The Coastline Paradox: A New Perspective
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ABSTRACT

The coastline paradox, which suggests that coastlines have indefinite lengths, is a widespread and misleading concept that has endured in scientific literature for over 50 years. This paper argues that the length of a coastline is real and finite. The measurement of coastlines allows for the quantification of coastline dynamics and engineering responses to these changes. The real difficulties in measuring sometimes complex coastal shapes have taken the appearance of an unreal impossibility. The paradox is resolved using three methods. The first examines definitions used to establish the features to which “coastline” refers. The second applies these definitions to the measurement of real coastlines. Finally, a geometrical analysis is carried out to resolve the paradox mathematically. The purpose of this paper is to help resolve the paradox and reduce confusion surrounding the topic, which will be of direct use for coastal communities and planners to assess and respond to coastline changes and sea-level rise.

ADDITIONAL INDEX WORDS: Coastal, geomorphology, fractals.

INTRODUCTION
The formulation of the concept now referred to as the “coastline paradox” was outlined in Mandelbrot’s (1967) paper “How long is the coast of Britain.” In this paper, Mandelbrot referred to and built on observations made by Richardson (1961) concerning differing Spanish and Portuguese estimates of the length of their shared border and their coastlines. Using the coastline of Great Britain as a case study, Mandelbrot (1967, p. 636) claimed more generally that, “Geographical curves are so involved in their detail that their lengths are often infinite or, rather, undefinable.”

Although Mandelbrot sometimes questioned whether this abstract mathematical concept applied to real coastlines (Mandelbrot, 1967), much of the citing literature highlights only the idea of immeasurability and not the potential misalignment with measuring real coastlines. Concepts such as scaling, fractals, and self-similarity are commonly referenced in mapping and geosciences, where they have found practical uses (Ghanbarian and Hunt, 2017; Perugini and Kruhl, 2015; Zuo and Wang, 2020). Indeed, Jiang claimed that it is a paradigmatic concept and that “scaling must become a dominant principle, if not the principle, of cartographic design” (Jiang, 2017, p. 68; see also Jiang, 2019; Jiang and Anders Brandt, 2016). Mandelbrot’s subsequent works on the topic may have also helped to perpetuate the association between the abstract mathematical concept and real coastlines, evidenced by titles such as “Stochastic models for the Earth’s relief, the shape and the fractal dimension of the coastlines...” and “The fractal geometry of nature” (Mandelbrot, 1975, 1977; Mandelbrot and Wheeler, 1983).

A typical example of distortion in the analysis of geographical data by the paradox concept is found in Galloway and Bahr’s (1979) paper titled “What is the length of the Australian coast.” This work correctly notes that an increase in the measuring resolution results in a longer coastline length measurement. The paper then concludes, in reference to Mandelbrot’s work, that “the study has demonstrated once again that coast length is indeterminate” (Galloway and Bahr, 1979, p. 3).

Using Quine’s terminology, the coastline paradox can be seen as a “falsidical paradox,” that is, one that appears false and is false (Quine, 1966). It appears counterintuitive that an object, once it becomes part of a coastline, should lose its capacity to be measured. General concepts of immeasurability from the realms of physics, due to the uncertainty principle or relativity, can be factored into measurements when relevant, such as the time-dilation corrections used in satellite positioning (Lucchesi et al., 2019). As such, the challenges involved in the measurement of all objects as revealed by fundamental concepts in physics have practical solutions and do not of themselves prohibit the measuring of a coastline. The attribution bias, or the human propensity to overlook the importance of smaller components of a system, may however be a hindrance, as it has been shown to be in some branches of engineering (Smith and Bahill, 2010).

Paradoxes are commonly used to examine fundamental beliefs in science, even forming the basis of new concepts in physics, particularly in the field of quantum mechanics (Popper, 1992). Just as Diogenes refuted Zeno’s arrow paradox, which disputed the possibility of motion, by walking about (Diogenes and Hicks, 1972), the coastline paradox too has an intuitive rebuttal. A coastline of infinite length would require a corresponding number of water molecules with which to line the boundary, in accordance with the meaning of “coastline.” A coastline of fractals would make the ocean disappear into the shore. The physical impossibility of this scenario provides...
strong evidence that the coastline paradox is flawed, with more rigorous proofs being outlined in this paper.

It is hoped that this information will be of immediate practical use to those in vulnerable coastal areas on the frontline of the effects of climate change by validating the concept of coastline measurement. The different length values that can be derived from these measurements will be analyzed and contextualized. The methods outlined herein make use of commonly used computer-aided design (CAD) or geographical information system (GIS) programs, with open-access satellite imagery being a sufficient data source for most applications.

