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'The Times They Are a-Changin'†

Bernard O. Bauer[1*], Douglas J. Sherman[2], Robert W. Brander[3], Philip D. Osborne[4], and Brian Greenwood[5]

[1]Earth, Environmental, and Geographic Sciences, University of British Columbia, BC, Canada

[2]Department of Geography, University of Alabama, Tuscaloosa, AL, USA

[3]School of Biological, Earth and Environmental Sciences, UNSW Sydney, NSW, Australia

[4]Golder Associates Ltd., Vancouver, BC, Canada

[5]Department of Physical & Environmental Sciences, University of Toronto Scarborough, Toronto, ON, Canada

†*Also the title of an early 1960s song written by Bob Dylan reflecting on the realities of living in a world of endless change with constantly shifting attitudes, norms, and expectations.*

INTRODUCTION

It has been argued that scientific discovery is inspired by serendipity although always favouring the prepared mind (Roberts, 1989). To this intersection of chance and wisdom in science (Copeland, 2019), should be added a healthy measure of historical contingency. Discoveries and insights into coastal system dynamics being made today would have been highly improbable in the past. Revolutionary advances in sensing technologies have enabled an immense expansion of empirical understanding and theoretical refinement since World War II, and these developments have influenced how coastal science was (is) conducted, especially with respect to fieldwork. Are things today better, worse, or just different than they were in the past?

THE GOLDEN ERA OF COASTAL GEOMORPHOLOGY

Many coastal geomorphologists active in field experimentation in the 1970s through to the 1990s might argue, as we do, that this was the Golden Era of coastal geomorphology. A thorough evaluation of a range of impact metrics (*e.g.*, numbers of publications, citations, patents, research grant expenditures, and faculty positions) would need to be conducted for that period, in contrast to periods before and after, to validate this assertion. Nevertheless, it is hard to deny that this Era produced many seminal contributions from a number of coastal and marine research centers and institutes that are now only vestiges of their former glory. Exceptions are few.

Why was this period such a productive one for coastal geomorphology? Our somewhat simplistic answer is that this was an age of discovery characterized by excitement, energy, and enthusiasm among a relatively small community of coastal researchers who wanted to explore the (largely) unknown – the nearshore. There was the prospect of making new discoveries with

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***Corresponding author: bernard.bauer@ubc.ca**

each new field or lab experiment because there were precious few measurements of nearshore processes with which to validate theoretical speculation and conceptual reasoning. The field was wide open and there was much to be done.

Opportunities were plentiful for those who expressed a modicum of interest and were not averse to a little risk, especially freshly minted professors and eager graduate students looking to build careers in something different than traditional academic disciplines (*e.g.*, Physical Geography, Quaternary Geology, Physical Oceanography, Marine Engineering). The need for research funding, mostly addressing applied problems (*e.g.*, coastal erosion, harbour sedimentation, hurricane damage, naval strategic objectives) was argued for by a cadre of senior and experienced scientists with savvy and strong connections. Eventually, substantial budgets were allocated to coastal science and engineering at local, regional, and national levels in the U.S, Canada, United Kingdom, Australia, New Zealand, The Netherlands, Japan, and elsewhere. Thus was made the *perfect storm* for scientific discovery in coastal science with the bringing together of: (a) a need for information, knowledge, and understanding; (b) significant enabling resources (both financial and technical); and (c) willing and talented participants.

Arguably, many of these elements of the *perfect storm* are still in place today, so what is different now? Quite simply, coastal geomorphology has become a mature science. Disciplinary maturation is a positive and inevitable trend in the evolution of scientific disciplines, accompanied by the proliferation of knowledge and institutions that support the discipline (*e.g.*, dedicated journals, funding agencies, conference venues, educational programs, and affiliated industries). But maturation is also characterized by a tendency for its practitioners to adhere to acceptable and accepted ways of doing things. This gradual evolution of conventional norms and practices is part of the social fabric of science, reinforced by those in positions of power and influence. In so doing, there is a trend away from an *anything goes*, free-wheeling, frontier-exploring enthusiasm in favour of scientific conservativism that adheres to the fashion of the period (Sherman, 1996). The aversion to risk is most evident, perhaps, in the way we now undertake field campaigns in contrast to 35 years ago.

