THE ROLE OF 'NATURALNESS' AND SERAL STAGE IN THE ASSESSMENT AND MANAGEMENT OF COASTAL SITES

Sacha Dunlop*, Sandro Lanfranco, Patrick J. Schembri,
Department of Biology, University of Malta, Msida MSD 2080, Malta
* corresponding author phone (+356)79272723, e-mail: sacha.dunlop@um.edu.mt

Abstract - Conservation and restoration of Mediterranean coastal habitats often requires rapid assessment of the 'state of health' of the environment. A potential solution to this issue may be represented by the implementation of a method for rapid assessment of the 'naturalness' of coastal areas. The degree of naturalness of a site is diagnosed by sampling and analysing the anthropogenicity of the ecosystem in the area, and, from its inverse interpretation, the naturalness grade that characterises the habitat may be deduced.

We are suggesting that the principal criterion for defining values of naturalness in the upper part of the scale should be the position of a terrestrial plant community along a sere. Using species richness as a criterion for naturalness would probably not be suitable, as this value is fundamentally a statistic and does not give any information regarding the 'state of health' of the ecosystem. As such, the identity of the species, rather than their number would be a better indicator of naturalness. A natural habitat, one that has been undisturbed by human actions, would be characterized by a primary climax community. Disturbances (man-made and otherwise) would act to erode the integrity of the climax community and would introduce other species (usually opportunistic species) which would occupy disturbed patches and coexist with the climax vegetation. A disturbance of very large magnitude would revert the succession to early seral stages which would subsequently proceed (if undisturbed) through a secondary succession, reaching a secondary climax.

When actively managed sites were compared to unmanaged coastal areas in the Maltese islands, it was found that the former were statistically more likely to show a higher position in the seral stage of the vegetation community. This emphasizes the fact that some kinds of human disturbances do not reduce the naturalness value of a site. In fact, active management and conservation practices that entail a proper strategic plan should be considered. This allows managers to spatially and temporally determine the position of a plant community along a sere and would provide them with a rapid indication of how different types and intensities of negative human disturbance affect coastal vegetation.

Introduction

'Naturalness' is a non-ecological parameter that reflects the inverse of the degree of human influence, where the lower the influence, the more natural the site [6]. In this definition, 'natural' is meant to describe a process, situation or system that is more or less free of human intervention [2]. The socio-economic importance of 'naturalness' is crucial, because society in general tends to value pristine landscapes in a world of ever-increasing urban areas. As a consequence, many authors have frequently used this parameter, however they adopted somewhat dissimilar approaches (Machado [7]; Angermeier [3]; Anderson [2]; Margules & Usher [8]). This is the result of the inherent difficulty in applying a theoretical and anthropocentric concept to biological conservation. Implicit to the definition of naturalness itself is the assumption that the presence of anthropogenic elements within ecosystems is negatively correlated with the preservation of the 'natural state' and biodiversity of a site. In fact, Cole *et al.* [4] argue that naturalness is a paradoxical parameter for managing biodiversity, and because management interventions are considered to be artificial practices that diminish the naturalness of a site, they even suggest that managers have gone "beyond naturalness" to maintain biodiversity. The reason for this is that the strictest definition of naturalness will always be violated as soon as active management interventions are introduced to restore habitat conditions to their 'natural state'. However, Götmark [6] remarks that the main problem in assessing naturalness is the failure of the assumption that all anthropogenic influences are negatively correlated with the value of a site for biological conservation. He points out that in certain situations, the occurrence of certain types of human interventions are indeed necessary and beneficial for the maintenance and enhancement of biological diversity. These types of interventions include holistic management intrusions that take into account the security of the entire biodiversity of a site. It is with this reasoning that Dunlop [5] developed an index of naturalness (IoN) that excludes beneficial human interventions from being assumed to deteriorate the 'natural state' of suitably managed coastal sites.

