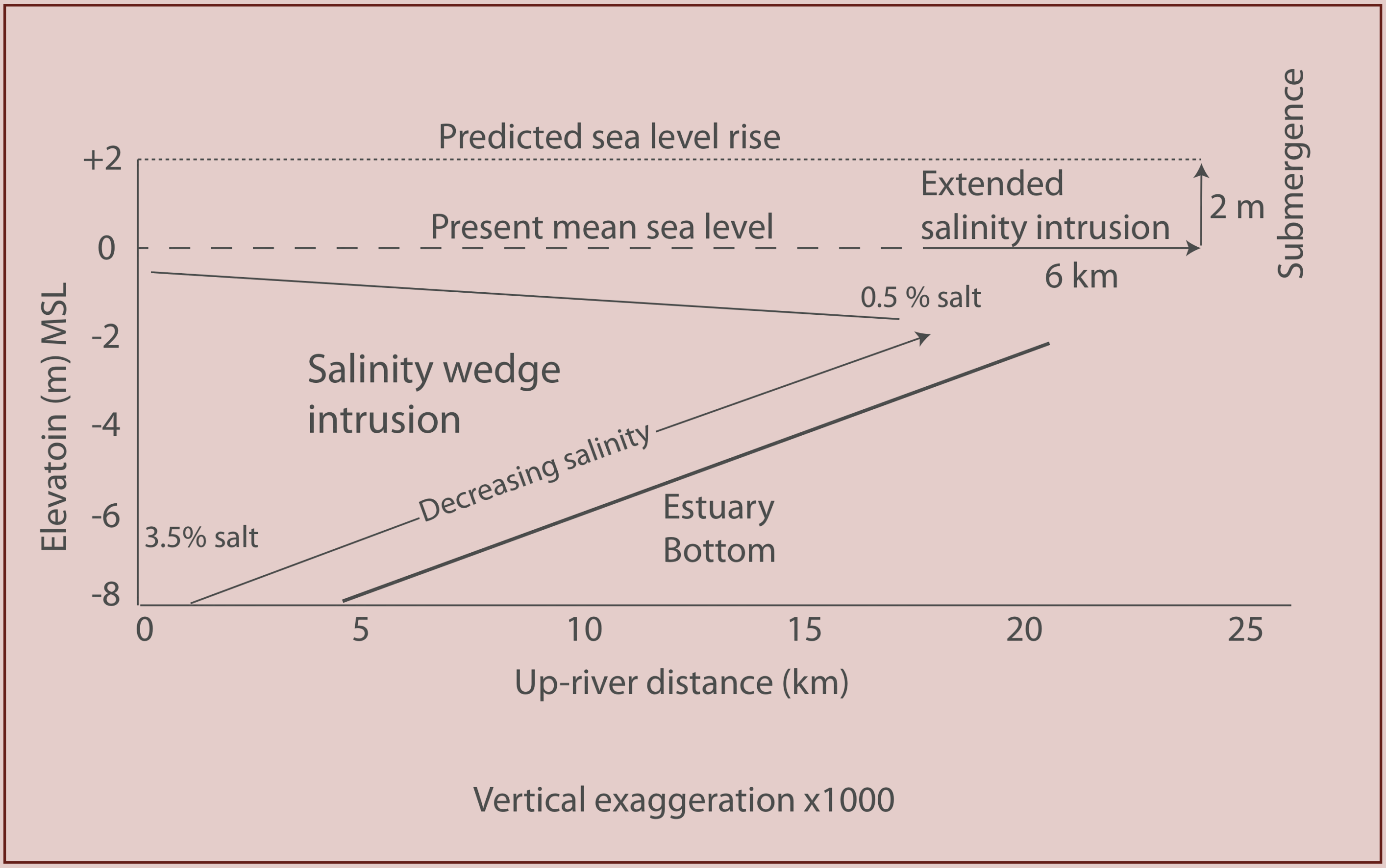

Figure 13. Diagram of salinity wedge and extended salinity intrusion of 6 km, assuming 0.00035 salinity gradient and a predicted global sea-level rise of 2 m during the next century or two.

Salinity wedges or layers of salt water extend inland from the tidal inlets to the up-river limit of salinity intrusion in all of Oregon's estuaries. The small shallow estuaries of the Oregon coast are partially mixed (vertically) on a seasonal basis. The salinity wedges reach maximum landward distances of 22-49 kilometers (km) in the Columbia River estuary (Columbia River Intrusion, 2011), 21-31 km in the Nehalem, Yaquina, Alsea, Siuslaw, Umpqua and Coos Bays (Percy *et al.*, 1974), and 3 km in the Sixes River (Boggs and Jones, 1976). The landward extents of salinity wedges are controlled by many factors including tidal basin bathymetry, tidal prism or volume

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of tidal exchange, and seasonal fluvial discharge. However, increased distances of salinity intrusion can be simply estimated from current salinity gradients and predicted global sea-level rise (Figure 13).

The salinity gradients are measured from maximum salinity and mean depth at the

Figure 14. Prehistoric spruce forest stumps in the Coquille estuary were killed by submergence and/or increased salinity intrusion in the lower reaches of the Coquille River following coseismic subsidence (estimated 0.5–1.0 m sea-level rise) from the AD 1700 rupture of the Cascadia subduction zone fault (Barnett, 1997). The spruce forest edge has been replaced by brackish salt marsh habitat.

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bay mouth to minimum salinity and mean depth at the maximum salinity intrusion distance. Using the current salinity gradients for the central Oregon estuaries (Nehalem to Coos Bay) and a predicted global sea-level rise of 2 meters, the salinity intrusions could extend an additional 5 to 7 km in landward distance. Both submergence and increased salt wedge intrusion could displace marine, brackish, and freshwater tidal habitats following a 1–2 m sea-level rise predicted for the next century or two (Figure 14).

Saltwater wedges also occur in subsurface aquifers that are hosted in sand barriers and beach plains. Measurements of current salinity gradients in barrier beach plains of the Columbia River littoral cell (Peterson *et al.*, 2007) range about 0.03-0.003 (Peterson *et al.*, 2002). Assuming a maximum global sea-level rise of 2.0 meters and a minimum salinity gradient of 0.003, the salinity intrusion in low gradient coastal sand barriers could extend an additional 0.6 km inland. Though of limited distance, the saltwater intrusions into shallow sand aquifers could impact water quality in ponds, wetlands, and shallow water wells that are located in narrow sand spits and beach plains of the Oregon coast.

ACKNOWLEDGEMENTS

These two sections about potential sea-level rise impacts on beaches and tidelands from predicted global sea-level rise in Oregon were reviewed, respectively by Dr. Peter Ruggiero, Oregon State University and Dr. Mark Darienzo, currently with Federal Emergency Management Agency, recently retired from Oregon Department of Land Conservation and Development. Steve Schell, board member of Oregon Shores Conservation Coalition, assembled the authors for the background sections produced for the Coastal Climate Change Adaptation Project. Kennett Peterson performed the initial editing of the two sections presented here. Michael Coe and Phillip Johnson completed the final technical editing of the two sections for the Coastal Climate Change Adaptation Project. Paris Edwards directs the Coastal Climate Change Adaptation Project for Oregon Shores Conservation Coalition and provided logistical support for the initial public presentations of these two sections in several coastal communities in Oregon.

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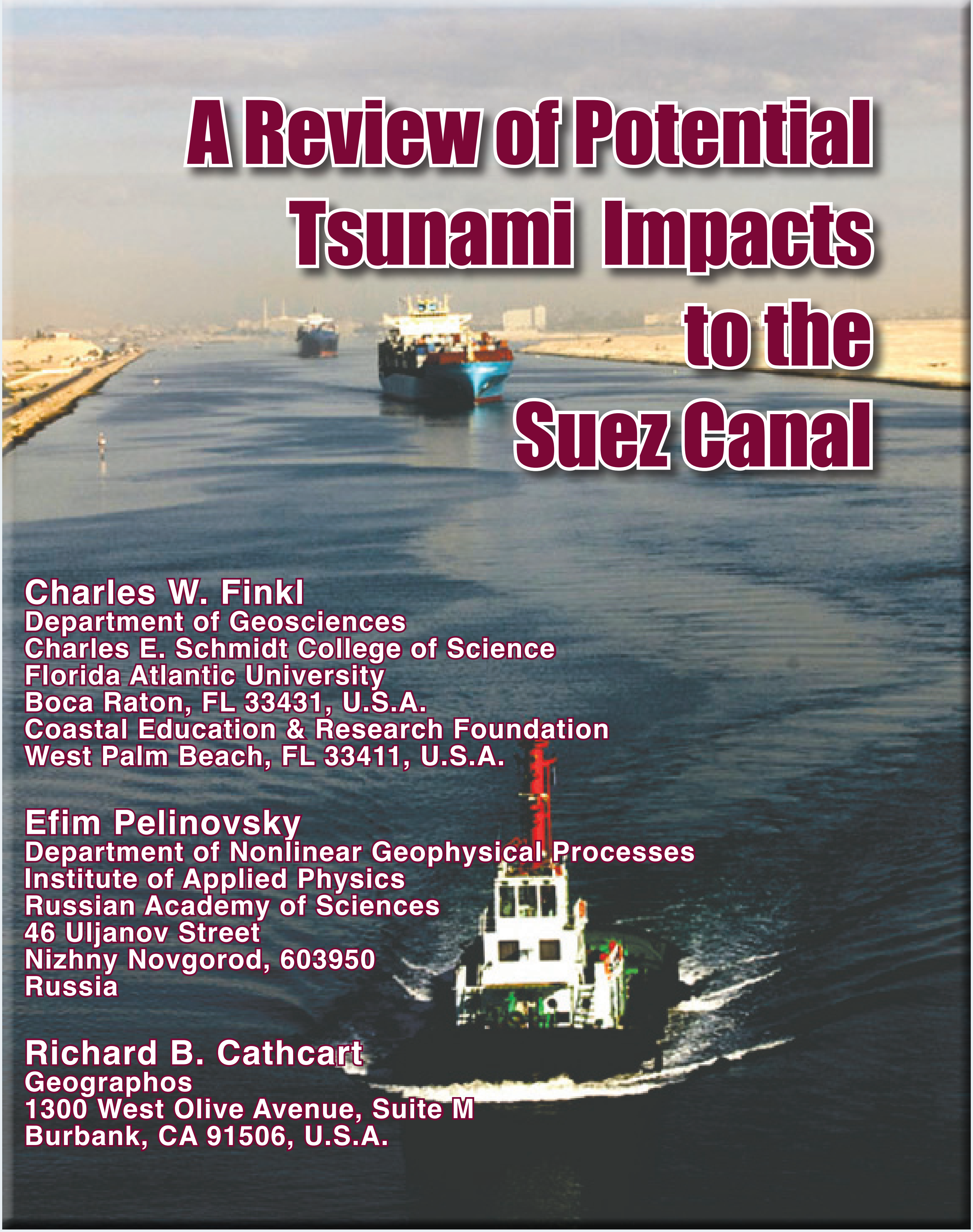

A Review of Potential Tsunami Impacts to the Suez Canal

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Tsunami Impacts to the Suez Canal

ABSTRACT

Tsunamis in the eastern Mediterranean and Red Seas, induced by earthquakes and/or volcanic activity, pose potential hazards to shipping and fixed harbor infrastructure within the Suez Canal. Potential vulnerabilities of the Suez Canal to possible tsunami impacts are reviewed by reference to geological, historical, archeoseismological, and anecdotal data. Tsunami catalogues and databases compiled by earlier researchers are perused to estimate potential return periods for tsunami events that could directly affect the Suez Canal and operational infrastructures. Analysis of these various records indicates a centurial return period, or multiples thereof, for long-wave repetition that could generally impact the Nile Delta, whereas numerical models indicate a multidecadal frequency. It is estimated that tsunami waves 2 m high would begin to break about 4 to 10 km down-canal, whereas a 10-m wave break would occur about 0.5 to 3 km into the Canal.