METHODS

The first component of the method is a definitional one. The term “coastline” and the idea of a shared measuring unit and methodology are human inventions with no absolute counterpart in reality. Ultimately, the measurement of a coastline relies on human convention and measuring technology. Further, the measurement is only of use if it is transferrable in some format meaningful to a third party.

The second part of the method for resolving the paradox analyzes the mechanics of a real coastline measurement. There exist several physical limits that are useful in solving the problem of measuring a coastline. The first limit is based on the smallest piece of matter that can influence the measurement being considered. The second is the minimum size that can be measured or recorded. The third is the time taken to complete the measurement. This combination provides a physical limit to the problem.

This leads to the third component of the method, where mathematical limits are encountered. This paper presents mathematical concepts pictorially, so that the information is immediately obtainable even to those without a mathematical inclination. This analysis is presented in three parts, starting with a geometrical examination of some natural limits to the measurement of coastline lengths. The second part examines the Koch snowflake as an example fractal to demonstrate a further resolution to the paradox. Finally, with an allowance for the quantitative measurement of coastlines, a discussion is made comparing coastline length and area for an idealized coastline during an erosion event.

The real-world measurement of coastlines is far removed from Mandelbrot’s technique, which relied on obsolete concepts in mapping to create the impression of a paradox. With digital elevation models (DEM}s) and an endless decimal system of units for interpolation, the premise of a rigid and fixed measuring unit underpinning the coastline paradox no longer applies.

To deal with ambiguous coastal areas, such as estuaries and river mouths, human convention is necessary to delineate the position of the coastline, just as it is necessary to define “coastline” in the first place. The United Nations Convention on the Law of the Sea (UNCLOS) provides a useful set of delineations, including for river mouths, which states:

If a river flows directly into the sea, the baseline shall be a straight line across the mouth of the river between points on the low-water line of its bank (UN General Assembly, 1982, Article 9, p. 402)

Considering its importance with regard to observing changes in sea levels and coastal dynamics, the meaning of “coastline” is rarely defined, even in specialist reference works (Allaby, 2020; Hancock and Skinner, 2000). Oertel did, however, provide a detailed analysis of the meanings of coastline, shore, and shoreline (Oertel, 2005). By this analysis, the “shoreline” is more temporally variable than the “coastline,” as it includes the full daily tidal range and other adjacent areas. By this convention, “coastline” can be defined as the line formed by the ocean meeting the foreshore at the mean water level.

Oertel’s solution to the issue of the increased length of a convoluted coastline was to exclude all concavities from the measurement of the coastline. However, these straight-line measurements exclude much of the morphological detail found in coastlines and are far removed from the definition of a coastline. A more appropriate term for this separate and important measurement is the “span” of a coastline. This concept of “span” is well defined in other branches of engineering, where, for instance, the span of a bridge is the shortest distance between its supports and the overall length of the structural components. The term is also analogous to the linear algebra usage, where, in this case, the coastline span is representative of every coastline shape that can be circumscribed by the same salient points. This provides an important geometrical limit to the spatial extent of a coastline that can be obtained nonarbitrarily (as opposed to choosing an arbitrary measuring unit), a method for which is provided below.

For context and validation of this methodology, a global example of similar proportions can be illustrated by observing the surveyed heights of Mount Everest made over 170 years by a variety of methods and nations. As Figure 1 indicates, differences in measured height appear to decrease with time.

The geomapping of Everest deals with many of the same technical and definitional obstacles found in coastal surveying, such as human agreement on the height of mean sea level. Yet, over centuries and with differing systems, humans across the nations (on the whole) appear to reach a consensus. This is achieved through a combination of more accurate measuring techniques and technologies combined with agreement on definitional entities such as the shape and height of the geoid (Ince et al., 2019) and concepts inherent in the use of satellite positioning, which incorporates international systems, the same speed of light, and multinational scientific knowledge. Ultimately, all of these measurements are based on human convention, technology, and physical laws.

RESULTS

From the definitional method, two results are apparent. The first is the elements of the natural world that correspond to the meaning of the term coastline, such as the water molecule, provide a natural limit to the minimum measurement size. Second, the technological limitations in measuring and calculating what is in essence a definitional object provide an additional natural limit.

