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Economic and subsistence values of the standing stocks of seagrass fisheries: Potential benefits of no-fishing marine protected area management

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1. Introduction

Despite the global importance of seagrass meadows, there is a growing evidence that they are experiencing an unprecedented level of damage, deterioration and overexploitation [1–3]. Seagrass meadows are increasingly threatened by overexploitation of their fauna, particularly within the Indo-Pacific [2,4,5]. This exploitation remains largely undocumented, but is thought to be increasing in areas of rapid human population growth [2,5,6]. Management of these habitats is increasingly a local economic and conservation priority.

For effective natural resource management decisions to be made it is often conducive to provide information to stakeholders about the status of a resource, thus enhancing local social capital [7]. Providing this information as a simple metric using concepts that people with minimal education or scientific knowledge can understand may promote continued local stakeholder support for management policies.

A monetary understanding of natural resources is useful to promote sustainable local use over the long-term. An example of the use of a simple metric would be to provide an indication of the present financial value of the resource. Local stakeholders can then make informed decisions on an immediate cost benefit basis [8,9]. This is particularly important within developing countries such as Indonesia, where the value of natural resources such as fishery standing stocks are rarely considered within government decision-making processes, which can exacerbate overexploitation and loss.

Within locally exploited subsistence fisheries, simple methods that integrate with marine monitoring programs to provide an immediate value of their current stock will allow local stakeholders to understand how the value of their standing stock is changing with time relative to management actions. This approach could allow for local recognition of the short- and longer-term financial value of the impacts of management policies such as the use of marine reserves and any resultant fish spillover. Such information is more transparent to stakeholders than reference to the biological indices commonly used to describe the status of a fishery standing stock. Whilst providing financial values of resources is important, these only remain important whilst resources are being utilised under present motivations. An understanding of resource economics must go hand-in-hand with an understanding of resource exploitation patterns for management to be effective (Cullen, 2007). These patterns will likely change with future generations, and as resources become scarcer.

Previous attempts have been made to place monetary values on the goods and services derived from seagrass meadows. The value of the world's seagrass meadows has been estimated at US $19,002 ha^{-1} yr^{-1} based on the ecosystem function of nutrient cycling [10]. Whilst seagrass shrimp fisheries in an area of Northern Queensland were estimated in 1993 to have a landed value of US $1.1 million yr^{-1} equating to US$1500 ha^{-1} yr^{-1} [11], and in the Gulf waters of South Australia seagrass supported fisheries have been valued at US$100 million yr^{-1} [12].

The use of MPAs to improve fishery yield is an increasing trend both in tropical and temperate regions [13–15]. Research has provided extensive empirical evidence demonstrating that the use of MPAs worldwide has led to increases in abundance, body size, biomass and reproductive output of exploited species [16–19]. Evidence now also describes how spillover of fish from MPAs can benefit adjacent fisheries [20,21]. Although such management strategies are widely utilised, there is little empirical data describing the economic benefits of these actions in specific cases, particularly within seagrass systems.

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This research used a combination of ecological and socioeconomic assessments to determine and describe the relative importance of seagrass meadows as a fishery ground in a national park in Indonesia. Analysis placed a minimum financial value upon the existing fishery standing stock that seagrass meadows support, were they to be fished. We subsequently utilised knowledge of spillover from other MPAs to model the effect that MPA management could have on the financial value of that standing stock through spillover and extrapolated potential values into a national context.

2. Materials and methods

This study was conducted in 2005 and 2006 on the inter-tidal to sub-tidal seagrass meadows around the Islands of Hoga and Kaledupa within the Wakatobi National Park (WNP), Indonesia (Fig. 1). The WNP is a small island group of approximately 1.39 million ha, off SE Sulawesi [22,23]. The Park is home to a culturally diverse population of approximately 80,000 people and has extensive reef and seagrass systems that are generally heavily exploited by numerous fishery activities [24,25].