THE GEORGIAN BAY EXPERIMENTS

The field experiences we describe here are based on a series of nearshore experiments conducted on the sandy lacustrine beaches of the southern shore of Georgian Bay (Lake Huron), Ontario, Canada from the late 1970s to the late 1980s. They involved the deployment of extensive arrays of wave staffs, electromagnetic current meters, pressure sensors, and optical back scatterance sensors, all linked back to a shore-based, computerized data-acquisition system in order to quantify the hydrodynamics and sediment transport dynamics during storms (Figure 1). These experiments involved a large number of personnel, especially graduate students, leading to numerous publications on how wave shoaling transformations and wave-current interactions were coupled to sediment transport processes and ultimately to bedform evolution and morphologic responses during storms. Initial work focused on assessing bedform existence across barred nearshores (Davidson-Arnott and Greenwood, 1974; Sherman and Greenwood, 1984), which led to studies on longshore currents (Greenwood and Sherman, 1984), low frequency energy and edge waves (Bauer, 1990; Bauer and Greenwood, 1988; 1990), beach cusps (Ghionis, 1986), and suspended sediment transport using early optical and acoustic sensors (Greenwood and Osborne, 1990; Osborne and Greenwood, 1992a,b; 1993). Technologies such as fixed, high-frequency sonars (Greenwood *et al.*, 1985) and acoustic Doppler velocimeters were still in developmental stages and not routinely deployed, as today. This mechanics oriented approach focused on mechanisms involving wave dynamics and sediment transport and complemented the Australian School, which modeled beach-scale morphodynamics based on non-dimensional parameterization of nearshore processes applied synoptically.

Figure 1. Resistance-type wave staff array deployed at Wymbolwood Beach, Georgian Bay, Ontario (1985). (Photo: B.O. Bauer.)

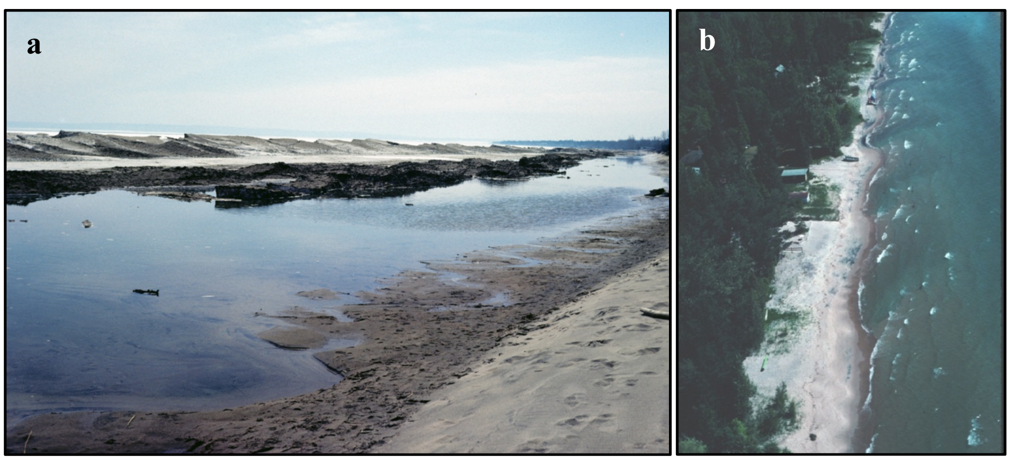

Figure 2. (a) Remnants of shore-fast ice during spring melt. Note chaotic nature of bathymetry due to reworking by ice during winter storms. (b) Barred nearshore system at Wymbolwood Beach following several early-summer storm events with two sinuous outer bars, transverse inner bars welded to shoreline, and swash cusps high on the beach. (Photos: B.O. Bauer.)

