Marine Pollution Bulletin 66 (2013) 176–184

Contents lists available at SciVerse ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

An integrative method for the evaluation, monitoring, and comparison of seagrass habitat structure

Andrew D. Irving [a,*], Jason E. Tanner [a], Sam G. Gaylard [b]

[a] South Australian Research and Development Institute (Aquatic Sciences), PO Box 120, Henley Beach, South Australia 5022, Australia
[b] Environment Protection Authority, 250 Victoria Square, Adelaide, South Australia 5000, Australia

ARTICLE INFO

Keywords:
Biological indicators
Coastal waters
Environmental indices
Environmental quality
Habitat degradation
Seagrasses

ABSTRACT

Assessing environmental condition is essential for the management of coasts and their resources, but better management decisions occur when large databases are simplified into more manageable units of information. Here we present the habitat structure index (HSI), which enables rapid assessment and direct comparison of seagrass habitat structure using scores of 0 (poor) to 100 (excellent) based on integrating five habitat variables: area, continuity, proximity, percentage cover, and species identity. Acquiring data to calculate the HSI can be done *in situ* or from video recordings, and requires relatively simple methodology of belt transects, estimating percentage cover, and basic taxonomy. Spatiotemporal comparisons can usefully identify locations and periods of seagrass habitat change, potentially providing an early warning indicator of habitat damage and decline in environmental quality. Overall, the integrative approach of the HSI represents a step toward simplifying the exchange of environmental information among researchers, coastal managers, and governing bodies.

1. Introduction

Government policies affecting the use and management of coastal resources are often fundamentally based on understanding the type and extent of natural habitats such as coral reefs and seagrass meadows (Edgar et al., 2007; Peterson and Estes, 2001). Knowledge of habitat extent alone, however, can overlook spatiotemporal variation in its quality and supply of ecosystem services (Barbier et al., 2011), which can determine whether management goals are met (e.g. Malakoff, 1998). Moreover, many common anthropogenic disturbances, such as eutrophication, initially cause habitat degradation rather than wholesale loss (Bellwood et al., 2004; Connell, 2007). Accordingly, greater sampling of habitat quality may enhance the development of early-warning indicators of habitat decline (Carballeira et al., 2012; Lagarde and Jaffrezic-Renault, 2011), with approaches that facilitate rapid assessment being ideally suited to shortening management response times and increasing success rates (Littler and Littler, 2007).

Defining habitat quality can be difficult because of the potentially large number of relevant variables. Indeed, there is a long history of sampling numerous physical (e.g. temperature, and turbidity), chemical (e.g. ammonium, and heavy metals), and biological characteristics (e.g. phytoplankton abundance) to characterise aquatic environments, particularly estuaries (Bortone, 2004). While useful, the need for integrative approaches that reduce such databases into more manageable units of information (e.g. a single habitat quality score) for making clearer management decisions has been highlighted as a major but critical challenge (Borja et al., 2008), even warranting special issues in scientific journals (e.g. Borja et al., 2009).

For benthic habitats, many studies define habitat quality through readily-measured structural characteristics, such as kelp density, coral height, and seagrass biomass, because they often correlate with ecosystem properties such as coastal productivity, nutrient cycling, and abundance of associated fauna (Bull et al., 2012; Syms and Jones, 2000). Usually, however, only one or two variables are sampled at any given time, which correspondingly only provides a partial understanding of habitat structure. Moving toward more integrative measures, recent Mediterranean studies combined structural features of benthic habitats (e.g. amount of living vs dead tissue, density, and species identity) to develop several ecological indices that help define coastal quality (Montefalcone, 2009; Montefalcone et al., 2007). Other studies have integrated aspects of benthic population structure with physical and chemical measurements to produce environmental indicators (Gobert et al., 2009; Martinez-Crego et al., 2010; Romero et al., 2007), though application to quantifying and comparing habitat structure *per se* is rare.

The purpose of this paper is to present a new technique for directly assessing and comparing seagrass habitat structure by integrating multiple variables. While not a primary focus, this method

* Corresponding author. Tel.: +61 400 118 825.
E-mail address: andrew.irving@adelaide.edu.au (A.D. Irving).