ADDITIONAL INDEX WORDS: *Coastal geohazards, seismic sea wave, tsunamigenesis, coastal erosion, coastal flooding, Mediterranean Sea, Red Sea, shore-protection structures.*

INTRODUCTION

The Suez Canal (Figure 1) is the most commercially utilized and the longest (160 km) excavated waterway in the world, rivaled only by the Panama Canal. The canal is an inland coastal ocean–connected saltwater body that links the Mediterranean Sea in the north with the Red Sea in the south (Fremaux and Volait, 2009). The north–south trending channel sits on a line of longitude at 32°18′15″ E across the Isthmus of Suez in Egypt (cf. Figure 1). Coordinates of the entrance on the Red Sea are 29°55′58.8N, 32°33′54″E (at Port Tawfik near the city of Suez), while the Mediterranean Sea entrances are 31°16′8.4″N, 32°19′22.8″E (Port Said) and 31°13′48″N, 32°20′49.2″E (Port Fouad). The canal mostly transits a desert environment and is bounded by sand banks, except for the northern 60 km bordered by extensive wetlands. Its commercial and military-strategic value provides immeasurable savings in vessel voyage distance, sailing time, and transport costs. The position of Earth's landmasses, coupled with patterns of market, production, and mining, converges maritime trade at the Suez Canal, making it a transportation chokepoint. In spite of the transportation bottleneck, the Suez Canal is ranked as a global infrastructure solution from a macroengineering perspective (Calon, 1994). By 2011, at least 50 ships were passing through the Suez Canal daily. That is, two ships enter the waterway every hour every day of the year, with approximately 25 ships floating in the channel at any one time during a 24-hour period.

Because the Suez Canal lies at sea-level and is without sea locks, it is susceptible to flooding by long waves (*e.g.*, Stiros, 2007). Tsunamis could thus damage and disrupt the canal's vital international role by impacting structures that facilitate the mass distribution of goods, services, and information.

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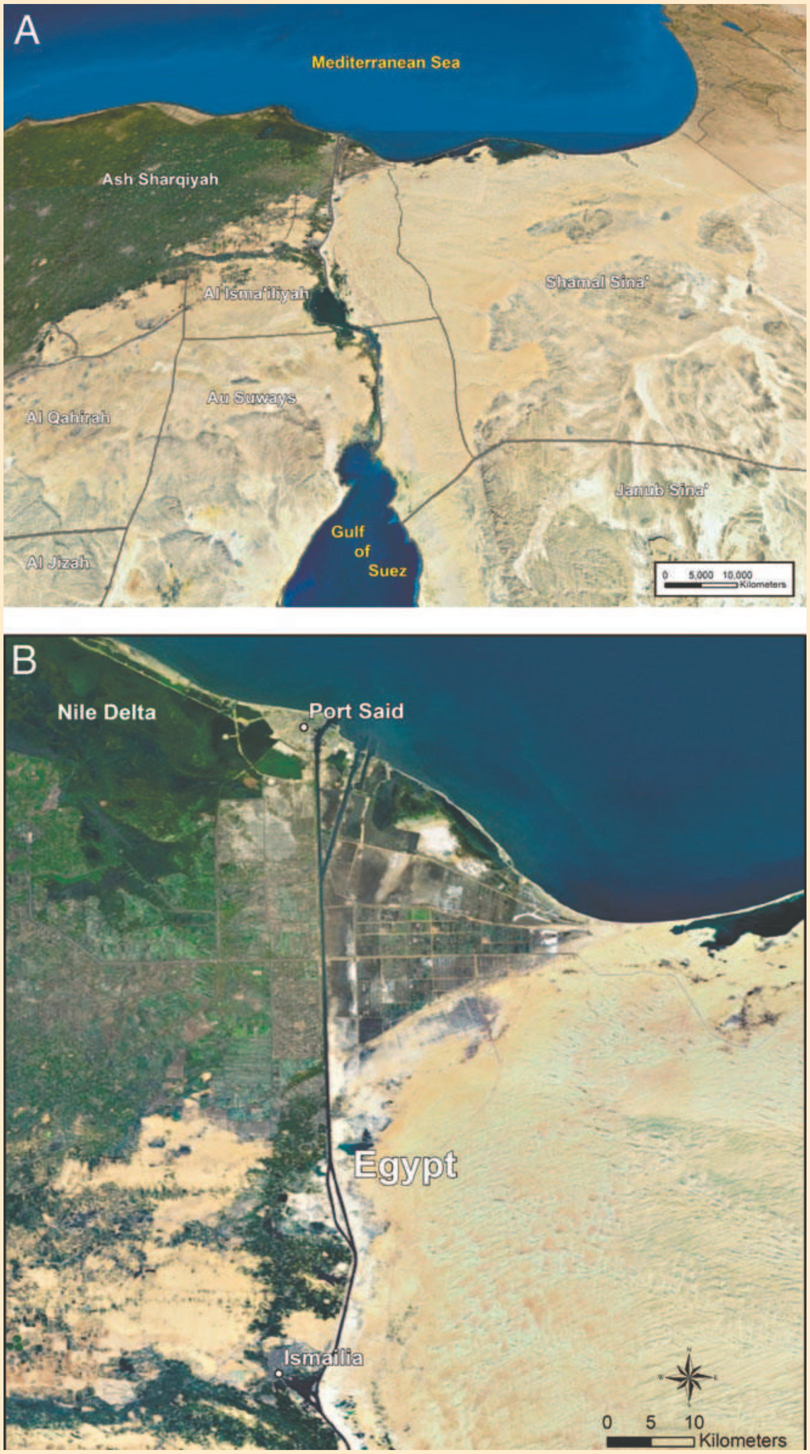

Figure 1. Location of the Suez Canal, Egypt, showing the overall setting of the study region and position of the excavated channel between the Mediterranean Sea and the Red Sea. (A) The Suez Canal lies on the eastern flanks of the Nile Delta and is susceptible to tsunamis originating in the eastern Mediterranean Sea basin. (Based on ESRI, i-cubed, USDA FSA, USGS, AEX, GeoEye, Getmapping, Aerogrid, and IGP). (B) Close-up of the Suez Canal viewed from above the Red Sea, looking northward toward Port Said on the eastern flanks of the Nile Delta. The north–south trending canal transits mostly desert regions until it reaches the fertile Nile Delta lowlands. The global digital elevation model (ETOPO2) represents gridded (2 3 2 min) elevation and bathymetry for the world. (Data derived from the National Geophysical Data Center's ETOPO2 Global 29 Elevations data set from September 2001).

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Although it is not possible to completely protect the harbors at either end of the uez Canal (*e.g.*, Ports Said and Fouad at its northern end and Ports Suez and Adabiya at its southern end) fromwidespread inundation, ingress of tsunamis into the canal per se could be mitigated by construction of controllable surge gates.

Limited hydrographic surveys constrain the accuracy of generalizations of the geohazard threat posed by future tsunamis to the main channel and nearby infrastructures. The extensive array of potentially impacted infrastructure includes a coast-parallel railroad, cross-canal bridges, tunnels, freshwater siphons, and a thermal power plant (Nassar, 1988). The specific fixed infrastructures of major significance include (1) the El Ferdan Railway Bridge (30.657° N, 32.334° E) with a span of 340 m, the longest swing bridge in the world, that was completed in 1963 and whose bridge piers can be eroded; (2) the 1063-m-long Ahmed Hamdi Tunnel (30°5′9″ N, 32°34′32″ E; Otsuka and Kamel, 1995) that has been passing vehicles under the Suez Canal since 1983, the entrance/exit of which can foreseeably be flooded by high levee-overtopping tsunami waves moving through the Suez Canal proper; (3) the 775-m-long El-Salam Syphon under Suez Canal conveying irrigation water to the Sinai Peninsula, which was completed in 1997 (Mazen and Craig, 1995; Serag and Khedr, 2001); (4) the Suez Canal overhead power-line crossing (29.9° N, 32.5° E) by which twin pylons elevate two 500-kV circuits to the required 152-m clearance above the waterway and have a wire span of about 600 m; and (5) the Suez Canal Bridge (30.8° N, 32.3° E) spanning 404 m and affording a waterway clearance of 70 m, which opened to vehicles during October 2001. Damage to the Ismailia Canal, which conveys freshwater from NW Cairo to the Suez Canal, could also be a macroproblem during posttsunami impact recovery operations (Sultan, Santos, and Helaly, 2011).

Prior tsunami events in the Mediterranean and Red Seas (Table 1) suggest potential impacts on the Suez Canal sometime in the future (*e.g.*, Sørensen *et al.*, 2012). Attention is focused on this important waterway because 12% of all tsunamis worldwide occur in the Mediterranean Sea Basin and, on average, one disastrous tsunami takes place there every century (*e.g.*, Govorushko, 2012). According to Papadopoulos *et al.* (2007) and the International Tsunami Information Centre (2011), there is a significant frequency of tsunami events in the Mediterranean, with 200 tsunamis being recorded over the last five centuries. Over the last four centuries, there have been 15 tsunamis every century around Italy. In 1628 BC, the coasts of the entire eastern Mediterranean were submerged by 60-m-high waves caused by a volcanic eruption on Santorini, a Greek island in the Aegean Sea. Earthquake-induced tsunamis originating near the Greek islands of Rhodes and Crete in AD 365 and 303 destroyed coastal developments as far away as Egypt's Nile Delta, the earlier tsnami killing thousands of people in the city of Alexandria (Galanopoulos, 1960; Pararas-Carayannis, 1992). Geological research and historical records report that many powerful tsunamis have taken the lives of thousands of people over the ages in this

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region. Because the area is clearly tsunami prone, the Suez Canal and its associated infrastructure are likely vulnerable to long-wave impacts in the future.

Shape and Size of the Canal

Opened to shipping in 1869, its maximum navigational depth was then 8 m. Port Said was constructed by 1871, formed by two breakwaters that extended seaward from the low sandy coast. By 1890, the depth had been increased to 8.5m. The first coal-fueled ship transited the Suez Canal in 1908, and diesel-powered ships were moving through the waterway by 1912. In 2011, cargo ships bigger than 10,000 gross tons made up about 93% of the world's total capacity. Over time, the increasing length and draft of large vessels promoted a gradual improvement in navigational conditions by enlargement of curves (*i.e.*, lessening of curvatures) and standardization of the waterway's navigable depth. Although there were narrower channel widths in the past, today the canal averages about 300 m wide with an effective navigation width of about 225 m at an 11-m water depth. The present cross-sectional configuration of the canal is shown in Figure 2.