Large lake environments offer many benefits for conducting nearshore process studies because, unlike marine environments where wave and tidal action is continuous, the inter-storm periods on lakes yield *flat calm* conditions, often lasting several days to a week or more. The absence of wave action was ideal for installing and testing instruments, orienting bi-directional current meters, conducting detailed rod-and level surveys with echo-sounding farther offshore to capture the local bathymetry, or for simply *holding down the boat* while feeding seagulls, tossing anchors, administering the 3-foot snorkel challenge, and generally living the dream. The storms brought large waves and strong currents that forced bathymetric change, reorganizing sediment from a chaotic pattern shortly after spring-time ice removal (Figure 2a) to sometimes beautifully rhythmic, multiple barred configurations (Figure 2b). Continuous monitoring for the duration of the storm provided essential information on the coupling between the hydrodynamics, sediment transport regime, and evolving morphologic conditions as the storm system tracked through the region with shifting wind speed and direction. Updated weather reports were acquired by driving to the nearest pay phone and calling the regional meteorological office for the latest forecast – personal computers, mobile phones, and the internet were futuristic ideas still in development.

Figure 3. Spools of cable leading from submerged instruments to a data acquisition system in the accommodation cottage. In the center of the photo are dozens of Depth of Disturbance (DOD) rods painted with fluorescent dye for greater visibility in water. (Photo: B.O. Bauer.)

Figure 4. The *portable* outboard motor being hauled to the aluminum boat on the beach. Ph.D. students got the light end. (Photo: B.O. Bauer.)

The typical field season lasted 6-8 weeks, beginning in late April (after the winter ice receded from the shore, conveniently coinciding with the end of the academic year) and extending through June, at which time the water was warm enough for cottagers, beach-goers, and boaters to occupy the shoreline regularly. Permission from government agencies such as the Coast Guard, regional district, or local constabulary to occupy the beach and deploy instruments was not sought or needed at the time. Sampling permits were unheard of. The entire operation was run on a shoe-string budget with labour provided willingly by aspiring young undergraduate and graduate students working toward degrees, but mostly wanting valuable field experience.

The basic entry requirements for participating in these field projects, arguably more important than academic credentials, were a recreational SCUBA diving certificate and reasonable physical strength and stamina. The former was to ensure a minimum level of diver training and ideally some comfort with working in very cold water (< 10^{o}C in late April and early May) for long periods of time. Strength and stamina were essential because the installation and removal of instruments involved unspooling, re-spooling, and moving heavy cables and reels weighing 150 pounds (68 kg) or more (Figure 3), carrying large iron mounts and anchors, and working in awkward, semi-buoyant positions that required considerable dexterity and upper body strength. A small, aluminum boat was used as a work platform (Figure 2b), launched daily from the beach, which involved hauling an old, over-sized outboard motor across the sand and mounting it on the transom (Figure 4). A gas-powered water pump was placed in the boat to assist with jetting in pipe anchors that held the guy-wires to stabilize the wave staffs (Figure 1). In the evening, the routine was reversed.

Down to (Risky) Business

It is dawn and a desultory rain tickles the surface of the otherwise dark, still water. The cottage has a moss roof, not by design, and it is primitive, unheated, and without hot water. Five disheveled figures are hunched over bowls of cold sugary cereal and steaming mugs of freshly brewed coffee. Their queasy stomachs (from over-consumption the previous night) can take little, but some source of energy is needed for the day ahead. In the background you can hear Jimmy Buffet singing quietly about Boat Drinks and Margaritaville. The boss already has the Hewlett-Packard data-acquisition system humming loudly and is dutifully backing up data from the day before, relishing the warmth provided by the behemoth racks of ageing electronics while shaking his head, yet again, about our youthful antics from the late night past.

