CLASSIFICATION OF MARINE SEAGRASSES BY LEAF FRACTAL DIMENSION ANALYSIS

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ABSTRACT

This particular study used the fractal dimensions of leaves of seagrasses that were found near the Marine Protected Area (MPA) of Punta, Panaon, Misamis Occidental to determine if the same can be used for classification purposes. The species of sea-grasses used were: Thalassia hemprichii, Syringodium isoetifolium, and Cymodocea rotundata. Findings revealed that the fractal dimensions can be used to differentiate one seagrass species from another sea-grass species to another species (f= 6.12, p= 0.015). However, leaf fractal dimensions alone cannot differentiate between (Thalassia hemprichii and Syringodium isoetifolium) while it can differentiate between (Thalassia hemprichii and Cymodocea rotundata) and (Cymodocea rotundata and Syringodium isoetifolium). The results may be due to few samples for each species of sea-grass. The empirical probability of misclassification using the technique is approximately 10.89%.

Keywords: *leaf fractal dimensions, taxonomy, sea-grass, marine protected area*

1.0 Introduction

Seagrasses are marine flowering plants that belong to various plant families (see Section 2) all in the order Alismatales. The term seagrass may have come from the observation in many species of these marine flowering plants. The leaves are long and narrow and they usually grow in large meadows looking much like a grassland, that is, they resemble terrestrial grasses of the family Poaceae. Seagrass beds form highly diverse and productive ecosystems harboring hundreds of associated species from almost all phyla. For instance, juvenile and adult fish, epiphytic and free-moving macro and microalgae, mollusks, bristle worms and nematodes can be seen in beds of seagrasses. Originally, it was thought that very few species feed directly on seagrass leaves (because of their low nutritional values). Recent scientific studies, however, have demonstrated that hundreds of species feed directly on sea-grasses including green turtles, dugongs, manatees, fish, geese, swan, sea urchins and crabs (Duarte et al., 1999). Furthermore, some fish species feed on the seagrass and feed their young in adjacent mangroves or coral reefs. Seagrasses are likewise important mechanisms for trapping sediments and slowing water movement causing suspended sediments to fall out thereby reducing sediment loads in the water and ultimately benefitting the coral reefs nearby. The ecological functions of seagrasses are therefore quite important in sustaining a healthy marine environment.

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As an important aspect of ecological research, accurate identification of the species of sea-grasses are necessary if estimation of their impact on the marine environment is to be ascertained. The use of fractal dimensions for classification purposes is a relatively new area of study. Traditional geometric morphometric techniques such as the Elliptic Fourier Analysis (EFA) and others have certain inherent shortcomings that may be satisfactorily addressed by fractal analysis. For instance, the EFA used ellipses to estimate the outline of geometric figures and so, it cannot be used in cases where there are "pointed" or rough features of the geometric figure under consideration (Neto et al., 2005; Boudon, et al., 2010). This study attempts to replicate the study of Almirol, Lapinig and Sabandal (2013) in using fractal dimensions as a tool for classifying and identifying seagrass species.

2.0 Concept of a Fractal and Fractal Dimensions

Classical geometry considers objects that have integral dimensions: points have zero dimension, lines have one dimension, planes have two dimensions and cubes have three dimensions. Within a plane, one can represent points and straight lines and other geometric objects as shown below:

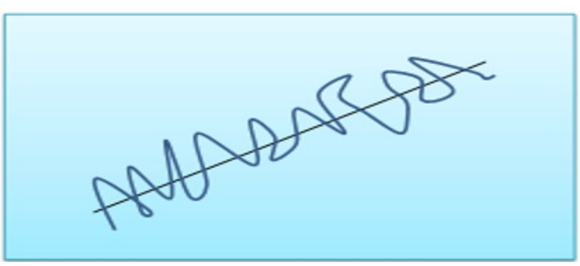

Figure 1. A fractal object in a plane

It is possible to represent geometric objects within a plane that are neither points nor lines like the squiggly line above. This squiggly geometric object cannot have dimension equal to 1 because it fills up more space than a line; it cannot have dimension equal to 2 because it does not form an area. Hence, its dimension λ has to be between 1 and 2 like $\lambda = 1.63$. We will say that the squiggly line is a fractal (a geometric object having fractional dimension).