Vegetation plays an important role in determining 'pressure-state-response' and naturalness models. Machado [7] uses hemeroby to assess the level of naturalness based on the abundance of native versus alien vegetation within ecosystems. One disadvantage of this approach is that it fails to describe the level of degradation of vegetation caused by human disturbance [5]. This is particularly evident in areas that are heavily impacted; resulting in the absence of both native and alien species [9]. Instead, Mucina [9] suggests that the assessment of the degree of man's influence on vegetation can be analysed by determining the disturbance in plant cover, changes in competitive hierarchy, invasion by opportunistic species and changes in species composition over time.

In this study we propose a simple way of combining the aforementioned ideas and developing them into a tool that is capable of rapidly assessing past and present aspects of human influence on coastal vegetation, using the naturalness concept. Since it is particularly difficult to identify the upper reference point (100% natural, i.e. the reference condition), we are suggesting that the principal criterion should be the position of terrestrial plant communities along a sere. Although species richness has been used in the past as a criterion for estimating the amount of past and present human influence (inverse of naturalness), Götmark [6] suggests that rather, it is the species composition – especially threatened taxa - that must be considered for the safeguarding of biodiversity from human influence occurring in ecosystems. This implies that undisturbed habitats would be characterized by a primary climax community and that the species composition of such communities would be generally known from literature and comparative studies performed at a local level. Past and present negative anthropogenic disturbances would act to erode the integrity of the climax community, allowing newly introduced (opportunistic) species to occupy disturbed habitat patches that coexist with the climax vegetation. The magnitudes of disturbance will have a significant effect on the vegetation community, providing even more opportunities for invading species to colonise these disturbed habitat patches. This can ultimately revert the succession to earlier seral stages which could potentially proceed through a secondary succession, reaching a secondary climax. We propose a simple way of quantifying and determining the position of the plant community along a sere, in terms of naturalness, in order to provide a rapid, comparative, temporal snapshot of the effects of past and present human influence occurring on coastal vegetation.

Materials and Methods

Prior to sampling, a number of assumptions were required to formulate the indicator that analyses the seral stage (SS) of the community. Firstly, a natural undisturbed habitat was assumed to be characterised by a primary edaphic climax community. The vegetation making up this community was compiled from literature and comparative studies performed on Maltese coastal vegetation. The integrity of a climax community was also assumed to degrade with human disturbance and revert to an earlier seral stage, subsequently providing an opportunity for colonisation by opportunistic species [9]. It was therefore assumed that human influences were directly or indirectly responsible for the regression of a natural ecosystem from the local edaphic climax. This approach is generally applicable to systems that are regressing from climax, rather than to early-succession stages that are still progressing towards a climax.

The seral stage was analysed in a total of 25 coastal sites that were sampled between July and September 2012, on the island of Malta (Central Mediterranean). These sites were selected following the suggestions proposed by Anderson & Schembri [1] in identifying the coastal zone of the Maltese islands, as well as using watershed basins as natural functional units of replicate sites [7].

A circular buffer zone of 500m radius was established at each site and a total of 500m^2 of this area was sampled by random positioning of five 10x10m quadrats. These were set up manually using a field measuring tape and a protractor. Large, heavy and distinctive markers were placed at each corner of the quadrat. In the case of sandy habitats, the quadrats were positioned in the vegetation layer that is adjacent to these sandy beaches. For each of the five 100m^2 quadrats, a small 1x1m quadrat was utilised to facilitate the process of measuring the total species cover. The seral stage of the community was subsequently determined by using Equation 1, which estimated the total percentage cover of climax vegetation as a percentage of the total plant cover in each site. Species were classified as either being climax or disclimax (included both alien and opportunistic species), by establishing a list of typical Maltese coastal species of plants that fall within these two polar categories. Some species were classified as generalist species because they could not be classified in either category, and were subsequently excluded from this analysis.

$$SS = \frac{\%\ \text{cover of climax species}}{\%\ \text{cover of total species}} \times 100\% \qquad (1)$$