While some coastlines may show similarities at different scales, such as ice cliffs, they more often display a variety of distinct patterns at different scales. This has been documented in geomorphological studies more generally. Dramis, Guida,
and Cestari (2011) highlighted not only the correlation between scale and the geomorphologic unit that can be mapped, but also the associated temporal scales over which these units change. This is in direct contrast to the self-similarity aspect of a mathematical fractal representation. Although solutions to the problems of incorporating multiple scales in geomorphological mapping have largely been solved (Gustavsson and Kolstrup, 2009), the application to coastlines has been slow. Coastlines are still often referred to as being fractal in nature.

The Giant’s Causeway in Northern Ireland, shown in Figure 2 below using satellite images, offers a simplified demonstration of the differing shapes that can be found at different scales on coastlines. The largest scale shows a broadly convex region shaped by continental forces (by necessity, every island is on average convex and circular). The next scale shows even scalloping, indicating a regional-scale morphological genesis (such as a dominant wave or wind direction). Similar concavities can be seen at the next scale down, but with distorted shapes and disordered positions. The coastline then appears angular, linear, and even hexagonal due to the single-event factor of cooling volcanic rock combined with megaclasts of unknown origin (McKenna, Jackson, and Cooper, 2011). Differing morphology at different scales is an unavoidable feature in many other coastlines, such as a logarithmically curved beach made of angular sand grains (Hsu et al., 2021) or a straight seawall made of circular driven logs.

By measuring coastlines at increasingly fine resolutions, it can be seen that the measured length does not increase in proportion to the increase in resolution. This is demonstrated in Figure 3, where a part of the coast of Culebra Island (Puerto Rico) is measured at different scales to provide an estimate of coastline length. This island is representative of many coastlines, as it comprises both a fixed rock component and a mobile sand component; however, the analysis is the same for any coastline. This shows the decreasing rate at which measured coastline length increases at finer resolutions. This is an unavoidable result of measuring a real object of finite size (such as a coastline made of some number of countable atoms). At some point, the measuring unit will approach the smallest detail resolvable in the coastline, and the diminishing returns

Figure 1. Height of Mount Everest as surveyed from 1850 to 2020 (Gulatee, 1956; V. O. A. News, 2020).

Figure 2. Giant’s Causeway (Northern Ireland) showing different morphologies at different viewing resolutions: (a) 4 km scale, broadly convex; (b) 400 m scale, concave; (c) 100 m scale, concave distorted; and (d) 40 m scale, linear/angular (Source: Google Earth).
of measuring at finer resolutions will become apparent. This is contrary to the precepts of the paradox, whereby coastline length increases indefinitely through the use of infinity and fractal dimensions. This also demonstrates that measurement of complex shapes with some arbitrary and fixed unit of length is not a useful method in cartography and helps to create the impression of a paradox in measurement.

Rather than assigning an arbitrary minimum unit size for the measurement (cf. Mandelbrot, 1967), the whole shoreline from low water upwards can be imaged as a three-dimensional DEM. This can be achieved in a variety of ways using satellite altimetry, photogrammetry, LIDAR, or ground surveying.

Each measured point then has its own coordinates in three-dimensional Euclidean space from which a surface can be created. This elevation model can be converted to a digital surface model such as a triangular irregular network (TIN), which makes use of linear interpolation between the space of neighboring points. Likewise, the mean water level, or geoid, can be separately calculated and imaged to an accuracy approaching the sub-centimeter range (Foroughi et al., 2018).

Combined with an endless decimal system of units, a definite measurement of coastline length that is not constrained by some artificial limit on measurement resolution can be achieved. The coastline can be abstracted and defined exactly as the intersection of the mean ocean surface with the surface of the adjacent shorelines. This is achieved by rendering components as multiples of some smallest measurement unit, applying a coordinate system based on this unit, and calculating the intersection points, all of which is achieved in practice via computer processing. In this case, a computer can possess in its memory an “absolute value” for the coastline length that does not change according to the resolution chosen by the human viewer zooming in or out of the object.