2.1. Field study sites

Three field sites of varying fishing pressure were surveyed for economically important fish and invertebrates. These sites were 1) Hoga no-fishing MPA; 2) Bounty Bay, a lightly fished site (2 km from the nearest village); and 3) Sampela, a heavily fished site (Fig. 1). The heavily fished site is so defined as it is immediately adjacent to a village, allowing easy fishing and low tide gleaning access. The lightly fished site is far from any village, but remains unprotected and open to fishing activities. The Hoga MPA is an area where fishing has been prohibited since 2001 [19]. The impact of fisheries management at these sites on reef groupers has previously been discussed [19]. The MPA is a small community/NGO management strategy and covers an area of seagrass approximately 500 m × 200 m; in 2006 management of the MPA ceased. All sites were comprised of inter-tidal seagrass meadows with similar mixed floral assemblages dominated by two species, *Thalassia hemprichii* (Ehrenberg) and *Enhalus acoroides* (L.f.) Royle. These assemblages also contained minor floral coverage (total cover <5%) of *Cymodocea rotundata* (Ehrenberg and Hemprich ex Ascherson), *Halophila ovalis* (R. Brown) Hooker f., and occasionally *Halodule uninervis* (Forsskal) Ascherson.

2.2. Fishery characteristics

The WNP contains a highly exploited multi-species fishery. Fishing communities in the WNP are comprised of commercial, subsistence and recreational fishers. Fisheries are thought to be exploited above the maximum sustainable yield, with a high proportion of the catch comprised of juveniles, whilst the average size of fish caught is decreasing [26]. Many commercial and subsistence fishermen are from *Bajo* ‘sea-gypsy’ communities who are landless and live on stilted villages within the inter-tidal. The *Bajo* are largely dependent on fishing with highly limited livelihood alternatives (Cullen, 2007). Proportionally the island communities, known as the *Pulo*, contain smaller numbers of fishers, however many *Pulo* choose to fish recreationally and for food rather than purchase fish.

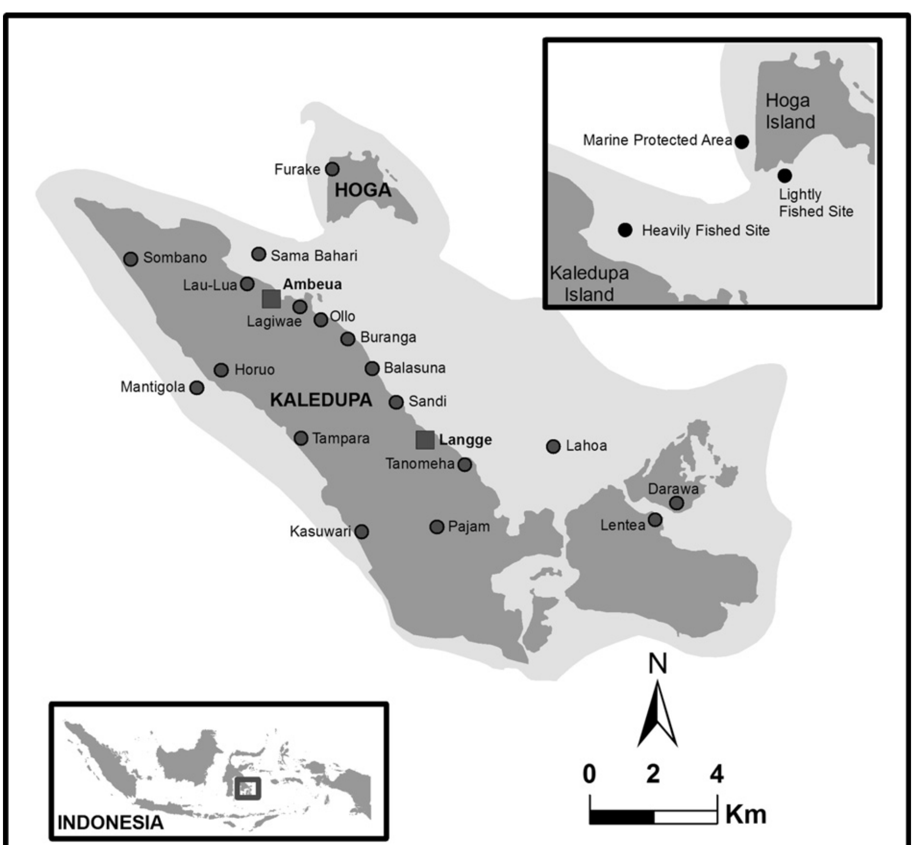

Fig. 1. Location of study sites (MPA, Lightly fished, Heavily fished) around the Island of Hoga within the Kaledupa sub-district of the Wakatobi Marine National park, SE Sulawesi, Indonesia (after Cullen, 2007).

The majority of fishers operate in small family groups, including the youngest and oldest family members either in selling, cooking or collection. As such the cost of labour is considered to be zero [27]. Most fishers utilise unpowered boats, with only the offshore pelagic fishers, of which there are few local people, using powered boats, therefore material costs can be considered to be negligible. Due to the complex nature of fisheries activities in the WNP it is not possible to provide an accurate cost estimate per kilogram of fish caught and hence this is not included in the present paper.