Based on Machado's guidelines [7], the dataset was ultimately converted to an 11-point naturalness scale. Sites were ranked from artificial '0' to pristine '10' using a Z-score grading system and the distribution of the dataset [5]. The naturalness values obtained were subsequently presented in an ArcGIS map and the mean values obtained from managed and unmanaged sites were compared using Two-Way ANOVA. Using a Pearson correlation matrix the SS values were correlated with Dunlop's [5] unpublished naturalness parameters of the same coastal sites. These parameters (CA, CW, TA) measure the abundance of waste, the types of anthropogenic disturbance and the intensity of land use cover. Additionally, the mean of these three parameters was also correlated with SS to test for its statistical significance.

Results

Seral stage (SS) analysis involved the measurement of percentage cover of climax coastal species with respect to the entire vegetation cover present on each of the sampled sites. A mean of 50.3%±22.8% was observed, along with a slightly positive skew of 0.406. One could also note that for the site at Valletta, a value of 100.0% was observed, suggesting that it could potentially be an outlier.

Table 1 – List of coastal sites sampled, coupled with their protection status (M = Managed, U = Unmanaged) as well as their SS cover and subsequent naturalness values.

Code	Site	Status	SS Cover	SS Naturalness
01	Ir-Ramla taċ-Ċirkewwa, Paradise Bay	M	38.3%	4.1
03	Ir-Ramla ta' Wied Musa, Ċirkewwa	U	59.8%	5.7
06	Aħrax tar-Ramel, Mellieħa	M	29.8%	3.5
08	Trunċiera ta' Qassisu, Mellieħa	M	45.5%	4.6
11	Ħarrieq, Mistra	M	33.4%	3.8
14	Ix-Xtajta tal-Qawra, Buġibba	U	54.6%	5.3

Code	Site	Status	SS Cover	SS Naturalness
15	Għallis, Baħar iċ-Ċagħaq	U	45.2%	3.2
16	Qalet Marku, Baħar iċ-Ċagħaq	U	34.1%	3.8
17	Ix-Xwiegħi, Baħar iċ-Ċagħaq	U	31.9%	3.2
18	Il-Ponta Irqieqa, Pembroke	M	75.8%	6.9
20	Il-Qaliet, San Ġiljan	U	33.1%	3.7
26	Il-Fossa, Valletta	U	100.0%	10.0
31	Id-Daħla ta' Rinella, Kalkara	U	30.9%	3.6
33	Blata l-Bajda, Xgħajra	U	79.7%	7.1
35	Bajja ta' San Tumas, Marsascala	U	22.9%	3.0
40	Il-Fossa, Marsaxlokk	U	39.0%	4.2
42	Il-Bajja ta' Birżebbuġa, Birżebbuġa	U	12.5%	2.2
43	Għar Ħasan Cliffs, Żurrieq	M	39.7%	4.2
46	Tas-Suldati, Blue Grotto, Żurrieq	M	29.4%	3.5
47	Ta' Berwieq, Għar Lapsi, Siġġiewi	M	60.5%	5.7
48	Rdum ta' Għar Bittija, Dingli	M	59.0%	5.6
50	Miġra Ferħa, Mtaħleb, Rabat	M	74.7%	6.8
54	Ta' Żamitellu, Ġnejna, Mġarr	M	73.6%	6.7
55	Ir-Ramla ta'Għajn Tuffieħa, Manikata	M	86.3%	7.6
59	Il-Prajjet, Mellieħa	M	73.6%	6.7

Figure 1 – Map showing the distribution of the coastal sites sampled and their seral stage naturalness values rounded up to the nearest whole number.

A Two-Way ANOVA was subsequently conducted to test the difference in the means of naturalness values obtained for managed and unmanaged sites. For this analysis the outlier observed at Site 26 was discarded. The means were recorded at 5.4±1.4 for managed sites, and 4.1±1.4 for unmanaged sites. The difference between means was found to be statistically significant ($F(1,2)=4.597$, $p=0.043$), implying that there is a significant difference in seral stage naturalness between the two types of coastal sites sampled.