The fractal dimension of an object defines its roughness, ruggedness or fragmentation. The higher the fractal dimension, the more rugged and irregular looking is the object. Thus, although fractals are rough and irregular objects, the pattern of irregularities are repeated over and over again. This is called the self-similarity property of fractal. Benoit Mandelbrot (1967) is acknowledged as the mathematician who opened roughness as a legitimate topic for investigation in modern science. He claimed that nature and natural processes are fractals, while uniform, smooth and continuous patterns are man-made concepts and pervade mathematical analysis. He also said that by introducing "randomness" into the situation, one gets more realistic fractal representations.

After the publication of Mandelbrot's book: *Fractals: The Geometry of Nature*, many scientists used fractals with great success (Cohen, 1987 on fractal antennae; Krummel et al., 1987) on forest fractals and others). It has found applications in various disciplines as well as in many areas of practical technology.

In Padua (2012), fractal geometry was translated to statistical language. A probability distribution akin to Pareto's distribution for incomes was proposed as a model for fractal random variables X:

(1).... $f(x) = \frac{(\lambda-1)}{\theta}\left(\frac{x}{\theta}\right)^{-\lambda}$, $x \geq \theta, \lambda > 0$

where λ = fractal dimension of x, $\theta = \inf_x \{x\}$. A maximum – likelihood estimator for λ based on a random sample of size n was provided as:

(2).... $\hat{\lambda} = 1 + n\left(\sum_{i=1}^{n} log\left(\frac{x_i}{\theta}\right)\right)^{-1}$

He then proceeded to show that for n=1:

(3)... $z = \hat{\lambda}\log\left(\frac{x}{\theta}\right) - 1 \underset{\sim}{d} Exp(\lambda - 1)$ or:

(4)... $q\ (z) = (\lambda—1)\ exp\ [\ -\ (\lambda -1)\ z]$

For a random sample of size n, the random variable:

(5).... $q = \hat{\lambda}\sum_{i=1}^{n} log\left(\frac{x_i}{\theta}\right) - n$

Has the same distribution as $q^* = \sum_{i=1}^{n} log\left(\frac{x_i}{\theta}\right) = \sum_{i=1}^{n} Z_i$ The distribution of (5) is therefore $Gamma\left(n, \beta = \frac{1}{\lambda-1}\right)$ where, $\lambda > 1$.

(6).... $h(q) = \frac{(\lambda-1)^n}{\Gamma(n)} q^{n-1} e^{-q(\lambda-1)}$, $q > 0, \lambda > 1.$

$$h(q) = \frac{(\lambda-1)^n}{\Gamma(n)!} q^{n-1} e^{-q(\lambda-1)}$$

Thus, if we have one sample of a species and if we are able to estimate its (geometric) fractal (see for example some available freeware like FRAK.OUT), then we are able to compare the fractal dimension for species (say, λ_1) with the specimen (λ_2):

(7).... $\mu = |\lambda_1 — \lambda_2|$.

We approximate the distribution of μ by an exponential distribution and obtain:

(8).... $\delta_s = P(u \geq \varepsilon) = \frac{1}{2}\left(1 + exp\left(-\varepsilon^{(\lambda_2 - 1)}\right)\right)$,

a similarity index where λ_2 = fractal dimension q specimen species. We refer to (8) as a similarity index. As the difference $\varepsilon = |\lambda_1 — \lambda_2|$ increases, the similarity index decreases. If $\lambda_1 — \lambda_2$ (hence, $\varepsilon = 0$), the fractal dimensions are identical and the two documents are 100% similar. This means that the two species contains exactly the same fractal characteristics: straight lines, curves, strokes, spacings, slants and so on, and, must therefore belong to the same species.

