Aligning conservation and research priorities for proactive species and habitat management: the case of dugongs in Johor, Malaysia

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TABLE S1 Our recommended management strategies (in bold) for conservation of the dugong *Dugong dugon* around the islands off the east coast of Johor, Malaysia (Fig. 1), with related actions and actual and expected outcomes.

Actions	Actual/expected outcomes
Establish/enable regulatory provisions	
Identify existing regulatory provisions/mechanisms available to establish or enable the setup of a protected management area for target species: (1) Invoke the Fisheries Act 1985, Part IX, Section 41 (1) (a) for legislative authority to afford special protection to aquatic flora & fauna & to protect, preserve & manage their habitats, with particular regard to rare or endangered species (2) Invoke Malaysia's commitments to the Convention on Biodiversity (CBD, 2010): Target 11 requires 10% of coastal & marine areas, especially areas of particular importance for biodiversity & ecosystem services, to be conserved & protected by 2020. Only <1% of Malaysia's marine areas are currently protected (Bertzky et al., 2012) Target 12 requires the conservation status of known threatened species to be improved & sustained (3) Invoke Malaysia's National Plan of Action for dugongs (DOFM, 2011): Objective 3 aims to protect, conserve & manage the habitats of dugongs Strategy 2 states that a suitable area for the protection & conservation of dugongs & their habitat needs to be established	Use of identified regulatory provisions/mechanisms to commence planning for subsequent establishment of a dugong protected/ management area in Johor, Malaysia (overall outcome)
Identify threats that affect or may affect target species	
Initiate actions to address threats that affect or may affect target species: (1) Designate dugong conservation area boundaries to limit extraction & development activities within & surrounding the designated area (2) Establish fishery management areas where only non-detrimental fishing gears (e.g. hook-and-line & fish traps) are permitted in dugong conservation areas (3) Establish designated ferry routes & sea traffic regulations in the dugong conservation area to limit speed & area of vessel movements	(1) Managed areas/ routes designed & delineated (1) & (3) Reduction in bycatch, stranding or collision incidents (e.g. in Florida regulations exist for speed limits in designated zones for the Florida manatee *Trichechus manatus latirostris*, which have

Actions	Actual/expected outcomes
	helped reduce the risk of collisions with boats; Calleson & Frohlich, 2007)
Monitoring & enforcement	
(1) Develop effective enforcement capabilities (i.e. trained manpower, sufficient resources)	(1) & (6) Regular patrols & monitoring undertaken
(2) Strong provisions to deter potential violators (e.g. stiff penalties, appropriate powers of enforcement)	(2),(3), (4) & (6) Reduced incidences of violations
(3) Park rangers to patrol dugong conservation area regularly to monitor for potential violations	(5) Increased awareness of the importance of dugongs & their habitats
(4) Land-based monitoring of illegal activities within the designated area (through watchtower)	(5) Seagrass areas monitored for the presence of dugong feeding trails
(5) Community-based watch group to be formed to assist with monitoring activities	
(6) Penalties for violating the dugong conservation area; regulations should be strictly enforced & sufficient to deter further violations	(5) A community-run dugong feeding trail monitoring programme established in this area (Mellors et al., 2008)
Reassess status of target species, threats, & effectiveness of management actions	
(1) Review new information against conservation targets & objectives	(1) Regular meeting of the committee (e.g. annually) to review available data & provide transparency in its deliberations & recommendations
(2) Creation of stakeholders' advisory committee to review scientific, economic & other data to make recommendations for adaptive management of habitat & wildlife to the government	(2) Status & effectiveness of implemented actions reviewed & reassessed on a regular basis

TABLE S2 Recommended focused research strategies (in bold) for conservation of dugongs around the islands off the east coast of Johor, Malaysia, with specific actions and actual and expected outcomes.