Pearson Correlation was also performed to analyse if there is any correlation between SS and any of the naturalness parameters that directly quantify human disturbance i.e. CA, TA, CW [5]. There was no significant correlation between SS and any of these parameters, respectively ($p=0.307$, $p = 0.726$, $p = 0.689$). When the mean of these three parameters was calculated and tested for correlation with SS, it was also found to be not significant ($p = 0.607$).

Discussion

Figure 1 reveals a slight east to west gradient in the seral stage naturalness of coastal sites. Managed and protected coastal sites showed statistically higher values of seral stage naturalness 5.4±1.4, than unmanaged coastal areas 4.1±1.4. In fact, the highest values of SS were mainly observed at managed western coastal areas, which are typically known for their lack of human disturbance. The north-eastern coast of Malta is extremely popular for recreational and touristic purposes, especially during the summer season. Conversely, the south-eastern coast of Malta is dominated by industrial and maritime activities, which explains the low SS values recorded in this region of the island.

The high SS cover values observed in certain managed sites suggests that plant conservation efforts implemented directly at these sites, have yielded noticeable results when compared to other coastal areas in Malta. Successful introductions and maintenance of native species, coupled with the eradication of exotic species, has helped actively managed sites to improve their SS naturalness vales. In fact, this analysis can be performed on a repeated basis, to observe spatio-temporal fluctuations in the seral stage of the vegetation community for each coastal site. This is particularly important because it allows coastal managers to monitor the progress of their site in a rapid way and on a regular basis.

Site 26 was classified as an outlier because it highlights an anomalous situation in which the analysis of SS naturalness is insufficient to determine the naturalness of a coastal site. The cover value obtained (100%) is based only on the sporadic encounter of a limited number of climax *Inula crithmoides* individuals present at the site. This implies that in cases when the vegetation cover is extremely reduced by anthropogenic disturbances, high values of SS may be incorrectly recorded due to the absence of patches dominated by opportunistic species.

Sites 17 (26.0%), 35 (22.9%) and 42 (12.5%) showed particularly low SS cover values. In these sites, a high abundance of opportunistic species that are typically characteristic of disturbed habitats were found. These include species of *Avena* and *Bromus*, and *Malva arboera* and *Parapholis incurva*. These low values could be the result of excessive human disturbance at these sites: camping, roads, parking areas and industrial facilities.

In most sites, exotic species were also encountered, the most common being species of *Agave*. Other commonly encountered exotic species included*: Aloe vera*, *Acacia cyclops*, *Carpobrotus edulis, Chamaerops humilis, Hylocerius* spp*., Leucaena leucocephala*, *Pelargonium* spp. and *Opuntia* spp. Alien species are known to threaten the ecological succession of characteristic local coastal habitats by outcompeting native species. These species usually entail certain characteristics that make them better adapted in these habitats. For example, *Agave americana* is a relatively large rhizomatous, succulent, alien plant (in Malta) with a very dense network of rhizome offshoots that draws an excessive quantity of nutrients towards it, and threatens the survival of native species when conditions are limiting. Additionally, this alien also has large leaves that shade smaller native plants, rendering photosynthesis an even tougher challenge for these plants. By considering the fact that alien species are definite non-natural entities (by definition), and that they may also threaten the characteristic native vegetation diversity in an ecosystem, one can safely assume that their presence inherently reduces the naturalness of a site [7]. The use of a simple native/alien ratio, such as the one suggested by Machado [7], was avoided because heavily impacted habitats may lack alien species, despite considerable impacts being observed on the vegetation community. It is for this reason that the native/alien ratio was indirectly included with the seral stage analysis itself, rather than adopting it as a separate parameter.