0025-326X/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpolbul.2012.10.017

Table 1
Calculated metric values and resulting HSI scores for the nine hypothetical transects used in the sensitivity analysis (Fig. 2). For these calculations, percentage cover values are assigned using the categories described in the text for the K metric, while species identity values for the S metric are defined as: *Posidonia* = 3, *Amphibolis* = 3, *Heterozostera* = 2, and *Halophila* = 1. Each transect measures 20 m × 1 m (scalar = 0.4422).

Metric	Transect								
	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
A	100.00	50.00	50.00	50.00	50.00	100.00	10.00	10.00	47.50
C	100.00	100.00	0.00	66.67	100.00	100.00	0.00	0.00	83.33
P	105.56	50.00	94.44	66.67	105.56	105.56	44.44	44.44	66.67
K	100.00	50.00	50.00	50.00	66.67	100.00	10.00	10.00	51.67
S	100.00	50.00	50.00	50.00	50.00	33.33	10.00	3.33	40.67
HSI	**100.00**	**62.54**	**56.66**	**56.61**	**77.34**	**90.90**	**21.09**	**20.68**	**59.27**

may also help evaluate the ecological quality of coastal areas and aid their management. An iconic feature of tropical and temperate coastlines, seagrass meadows naturally create extensive habitat for fish, invertebrates and algae (Bruno and Bertness, 2001), while providing ecosystem services such as carbon sequestration, nutrient cycling and coastal stabilization (Romero et al., 2006). However, the susceptibility of seagrasses to anthropogenic impacts has caused serious habitat degradation and loss of nearly one-third of the global seagrass area (Waycott et al., 2009).

Identifying variables that describe seagrass degradation is aided by understanding seagrass population dynamics. Some seagrasses form extensive and continuous monospecific meadows, but many exist in a mosaic of patches of different size, shape, species identity, and age (Duarte et al., 2006). Whether from natural or anthropogenic disturbances, seagrass degradation and loss typically involves the initiation or continuation of fragmentation within meadows (Duarte et al., 2006; Walker et al., 2006), increasing the number of patches while reducing habitat area. Patches of bare sand can become 'blowouts' (*sensu* Clarke and Kirkman, 1989), which further impact seagrasses as destabilised sediments along the meadow edge are eroded by wave action. Importantly, natural recovery does occur (Walker et al., 2006), often beginning with the colonisation of disturbed areas by faster-growing 'opportunistic' genera before slower-growing but competitively dominant genera establish (Clarke and Kirkman, 1989).

2. Materials and methods

2.1. Selected variables

Seagrass habitats are often quantified at the molecular (leaf nitrogen content, and photosynthetic performance), individual (leaf length and surface area), and population level (plant density,

P 100	P 90	P 60	P 20			H 70	H 90	H 90	H 100	H 100	H 60	H 10		P 50	P 50	P 60	P 50		P 30

Fig. 1. A hypothetical transect measuring 20 m × 1 m and showing the taxa present and their percentage covers within each 1 m^2 of the transect. P = *Posidonia*, H = *Heterozostera*, while empty quadrats indicate that seagrass was absent.

(a)	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100
(b)	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100	P 100										
(c)	P 100		P 100		P 100		P 100		P 100		P 100		P 100		P 100		P 100		P 100	
(d)	P 100	P 100	P 100							P 100		P 100	P 100	P 100	P 100	P 100			P 100	
(e)	P 50	P 50	P 50	P 50	P 50	P 50	P 50	P 50	P 50	P 50	P 50	P 50	P 50	P 50	P 50	P 50	P 50	P 50	P 50	P 50
(f)	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100	Ha 100
(g)										P 100			P 100							
(h)										Ha 100			Ha 100							
(i)	P 100	P 60 H 40	P 20 H 50	H 50	H 10				Ha 50	Ha 50					A 10 H 50	A 50 H 10	A 90 P 10	A 50 P 50	P 100	P 100

Fig. 2. Nine hypothetical transects used to assess the sensitivity of the HSI calculations. Transects vary in the five metrics used to calculate the HSI, but all measure 20 m × 1 m for ease of comparison. Each square represents 1 m^2 of the transect and shows the taxa sampled and their percentage covers. P = *Posidonia*, A = *Amphibolis*, H = *Heterozostera*, and Ha = *Halophila*.