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Monitoring in the Western Pacific region shows evidence of seagrass decline in line with global trends

Frederick T. Short [a,b,*], Robert Coles [c], Miguel D. Fortes [d], Steven Victor [e], Maxwell Salik [f], Irwan Isnain [g], Jay Andrew [h], Aganto Seno [i]

[a] SeagrassNet, Washington State Department of Natural Resources, Olympia, WA 98504, USA
[b] University of New Hampshire, Durham, NH 03824, USA
[c] Seagrass Group – TropWater, James Cook University, Cairns, Queensland 4870, Australia
[d] Marine Science Institute, CS, University of the Philippines, Quezon City 1101, Philippines
[e] The Nature Conservancy, Koror 96940, Palau
[f] Department of Fisheries, Tofol, Kosrae 96944, Federated States of Micronesia
[g] Sabah Parks, 88100 Kota Kinabalu, Sabah, Malaysia
[h] Palau International Coral Reef Center, Koror 96940, Palau
[i] Komodo National Park, Labuan Bajo, Flores, NTT 86554, Indonesia

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ABSTRACT

Seagrass systems of the Western Pacific region are biodiverse habitats, providing vital services to ecosystems and humans over a vast geographic range. SeagrassNet is a worldwide monitoring program that collects data on seagrass habitats, including the ten locations across the Western Pacific reported here where change at various scales was rapidly detected. Three sites remote from human influence were stable. Seagrasses declined largely due to increased nutrient loading (4 sites) and increased sedimentation (3 sites), the two most common stressors of seagrass worldwide. Two sites experienced near-total loss from of excess sedimentation, followed by partial recovery once sedimentation was reduced. Species shifts were observed at every site with recovering sites colonized by pioneer species. Regulation of watersheds is essential if marine protected areas are to preserve seagrass meadows. Seagrasses in the Western Pacific experience stress due to human impacts despite the vastness of the ocean area and low development pressures.

1. Introduction

Seagrass meadows form the foundation of important shallow-water coastal systems and associated biodiversity globally (den Hartog, 1970; Green and Short, 2003, Duarte et al., 2008, Short et al. 2011). They provide an assortment of ecosystem services to resident species including the endangered dugong and green turtle, interconnected habitats (mangroves and coral reefs) and populations through direct (nursery and foraging areas) and indirect (carbon and nutrient sequestration and export) means as well as supporting the needs of human populations (fisheries, biological filtering, hydro-dynamic buffering). Nowhere is the importance of seagrass systems more evident than in the tropical Western Pacific region, which represents the highest biodiversity of seagrass species, the broadest area of seagrass meadow cover, and the largest gap in information on global seagrass distribution and status (Spaulding et al., 2003; Short et al., 2007; Waycott et al., 2009; Short et al., 2011).

Differences in the life history strategies of tropical seagrasses result in varying species assemblages. *Enhalus acoroides* is a slow turnover, persistent species with low resistance to perturbation (Bridges et al., 1981; Walker et al., 1999). In contrast, *Cymodocea serrulata, Halodule uninervis* and *Halophila ovalis* are more ephemeral (Birch and Birch, 1984). *H. uninervis* and *H. ovalis* are considered pioneer species, growing rapidly and surviving well in unstable or depositional environments (Bridges et al., 1981; Birch and Birch, 1984). *C. serrulata* is found associated with deep sediment layers, and has been linked to increased sediment accretion (Birch and Birch, 1984).

As with shallow coastal systems globally, seagrass habitats of the Western Pacific face a number of threats including the damage caused by rapidly growing human populations, declines in water quality, loss of biodiversity, and erosion of habitat structure (Short

* Corresponding author. Address: SeagrassNet, University of New Hampshire, Jackson Estuarine Laboratory, 85 Adams Point Road, Durham, NH 03824, USA. Tel.: +1 603 659 3313.
E-mail address: fredtshort@gmail.com (F.T. Short).

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and Wyllie-Echeverria, 1996; Orth et al., 2006). Deforestation of watersheds, destruction of mangroves, agriculture and aquaculture practices – all exacerbate sedimentation and habitat loss (Grech et al., 2012). The aim of SeagrassNet is to establish seagrass monitoring worldwide: preserving seagrass habitat, increasing awareness, and tracking the status of seagrasses as an indicator of trends in environmental health, using a standardized protocol (Short et al., 2006a). Teams have been established to monitor seagrass habitat simultaneously four times a year, using the same protocol, in 33 countries at 122 sites worldwide. In each case, it is the quarterly, repeated sampling of a series of specific locations across a seagrass meadow that provides evidence of change in the seagrass environment, including distribution, species composition, and abundance. The protocol (Short et al., 2006a) is based on a statistically valid and peer-reviewed sampling scheme (Burdick and Kendrick, 2001); results are comparable over time at a given site, and the repeated measures monitoring allows trend detection over relatively short time periods (1–2 years) even within diverse (3–7 species) communities. The protocol captures increments of change at seagrass sites representative of the area; widespread use of the protocol allows comparisons across countries, regions, and the world (Short et al., 2006b; Freeman et al., 2008).

The present study examines the spatial and temporal dynamics of monitoring sites in multi-species seagrass populations at various locations across the Western Pacific including insular Southeast Asia and northeast Australia (Fig. 1). These locations represent the variety of geographic and environmental conditions in which seagrasses occur and we use them to report on trends in seagrass condition in the Western Pacific.