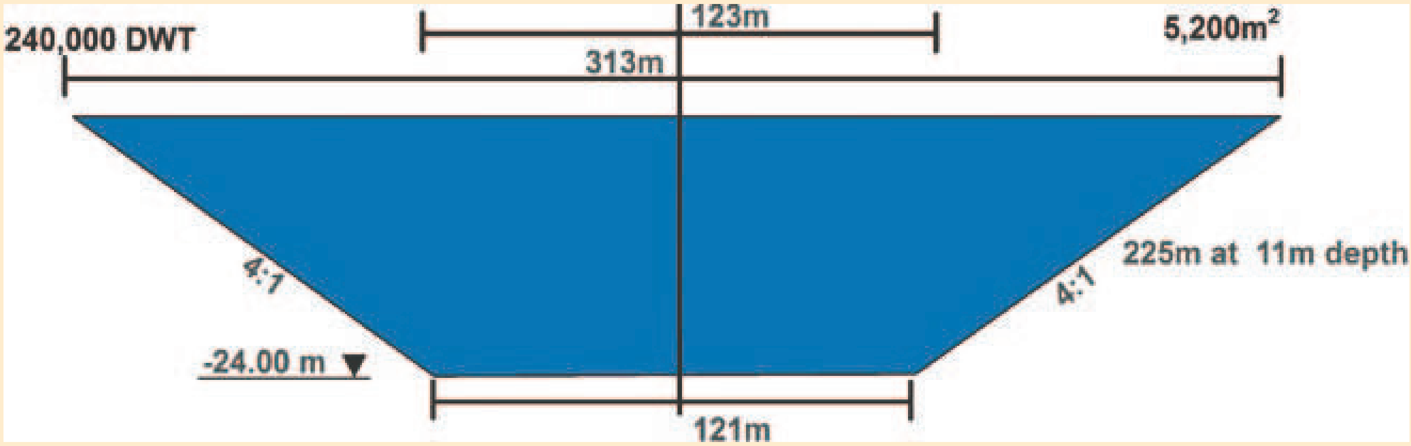

Figure 2. Cross-section of the Suez Canal showing major dimensions ca. 2010 with a surface width of 313 m, a basal width of 121 m, and an effective navigational width of 225 m at an 11-m depth that allows passage of a typical Suezmax vessel. The present configuration of the canal is the shape of a waterway that would accommodate the incursion of a tsunami, breaking wave front, and flood wave. (See Figure 7 for further explanation. Based on a diagram from the Suez Canal Authority's Web site).

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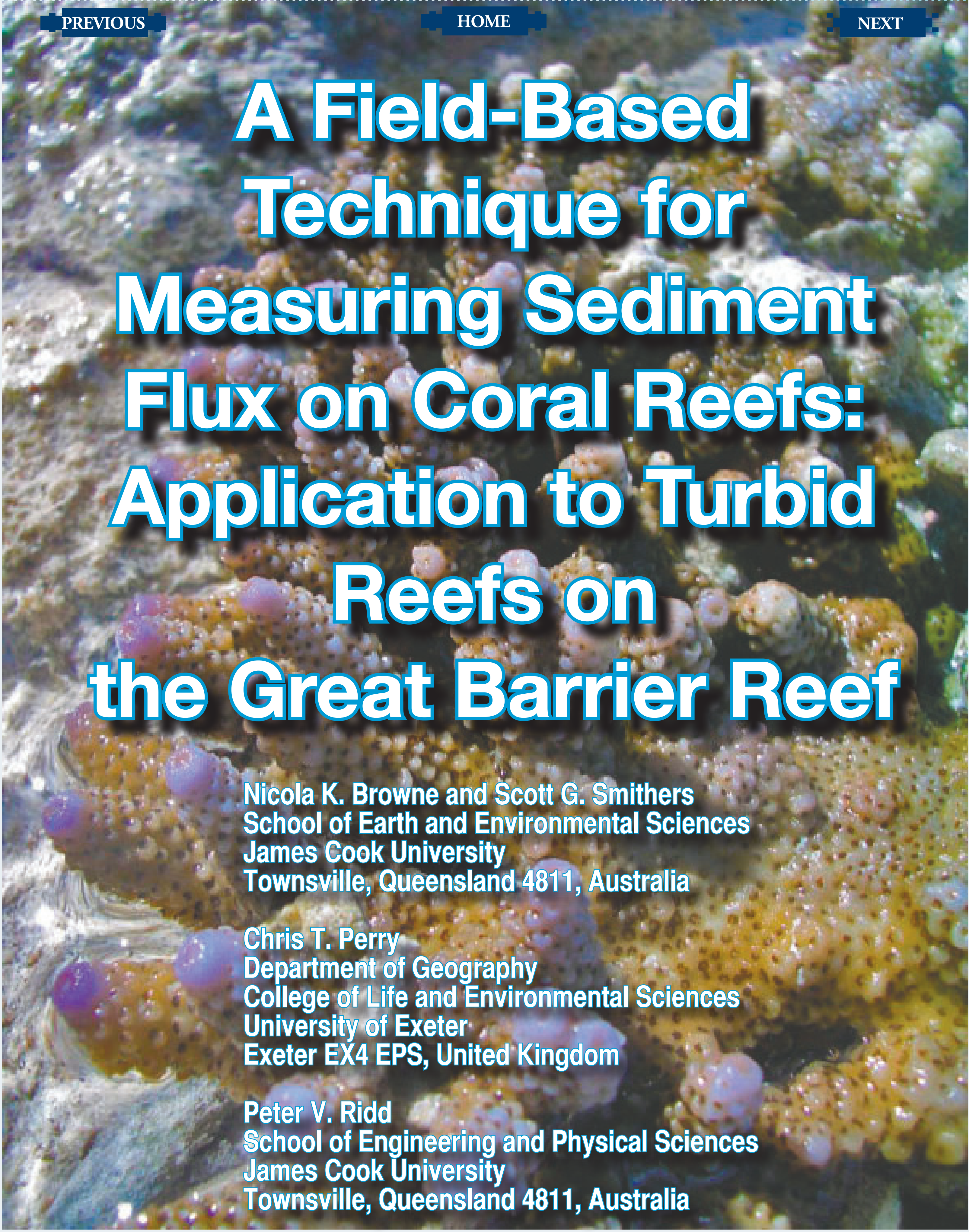

A Field-Based Technique for Measuring Sediment Flux on Coral Reefs: Application to Turbid Reefs on the Great Barrier Reef

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ABSTRACT

Inshore turbid reefs on the Great Barrier Reef (GBR) are exposed to high and fluctuating sediment loads normally associated with poor reef growth, but many have high coral cover (.30%) and diversity (.50 species). Previous assessments of sediMent regimes on these reefs have largely relied on sediment trap data, which overestimate sedimentation rates and may not accurately reflect sedimentary conditions. A new approach, based on paired sediment trays, is described here that allows the sedimentation rate, sediment resuspension, and total mass of mobile sediments transported on to and off of a site per unit time and area (termed the two-way total sediment flux) to be measured or calculated. The sediment trays were deployed on Middle Reef and Paluma Shoals, two inshore turbid reefs on the GBR where the two-way total sediment flux ranged from 34 $g/m^2/d$ in protected reef habitats to more than 640 $g/m^2/d$ in higher-energy settings. Mean sedimentation rates, calculated using data from four sites across these reefs, of less than 122 $g/m^2/d$ are considerably lower than published rates estimated for nearby coral reefs, largely because sediment traps limit sediment resuspension. At each tray installation, sediments were collected every 4 to 6 weeks to measure variations in net sedimentation through the year, and resuspension rates were calculated by comparing 100 g of preanalysed sediments placed on trays at deployment to sediments recovered 2 weeks later. These data demonstrate that despite high sediment delivery rates, net sedimentation may still be relatively low and potentially less of a threat to benthic communities on turbid reefs than previously assumed. Sediment trays provide a comprehensive assessment of sediment regimes that, together with ecological assessments of coral cover, improve our understanding of the sedimentary pressures affecting inshore turbid reefs and their ability to tolerate sedimentation.

ADDITIONAL INDEX WORDS: *Sedimentation, sediment resuspension, turbidity, community assemblages.*

INTRODUCTION

Detailed knowledge of sediment regimes is required to understand how marine ecosystems respond to high sediment loads. Excessive sediment loads can negatively affect coastal coral reefs when they form a suspended load, which increases turbidity and limits light penetration to depth (Rogers, 1990; Wolanski and De'ath, 2005), or when sediments are deposited and smother reef benthos (Loya, 1976). The inshore reefs of the Great Barrier Reef (GBR) are exposed to high sediment loads (Devlin and Schaffelke, 2009; Wolanski *et al.*, 2005; Wolanski *et al.,* 2008; Woolfe *et al.*, 1998) and as such are widely perceived to be degraded systems with low coral cover and diversity (Done *et al.*, 2007; Smith, Gilmour, and Heyward, 2008). However, various investigations show that these inshore reefs can support diverse and distinctive coral assemblages adapted to elevated sedimentation and turbidity conditions (Ayling and Ayling, 1999; Perry and Smithers, 2006; Veron, 1995). Although conceptual models have been proposed to explain turbid zone reef growth and other reef types (Kleypas, Buddemeier, and

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Gattuso, 2001; Woolfe and Larcombe, 1999), quantitative data documenting the sediment regime where these reefs initiate and grow are rare.

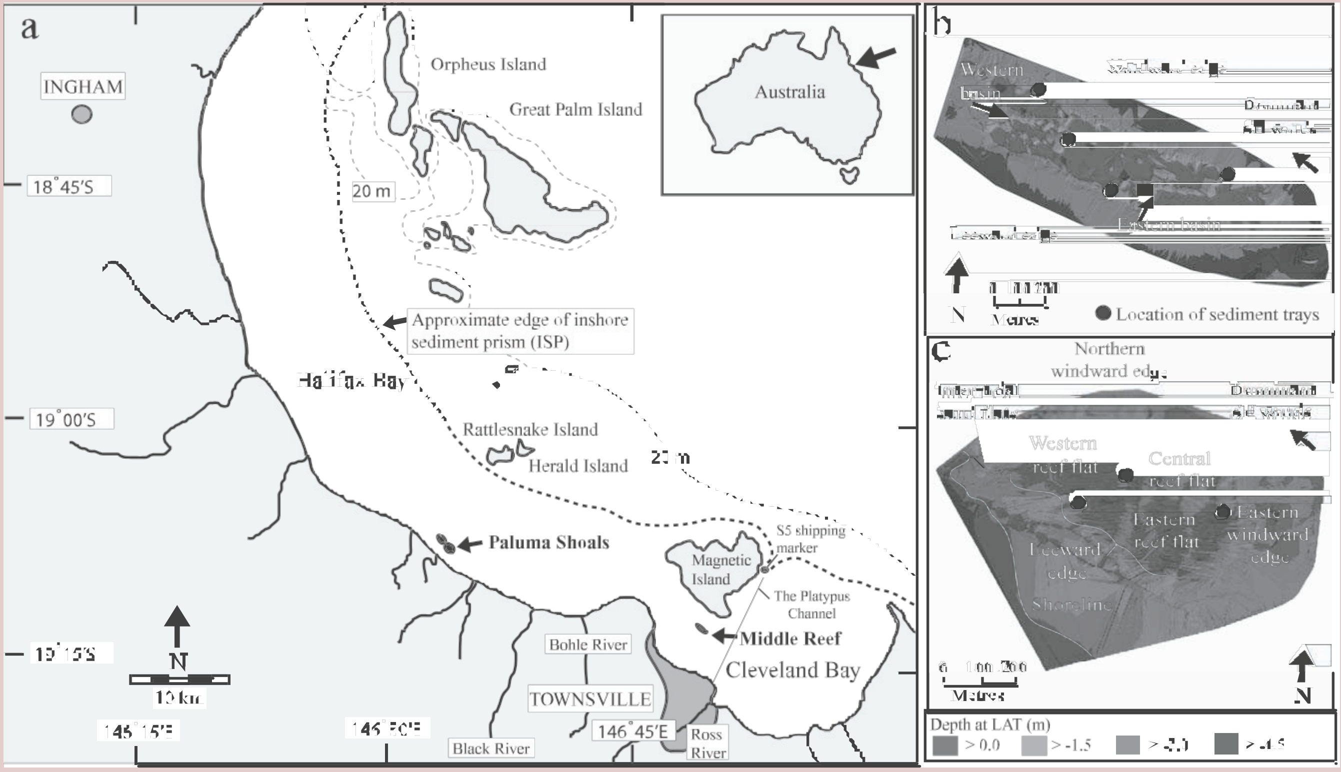

Figure 1. (a) Location of Middle Reef and Paluma Shoals on the central GBR. (b) Annotated image of Middle Reef, showing its discontinuous reef flat, two linear basins, and the base of the reef slope. (c) Annotated image of Paluma Shoals, showing the extent of the reef flat and the windward and leeward edges.