As seen above, an estimate of the coastline length can also be made using aerial or satellite images analyzed with CAD or GIS software using standard built-in functions. Further, there are add-ins for software such as the Digital Shoreline Analysis System (DSAS) for Esri ArcGIS that specifically facilitate automated coastline measurements obtained directly from imagery. Optical satellite remote sensing is a widely used and powerful tool in assessing coastlines, but it is constrained by the pixel resolution of the sensor and the variations in water level over the large areas captured in the images (Teodoro, 2016). It also relies on the estimation of coastline position from light intensity, color, or satellite altimetry (Stammer and Cazenave, 2018). However, this method is suitable for most large-scale measurements used in coastal planning and is perhaps the ideal candidate to act as the standard for “coastline

Figure 3. Section of the northern coastline of Isla Culebra (Puerto Rico) measured with different unit lengths (Source: Google Earth).
The absolute coastline length can be measured, if needed, using instruments with measurement resolution approaching the definitional size limits of the object, such as the water molecule. Supplemented with deep-learning, entire coastal zones can be imaged to the resolution of individual pebbles or the surface roughness of coral structures (Finkl, 2004; Soloy et al., 2020).

The third factor in surveying a rapidly changing environment is time. The rate of surveying needs to be faster than the effects of tidal-, eolian-, and wave-driven change in topography. This is also an area in which satellite imagery has the advantage of recording a very large area at one instance in time. However, the large area captured by satellite imagery requires a corresponding correction to be made to compare the coastline with respect to mean sea level.

Using these methods, once a shoreline has been imaged, the area can be investigated according to the task at hand, such as calculating quantities of rock armor or sandbags or estimating wave overtopping and runup. In these cases, the minimum resolution required is based on the dimensions of the object of interest or the scale of the physical process being studied. This is in the order of meters for bulk installations such as sandbags and seawalls down to nanometers for the study of the morphology of coral structures (Nash et al., 2019).

Mathematical Results

There are several natural limits to the mathematical components of the paradox, two of which are discussed here, and a simplified example of the minimum unit description of a coastline is analyzed in the discussion.

The first mathematical limit is produced using a planar offset or projection of the true coastline length (even if this did somehow comprise an infinite fractal perimeter). This geometrical technique involves placing lines parallel to themselves at some specified distance. This offsetting projects the coastline shape onto a flat two-dimensional plane. This is a built-in function of most CAD and GIS programs. Indeed, a thick line tracing a coastline on a map is essentially an offset to the scale of the thickness of the line. While small arbitrary offsets such as those found in the UNCLOS definitions retain some coastline features, very large offsets tend towards circular arcs joining several salient points. Figure 4 illustrates the effect of projecting an offset coastline shape back onto the original image with increasing offset distances.

This process reaches a geometrical limit whereby all coastline shapes become a series of salient points circumscribed by the sum of their spans. This is equivalent to the length and shape of a taught rope wrapped around a coastline extruded into three dimensions. This also provides a methodology for finding Oertel’s (2005) definition of coastline, which here is termed “span.”

Figure 5 illustrates coastline spans for a selection of global island shapes alongside the UNCLOS offsets. The span can be a good approximation for coastline length for some island shapes. It also has the practical application of describing the shortest distance for a watercraft to circumnavigate the island and has applications beyond coastal science and engineering.

If this offsetting process is continued, as shown in Figure 6, all island shapes tend towards the same area/coastline ratio. Every shape at this limit is composed of circular segments joined at points that represent the convex salient points of an island.

The second mathematical limit involves examining the fractal aspects of the paradox. The Koch snowflake pattern, which is commonly used to illustrate fractal behavior, is shown in Figure 7 through four stages, or iterations. It is obtained by adding triangles made by dividing lines into thirds. By this method, a form of self-similarity can be achieved at different scales.

A common representation of fractal behavior uses the summation of an infinite series representing this fractal pattern, which shows that while the area approaches a limiting value, the perimeter length increases indefinitely. This is indeed an interesting result and requires the use of fractional

Figure 4. The projection of coastline offsets back onto the original image at increasing distances.

Figure 5. Coastline span and United Nations Convention on the Law of the Sea (UNCLOS) coastline offsets (United Nations General Assembly, 1982).
dimensions to avoid the constraints of real Euclidean space. This result is shown in the graph in Figure 8. As this uses a fractional measuring system (necessary for this type of decreasing infinite series), it is referred to here as the fractional method.

It must be noted that some works addressing the fractal characteristics of real objects include the caveat that coastlines are not actually infinite, and that fractal analysis is an approximation. This, however, is not a minor difference or a quibble between the very small and the infinite, but rather a fundamental difference in the methods used to carry out the measurement. If at some point there is some smallest size, then, in a fractional system, this size can be set as the measuring unit to capture every detail in the fractal. This is referred to here as the integer system. For a real coastline, the fundamental measuring unit is the water molecule (with the sensor pixel being used for less accurate satellite-based measurements). From this, every observed length can be expressed as a multiple or fraction of this base unit. The choice of minimum unit size will affect length measurements, with smaller units resolving finer details and thus producing greater lengths (up to the limit of resolution as discussed above). However, from a mathematical perspective, the choice of unit is less important than the assignment of some fundamental unit, which removes the problems associated with infinities. Figure 9 represents the same process as shown in Figure 8 but using the integer measuring system.