It is also possible to determine what values of ε will yield high similarity index thus:

(9)... $\delta_s \geq 1 - \alpha \Leftrightarrow \varepsilon \leq \left[\log\frac{1}{1-2\alpha}\right]\left[\frac{1}{\lambda_2 - 1}\right]$, $0 \leq \alpha \leq 1$,

for instance, if $\alpha = 0.05$, then the values of ε above will indicate 95% similarity index or greater.

3.0 Research Design and Methods

This particular study is designed to assess the viability of using fractal analysis in classifying and identifying leaves of seagrasses based on its fractal dimensions. The researchers randomly collected species of seagrasses near the Marine Protected Area (MPA) in Panaon, Misamis Occidental. A total of three (3) seagrass species of five samples per species were collected. After the collection, the leaves were washed with clean water then air dried for few hours. The cleaned specimens were mounted on a white cardboard background prior to the actual photography using a digital camera. Room lighting and dust contamination were controlled in order that the specimen's features are only caught on camera. Fractal dimensions of each samples were calculated using FRAKOUT software.

4.0 Results and Discussions

Figure 1, 2 and 3 shows the seagrass leaves used and tables 1, 2 and 3 on the other hand, show the necessary statistics for fractal dimensions comparison.

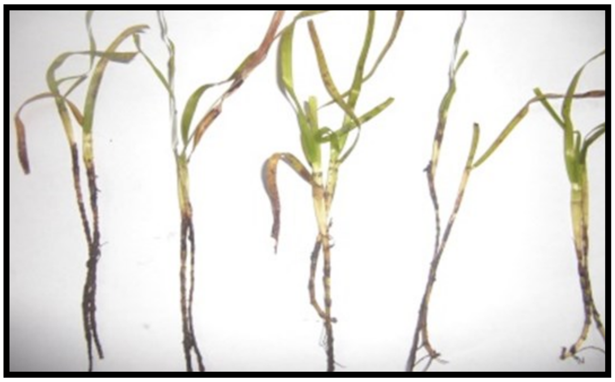

Figure 1. *Thalassia hemprichii isoetifolium*

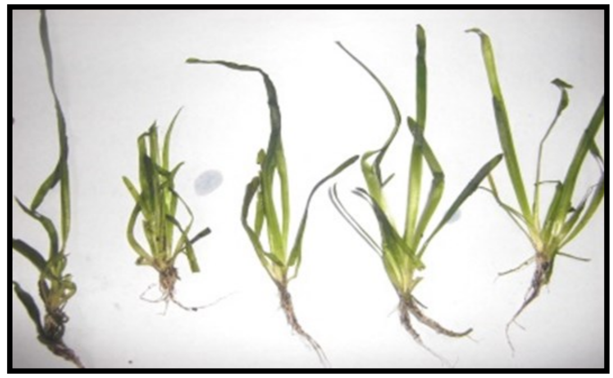

Figure 2. *Cymodocea rotundata*

Figure 3. *Syringodium isoetifolium*

Table 1. Summary of empirical fractal dimensions of seagrass leaves

Trial	*Thalassia hemprichii*	*Syringodium isoetifolium*	*Cymodocea rotundata*
1	1.5295	1.5508	1.5828
2	1.5638	1.5500	1.5747
3	1.5499	1.5127	1.5888
4	1.5591	1.5408	1.5969
5	1.5032	1.5154	1.5456

Table 2. Means and standard deviations of the fractal dimensions

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Thalassia hemprichii	5	1.5411	1.5499	1.5411	0.0249	0.0112
Syringodium isoetifolium	5	1.5339	1.5408	1.5339	0.0186	0.0083
Cymodocea rotundata	5	1.5778	1.5828	1.5778	0.0197	0.0088

Table 3. One-way ANOVA of the seagrass leaves

Source	DF	SS	MS	F	P
Factor	2	0.005536	0.002768	6.12	0.015
Error	12	0.005428	0.000452		
Total	14	0.010964			

