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Seagrass on the edge: Land-use practices threaten coastal seagrass communities in Sabah, Malaysia

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ABSTRACT

Seagrass meadows are susceptible to coastal environmental impacts and serve as early indicators of system-wide degradation. Two SeagrassNet monitoring sites were established in Sabah (Malaysia) in 2001 in the Tunku Abdul Rahman National Park: one a pristine, reference site and one anticipating impacts from nearby, ongoing waterfront development. At both sites, percent cover of all seagrass species declined significantly between 2003 and 2005. Water temperature, fine sediment and specific leaf biomass increased, while percent surface light intensity reaching the plants decreased. Evidence suggests that the temperature changes observed during the monitoring period were not sufficient to impact seagrasses; rather, the documented reduced subsurface light intensity caused the observed seagrass declines. Concomitantly, satellite imagery revealed a persistent sediment plume in these coastal waters associated with deforestation. SeagrassNet monitoring quickly documented seagrass losses and identified the causal environmental factor, providing timely information for management consideration.

1. Introduction

Management of coastal marine resources necessitates understanding how human activities influence marine communities. Timely information on potential threats to marine systems is important because coastal areas are facing rapidly increasing development and pressure from human population growth worldwide. In tropical systems, three marine communities are particularly affected by coastal development: coral reefs, mangroves, and seagrasses (Spaulding et al., 2003). Although seagrasses are an important part of tropical marine ecosystems and provide valuable ecosystem services, they have received relatively little attention in both scientific and popular media (Orth et al., 2006). SeagrassNet, a global monitoring program for seagrasses, was founded in 2001 to address the lack of systematic information on seagrass status and health (Short et al., 2006) and to take advantage of the sensitivity of seagrasses as "coastal canaries", i.e., early indicators of system change (Orth et al., 2006). Here, we present an example from SeagrassNet findings for Sabah

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(Malaysia) in which seagrass monitoring quickly and scientifically documented how land-based practices impacted the health of coastal marine communities.

Seagrass beds provide nursery areas, habitat for fish and shellfish, and food for herbivores such as dugong and sea turtles (Dorenbosch et al., 2006; Hemminga and Duarte, 2000). Additionally, they filter suspended sediments and nutrients from coastal waters, dissipate wave energy and stabilize sediments (Koch, 2001; Orth et al., 2006). Coastal communities experiencing a loss of seagrasses also lose the ecosystem services that seagrass beds provide (Orth et al., 2006; Vermaat et al., 1997). A wide variety of factors can adversely influence seagrass ecosystems, including commercial dredging (Neckles et al., 2005), food collection or dynamite fishing (Sidik et al., 2006), removal of herbivores (Jakobsen et al., 2006), and increased storm intensity attributable to climate change (Short et al., 2006). However, globally, the greatest threat to seagrasses involves human activities that reduce water quality, decreasing light reaching the plants (Short and Wyllie-Echeverria, 1996). Water quality in seagrass beds is often affected by sediment subsidies from coastal development (Coles et al., 2003), land-based forestry practices (Terrados et al., 1998), dredging (Erftemeijer and Lewis, 2006), and eutrophication (Short et al., 2006; Vermaat et al., 1997).

Seagrasses require high light levels to thrive (Duarte et al., 1997; Erftemeijer and Lewis, 2006; Short and Wyllie-Echeverria, 1996; Vermaat et al., 1997). Seagrass minimum light requirements differ between species and systems, yet they are consistently an order of magnitude higher than terrestrial plants or other photosynthetic marine organisms (Dennison et al., 1993). Tropical/sub-tropical seagrass genera such as *Halodule* and *Syringodium* often require more than 24–37% surface light intensity (Dennison et al., 1993; Kenworthy and Fonseca, 1996). Seagrasses may survive near minimum light levels, buffering the adverse effects of low light through morphological adaptation (Tanaka and Nakaoka, 2006), but plants living near or at minimum light levels cannot survive over time if additional light reduction occurs (Short et al., 1995).