This integer method presentation of an identical pattern reveals the extent to which the paradox refers only to the multiplicative behavior of fractional area calculations, rather than coastlines or fractals. This is a key result—once the existence of some smallest unit of measurement is identified (whether it be a water molecule or sensor pixel), the exponential growth of the object’s perimeter with respect to area disappears. The limit of the measurement of finite parts then becomes trivial; it is just the sum of all the lengths that comprise the object’s perimeter.
DISCUSSION

The rational assessment of coastline length as outlined in this paper is of direct use to coastal planners and communities defending against ocean inundations. There are two main reasons for this. First, the ambiguity of whether coastline measurements are real or have any independent validity is removed, which allows the practical task of measurement to take place. Second, by viewing the increased length of a convoluted coastline as a physical reality rather than a paradox, the hydrodynamic and morphological implications of these shapes can be properly assessed. In practice, coastlines are regularly measured, and coastal science at large is not affected by the concept of the paradox. However, those without the expertise or experience in this field may be needlessly confused by the idea of immeasurability. Once it is accepted that coastlines have a finite length that can be measured, different erosion scenarios that engage with the effect of coastline convolutions can be modelled and quantitatively compared. This allows the planner to determine the appropriate engineering response and allocation of resources, whether it be sandbags, seawalls, or artificial reefs, and optimize their positioning.

Using a simplified example, Figure 10 illustrates the variety of different coastline lengths and configurations that can occur within the same erosion event. This shows that, as land is eroded, it can be described by a range of coastline perimeters of different lengths. This means that, in cases that mimic the embayment erosion pattern 2 in Figure 10, a coastline of twice the length of pattern 1 needs to be protected for an identical land area. When applied to coastal disaster planning or coastal protection, the use of excessive amounts of resources (not to mention unwanted hydrodynamic effects) can be avoided. It must be noted, however, that a longer length of porous or rough material, for instance, can absorb more wave energy. As such, the purpose of the engineering response should be used in conjunction with the length minimization concepts discussed here to optimize the configuration of coastal protection works.

Coastline length is one of many measurements that can be made in the coastal zone. Indeed, the different temporal scales that differentiate the shoreline from the coastline, as discussed in the definitional section of this paper, indicate that ‘absolute coastline length’ may serve only as an archival or specialist measurement. In this capacity, it can be used as a baseline for detecting coastline change by direct comparison of multitemporal imagery. This is widely carried out in practice using satellite and aerial imagery, where Landsat databases, for instance, are used to provide multidecadal analyses of coastline dynamics (Apostolopoulos and Nikolakopoulos, 2021; Bishop-Taylor, 2021; Hu and Wang, 2022). The combination of multitemporal coastline position data with statistical analysis can then be used to make predictions of future changes (Basheer Ahammed and Pandey, 2022; Hossain et al., 2022).
In addition, the absolute coastline length may find uses in analyses of the dissipating effects on wave action caused by shoreline roughness and shape.

Survey methods that measure the full range of the shoreline surface from low to high water also provide a more useful range of information for those defining boundaries or facing inundation from the sea. Low water is used as a baseline in the coastline offsets found in the UNCLOS (UN General Assembly, 1982), whereas the high water level and morphology of the backshore zone are useful for predicting wave runup, overtopping, and storm surges. In these instances, the mean coastline length is less useful than the shoreline surface that intersects with the extremes in tidal range.

As shown in Figure 10, different erosion scenarios of the same land area produce significantly different coastline lengths. This impacts how much land can be protected by coastal managers with limited budgets, time, and resources. The concept of surrendering land and outlining setbacks has been discussed in coastal management literature (Lincke et al., 2020). However, this rarely occurs in practice, and the ideal positioning of coastline protection works is not always achieved because these works are often implemented reactively or even during or shortly before extreme weather events.

The implications of the paradox also involve coastal threats other than erosion. For example, oil spills have different impacts depending on the roughness or complexity of the shoreline. This has led to the development of a Shoreline Environmental Susceptibility Index, which delineates the response of different shoreline types to oil spills (Adler and Inbar, 2007). This index is a direct analogue to the absolute coastline length, that is, detailing coastline morphology to its finest detail. Oil spills can adhere so closely to the coastline that the absolute coastline length down to the smallest morphological scales becomes relevant in assessing the impact and response to these disasters. Less oil adheres to a featureless coastline than a highly convoluted one.