Actions	Actual/expected outcomes
Studies to further understanding of the biology & ecology of target species	
(1) Continue research efforts using systematic aerial surveys (2) Towed & passive acoustic surveys in dugong areas	(1) & (2) Seasonality patterns (if any) in the dugongs' distribution ascertained (1) & (2) Understanding of tidal state influences on dugong occurrence (Sheppard et al., 2009) (1) & (2) Relative abundance & trend in the vicinity of the Johor east coast islands calculated (1) & (2) Information gathered on behaviour & ecology of dugongs (e.g. identify breeding seasons, if any) (1) & (2) High-use habitats mapped & assessed (Lanyon et al., 2005) (1) & (2) Dugong 'vocal hotspots' in feeding grounds & other habitat use identified (Tsutsumi et al., 2006)
(3) Undertake genetic studies using samples from dugongs stranded along Johor's coastline	(3) The genetic diversity & structure of the local dugong population are known & comparisons made with populations from neighbouring countries to further understand the local population's movements & migration patterns, if any (Tikel, 1997)
Studies to further understand habitats & threats present in the area, with emphasis on habitats relevant to the target species	
(1) Undertake further seagrass mapping in line with global efforts (e.g. Seagrass Watch), particularly those potentially present in the areas around Pulau Sibu, where dugong & turtle sightings were concentrated, as well as other Johor islands where seagrass information is not currently available	(1) The seagrass areas around the dugong conservation area & its surroundings mapped & an inventory of seagrass diversity & biomass in those areas created to add to available information available (Affendi et al., 2005; Ooi et al., 2008, 2011b)
(2) Undertake a detailed environmental economics study on the seagrass meadows around the Johor islands & the Johor coastline	(2) Assessment of contributions of ecosystem services to human welfare and to the country's total economic value (Guerry, 2005; Tallis & Polasky, 2009; Wang et al., 2010), which in turn aids the objective of achieving enhanced conservation at the level of decision-makers (Tallis & Polasky, 2009; Fisher et al., 2011)

Actions	Actual/expected outcomes
(3) Empirical documentation of putative threats & their effects, including identifying the types & levels of fishing practices prevalent in the area	(3) Fisheries–dugong interactions better understood, including possible locations & levels of bycatch in the area (Northridge & Hofman, 1999)
(4) A marine traffic study to collect information such as types of vessels present, traffic density, frequency of vessel traffic, mean vessel speed, & routes taken	(4) Areas of possible vessel–dugong interactions identified & assessment made on how marine traffic affects the dugongs in the area (Gerrard, 1998; Hodgson & Marsh, 2007)
(5) Undertake study to assess the levels of contaminants present in the sediments & seagrasses surrounding the Johor islands	(5) Dugongs' potential exposure to contaminants through seagrass/sediment ingestion during feeding ascertained (McLachlan et al., 2001; Wetzel et al., 2012)
(6) Undertake study on body burdens of contaminants of interest in stranded dugongs	(6) Significant sublethal effects of contaminants on critical biological systems such as immune & reproductive systems assessed (Vetter et al., 2001; Marsh et al., 2011; Wetzel et al., 2012)
(7) Undertake assessment of cumulative impacts from past, current and future planned developments of nearby coastal areas on the surrounding seagrass habitats	(7) Improved understanding of how these habitats are affected by development activities. Development can affect seagrass habitats through a variety of means, which may lead to loss of these habitats & transfer of contaminants to dugongs (Duarte, 2002; Wetzel et al., 2012)
Studies on economic alternatives to promote conservation & provide alternative livelihoods	
Feasibility studies conducted to identify economic alternatives to fishing that can instill conservation values in local communities in addition to providing financial incentives. Socio-economic aspects should be incorporated into the study, such as local communities' perceptions of development, dugongs & seagrass ecosystems, traditional beliefs & knowledge & economic viability of the proposed alternatives	Implementation of alternatives that have been proven successful in other parts of the world, such as inclusion of local communities as environmental managers or monitors (Danielsen et al., 2000; Pratt et al., 2004; Mellors et al., 2008), development of locally made handicrafts featuring dugongs (Adulyanukosol et al., 2010), shifting from artisanal to pelagic fisheries (Kiszka et al., 2007), & dugong-watching tourism using watercraft (Gerrard, 1999) & static platforms (Adulyanukosol et al., 2010)