Collecting reliable and representative data on sediment regimes is difficult (Jurg, 1996). Previous research has largely relied on sediment trap data, but these data can be problematic because the rate at which sediments collect in traps is reliant on trap geometry, sediment grain size, and suspended sediment concentrations (Gardner, 1980). Sediment traps also tend to collect coarse sediments and underestimate fines, and they commonly overestimate sedimentation rates in high- energy settings where resuspended sediments are trapped rather than transported farther downcurrent (Jurg, 1996; Storlazzi, Field, and Bothner, 2011; Thomas and Ridd, 2004). The balance between deposition and resuspension has major implications for coral reef health and reef accretion rates; therefore, it is important to evaluate and quantify these processes. Other techniques applied to assess sediment regimes on reefs include anchored tiles, reference to horizon markers, and measurements of changes in suspended sediment concentrations. Sophisticated instruments like sediment accumulation sensors that continuously measure sedimentation rates (Thomas and Ridd, 2005) have also been used, but these tend to have high cost and low spatial coverage (see Thomas and Ridd, 2004, for a review).

Here, we present a new methodology to better quantify sedimentation, sediment

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resuspension, and fluxes across a coral reef. The approach is based on paired sediment trays that have been designed to greatly reduce problems associated with sediment traps. The trays allow for sediment deposition and resuspension and therefore assessment of net depositional rates. They do not, however, account for sediment advection past the trays and measure only those sediments that settle on the reef, unlike sediment traps that may also trap sediments in suspension. An experiment was designed using paired sediment trays deployed for 1 year on two inshore turbid reefs on the GBR that experience high and fluctuating sediment loads. On deployment, one tray was covered with a known mass of preanalysed sediments, which were recovered 2 weeks later to determine shorter-termseasonal sediment resuspension rates. Specifically, we (1) assessed spatial and temporal differences in the rate of net sediment deposition, (2) described the nature of sediments deposited and resuspended, (3) distinguished between intra-annual depositional rates and annual sedimentation rates, and (4) quantified the total mass of mobile sediments at each site. Our data reveal new insights into sediment regimes on inshore turbid reefs and demonstrate the utility of this simple but effective methodology.

SITE DESCRIPTION

Middle Reef

Middle Reef (19°119’70” S, 146°48’70” E) is located in Cleveland Bay (<15 m) on the central GBR, approximately 4 km offshore from Townsville, Australia’s most populous tropical city (Figure 1a). Cleveland Bay has a 4-m-thick layer of muddy sand and sandy mud of mainly terrigenous origin deposited over a muddy Pleistocene clay unit (Carter, Johnson, and Hooper, 1993; Lou and Ridd, 1997). Swell waves are the main agent of resuspension, and resuspended sediments from the southern sections of the bay are transported northwards by tidal and wind-driven currents through the Western Channel as turbid water (Lou and Ridd, 1996). Turbidity at Middle Reef can rise to more than 20 nephelometer turbidity units (NTU) when significant wave height (Hsig) exceeds 1 m for 1 or 2 days (Larcombe *et al.*, 1995).

Middle Reef is a linear feature (1.2×0.3 km) aligned with the dominant NW currents that flow between Magnetic Island and the mainland (Figure 1b). Two prominent linear basins (10–20 m wide) that are around 3mdeep separate four reef flats and provide reef-slope habitat that is relatively sheltered from high wave energy (Browne, Smithers, and Perry, 2010). Coral cover extends to approximately 3.7 m below lowest astronomical tide (LAT) at Middle Reef, and mean live hard coral cover across the reef was 39.5%. For a comprehensive description of coral community abundance and composition, refer to Browne, Smithers, and Perry (2010).

Paluma Shoals

Paluma Shoals (19°5′43″ S, 146°33′5″ E) is located in central Halifax Bay (<15 m) approximately 30 km north of Townsville (Figure 1a). Halifax Bay is dominated by mixed siliclasticcarbonate sediments and is characterised by a shore-attached terrig-

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enous sediment deposit, termed the inshore sediment prism (Belperio, 1988; Carter, Johnson, and Hooper, 1993). During the dry winter months, persistent SE trade winds generate swell (periods >6 s; Larcombe *et al.*, 1995) and drive shore-parallel currents that transport sediment northwards (Larcombe and Woolfe, 1999). Maximum turbidity measurements of 175 NTU have been recorded, with an estimated 40 days per year exceeding 40 NTU (Larcombe, Costen, and Woolfe, 2001).

Paluma Shoals consists of a larger southern shoal (500 × 820 m) and smaller northern shoal complex, both of which extend down to approximately 3.5 m below LAT on the windward slope (Palmer *et al.*, 2010; Smithers and Larcombe, 2003). The southern shoal is a connected to the mainland at its NW end via intertidal sand flats (Figure 1c). The tops of massive *Goniastrea* colonies emerge when the tide is at +0.85m LAT, and the reef flat is fully exposed at +0.5 m LAT. Coral cover extends to approximately 3.5 m below LAT at Paluma Shoals, and mean live hard coral cover was 29.2% (SE = 3.94). Smithers and Larcombe (2003) describe the Holocene evolution of the reef at Paluma Shoals, and a description of coral community and sedimentology is presented by Palmer *et al.* (2010).

MATERIALS AND METHODS

Apparatus and Sediment Collection

Each sediment tray array consisted of two stainless steel sediment trays (35×20 cm at the base of the tray) secured in an aluminium frame and stabilised with a 20-kg weight attached at one end and steel pegs at the other (Figure 2). The trays were approximately 2.5 cm deep and were laid as close as possible to the reef substrate (maximum distance above the substrate was 2 cm) within the natural relief of the surrounding reef surface. Trays were orientated with the shorter edge facing the prevailing water movement to minimise the possible influence of turbulence at the tray edge. Sediment tray arrays were deployed in September 2009 at a leeward and a windward location (−1.5 to −3 m) and at a central location at each reef (0.5 m; Figure 1). The number of paired trays were sufficient for inter- and intrareef replication (tested using one- and twoway analyses of variance) while meeting marine permit regulations. Sediments were collected from the sediment trays *in situ* using a handheld airlift underwater vacuum and suctioned into in a plastic container before being brought to the sea surface. Sediments were then flushed from the container into plastic bags for transport to the laboratory.

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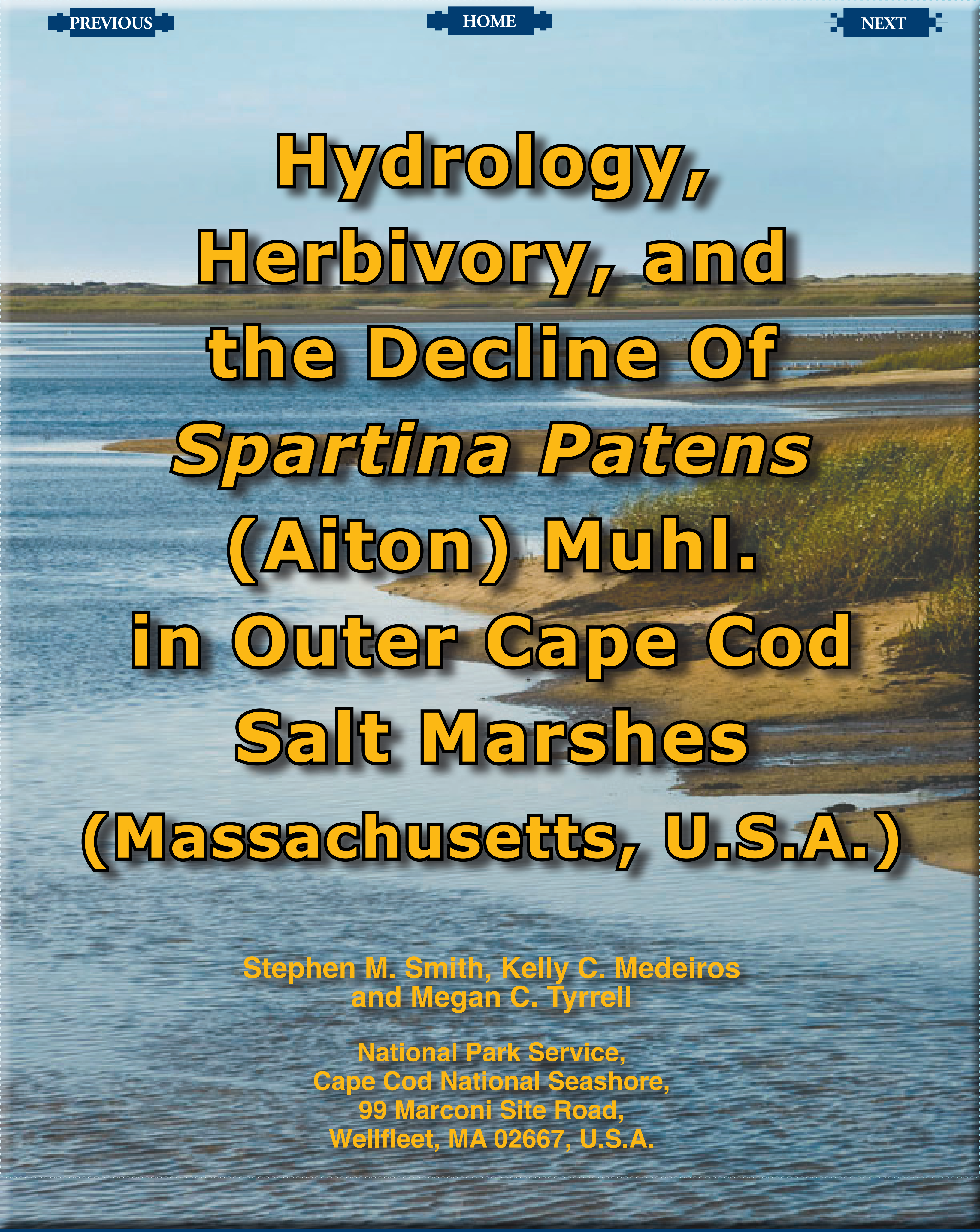

Hydrology, Herbivory, and the Decline Of *Spartina Patens* (Aiton) Muhl. in Outer Cape Cod Salt Marshes (Massachusetts, U.S.A.)

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The Decline of *Spartina Patens* in Cape Cod

Abstract

Salt marsh dieback in different regions of the United States exhibits considerable variability in symptoms, processes, and theoretical or proven causes. On Cape Cod (Massachusetts), where losses within the low-marsh zone (elevations below mean high tide, dominated by smooth cordgrass [*Spartina alterniflora* Loisel.]) have been particularly severe, recent studies suggest that intense grazing pressure from increased abundances of a native, herbivorous, purple marsh crab (*Sesarma reticulatum*) is to blame. Low-marsh dieback is spatially heterogeneous because it is closely related to the distribution of the crabs' preferred substrate (peat vs. sand or mud). However, vegetation losses have also occurred in the high marsh, which is comprised of mainly saltmeadow cordgrass (*Spartina patens* [Aiton] Muhl). In contrast to the low marsh, high-marsh losses consistently occur along the seaward-most edge of this zone, suggesting a link with hydrology (flooding frequency). In this study, we attempted to determine the relative contribution of environmental factors and crab herbivory to high-marsh dieback. To do this, we (1) characterized tidal regimes in dieback vs. healthy areas, (2) assessed the extent of herbivory on S. patens using crab-exclosure cages, (3) documented the ability of *S. patens* to recover from simulated grazing (clipping) in different marshes and in different areas of individual marshes, and (4) estimated densities of *S. reticulatum* in two high-marsh dieback areas. The results indicate that *S. patens* losses are likely the result of a combination of stressors. Flooding frequency and salinities are higher in dieback areas, which impart a higher level of physiological stress. Plants growing there also seem to have a much-reduced capacity to recover from both simulated and actual grazing by the herbivorous crab, *S. reticulatum.* Continued losses of high-marsh vegetation could eliminate this community from coastal wetlands on Cape Cod, Massachusetts.