Time to get in the water, lads – no rest for the wicked!

The work was labor-intensive, invigorating, sometimes frustrating, and often risky. Despite very cold water conditions, a dry suit normally used in frigid waters by recreational divers was untenable because working with sharp-edged metal anchors, pipes, and guy wires, held together with nuts and bolts inevitably led to rips and tears that weren't easy to repair. A neoprene wet suit absorbed the punishment and was also ideal for accommodating certain inevitable body functions after many hours in the cold water. Thick material was preferred for warmth and durability even though mobility was hampered, and considerable discomfort was experienced when trying to slip into a damp, cold, tight-fitting suit comprising bib bottoms, jackets, and chicken vests. Corn starch was used, not for cooking, but to overcome frictional resistance between skin and rubber. Three-finger mitts that resembled lobster claws protected hands from the cold much better than five-fingered gloves, but dexterity was an issue. Hot showers at the end of the day were negotiated with the neighbour across the street on a per use basis.

Personal discomfort aside, there were many activities undertaken during these experiments that would likely be judged unnecessarily risky, if allowable at all, by today's standards. A key objective of these experiments was to document morphodynamic change during storms, when wave and current action were most pronounced. These early experiments relied on divers working through the height of a storm and attempting to take measurements (sometimes unsuccessfully) on bedform dimensions and bed disturbance and to obtain direct samples of suspended sediments. This required ignoring essentially everything that was taught in diver training regarding safety. Nothing in a recreational diving certification program prepares you to work in very cold water at depths of 1-3 m in near-zero visibility while shoaling waves (of average height 0.7-2 m) are breaking overtop (Figure 5). Fear and angst pervade in these conditions, although eventually you learn how to adapt to this hostile nearshore environment and even enjoy it. We were young, naively confident, and far too arrogant to appreciate the risks.

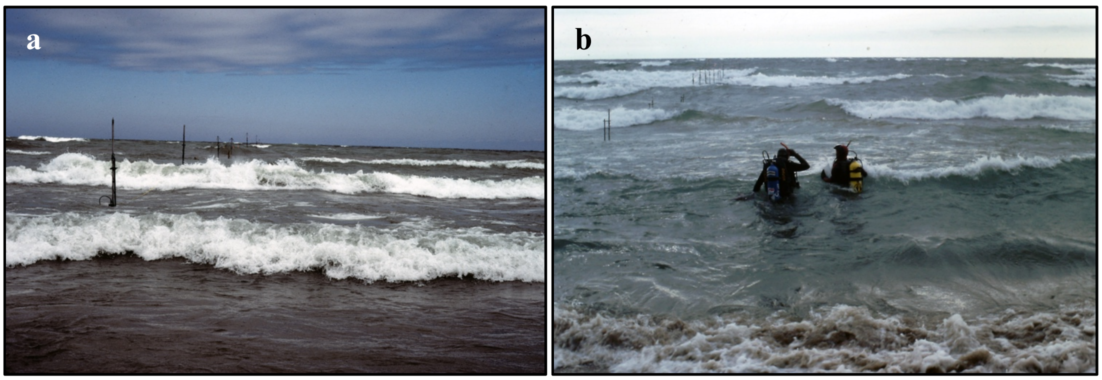

Figure 5. (a) Typical storm wave conditions. (b) Divers entering water to do a bedform run during waning portions of a storm. Note drag bag and clipboard being carried by divers for bedform sampling. (Photos: P.D. Osborne.)