In this study, we report a marked decline at two SeagrassNet monitoring sites in western Sabah, Malaysia. Of the world's approximately 60 species of seagrasses, 10 are found in this area of Malaysia (Sidik et al., 2006), making it a "hot spot" for species diversity (Short et al., 2007). When these two monitoring sites were established by SeagrassNet in 2001, one was anticipated to be influenced by nearby coastal development and the second was considered a pristine reference site; however, similar seagrass losses at both sites indicated a large scale impact. We argue that carefully designed seagrass monitoring can scientifically and rapidly demonstrate anthropogenic impacts to coastal marine communities and provide certainty of the immediate cause, in this case, reduced light.

2. Materials and methods

The data presented here result from a joint monitoring effort of the Sabah Parks Marine Research Unit in Malaysia and SeagrassNet, based at the University of New Hampshire (USA). SeagrassNet is a global seagrass monitoring program that operates with local teams trained in the program's standardized protocol. SeagrassNet was established in 2001 to scientifically measure changes in seagrass ecosystems, including distribution, species composition, and abundance, along with environmental parameters such as sediment characteristics, temperature and light. The same protocol is now used at 86 sites in 27 countries worldwide (http://www.SeagrassNet.org) and is based on the statistical sampling design described in Burdick and Kendrick (2001). Sites are chosen based on a set of parameters designed to locate typical or representative seagrass beds for the area under consideration (Short et al., 2006). The repeated, quarterly sampling of fixed transects allows trend detection over relatively short time periods (less than 2 years). SeagrassNet does not survey or map the seagrasses of a region, nor does a single site characterize region-wide trends; however, SeagrassNet protocol captures incremental changes within a specific meadow that is representative of the area, and widespread use of the protocol allows comparisons of trends across countries, regions, and the world.

During 2001, two SeagrassNet sites were established on the island of Pulau Gaya in the Tunku Abdul Rahman National Park offshore from the city of Kota Kinabalu in Sabah, Malaysia (Fig. 1). In July 2001, the Sabah SeagrassNet team received training and conducted their first field sampling at Kuari Bay (hereafter SB5.1; Latitude: 6°0.498′N, Longitude: 116°2.038′E), a pristine, reference site within the actively managed part of the national park. In October 2001, an additional site was started at Police Beach (hereafter SB5.2; Latitude 6°2.14′N, Longitude 116°0.904′E), an area with a recent history of dynamite fishing and anticipated to be impacted by construction of a growing community of "stilt houses" nearby. The two sites span tidal–flat depth gradients of 0.7 m at SB5.1 (Kuari Bay) and 0.5 m at SB5.2 (Police Beach). In Sabah, the tidal range is 1–2 m.

Following the SeagrassNet protocol, the sites established in Sabah consisted of three fixed, parallel, 50 m cross transects referred to as cross transects A, B and C with cross transect A closest to shore and C most seaward; midpoints of these cross transects were established on a transect laid out seaward, perpendicular to the shore. Quarterly sampling (January, April, July, and October) was done at twelve 0.25 m^2 quadrats placed at predetermined random locations along each cross transect. During each quarterly sampling measurements were made of: (1) species composition in the 0.25 m^2 quadrats along the cross transects, (2) seagrass abundance (cover, canopy height, density, and biomass), (3) light and temperature, (4) sediment composition, and (5) each 0.25 m^2 quadrat was photographed to create a permanent record.

2.1. *Percent cover*

Seagrass percent cover by species was visually estimated in each 0.25 m^2 quadrat using a photo guide of percent cover. Any evidence of grazing was identified and noted. Visually estimated total percent cover of all seagrass species combined was examined for each site and cross transect using a repeated-measures analysis of variance (ANOVA). Each percent cover was converted to a proportion (0–1) then arcsine, square-root transformed to maintain a normal distribution.