2.3. *Fish surveys*

Underwater visual surveys were undertaken to estimate the population of fish known locally to be of commercial value. Six 100 m × 10 m belt transects [28] were conducted at each of the three sites. Three transects were conducted near to the shore (≈10 m from the reach of the highest tide) and three were conducted 100 m seaward of the shore. All surveys were carried out at high tide close to mid-day. All locally harvested fish (for commercial and subsistence purposes) were identified to species level and their total length estimated (see Table 1). Visual size estimates were made following an underwater training exercise utilising model fish [28]. Use of equations for length/weight relationships found in *Fishbase* [29] enabled fish length data (cm) to be converted to biomass (g). Due to natural fish avoidance behaviour evident in this survey type [30]; and diel variability [31] it can be assumed that fish biomass calculated in the present study represents a minimum estimate.

2.4. *Invertebrate surveys*

Invertebrates of local economic importance (see Table 1) were recorded at low tide at night along the same six 100 m × 10 m belt transects as used for the fish surveys. Observing invertebrate fauna in dense seagrass is difficult to an untrained eye, therefore four observers were used, including a local fisherman experienced in spotting economically important fauna. All fauna within the transect area was collected, identified, recorded and released.

2.5. *Market surveys*

Market surveys were conducted between March and October 2005. Surveys included static market and wandering trader surveys to investigate fish prices at the point of sale on the local market. A pre-prepared survey sheet was used to record date, time, species, size (length, weight, width or other appropriate measurement unit), number of individuals, and price paid by the consumer. For invertebrates; species, diameter, carapace size (if appropriate), number in sale, price of sale, time of day and location of sale was recorded. Twenty surveys were carried out at random around the Ambeua market on Kaledupa (see Fig. 1).

2.6. *Household survey*

A household survey was conducted between March and October 2005 and included ten percent of all households from all villages within the Kaledupa sub-district (Fig. 1). One individual from each household was interviewed, with the head of the household targeted. This resulted in 440 interviews with respondents randomly selected from complete village lists. Interviews were developed for the purpose of income assessment, investigation of natural resource use patterns, and local levels of marine resource dependence for livelihoods (food and income). All villages in the Kaledupa sub-district were included in the survey to provide a holistic approach without bias [32]. Key-informant interviews with middlemen and market traders were used as a means of

Table 1
Species identified in the present study as having commercial importance within the Wakatobi Marine National Park Indonesia.

Commercial fish species		Commercial invertebrates species	
Balistapus undulatus (Park, 1797)	*Lutjanus ehrenbergii* (Peters, 1869)	*Achtinopyra lecanora* (Jaeger)	*Murex* sp.
Calotomus spinidens (Quoy & Gaimard, 1824).	*Parupeneus barberinoides* (Bleeker, 1852)	*Actinopyga echinites* (Jaeger)	*Portunas pelagicus* (Linnaeus)
Caragidae sp.	*Parupeneus barberinus* (Lacepède, 1801)	*Actinopyga miliaris* (Quoy and Gaimard)	*Rhinoclavis sinensis* (Gmelin, 1791)
Caranx ignobilis (Forsskål, 1775)	*Parupeneus indicus* (Shaw, 1803)	*Antrina* sp.	*Stichopus horrens* (Selenka, 1867)
Caranx melampygus (Cuvier, 1833)	*Parupeneus multifasciatus* (Quoy & Gaimard, 1824)	*Bohadschia similis* (Semper, 1868)	*Stichopus varigatus* (Semper)
Cheilinus chlorourus (Bloch, 1791)	*Scolopsis bilineatus* (Bloch, 1793)	*Bohadschia vitiensis* (Semper, 1867)	*Strombus gibberulus* (Linneaus, 1758)
Cheilinus undulatus (Rüppell, 1835)	*Rhinecanthus aculeatus* (Linnaeus, 1758)	*Cockle* sp.	*Strombus lentiginosus* (Linneaus, 1758)
Cheilio inermis (Forsskål, 1775)	*Scolopsis frenatus* (Cuvier, 1830)	*Conus mamoreus* (Linne, 1758)	*Strombus vomer* (Röding, 1798)
Choerodon anchorago (Bloch, 1791)	*Scolopsis lineatus* (Quoy & Gaimard, 1824)	*Cymbiola* sp.	*Tectus* sp.
Coris batuensis (Bleeker, 1856)	*Scolopsis monogramma* (Kuhl & Van Hasselt, 1830)	*Cypraea tigris* (Linneaus, 1758)	*Tripneustes gratilla* (Linnaeus)
Epinephelus merra (Bloch, 1793)	*Scolopsis temporalis* (Cuvier, 1830)	*Dolabella auricularia* (Lightfoot, 1786)	
Gerres filamentosus (Cuvier, 1829)	*Scolopsis trilineata* (Kner, 1868)	*Haliotis asinine* (Linnaeus)	
Halichoeres trimaculatus (Quoy and Gaimard, 1834)	*Siganus canaliculatus* (Park, 1797)	*Holothuria difficilus* (Selenka)	
Hemiramphus far (Forsskål, 1775)	*Stethojulis bandanensis* (Bleeker, 1851)	*Holothuria hilla* (Lesson, 1830)	
Labridae spp.	*Stolephorus indicus* (van Hasselt, 1823)	*Holothuria leucospilota* (Brandt, 1835)	
Leptoscarus vaigiensis (Quoy & Gaimard, 1824)	*Sufflamen chrysopterum* (Bloch & Schneider, 1801)	*Holothuria pervicax* (Selenka)	
Lethrinus amboinensis (Bleeker, 1854)	Trachinotidae sp.	*Holothuria rigida* (Selenka, 1867)	
Lethrinus genivittatus (Valenciennes, 1830)	*Upeneus arge* (Jordan & Evermann, 1903)	*Holothuria scabra* (Jaeger, 1833)	
Lethrinus harak (Forsskål, 1775)	*Upeneus moluccensis* (Bleeker, 1855)	*lambis lambis* (Linneaus, 1758)	
Lethrinus variegates (Valenciennes, 1830)	*Upeneus vittatus* (Forsskål, 1775)	*Malleus malleus* (Linneaus, 1758)	

