SUPPLEMENTARY ONLINE MATERIAL 2: DETAILED METHODOLOGY

Data collection

A series of workshops were undertaken involving the staff from the 16 PA sites. The sites were selected by their respective management agencies to undertake the METT assessment based on the criteria that each site has management presence at the site level and there are staff undertaking management activities at the site.

Seven facilitated workshops were undertaken between June 2022 and November 2023 involving staff from seven PA management agencies across Malaysia (Table 1). Five workshops were carried out in Peninsular Malaysia while a workshop each was carried out in Sabah and Sarawak (Table 2). The workshop included an introductory session on Protected Area Management Effectiveness (PAME), the use of available tools in the evaluation of PAME process as well as an introduction to the METT assessment template. Emphasis was placed on the management performance aspect of the PAs, which includes reviewing the current status of the sites' management objectives delivery and the conservation outcome of the key habitat or species found within each site.

Table 1. PA management agencies involved in the METT workshop

Peninsular Malaysia 1. Department of Wildlife and National Parks (PERHILITAN) Peninsular Malaysia
Sarawak 2. Sarawak Forest Corporation (SFC)
Sabah 1. Sabah Forest Department 2. Sabah Foundation 3. Sabah Parks 4. Sabah Wildlife Department 5. Reef Guardian

Table 2. Details of workshops conducted throughout the study

Workshop	Description	Attendees	
Peninsular Malaysia			
1	This workshop was carried out to introduce and capacity build management effectiveness and METT for staff from eight PA sites managed by PERHILITAN. The METT assessment for the Penang National	Penang National Park	3
		Tengku Hassanal Wildlife Reserve	1
		Tasek Bera Ramsar Site	1
		Pahang National Park	2
		Kelantan National Park	1

	Park was also undertaken in this workshop. Attendees were mainly the PA managers and rangers from their respective sites.	Terengganu National Park	1
		Sungkai Wildlife Reserve	1
		Sungai Dusun Wildlife Reserve	1
		Paya Indah Wetlands	1
		Tanjung Tuan Wildlife Reserve	1
		Protected area division	4
2	This workshop was carried out to capacity build PA staff on conducting management effectiveness assessment using METT. The METT assessment for Tengku Hassanal Wildlife Reserve and Tasek Bera Ramsar Site were also undertaken in this workshop. Additionally, the METT assessment for Penang National Park was also finalised in this workshop. Attendees were mainly the PA managers, officers and rangers from their respective sites.	Penang National Park	1
		Tengku Hassanal Wildlife Reserve	4
		Tasek Bera Ramsar Site	4
		Pahang National Park	5
		Kelantan National Park	1
		Terengganu National Park	1
		Sungkai Wildlife Reserve	1
		Sungai Dusun Wildlife Reserve	2
		Paya Indah Wetlands	1
		Tanjung Tuan Wildlife Reserve	1
		Protected area division	5
3	In this workshop, the METT assessment for Pahang, Kelantan and Terengganu National Parks were undertaken. Besides that, Tengku Hassanal Wildlife Reserve and Tasek Bera Ramsar Site also attended to finalise their METT assessment from the previous workshop. Attendees were mainly the PA managers, officers and rangers from their respective sites.	Penang National Park	3
		Tengku Hassanal Wildlife Reserve	3
		Tasek Bera Ramsar Site	4
		Pahang National Park	4
		Kelantan National Park	2
		Terengganu National Park	3
		Sungkai Wildlife Reserve	1
		Sungai Dusun Wildlife Reserve	2
		Paya Indah Wetlands	1
		Tanjung Tuan Wildlife Reserve	1
		Protected area division	4
4	This workshop was conducted to carry out the METT assessment for Sungai Dusun Wildlife Reserve. Attendees were mainly the PA manager and officers from Sg Dusun Wildlife Reserve.	Sungai Dusun Wildlife Reserve	5
		Kelantan National Park	1
		Pahang National Park	1
		Tengku Hassanal Wildlife Reserve	1
		Tasek Bera Ramsar Site	1
		Paya Indah Wetlands	1
		PERHILITAN Selangor	1

		Wildlife Conservation Centres (WCC)	1
		Natural Environment Recreation Division	1
		Ex-Situ conservation division	1
		Protected area division	6
5	This workshop was conducted to carry out the METT assessment for three PA sites: Tioman Wildlife Reserve, Tanjung Tuan Wildlife Reserve and Sungkai Wildlife Reserve. Attendees were mainly the PA managers, officers and rangers from their respective sites.	Tanjung Tuan Wildlife Reserve	1
		Sungkai Wildlife Reserve	1
		PERHILITAN Tioman	1
		PERHILITAN Melaka	1
		Kelantan National Park	1
		Wildlife Conservation division	1
		Natural Environment Recreation Division	1
		Ex-Situ conservation division	1
		National Wildlife Rescue Centre	1
		Protected area division	5
Sarawak			
6	This workshop was undertaken to introduce and capacity build PA staff from five PA sites managed by SFC in Sarawak on management effectiveness and METT. Besides that, the METT assessment for these five sites were also undertaken in this workshop. Attendees were mainly the PA managers, officers and rangers from these sites.	Sarawak Forest Corporation	1
		SFC Santubong National Park	3
		SFC Kuching Wetland National Park	3
		SFC Gunung Mulu National Park	3
		SFC Niah National Park	3
		SFC Bako National Park	3
		SFC Totally Protected Area Planning Section	1
Sabah			
7	This workshop involved five PA management agencies and the METT assessment was initiated for eight sites in Sabah. However, due to time limitation, only the Sugud Island Marine Conservation Area (SIMCA) was able to complete the METT assessment. Attendees are mainly the PA manager and officers from these sites.	Sabah Forest Department	5
		Yayasan Sabah	4
		Sabah Parks	2
		Sabah Wildlife Department	1
		PERHILITAN	2
		Reef Guardian (non-profit organisation)	1

It was also emphasised to the staff that METT is a self-monitored assessment which is not typically audited by external parties in ensuring and verifying their veracity and compliance. The assessment is highlighted as a baseline from which the site may refine and prioritise future management actions for an overall improved management of the site. This gave an assurance to the staff to be as truthful as needed to answer the assessment questionnaire without the fear of getting any repercussions for possible low METT scores.