Table 4. Summary of t-values for comparing fractal dimensions

Pair	Mean difference	t-value	p-value
Thalassia vs *Syringodium*	0.0072	0.51	0.623
Thalassia vs *Cymodocea*	-0.0367	-2.58	0.036
Syringodium vs *Cymodocea*	-0.0439	-3.62	0.009
		Probability of Misclassification	0.1089

All the seagrass leaves showed relatively high fractal dimensions. *Cymodocea rotundata* registered the highest fractal dimension among all segrasses considered. This means that of the three (3) species, *Cymodocea rotundata* has the most complex and rugged features *Thalassia hemprichii* and *Syringodium isoetifolium* recorded similar fractal dimension implying that these two species of sea-grasses have similar roughness features. Figure 4 shows the fractal dimensions of the three (3) seagrass species:

The graph of the fractal dimensions of the three seagrass species clearly illustrate that *Cymodocea rotundata* consistently registered the highest fractal dimension while the other two species sometimes have intersecting fractal dimensions (blue and red curves). It is therefore quite easy to distinguish this particular sea-grass species from the other two species.

Comparison of the fractal dimensions between seagrasses revealed that the fractal dimensions of the three (3) seagrasses leaves are significantly

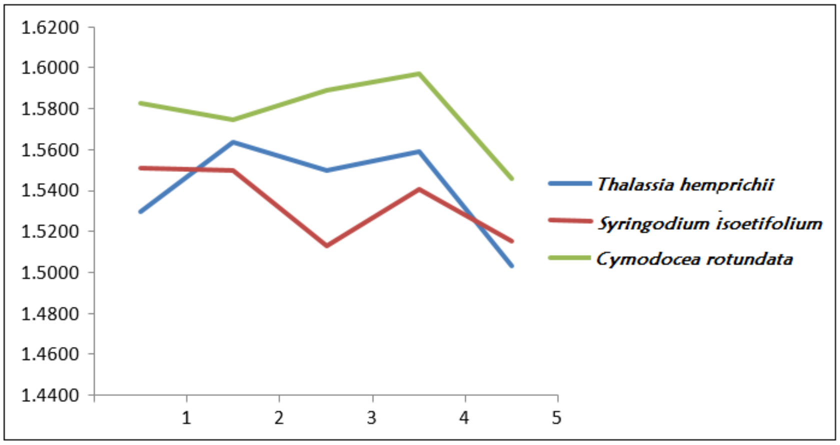

Figure 4. Fractal dimensions of the three seagrass species

different (f=6.12, p=0.015). The high computed value could be attributed to the small standard errors of the mean (fractal dimension) computed for each species. The significant difference noted for the fractal dimensions of the three (3) species imply that the use of fractal dimensions to differentiate across species is quite effective.

Further analysis, however revealed that both *Cymodecea rotundata* and *Syringodium isoetifolium* are unrecognizable while *Thalassia hemprichii* could easily be detected by the proposed methodology.

Some scientists like Mancuso (1997) and others (Ng et al., 2002), used twenty (20) number or of observed leaves. The larger sample size reduces the standard error of the mean of the fractal dimensions. It is therefore very likely that for larger samples, results would be very different from the current findings. Due to very limited time and resources, however, we were constrained to use only five (5) samples for each species. The researchers therefore, wish to recommend the use of larger sample sizes in future studies (between fifteen to twenty) Likewise, it may be possible to correlate the fractal dimensions with the carbon absorption capacities of the plants.

4.0 Conclusion

The use of fractal dimensions of leaves of seagrasses is a potential powerful technique in classifying and allocating sea-grasses according to their appropriate binomial nomenclature. Misclassification probability was recorded at (10.89%). However, leaves belonging to the same mangrove species have equally high similarity index exceeding 90%.

Acknowledgement

The authors are grateful to Dr. Roberto N. Padua for his technical assistance and guidance in the use of fractal statistics.

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