verification for some of the monetary and species use data gathered in the market surveys and the household surveys, 20 key-informant interviews were also conducted.

2.7. Data analysis

Mean and standard errors of ecological data are presented. One-way analysis of variance (ANOVA) in MiniTab™ v13 allowed differences between sites to be examined. To convert ecological survey data into economic values per hectare for harvested fish and invertebrate species, market values (per individual or per kilogram) were used. A similar methodology of extrapolating fisheries or ecological data into monetary terms has been used in other reef and seagrass studies [11,16,33]. Invertebrate species were generally bought and sold by abundance (irrespective of size) rather than weight; therefore values per individual were used to calculate total harvested invertebrate value. Values included in the analysis were based on current market values representing the price at the time of the survey. It is therefore important to consider that such values are a product of the market place and processes of supply and demand. Calculated values may vary according to factors such as seasonality therefore represent an estimate appropriate for spatial comparison.

In order to model the hypothetical yet potential fish spillover from the MPA we used data from the Philippines determined for a similar seagrass and fringing reef environment close to a small island [21]. We used this relationship as a proxy for estimating value. Mathematical integration of this equation allowed for the calculation of a total value for the potential spillover from each side of the MPA. Robust data on marine reserve spillover is scant [34,35]. The use of the findings from the Philippines [21] provides an opportunity to demonstrate what the spillover benefits have the potential to achieve.

3. Results

Seagrass meadows were the preferred collection ground for 60% of invertebrate collectors and were the most popular fish collection ground for fishers and gleaners (40% of collectors) (Fig. 2). Exclusive coral reef fishing was conducted by 20% of both invertebrate and fish collectors (Fig. 2). Some collectors utilised both seagrass and reef habitats as many fishing methods (e.g. fish fences) exploit the tidal and diel movements of fish and some invertebrates between adjacent habitat types, whilst low tide gleaners access the reef only at extreme low tides. Approximately 70% of households preferentially consumed fish that came from seagrass habitats; this was in contrast to around 20% who preferentially consumed reef fish (Fig. 3).

Fish abundance across the three sites averaged 1070.2 ± 454.9 fish ha^{-1}, the large standard error illustrates that there was high variation between the three sites. The Marine Protected Area (MPA) had significantly more fish ($F_{2,17} = 1.9$, $p < 0.05$) than the other two sites (Table 2) with around a ten-fold increase in the number of fish compared with the heavily fished site, and approximately three times higher fish abundance than the lightly fished site. Due to a higher proportion of mature fish recorded within the MPA, these abundance figures translate into even greater disparity when considering fish standing stocks (tons ha^{-1}) between sites (Table 2) ($F_{2,17} = 5.0$, $p < 0.001$). The MPA had approximately 50 times the standing stock of the heavily fished site, and 45 times that of the lightly fished site. Fish species richness was also significantly greater in the MPA ($F_{2,17} = 22.3$, $p < 0.001$) than in the other sites (Table 2). These elevated fish stocks support findings from coral reefs within the vicinity of the study sites [19,36].