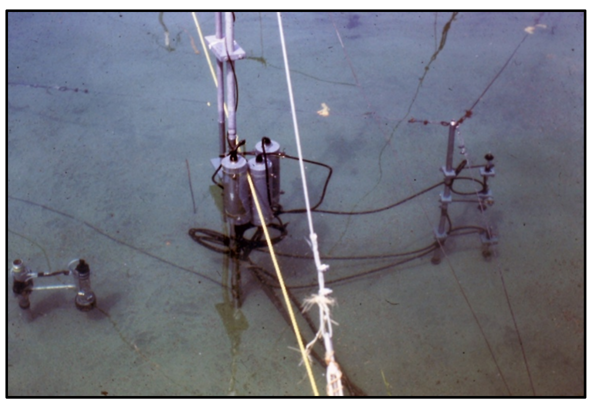

Figure 6. Example of an instrument station with three electromagnetic current meters in a vertical array (right), wave staff (middle) to which instrument housings were attached, and a sonic transducer (left). Note potential for entanglement in cables and guy wires. (Photo: B.O. Bauer.)

The experienced divers taught the new recruits all the tricks of the trade (eventually), although making predictable errors was part of the *rite of passage* and a fundamental learning experience. Swimming is not an option under storm waves in shallow water, and fins are a liability. Ropes were installed as a *highway* through a maze of guy wires, turnbuckles, and cables, thereby enabling a diver to move from one instrument station to another where bedform measurements were taken (Figure 6). We learned to wrap one leg around the rope and then *hold in place* while attempting to take photos or measurements. *Holding in place* is actually a misnomer because one quickly learns that to take a firm hold of a rope when short-period waves are crashing over you leads to rope burns and rapid muscle fatigue – it is virtually impossible to hold on tight because the fluid drag on your body induces a horizontal force equivalent to gravity. One learns to oscillate back and forth with the wave action, just like the particles of sand forming oscillatory ripples, with little net drift. The lulls between wave crests and troughs provided the brief opportunity to take bedform measurements (Figure 7).

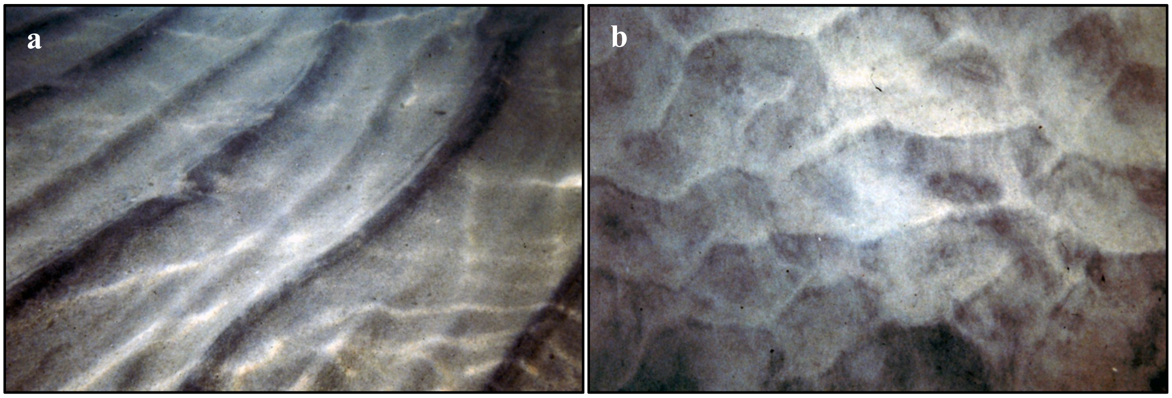

Figure 7. Examples of ripples developed during storms. (a) Sinuous, long-crested oscillatory ripples. (b) Complex, three-dimensional wave ripples. (Photos: D.J. Sherman.)

What safety concerns could there possibly be with a carefully conceived *experimental design* that requires diving during storms? Well, the short-period wave action combined with three-dimensional arrays of instrument towers (not to be disturbed) in close proximity to angled guy wires and exposed metal anchors, with the rope *highway* snaking through the middle and needing to be negotiated by a pair of divers with pressure gauges hanging from their buoyancy vests, dragging along a camera, clipboard, pencil, ruler, and sample bags meant that entanglement was inevitable and something usually *got away* (FYI, pencils float, but cameras don't). Returning with fewer tools than you left with was typically met with a lambasting of some sort, either comical roasting from your colleagues or something worse from the boss if the loss involved data.