2. Methods

Standard SeagrassNet methods were used (Short et al., 2006a, www.SeagrassNet.org). To summarize the monitoring protocol, a site consists of three, fixed, parallel 50 m transects, their midpoints located on a line laid out seaward, perpendicular to shore. The transects are at the nearshore, mid-depth, and deep parts of the seagrass bed. Monitoring was conducted at the 10 sites across the Western Pacific, over periods ranging from 3 to 8 years per site (Table 1, Fig. 1). Some sites experienced breaks in data collection from 1 to 2.5 years. All site monitoring commenced between 2001 and 2004 and was conducted at set times, four times per year. The sites themselves were chosen based on a set of parameters (Short et al., 2006a) designed to locate a typical or representative seagrass bed given the range of conditions of the area under consideration, either a site distant from anthropogenic stressors or one considered by the monitoring team to be affected by an ongoing stressor or having a potential stressor. The quarterly sampling is done at twelve 0.25 m^2 quadrats placed at pre-determined, random locations along each of the transects. Seagrass percent cover by species is visually estimated per quadrat using a photo guide representing various cover conditions. Percent cover data provide a good representation of overall ecosystem status in Western Pacific seagrass; seagrass decline is defined as the loss of percent cover over time (Freeman et al., 2008; Mellors et al., 2008; Coles et al., 2005; McKenzie et al., 2012).

Countries and locations were selected to represent wide geographic coverage of the Western Pacific region. In each location representative meadows were selected using knowledge from previous visits by seagrass scientists and local advice. To avoid potential bias, at least two sites were monitored at each location when possible, at least one of which was remote from population centers. Representative meadows included the dominant seagrass community type and average abundance. Intertidal sampling ensured local scientists and community members could carry out the quarterly monitoring long-term.

Change in distribution of seagrasses over time is captured by measurement of the position of the meadow relative to the permanent transects. Species composition is measured along the transects, and seagrass abundance is determined via measurements of plant percent cover, canopy height, density, and biomass. Voucher specimens are collected and prepared as herbarium sheets of each seagrass species (with flowering parts if present), archived at the International Seagrass Herbarium at the Smithsonian, Washington, DC, USA. Each quadrat is photographed quarterly to create a permanent record. Water temperature is monitored continuously with two Hobo Pendent data loggers at each site (Short et al., 2006a).

Correlation analysis with least square regression was used on data from the Western Pacific sites to examine trends over time with repeated-measures ANOVA for differences between transects and sites using JMP (SAS Institute Inc. Version 8.0). Significance was determined at $p < 0.05$ except for two instances of $p < 0.06$, as indicated.

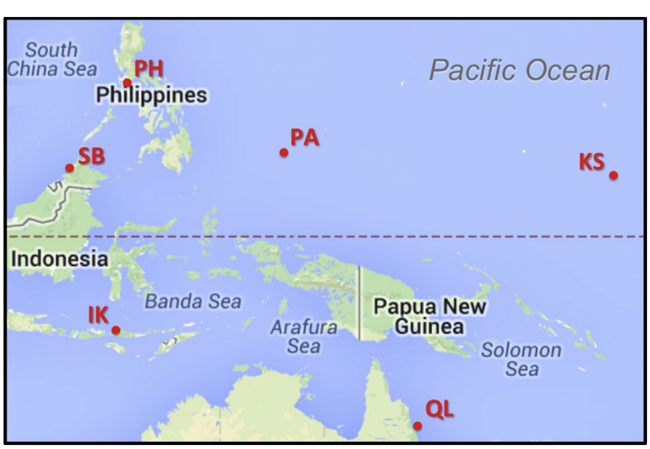

Fig. 1. Map of the Western Pacific with the position of the SeagrassNet sites in Kosrae (FSM; KS), Palau (PA), Mindoro (Philippines; PH), and Sabah (Malaysia; SB), Komodo (Indonesia; IK), Queensland (Australia; QL). Dashed line is the Equator.

3. Results

All ten sites were located within 17° of the Equator, with all but two sites in the Northern Hemisphere (Table 1). Three to seven seagrass species were found in each of the ten Western Pacific SeagrassNet sites analyzed here. Komodo, Indonesia had the most, with seven seagrass species while Kosrae, Federated States of Micronesia and one site in Palau had the lowest, at three species each. *Thalassia hemprichii* and *Cymodocea rotundata* were found at nine of the sites, with *T. hemprichii* absent only from a site in Malaysia and *C. rotundata* absent only from a site in Palau. *H. ovalis* was found at eight sites, *H. uninervis* at seven sites, *E. acoroides* at six and *C. serrulata* at four. *Syringodium isoetifolium* was found only in Komodo. The two Kosrae sites had all the seagrass species known to exist there (Green and Short, 2003), while other sites did not fully represent their country's seagrass species diversity. Seagrass percent cover at the site level (mean of total cover of the 3 transects at each site with replicate quadrats, $n = 12$) ranged from 2.4% (Sabah, SB5.2) to 90.1% (Kosrae, KS1.2).

Seagrass percent cover was stable at three of the ten sites (Fig. 2): Kosrae (KS1.1), the Philippines (PH4.1) and Australia (QL8.1). All three sites showed species shifts (Table 2) even though the overall site cover did not change. At the other seven sites, declines in seagrass percent cover occurred: PA3.1 (18%/y), SB5.1 (56%/y), SB5.2 (78%/y), IK16.1 (5.4%/y); PA3.2 (1.9%/y), PH4.2