External facilitators were appointed to facilitate the staff from the site in answering the assessment questions. The facilitators explained each section on the template in detail with the staff to ensure their complete understanding of the questions and elicit applicable answers for each questions together with their justifications and evidence. However, the facilitators ensured to avoid influencing the answers given by the staff to preserve the transparency of the assessment and not skew the resulting assessment scores and results.

When undergoing the METT assessment, certain PA carried out the assessment for their site in the same workshop. Although this might create competitions among the staff, but another aspect that the staff can benefit is that they can learn from other sites and adapt it to their own. By observing and analysing the successful strategies and practices implemented as well as failures at other sites, they can gain insights that are applicable to their own PA. This collaborative learning environment encourages knowledge sharing, promotes best practices, and ultimately enhances the overall effectiveness of each site.

Data analysis

A violin plot was developed using an online computing platform, Kaggle (www.kaggle.com) (Kaggle, 2024) using Python programming language to visualise the METT score distribution across the different IUCN management categories. A Python visualisation library, Plotly Express, was used to create the violin plot overlaid with the box plot within the Kaggle platform. The violin plot uses Kernel Density Estimate (KDE) to aid in the visualisation of the data distribution which specifically creates a smoothed curve where the spread of the data is most concentrated (Hintze & Nelson, 1998; Hu, 2020). Violin plots have a few characteristics, which are i) width of the violin that represents the density of the data point within the range; ii) mirrored density curve around the central axis, producing a violin shape; and iii) peaks and valleys of the violin plot that represent the highest and lowest points of the dataset spread (Hintze & Nelson, 1998; Hu, 2020). A box plot was overlaid onto the violin plot to better showcase the median, quartiles and outlier values. The KDE for the violin plot was calculated as follows:

$$f(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right)$$

where $f(x)$ is the estimated density at a specific value x, n is the number of data points, h is the bandwidth, x_i are the data points and K is the kernel function (Chen, 2017; Gramacki, 2018; Silverman, 1986; Węglarczyk, 2018). Gaussian kernel was used for this analysis, as follows:

$$K(u) = \frac{1}{\sqrt{2\pi}} e^{-\frac{u^2}{2}}$$

where,

$$u = \frac{x - x_i}{h}$$

and u represents the standardised distance between the data points which is used calculate the kernel function (K) at the point u to estimate the density at u (Gramacki, 2018; Silverman, 1986). The bandwidth (h), which determines the smoothness of the density estimate curve, was determined using the Silverman's rule of thumb (Silverman, 1986):

$$h = 1.06\sigma n^{-\frac{1}{5}}$$

where σ is the standard deviation of the data and n is the sample size.

The width of the violin represents the density of the METT scores with wider curves representing more PAs with similar scores at that range and the median value of the scores presented within the violin. Violin plot provides information on the spread and distribution of the overall METT scores across the PA management categories and this is of use for higher management levels of the PA management agencies that manage and oversee large number of sites to understand the variability of sites' management capacities within the PA category. This also allow the sites to identify low-scoring questions and refining actions to improve these scores in subsequent assessment (Stolton *et al.*, 2021).

Besides the quantitative analysis of the METT scores across the 16 PAs in Malaysia, this paper also includes a qualitative analysis of the METT assessment results from sites that were analysed individually to identify common successes and challenges in order to understand the PA management norms across Malaysia. The strengths and weaknesses of the PAs were assessed and analysed by looking at the scores that each sites obtained for the METT-4 questionnaire and the METT management element to which it corresponds. The top ten METT questions with the highest score (score of three) and lowest scores (score of either zero or one) for most of the PAs were identified and visualised in a graphical representation.

Common threats across the 16 PAs were identified using the frequency of the threats at the individual site as well as the major threats across the sites with the use of aggregate scoring. Aggregate scoring is a method of quantifying and grouping individual scores into a single overall score which allows for easier analysis and interpretation of the overall results (Grabisch *et al.*, 2009). For this study, we used aggregate scoring to determine the most

significant threat for each of the PA category. Information on the threat category, details, extent and severity were compiled from the Detailed assessment of threats tab of each site's completed METT. The threats extent and threats severity categories which are Low, Medium, High and Very High were assigned the score of 1, 2, 3 and 4, respectively. From this, the aggregate score for each threat category was calculated using the formula:

$$Aggregate\ Threat\ Category\ Score = \sum (S_i \times E_i)$$

where,

S_i = Severity of threat (on a scale from 1 to 4, where 1 = Low and 4 = Very High)
E_i = Extent of threat (on a scale from 1 to 4, where 1 = Low and 4 = Very High)

In summary, the aggregate threats category score is the summation of the aggregate score of each individual threat within each threat category.

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