Getting hung-up on a guy wire (usually between the valve of SCUBA tank and the diver's body) was a frequent occurrence, typically only resolved with the assistance of your diving buddy. Face masks were repeatedly bumped in the poor visibility, sometimes violently, yielding a rush of cold, gritty water entering your nose and eyes. One needs to overcome a natural instinct to panic and gasp for air. Instead, the strategy is to pause, continue breathing calmly through your regulator, replace your mask, and purge the mask of water by blowing air out your nose while holding the top of the mask to your face. In order to reinforce this skill and train new divers not to panic, experienced divers would often purposely knock off masks, or turn off oxygen valves, during calm conditions (*e.g.*, while installing instruments), not to be mean, but rather to build comfort with the inevitable. This would be a highly irregular and ill-advised practice for recreational diver training, but it was a key to survival in these experiments.

A critical element to a successful research dive during the Georgian Bay experiments was buddy-to-buddy communication. This was essential in securing the needed measurements and being efficient and accurate, but it was also critical in turning potential disasters into minor inconveniences. Buddy pairs established dive plans and communication protocols (elaborate hand signals or tool taps on metal pipes), however truly effective communication involved anticipating the needs of your buddy, making signalling redundant. It is difficult to articulate the depths of trust and dependence that are forged through the shared experience of averting near disasters. It comes as quite a surprise to recreational divers when they expend a full tank of air in less than 10 minutes (part-way through a measurement run) because of the chaotic conditions in the surf zone. Your buddy can be a life-saver if you have failed to keep track of your pressure and you come to the realization that you are almost out of air because each subsequent breath is more difficult to extract from your regulator. Because of the entanglement concerns, several divers opted not to attach an octopus regulator to their tank, in which case it became necessary to share one regulator (buddy-breathe) on the way back to shore.

Recreational divers learn to adjust the amount of lead on their weight belts so that they are only slightly negatively buoyant at the surface. A typical weight belt for a recreational dive might contain anywhere from about 5 lbs to 10 lbs (approx. 2-5 kg). Fieldwork diving? Forget about it! Buoyancy was the enemy. The trick to diving during storm conditions was to load up with lead so as to keep you pinned to the bottom. Often this required 30-45 lbs (approximately 13 to 20 kg) or more of weight (on your belt, tucked into the pockets of your BCV, or strapped to your ankles), which made walking back and forth from the beach and surf zone quite a chore, but was critical to staying near the bottom while taking measurements. What could possibly go wrong?

Aside from the obvious inability to get to the surface easily in an emergency, which required using precious air to fully inflate your BCV to full capacity or to ditch your weight belt, there were cases when the buckle of the weight belt popped open unexpectedly. The obvious symptom was seeing your buddy in an inverted position hanging on to the rope with both hands while the feet were bobbing toward the surface. A single diver cannot easily extract oneself from such a dilemma because the only option is to let go of the rope, float to the surface, and body surf to shore. This left your buddy alone to decide whether to continue with the bedform run or return to shore. The preferred solution to this dilemma was for your buddy to grab you, pin you to the bottom, re-positioning the weight belt on your back, and then give you the signal to re-cinch the buckle. Carry on as planned!

After the storm was over and calm conditions returned to the lake, it was the divers' responsibility to document bathymetric change. The extent of erosion and re-deposition during and after the storm was monitored using Depth-of-Disturbance (DOD) pins (Greenwood and Hale, 1980) that required manual and rather tedious measurements using a ruler. The data were recorded on a Mylar sheet affixed to a clipboard and later transcribed and entered into spreadsheets. Because of the limited number of divers, and in some cases an urgent need to take the full set of measurements (including box coring, echo sounding, profiling) before the next storm arrived, a single diver was typically sent to take the DOD measurements because this was effectively a one-person task. Of course, this contravenes everything taught to recreational divers about not entering the water alone. The agreement among the dive team (unbeknownst to the boss) was to tie a floating detergent bottle (spray-painted in a bright fluorescent color) to the diver using a length of light rope so that progress could be monitored from ashore. The movement of the float, along with a constant stream of bubbles, were taken as an indication that the diver was still alive and moving through the DOD grid.