ADDITIONAL INDEX WORDS: *Salt marsh, Spartina patens, vegetation loss, Cape Cod.*

INTRODUCTION

Salt marsh dieback along the Atlantic and Gulf of Mexico coastlines of the United States has received considerable attention in recent years. The list of potential causes includes drought, disease, herbivory, and combinations of various stressors (Alber *et al.*, 2008). Most dieback, and consequently, most scientific study on this phenomenon, has occurred within the low-intertidal zone (hereafter, referred to as the low marsh), which is dominated by smooth cordgrass (*Spartina alterniflora* Loisel.) (LaMondia and Elmer, 2007; Mendelssohn and McKee, 1998; Ogburn and Alber, 2006; Silliman and Bertness, 2002; Silliman *et al.*, 2005). *Spartina alterniflora* dieback has been reported from numerous locations, ranging from Louisiana to Maine. In New England, losses have been most severe on Cape Cod, Massachusetts, where unlike dieback events in southern states, there is no phase of browning or standing dead vegetation. The rapid disappearance of vegetation has been shown to be the re

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sult of intense herbivory by a native, burrowing purple marsh crab (*Sesarma reticulatum)*. This species has undergone a population explosion, which is hypothesized to be due to a reduction in predation pressure (Bertness, Holdredge, and Altieri, 2009; Holdredge, Bertness, and Altieri, 2009).

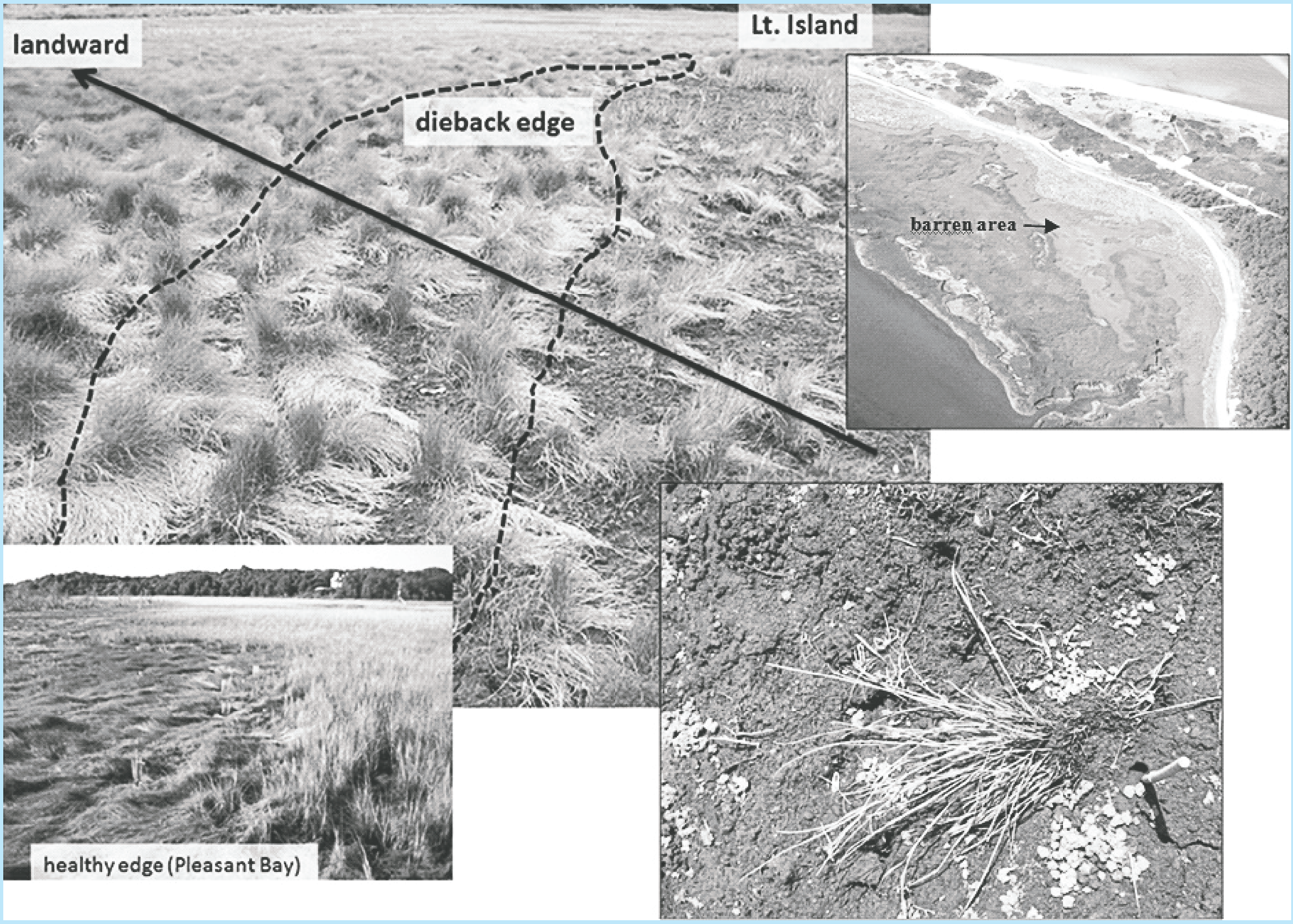

Figure 1 Photographs of a marsh dieback showing thinning and hummocked *S. patens* along the seaward-most edge (top left), aerial view of barren area (top right), healthy high-marsh edge adjacent to *S. alterniflora* **(bottom left), and remnant plants in dieback area with standing, dead foliage (bottom right).**

A rapid decline in high-marsh vegetation, consisting primarily of *S. patens,* has also occurred on Cape Cod. *Spartina patens* losses are detectable in aerial photography in approximately 35% of high-marsh areas, undergoing as much as 50% decline in some areas during the past 20 years (Smith, 2009). The diminishing cover of high marsh is not the result of landward encroachment by *S. alterniflora*. In fact, *S. patens* often disappears long before any *S. alterniflora* colonizes the area. This scenario does not follow conventional models of marine transgression, where the low/high marsh boundary shifts landward because of the competitive superiority of *S. alterniflora* over *S. patens* under an increased flooding regime, and there are no major vegetation losses between zones (Kirwin and Murray, 2008).

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Nocturnal observations within Cape Cod marshes confirm that *S. reticulatum* readily consumes *S. patens* as well as S. alterniflora. Yet, the latter is normally quite tolerant of grazing (Johnson and Foote, 1997), and its resiliency to this type of disturbance is evidenced by S. patens in New England regularly being cut for hay for hundreds of years without causing dieback (Buchsbaum *et al.*, 2009; Williams, Noblitt, and Buchsbaum, 2001). Moreover, the disappearance of *S. patens* only occurs along its seaward-most edges, unlike *S. alterniflora* dieback, where losses occur throughout the entire low-marsh zone. In addition, extensive hummocking occurs—even in the absence of any crab burrows. Hummocking has been discussed as a symptom of flooding stress (DeLaune, Nyman, and Patrick, 1994; Nyman *et al.*, 1995; Roberts, 2000; Windham, 1999). Finally, there are variable amounts of standing dead foliage in these dieback areas (Figure 1). The latter suggests that plants, or portions or plants, are exhibiting mortality without being consumed.

In an attempt to unravel the relative importance of bottom–up vs. top–down factors in high-marsh dieback, hydrologic monitoring and a series of manipulative field experiments using crab-exclusion cages, simulated herbivory, and transplants were conducted at a variety of dieback sites and in a number of healthy reference marshes. In addition, assessments of *S. reticulatum* densities were conducted by pitfall trapping during the course of an entire growing season in two high-marsh dieback areas.

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In Memorium: Dr. Saskia ‘*Kiek*’ Jelgersma

Dr. Saskia ‘*Kiek*’ Jelgersma was an internationally renowned geologist in the Dutch Geological Survey who revolutionized the investigation of sea-level changes and developed a methodology that has been employed by investigators of recent sea-level and coastal changes. Her approach was interdisciplinary; she used biological (pollen, diatoms, and shells), geological (sediments), archaeological, absolute dating (radiocarbon), and surveying techniques to determine the rates and directions of sea-level movements, changes of coastline, land subsidence, sediment consolidation, and coastal vegetation history. Her doctoral thesis on ‘Holocene Sea-Level Changes in The Netherlands’ was published in 1961 in the Memoirs of the Geological Survey (of The Netherlands), in the same year that the late Professor Rhodes Fairbridge of Columbia University in the City of New York wrote a seminal work on sea-level changes published in The Physics and Chemistry of the Earth. Their sea-level curves could not have been more different: Jelgersma’s curve showed a steadily rising sea-level for the past 8000 years for The Netherlands whereas Fairbridge’s curve for the earth was oscillating. Since then a lively discussion continuing to the present day ensued between those who subscribe to one or the other interpretation. Throughout this period, Jelgersma consistently and strongly argued her case gaining added respect from some but alarm from others for the obduracy she displayed. The great strength of Jelgersma’s research lay in the objective criteria used in the selection of sites and samples, all of which came from similar old environments now buried beneath younger sediments in Holland and all dated in Professor H. de Vries’s laboratory in Groningen. In contrast, Fairbridge used a range of different materials dated in many laboratories from coastal sites on every continent. After her research on sea-level changes was published, she collaborated with Dr. J. de Jong and Dr. W.H. Zagwijn in the Geological Survey and Dr. J.F. van Regteren Altena in the State Archaeological Service on an investigation of sand dunes along the Dutch coast, and was able to demonstrate a remarkable cyclicity of dune building and erosion related to changes of climate.

One of Dr. Jelgersma’s earliest reports in the Geological Survey was for the Delta Commission of the Ministry of Transport, Public Works and Water Management, which had been established shortly after the disastrous North Sea foods of 1953. In this report, she used data on past sea-level changes to extrapolate future

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changes so that the height of the proposed dykes in the Delta Plan in Zeeland could be determined. This was in 1954 and more than 30 years before the establishment of the Intergovernmental Panel on Climate Change (IPCC) by the World Meteorological Organization and the United Nations Environment Programme in 1988.

From the sure foundation of her fundamental research on the evidence for and nature of sea-level changes in Holland, her research became more strategic. In 1987, she organized a session on the impacts of future rise in sea-level on European lowlands at Noordwijkerhout in The Netherlands and in 1989 was a member of the organizing committee, with Professor Rhodes Fairbridge, Professor Roland Paepe, and Professor H. Faure for a NATO Advanced workshop on the 'Greenhouse Effect, Sea-Level and Drought' in Fuerteventura, Canary Islands, Spain. The international significance of her work was recognized in her election as President of the Commission on Quaternary Shorelines of INQUA (International Union for Quaternary Research) in 1987 and subsequently the award of Honorary Life Fellow. The import of Jelgersma's research on sea-level changes is as relevant today for people living on or near the coast (half of the world's population) as it was fifty years ago and essential for the management and risk assessment of coastal zones.

The second of three daughters, Saskia 'Kiek' Jelgersma was born on 9 May 1929 in Oegstgeest, north of Leiden. Her father was Dr. Hendrik Cornelius Jelgersma (1893-1982), a neurologist and psychiatrist and a nephew of Professor Gerbrand Jelgersma, founder of the Jelgersma clinic in Leiden University. Her mother was Jonkvrouw (Lady) Henriette Augusta van Foreest (1893-1986). The three daughters grew up in a house in the grounds of the clinic in Oegstgeest.