It must also be noted that the idea of the coastline paradox has seeped into many fields other than coastal management and engineering. The following appeared in a law publication in which a useful summary of the development of the coastline paradox was given, including an examination of the different coastline lengths given by different U.S. surveying bodies (Stoa, 2020). This review shows that estimates for the length of the coastline of Maryland by official surveying bodies range from 31 miles to 3190 miles (48 to 5133 km), an order of magnitude 100 times larger. However, this work then claims, “Follow this logic down to the atomic level, and the length of a coastline—any coastline—approaches infinity.” The results presented here indicate the coastline would not approach infinity but has a finite length.

The multidisciplinary impact of geographical delineations highlights the importance of resolving the coastline paradox. The accurate definition and delineation of the concept of coastline will find use beyond the realms of coastal science and engineering to national boundaries and international law. Even at the community level, the assessment of ocean frontage property and littoral rights are affected by the implications of the paradox (Stoa, 2020). A standard measuring unit for “human-scale” coastline length measurements and for international delineations should perhaps be based around the finest satellite image resolution that has global coverage, so it can be applied with equity to all coastlines. This is in the order of 1 m, which also aligns with the International System of Units (SI) unit for length.

As humans physically construct the shoreline in attempts to control the effects of the ocean, the coastline paradox suffers another diminution. In this case, the concrete, sandbags, boulders, or any otherwise measurable materials become the coastline. In this ever more common scenario, the people and ecosystems in harm’s way are not only measuring the coastline, but creating it. These artificial coastlines are made of elements of known and finite size; in their very construction, they refute any notion of a coastline paradox.

**CONCLUSIONS**

There are real difficulties in determining the length of a coastline; however, immeasurability and the infinite nature of fractals are not among them. This paper has shown that the increased length of a convoluted coastline is not paradoxical but rather an inherent geomorphological feature that has implications for coastal management and protection. In contrast to a fractal description, real coastlines are finite and generally not self-similar at different scales. This is in accordance with the morphological genesis of coastlines, which are produced by different mechanisms at different scales and over different time frames.

This paper has resolved the paradox mathematically by making allowance for the finite composition of coastlines, which brings about a natural limit to the smallest relevant measurement size. This measurement unit can be the physical size limit that defines the object, corresponding to the water molecule, or the technological measuring limit, corresponding to the sensor pixel size. Regardless, the key concept is that the existence of some smallest meaningful measurement unit removes the mathematical mechanism by which fractals are produced. Offsetsetting and projecting coastline measurements onto a flat two-dimensional plane also can remove any notion of fractals and smooth out coastline complexity, leading to further geometrical limits.

Three concepts in coastline measurement have been uncovered by this work. (1) Absolute coastline length: This is the actual length of the coastline based on the smallest unit of measurement relevant to the definition of coastline, which corresponds to the size of a water molecule. This absolute length for any given moment in time is invariant and only changes by erosion or accretion over time and is unaffected by the resolution chosen by the viewer. Satellite data supplemented with aerial and ground-based surveying with the option of integrating a deep learning component can be used to obtain this absolute measurement. (2) Coastline length: This is the length used in practice for the day-to-day analysis of coastlines and is an estimate of absolute length. This can be measured quickly, although to a lesser degree of accuracy than absolute length, using satellite imagery and altimetry. For most purposes, satellite imagery is adequate to delineate the coastline using a minimum unit equal to the sensor pixel size, which produces resolutions in the order of meters and is
sufficient for planning coastal protection works or measuring coastline change. (3) Coastline span: This measurement differentiates between the distance along a coast and the distance between the salient points that contain the coastline. The span also appears as a limit to the offsetting and projection technique noted above. In this case, the span becomes the shortest distance around an island.

The information in this paper is critical to a wide range of groups, from the planner assessing coastal protection works to the resident sandbagging their property. While fractal measurements are commonly referenced in scientific literature, they are generally not helpful to those who require accurate measurements of a coastline for planning, engineering, or scientific purposes. The question remains as to whether fractals have any use in understanding coastal processes. Increasing access to global coastal surveying and LIDAR databases to measure absolute coastline length will allow the full extent of these relationships to be determined. However, coastal planners and communities do not need to be concerned with fractal analysis and can have confidence that coastlines have a finite length that can be measured as well as any other real object.

**LITERATURE CITED**