HOW ARE THINGS DIFFERENT NOW?

In retrospect, it was not a safe practice to send divers out alone, even with a floating bottle in tow! Today, this would (should) never happen. We live and work in an age of legal liability that strongly encourages risk-aversive behavior, especially at the institutional level. It is highly unlikely that anyone would be allowed to participate in a nearshore process experiment as a diver without completing a comprehensive research diving program, as is mandatory at many research-intensive universities with marine science programs. Such programs are often geared toward marine biology or oceanography where skills in deep diving, mixed gas breathing, safety training, sampling protocols, and conservation practices are taught. Arguably, many of these skills, although valuable, are only peripherally relevant to diving in the nearshore environment. From an institutional perspective, however, making such courses mandatory will place the university on firmer legal footing should anything go awry.

Diving in the nearshore environment, especially during storms, is becoming a lost art that is increasingly irrelevant in today's world of technological innovation. Remotely-controlled optical and acoustical sensors now have the capacity to sense and record data with great spatial and temporal resolution in ways that divers never could, and with little risk to human life and limb. Mobile platforms like the CRAB (Birkemeier and Mason, 1984) are able to carry large instrument arrays into hostile wave environments. Bottom scanning systems (Hay and Wilson, 1994) have largely replaced manual bedform measurements by divers. Video systems such as Argus (Holman and Stanley, 2007) are widely used, but are gradually being replaced by shoreline change detection systems using satellite-based sensors that provide global coverage (Luijendijk *et al.*, 2018). Even when massive budgets are not available to support the implementation of advanced technologies, many nearshore researchers are now opting to work in meso- or macro-tidal environments that facilitate instrument deployment during low-tide stages without SCUBA and virtually no risk to personnel. Divers have become largely redundant in nearshore processes research, providing secondary support services rather than being primary participants.

The scale of coastal geomorphological research has shifted away from field studies such as ours that were designed to examine small scale processes (*e.g.*, suspended sediment transport, bedform evolution, bottom friction) that are critical to understanding how, for example, the net direction of nearshore transport is influenced by higher-order wave statistics (*e.g.*, asymmetry, and skewness), low frequency modes of energy, and wave-current boundary layers. Contemporary research, in contrast, is dominated by the use of complex models that incorporate this small-scale knowledge to enable inquiries into large-scale evolution of coasts under scenarios of sea-level rise and increasing storminess. To be sure, there are many advantages to the technologically advanced state of coastal science today, especially with respect to the ability to collect and manipulate large data sets of high quality covering ever-expanding spatio-temporal domains. Perhaps more importantly, a branch of science that was traditionally male dominated is now (hopefully) more accessible to all manner of participants regardless of gender or physical (dis)ability, although much improvement is still needed (Vila-Concejo *et al.*, 2018). But, has anything been lost?

We would argue that there is no longer a sense of intimate, visceral understanding of nearshore processes in the way that a diver gains while being immersed in the turbulent action of waves and currents during a storm, while still taking the opportunity to marvel at the movement of sand grains back-and-forth across a ripple crest. In an age when *experiential learning* and *immersive experiences* are being touted by universities as effective educational strategies, coastal geomorphologists seem to be adopting methods that are less and less *invasive* and more detached from the fundamental dynamics that make the nearshore environment such an interesting and exciting place to conduct research. Is risk aversion affecting the types of scientific questions we are able to ask? Or are we a bunch of aging, white males – simply holding on to overly-romanticized memories of the *good old days*?

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