Her interest in geology was first aroused when she observed dune sands overlying shell-rich beach sands in a boring in the grounds of a dairy in the village of Oegstgeest on her way to and from school. But it was archaeology that attracted her interest during an excavation of a Roman fort by Professor Van A.E. Giffen, who suggested she read for a degree in archaeology at the University of Leiden. Without Latin or Greek this was then impossible and instead from 1948 until 1951 she read for a degree in geology, intending to transfer to archaeology later. However, as she describes, 'I started the study of geology, but I liked it so much that I never switched to archaeology.'

She continued at the University of Leiden reading for an MSc in Geology, Palaeontology and Petrography which was awarded in 1954. She applied unsuccessfully to Shell for the post of palynologist (pollen analyst): Shell did not then employ women scientists. Later that year, she obtained a short-term contract as a geologist with the Geological Survey of The Netherlands in Haarlem to write a report on past and future sea-level changes in Zeeland, on the strength of which she was appointed a permanent member of staff at the Survey and was allowed to continue her research on sea-level changes in the University of Leiden under the supervision of Professor A.J. Pannekoek.

In 1959, she was awarded a research fellowship in the Limnological Research Centre, Department of Geology in the University of Minnesota, travelling there by boat to New

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York and onward in her Peugeot car. She developed the palynology laboratory there and worked on the vegetational history of several lake basins with Professor Herb Wright demonstrating to the incredulity of her hosts the existence in North America of the return of a period of intense cold about 12,900 years ago and thought at the time to be exclusively a European phenomenon.

On her return to The Netherlands in 1960, she was appointed Senior Geologist in the Survey, a post she held until her retirement in 1995. She found the subsurface mapping, which she undertook as advisor to the National Institute of Water Supply on drinking and industrial water, a great pleasure referring to it as 'a crossword puzzle.'

Dr. Jelgersma travelled extensively giving lecture courses in the 1980s in the Earth Technology Institute, Free University of Brussels in Belgium, Departments of Geology in Qingdao and Nanjing in China and the Asian Institute of Technology in Bangkok, Thailand. But one of the greatest pleasures she had was her association with the Department of Geography and the Environmental Research Centre in the University of Durham, where she collaborated with Professor Michael Tooley, and for him and successive generations of research students arranged radiocarbon dating facilities, without which their research on sea-level changes could not have advanced to the present refined state and import.

She would join field excursions to the coast and was described as an unstoppable tank rolling across a marsh sweeping all before her, with plumes of smoke rising from one of the many Gauloise cigarettes she smoked, and the frequently uttered command to those behind her, 'Come on! Hurry up!' To some she was unapproachable, intransigent, and would not brook criticism, which led one Fellow of the Royal Society of London to remark after an exchange of views during an international conference in London, 'I am rather scared of that Dutch lady.' To others, she displayed quite a different mien – compassionate, solicitous and generous in her support.

She was a Councillor in Bergen for over twenty years and chairman and treasurer for many years of several charities and foundations (such as the Jelgersma van der Hoop Foundation established in 1934 and the van Foreest and Margaretha Splinter Fund) for which she was admitted to the Order of Orange Nassau (Lid van de Orde van Oranje Nassau) on the occasion of the Queen's birthday on 30 April 2010. For her contributions to coastal and sea-level science and to the geology of The Netherlands, she received on October 22 1997, the signal honour of the Van Waterschoot van der Gracht Medal which was awarded during the Staring Memorial Symposium 'Sea-Level and Science Fiction' in Amsterdam. The title was of her composition and underscored the disdain she had for the IPCC and its conclusions on future sea-level rise based on computer models bereft of empirically-based geological evidence.

Saskia 'Kiek' Jelgersma was a complex person who will be remembered for her outstanding research, her deep sonorous voice, her love of malt whisky, especially

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Knockando, and of Spanish wine, art and culture: one of her favourite artists was Diego Velasquez and his painting of the 'Rokeby Venus' the title of which she scored out on the cards she sent and replaced it with 'Saskia at her toilette,' though she could not have looked less like the subject of the painting. She enjoyed good food and wine, and her contribution was a skilfully made tapenade before a dinner party, and at home she was exultant at the chance to take her guests to Het Huis Met De Pilaren in Bergen or Hotel Meyer in Bergen-aan-Zee.

Saskia Jelgersma was unmarried. Her elder sister, Professor Henriette Bosman-Jelgersma, pre-deceased her. She is survived by her younger sister Merit Jelgersma. She died in hospital in Alkmaar, a few miles from the home she loved in the dunes at Bergen-aan-Zee, on 7 May 2012.

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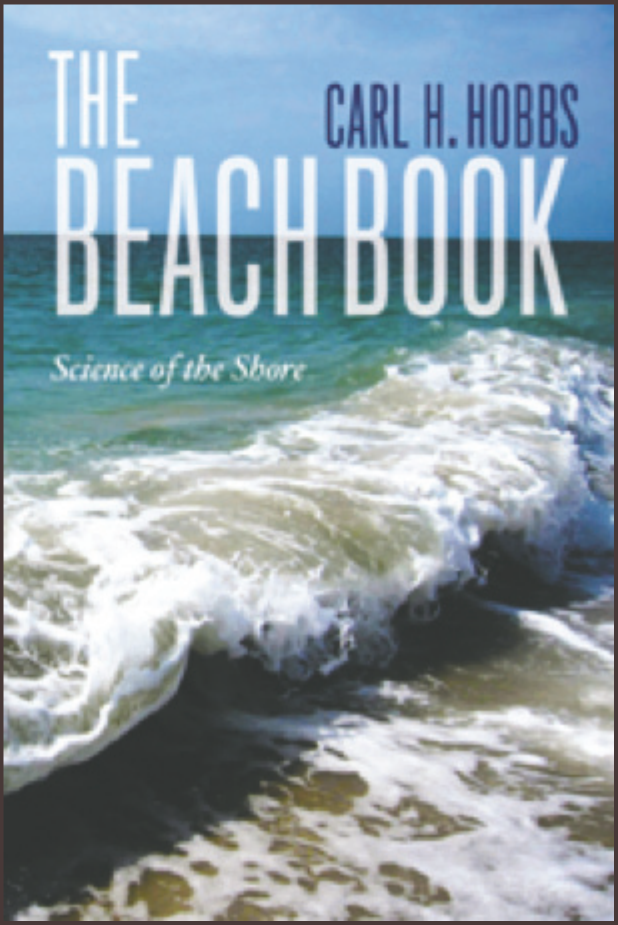
The Beach Book: Science of the Shore

Carl Hobbs

Paper, 192 pages, 40 illus., Maps: 5, Charts: 2, Graphs: 12,
ISBN: 978-0-231-16055-1
$19.50 / £13.50
June, 2012
Cloth, 192 pages, 40 illus., Maps: 5, Charts: 2, Graphs: 12,
ISBN: 978-0-231-16054-4
$60.00 / £41.50

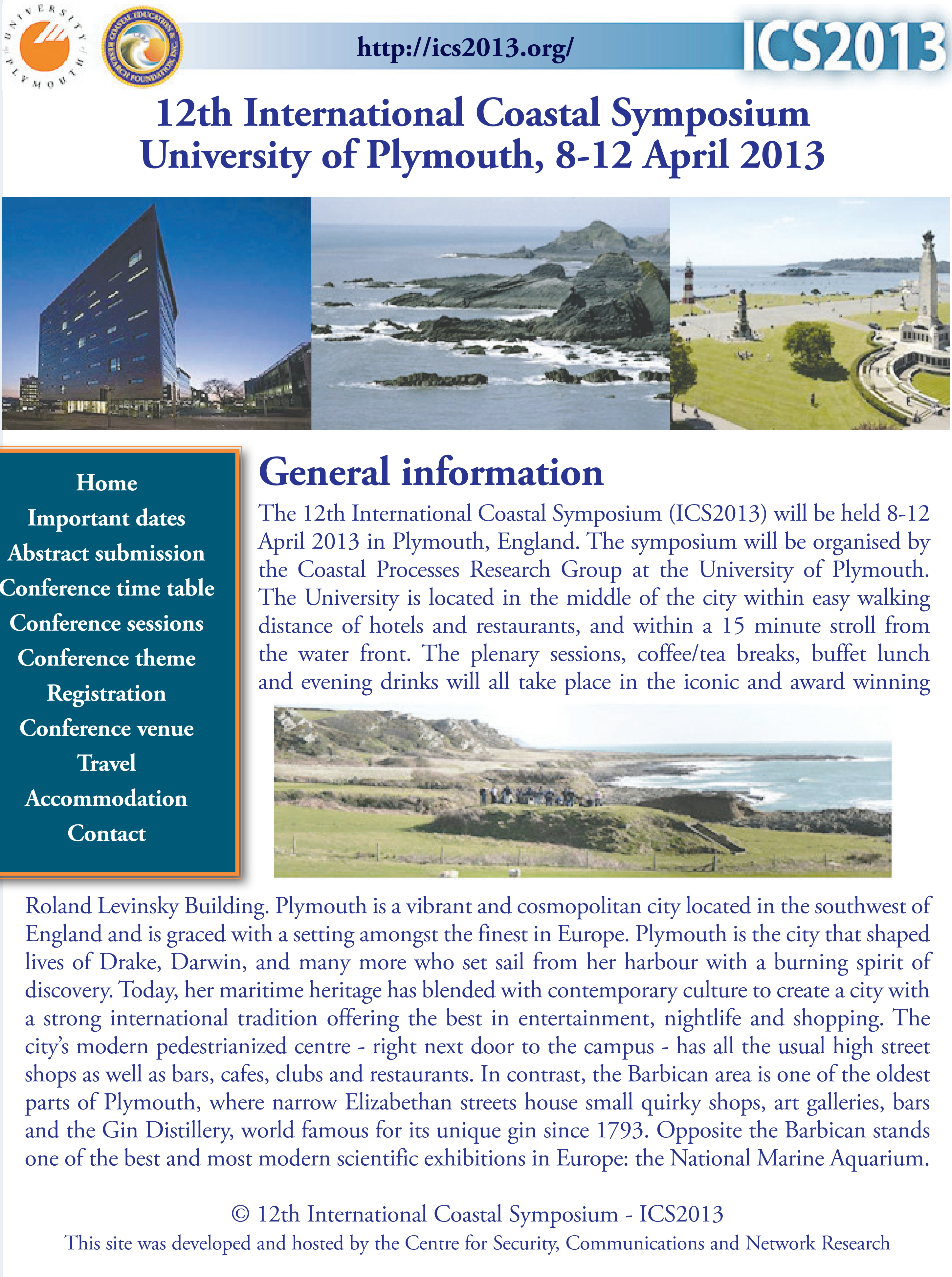
Waves and tides, wind and storms, sea-level rise and shore erosion: these are the forces that shape our beaches, and beach lovers of all stripes can benefit from learning more about how these coastal processes work. With animation and clarity, The Beach Book tells sunbathers why beaches widen and narrow, and helps boaters and anglers understand why tidal inlets migrate. It gives home buyers insight into erosion rates and provides natural-resource managers and interested citizens with rich information on beach nourishment and coastal-zone development. And for all of us concerned about the long-term health of our beaches, it outlines the latest scientific information on sea-level rise and introduces ways to combat not only the erosion of beaches but also the decline of other coastal habitats.



The more we learn about coastline formation and maintenance, Carl Hobbs argues, the better we can appreciate and cultivate our shores. Informed by the latest research and infused with a passion for its subject, The Beach Book provides a wide-ranging introduction to the shore, and all of us who love the beach and its associated environments will find it timely and useful.