The biggest flaw with this approach lies in the fact that the position of the seral stage of the coastal community is only assumed to be influenced by human disturbances. Realistically, natural disturbances should also be considered because these may revert natural assemblages to intermediate stages [7]. It is for this reason that SS analysis should always be accompanied with a survey of the different types and intensities of human disturbances occurring on each site, to allow for a correlation between these parameters. In fact, Dunlop [5] accounts for this in his index of naturalness by also including an additional three naturalness parameters that mask certain anomalous situations and give a more holistic view of the natural state of coastal sites. This is particularly important because even though SS is expected to decrease in value with an increase in human disturbance, the Pearson Correlation Matrix revealed that there was actually no significant correlation between SS and the other naturalness parameters used by Dunlop [5].

However, one must also realise that coastal area managers would most likely survey their sites on a regular basis and could therefore be able to differentiate between natural (strong wind currents, land erosion etc.) and/or man-made disturbances impacting on the vegetation community. Obviously, in the case of catastrophic natural disturbances (tsunamis, floods, volcanic eruptions, earthquakes, hurricanes, tornados etc.), the differentiation between artificial and natural impacts on vegetation would be unmistakeable.

Another important limitation is that in order to allow for the spatio-temporal comparison of the vegetation seral stage, the analysis is seasonally restricted. The reason for this is that sampling at different seasons may fail to account for the presence of annual or geophytic species. In fact, *Oxalis pes-caprae*¸ a very common geophytic alien species in the Maltese islands, was dominant during the winter season, but absent during summer.

Conclusion

The analysis of the seral stage of the coastal vegetation community can give better insight on the types and intensity of past and present human influence on plant composition. The method is fairly rapid and accurate particularly when it comes to describing the effects of human disturbance on vegetation. In fact, in managed and protected coastal sites, the SS naturalness value was found to be significantly higher than that of unmanaged sites.

On its own, the SS parameter may overlook natural disturbances, and may show some weaknesses in anomalous circumstances. Therefore, when it comes to assessing the holistic naturalness of a coastal site, it is suggested to include the analysis of seral stage amongst other naturalness parameters. Alternatively, the SS parameter can also be used as a separate tool by managers of protected areas who are exclusively interested in monitoring the dynamics of the plant communities of their sites. This enables them to quantify the progress of the vegetation community succession and allow for comparison across space and time.

References

[1] Anderson, E.W., & Schembri, P.J. - *Coastal zone survey of the Maltese Islands report.* (1989), Beltissebh, Malta: Planning Services Division, Works Department; xii + 121pp. + 100 hand-drawn colour maps + 19 synoptic maps.

[2] Anderson, J. E. - *A conceptual framework for evaluating and quantifying naturalness*, Conservation Biology. (1991) 5(3), 347-352.

[3] Angermeier, P. L. - *The natural imperative for biological conservation*, Conservation Biology. (2000)*14*(2), 373-381.

[4] Cole, D. N., & Yung, L. (Eds.). - *Beyond Naturalness: rethinking park and wilderness stewardship in an era of rapid change*. (2010), Island Press.

[5] Dunlop, S. - *The application of an Index of Naturalness for the Maltese Islands*, Unpublished BSc (Hons) dissertation. Faculty of Science, University of Malta. (2013) xii+99pp.

[6] Götmark, F. - *Naturalness as an evaluation criterion in nature conservation: a response to Anderson*, Conservation Biology. (1992) 6(3), 455-455.

[7] Machado, A. - *An index of naturalness,* Journal for Nature Conservation. (2004) 12, 95-110.

[8] Margules, C., & Usher, M.B. - *Criteria used in assessing wildlife conservation potential: A review,* Biological Conservation. (1981) 21, 79-109.

[9] Mucina, L. - *Vegetation condition & vegetation mapping I: critical global review of approaches to assessment of vegetation condition,* Unpublished draft report to the Department of Environment & Conservation. (2009), Science Division, Curtin University of Technology, Perth, WA.