About the Author

Carl H. Hobbs is a professor of marine science at Virginia Institute of Marine Science at the College of William & Mary. His research interests include coastal geology and processes, the geologic history of the Chesapeake Bay and the surrounding region, marine archaeology, and the environmental consequences of marine sand mining and beach nourishment. Additionally, with colleagues from the Center for Archaeological Research and the Department of Geology at William & Mary, he has investigated physical changes to Jamestown Island that have occurred since the beginning of the Holocene, when humans first inhabited the region.



12th International Coastal Symposium
University of Plymouth, 8-12 April 2013

General information

The 12th International Coastal Symposium (ICS2013) will be held 8-12 April 2013 in Plymouth, England. The symposium will be organised by the Coastal Processes Research Group at the University of Plymouth. The University is located in the middle of the city within easy walking distance of hotels and restaurants, and within a 15 minute stroll from the water front. The plenary sessions, coffee/tea breaks, buffet lunch and evening drinks will all take place in the iconic and award winning Roland Levinsky Building. Plymouth is a vibrant and cosmopolitan city located in the southwest of England and is graced with a setting amongst the finest in Europe. Plymouth is the city that shaped lives of Drake, Darwin, and many more who set sail from her harbour with a burning spirit of discovery. Today, her maritime heritage has blended with contemporary culture to create a city with a strong international tradition offering the best in entertainment, nightlife and shopping. The city's modern pedestrianized centre - right next door to the campus - has all the usual high street shops as well as bars, cafes, clubs and restaurants. In contrast, the Barbican area is one of the oldest parts of Plymouth, where narrow Elizabethan streets house small quirky shops, art galleries, bars and the Gin Distillery, world famous for its unique gin since 1793. Opposite the Barbican stands one of the best and most modern scientific exhibitions in Europe: the National Marine Aquarium.

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12th International Coastal Symposium

Plymouth University, 8-12 April 2013

History of ICS

The Coastal Education & Research Foundation (CERF) and the Journal of Coastal Research (JCR) have been organizing the International Coastal Symposium since 1990, with the first meeting in Skagen, Denmark. Local hosts and organizers cooperate under the umbrella of CERF-JCR to provide meeting venues, agendas, and field excursions. Proceedings of the ICS traditionally appear as printed volumes in special issues of the JCR. The proceedings are sent to the Thomson Reuters Web of Knowledge (formerly ISI Web of Knowledge) for abstracting and electronic searches on the web.

Previous CERF-JCR meetings:

- 1st ICS: Skagen, Denmark (Hosted by Per Bruun and N. Kingo Jacobsen, ICS1990; JCR Special Issue No. 9)
- 2nd ICS: Hilton Head Island (Hosted by Per Bruun and Charlie Finkl, ICS1991, 1993)
- 3rd ICS: Hornafjörður, Iceland (Hosted by Gísli Viggósson, ICS1994)
- 4th ICS: Bahia Bianca, Argentina (Hosted by Gerardo M.E. Perillo, ICS1996)
- 5th ICS: Palm Beach, Florida (Hosted by Charlie Finkl and Per Bruun, ICS1998; JCR Special Issue No. 26)
- 6th ICS: New Zealand (Hosted by Terry Healy, ICS2000; JCR Special Issue No. 34)
- 7th ICS: Templepatrick, Northern Ireland (Hosted by Andrew Cooper and Derek Jackson, ICS2002; JCR Special Issue No. 36)
- 8th ICS: Itajaí, Santa Catarina, Brazil (Hosted by Antonio Klein, ICS2004; JCR Special Issue No. 39)
- ICS: 2nd ICS in Iceland: Höfn the Town of Hornafjörður (Hosted by Gísli Viggósson, ICS2005)
- 9th ICS: Gold Coast, Queensland, Australia (Hosted by Charles Lemckert, ICS2007; JCR Special Issue No. 50)
- 10th ICS: Lisbon, Portugal (Hosted by Carlos Pereira da Silva, ICS2009; JCR Special Issue No. 56)
- 11th ICS: Szczecin, Poland (Hosted by Kazimierz Furmańczyk, ICS2011; JCR Special Issue No. 64)

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12th International Coastal Symposium

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Why come to Plymouth?

There are, at least, 12 good reasons to come to Plymouth for ICS2013

1. One of the largest gatherings of international coastal scientists in the world
2. All presentations in tiered lecture theatres with more than 100 seats
3. Three outstanding keynote speakers
4. All presentations and posters can result in a peer-reviewed journal article to appear in a special issue of Journal of Coastal Research.
5. Extremely good value for money (registration costs half that of ICCE)
6. Complementary drinks and finger food in the evening during poster sessions
7. Icebreaker in the National Marine Aquarium
8. Conference fees for all delegates (including students) includes conference dinner followed by concert of one of the best live bands in the southwest of England (Joey the Lips)
9. A variety of professional field trips on offer to one of the most spectacular coastlines of Europe
10. Break-out rooms available for small meetings and workshops
11. Conference programme designed to provide ample networking opportunities for fostering strong links between delegates
12. Conference held in safe and friendly city with a strong maritime history and spectacular coastal setting

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Important dates

- Call for 1-page abstracts: 12 March 2012
- Close of Call for Abstracts: 1 June 2012
- *Abstracts to be reviewed during June 2012*
- Acceptance of Abstracts: 31 July 2012
- Early Registration: 1 August 2012 - 30 November 2012
- Submission of full 5-page articles: 30 November 2012
- *Papers to be reviewed during December 2012 and January 2013*
- Receipts of revised full articles: 28 February 2013
- Late registration: 1 December 2012 - 1 March 2013
- Conference: 8-12 April 2013

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Organisation

ICS2013 is organised by members of the Coastal Processes Research Group, who form the Local Organising Committee, led by a small Steering Group. The scientific aspects of the conference are overseen by the Scientific Board, made up of international coastal scientists, who are responsible for reviewing the abstracts and serve as editors for the Special Issue of Journal of Coastal Research. Additional guidance is provided by the ICS Advisory Committee, comprising of previous conference organizers.

Steering Group

Daniel Conley
Gerd Masselink (chair)
Joanne Murphy
Paul Russell
Tim O'Hare

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Gerd Masselink
Grisha Shapiro
Joanna Murphy
Jon Miles
Ken Kingston
Mark Davidson
Paul Russell
Tim O'Hare
Tim Poate

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ICS2013

12th International Coastal Symposium

Plymouth University, 8-12 April 2013

Contact details

For further information please contact:

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Fax: +44 (0)1752 588982
email: pde@plymouth.ac.uk

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GI 2012 SLANDS

university of the azores
august 5 - 11

2nd Advanced International Summer School on GIS and Islands

Climate Change and Coastal Environmental Planning

Biology Department, University of Azores, São Miguel Island, Portugal

GIslands 2012 is an International Summer School on Geotechnologies applied to Climate Change and Coastal Environmental Planning funded by Science, Technology and Equipment Secretary of the Azores Regional Government, and organized by the Research Center in Biodiversity and Genetic Resources (CIBIO-Azores) at University of the Azores, situated in the beautiful Azores archipelago in North Atlantic. GIslands 2012 Summer School has selected a diverse and multinational team of lecturers from Spain, United Kingdom, USA and Portugal, with significant experiences in Maritime Spatial Planning (MSP), Integrated Coastal Zone Management (ICZM), Geographic Information Systems (GIS), Remote Sensing, Environmental Modeling and Spatial Data Infrastructure. In this 7-day course, lecturers will share their experiences. Students will also present their research related to Climate Change and Coastal Environmental Planning and learn through theories and hands-on experiences on how to apply Geotechnologies on Climate Change and Coastal Environmental Planning.

GIslands 2012 Summer School will provide students with:

An interesting 7-day course to learn about application of Geotechnologies to Climate Change and Coastal Environmental Planning with experienced lecturers

The opportunity to network and exchange knowledge among students in the related fields of Climate Change, Coastal Environmental Planning and applied Geotechnologies

The opportunity to publish original papers in “Special Issue on Climate Change and Coastal Environmental Planning” in book

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GI 2012 SLANDS

university of the azores
august 5 - 11

2nd Advanced International Summer School on GIS and Islands

Climate Change and Coastal Environmental Planning

Registration and Abstract Submission

GIslands 2012 is open to local and international students (at Masters, PhD or Post-Doctorate levels) or professionals in the related fields of Marine & Coastal Sciences (MSP, Ocean Governance, Oceanography, Marine Biology, Marine Geology, Fisheries, ICZM, etc.) and Applied Geotechnologies (GIS, Remote Sensing, GPS).

Participants are invited to present their work/case-study at the course and to apply for GIslands 2012 participation. Those who would like to publish their work in the "Special Issue on Climate Change and Coastal Environmental Planning" should submit a short paper otherwise an abstract submission is required

The official language of the Summer School is English.

Applicants will be evaluated based on:
1. Submitted short paper/abstract

Please consult the Short Paper or Abstract Submission guidelines.
2. CV

Please submit a Short CV (2 pages max. – A4 format).

IMPORTANT DATES

Short papers and abstracts should be submitted until the 15th June 2012

Acceptance results will be published the 30th June 2012

Contact: geografia@uac.pt

GIslands 2012 participation is free of charge. Unfortunately, the Organizing Committee has no available funds to support travel, accommodation and feeding costs. After acceptance, each participant must guarantee these costs as other personal expenses.

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GIslands 2012
university of the azores
august 5 - 11

2nd Advanced International Summer School on GIS and Islands

Climate Change and Coastal Environmental Planning

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Departamento de Biologia

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Portugal

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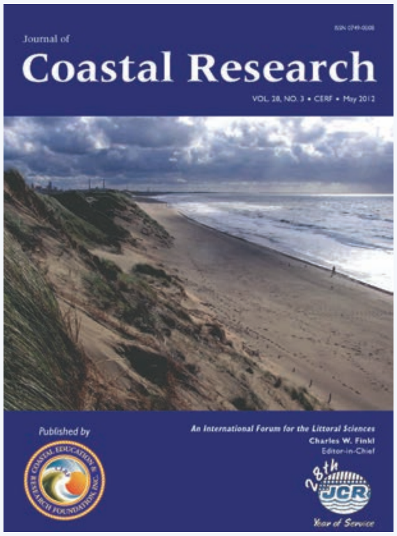
Publish Your Coastal Photographs In The JCR!

As a CERF member, you have the unique opportunity to become a published photographer in our internationally renowned Journal!

All possible submissions must depict some coastal or underwater/marine scene and must be high-quality (>300 dpi) image files in either a jpg, tiff, or gif format. In addition, a short caption must accompany the photograph. The caption should include the specific location of the photograph, the date taken, the geological or coastal significance, and your CERF member contact information (full name, title, phone, email, and CERF member number). Example captions can be found on the Gallery page of this website.

While most submissions will be selected for either the CERF website or inside the JCR, a chosen few will actually be selected to be the cover image of a JCR Issue! So dust off those cameras and submit your photos.



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Submit your photo and information by email attachment to

CMakowski@cerf-jcr.com

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Volume 28, Issue 2

March 2012

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Vancouver, British Columbia

This coastal seaport city is the hub of Greater Vancouver. With over 2.3 million residents, it is th...

The Coastal Education & Research Foundation *[CERF]* is a nonprofit foundation dedicated to the advancement of the coastal sciences. The Foundation is devoted to the multi-disciplinary study of the complex problems of the coastal zone. The purpose of CERF is to help translate and interpret coastal issues for the public and to assist in the development of professional research programs. Our Society specifically supports and encourages field and laboratory studies on a local, national, and international basis. Through the mediums of renowned scientific papers, book and encyclopedia series, and the world wide web, CERF disseminates accurate information to both the public and to coastal specialists around the world on all aspects of coastal issues in an effort to maintain or improve the quality of our planet's shoreline resources.

We encourage you to navigate through our website and explore the many benefits and opportunities that CERF offers. One such benefit to CERF members is the internationally acclaimed, *Journal of Coastal Research* (JCR), which offers the most current published research from today's top coastal scientists.

Be sure to visit the Coastal Education & Research Foundation *[CERF]* website. There is a multilingual tool that displays the text in over 12 languages, continually updated announcements, past ICS proceedings, Open Access Articles, and much more!

http://www.CERF-JCR.org

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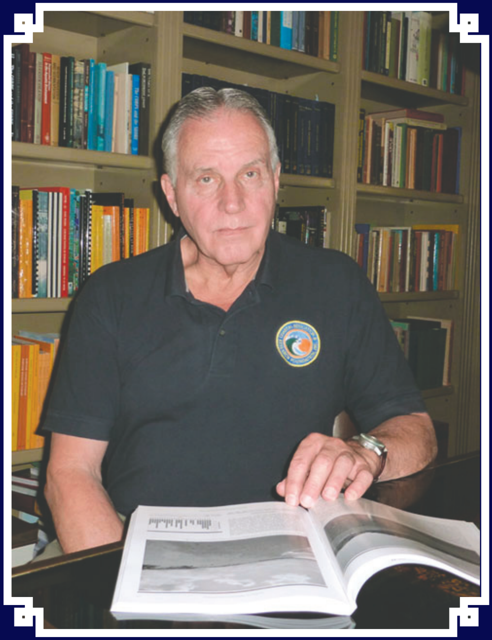

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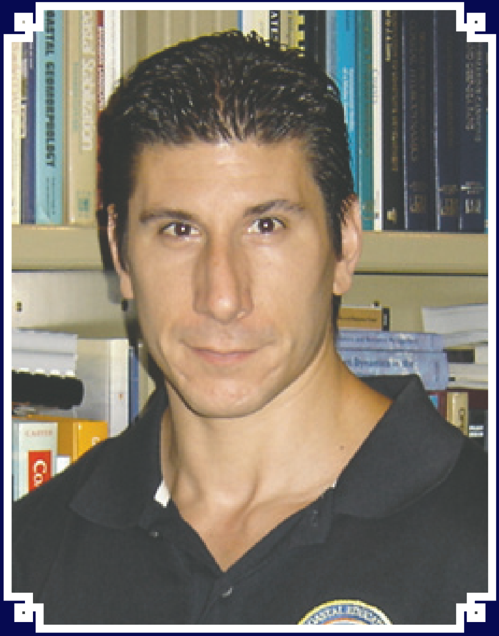

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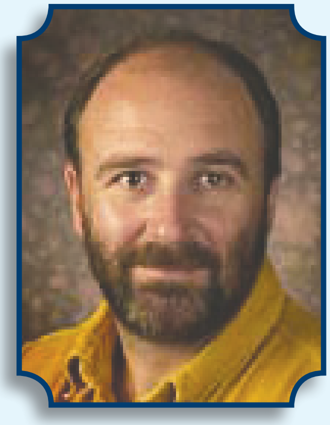

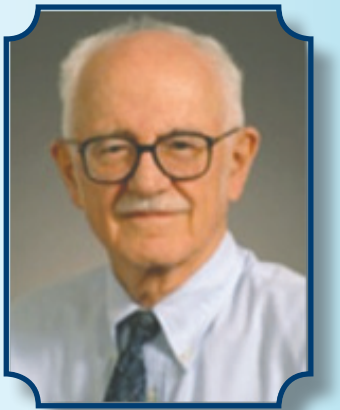

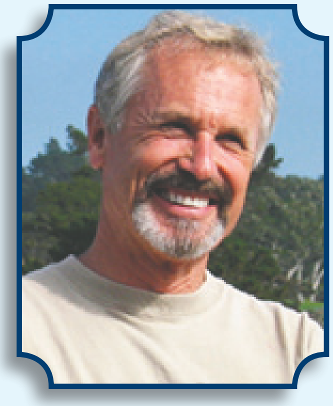

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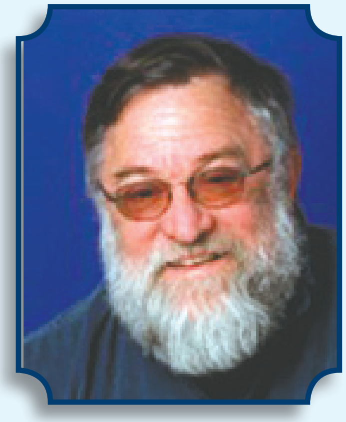

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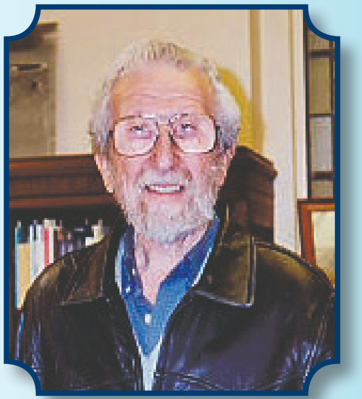

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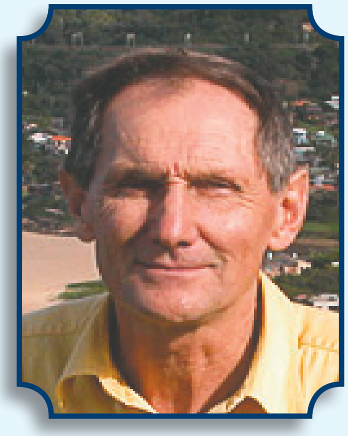

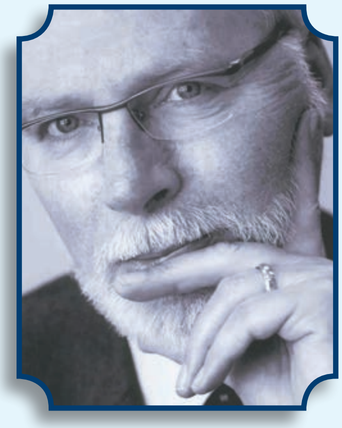

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Next Issue of Just CERFing coming July 2012.

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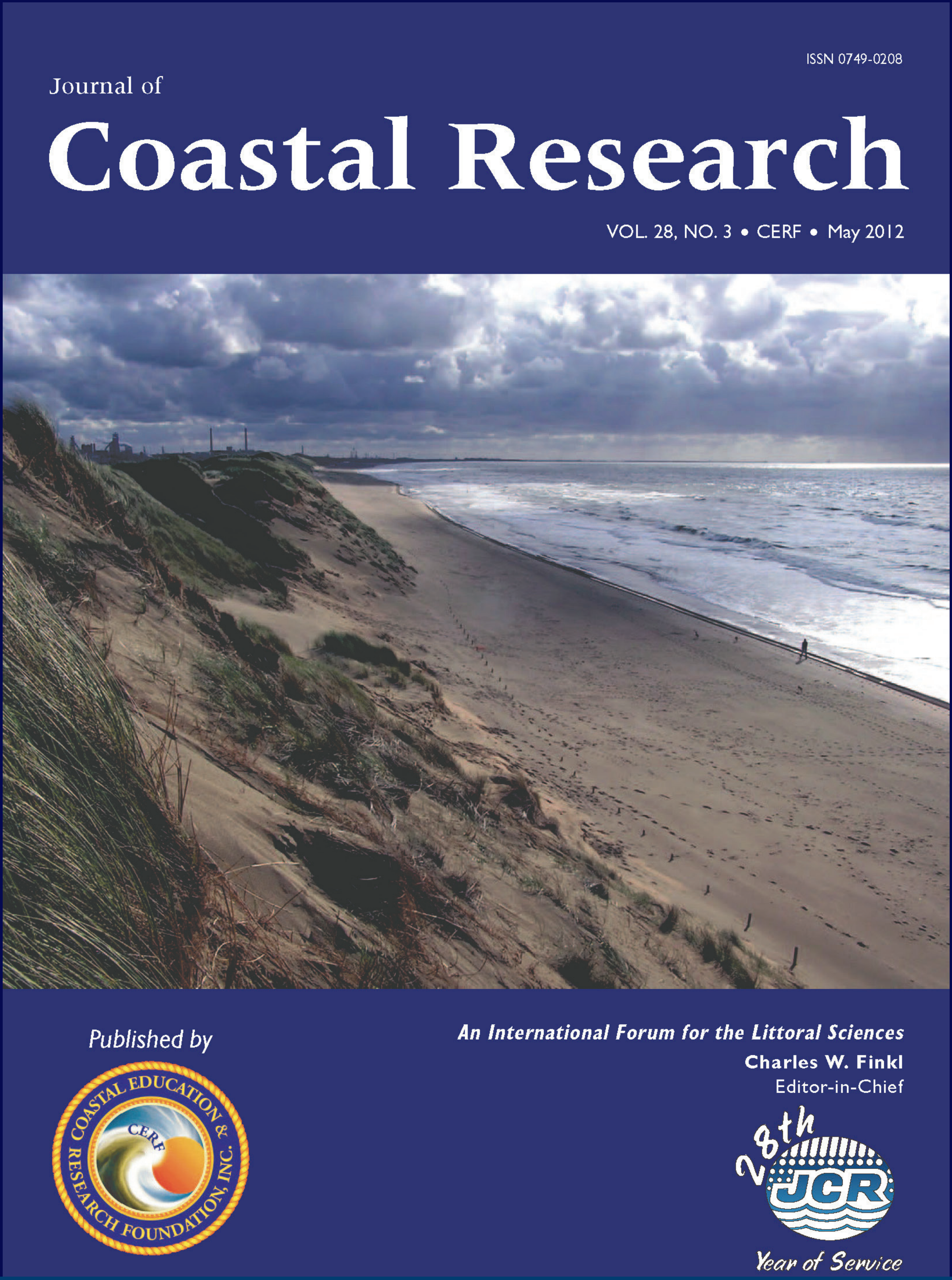

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COVER PHOTOGRAPH AND FRONT MATTER: ERODING DUNES, COAST OF THE NETHERLANDS

Eroding dunes and a steel mill occur side by side on this September 29, 2008 photograph of the Netherlands coast near the town of Heemskerk. The image captures the vulnerability of both the natural and the developed part of the southern North Sea shoreline to coastal erosion, and highlights the need for coastal-protection measures such as large-scale sand nourishments. The steel mill is an exponent of one of Europe's economically most valuable regions. It is located at the groin-delimited entrance to the North Sea Canal. This canal to the port of Amsterdam was dug through the dune belt in the 19th century to directly connect the city and the North Sea. On either side of the canal, coastal dunes extend about 5 km inland from the shore, offering ample protection from storm surges to the adjacent coastal lowland. The frontal dune that marks the seaward side of the dune belt is part of the primary water-defense system of the Netherlands. Its crest height has to meet safety standards defined on the basis of calculated exceedence probabilities, giving it the appearance and function of a sand dike. In an effort to combine this safety function with natural processes, the sand dike is locally allowed to develop into a slightly undulating frontal dune with blowouts that allow inland sand transport by wind. This approach is part of a policy called dynamic dune preservation. Where dune erosion does not form a threat to the country's economic and human interests, measures are taken to add some flexibility to a formerly rigid approach of keeping the coastline in place. On the other hand, the government has reinforced its efforts to hold the sea at bay around coastal towns and at weak links in our chain of dunes. At some of these locations the coast is even prograding a bit, primarily in response to beach and shoreface nourishments. Despite its proximity to the North Sea Canal, no nourishment has taken place at the location shown in the photograph. Here, the coastline has receded at an average rate of about 1 m/yr during the past 50 years. Erosion takes place mainly during extreme events. At Heemskerk, one recent erosive event temporarily exposed 18th-century storm-surge beds that may help to set future safety standards. **(Photograph by Marcel Bakker, Geological Survey of the Netherlands, Haarlem, The Netherlands).**