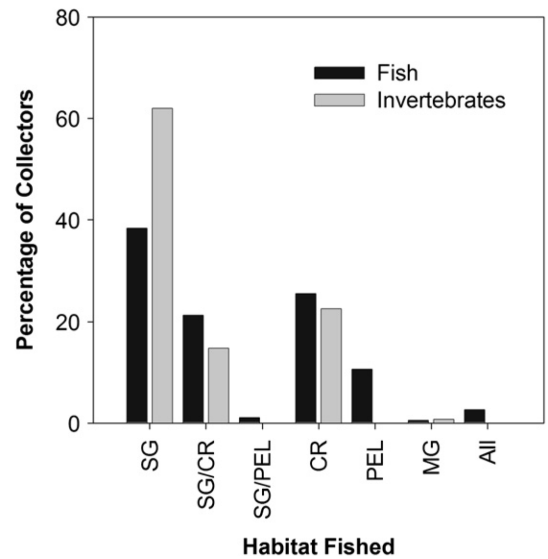

Fig. 2. Percentage of invertebrate and fish collectors (fishermen and subsistence collectors/fishers) that used each marine habitat type as their major collection ground in the Kaledupa sub-district of the Wakatobi Marine National Park, Indonesia (SG = seagrass, CR = reef, MG = mangrove, PEL = pelagic).

In contrast to the fish stocks, the abundance of harvested invertebrates was significantly higher at the heavily fished site ($F_{2,17} = 22.3$, $p < 0.001$) than at the other two sites by 3.4–5.8 times. Invertebrate richness was also significantly higher at the heavily fished site ($F_{2,17} = 3.0$, $p < 0.05$). Lowest invertebrate abundance was within the MPA.

The transformation of fish and invertebrate standing stocks into financial values demonstrates that seagrass meadows within the northern area of the WNP (across all three sites) have a minimum estimated value of US$ 97.5 ± 41.4 ha^{-1} (Table 3). As less than 0.01% of the WNP receives MPA status, the mean value of those seagrass meadows under no protection (heavily and lightly fished sites) is US$ 77.9 ± 40.4 ha^{-1}. Within the MPA, fish contributed the majority

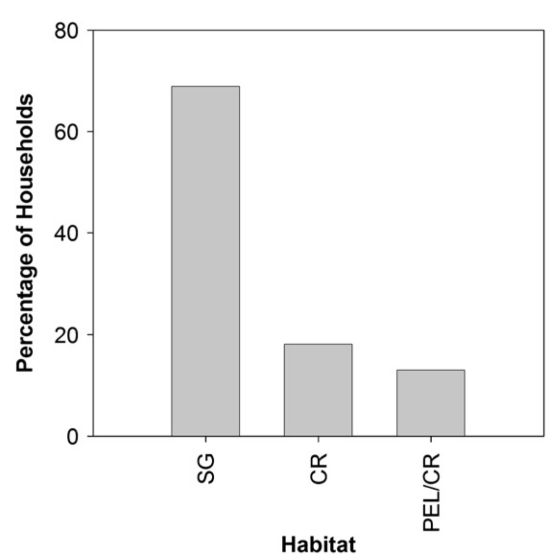

Fig. 3. Percentage of households within the Kaledupa sub-district of the Wakatobi Marine National Park, Indonesia preferentially consuming food from each marine habitat type (SG = seagrass, CR = reef, PEL = pelagic).

Table 2
Summary statistics (Mean ± SE) for ecological surveys of harvested seagrass fish and invertebrate standing stocks (those species known to have commercial or subsistence harvesting importance) at three sites (MPA (MP), Lightly fished (LF), Heavily fished (HF)) in the Kaledupa sub-district of the Wakatobi Marine National Park Indonesia. Statistical differences following inter-site one-way ANOVA analysis are presented as the ANOVA pair-wise statistical differences following tukey's post-hoc analysis. The pair-wise comparisons listed were statistically different at the 95% level ($P < 0.05$).

Site location	MPA	Lightly fished	Heavily fished	All sites	*P*-value	Pair-wise differences
Harvested fish abundance (No ha^{-1})	4075 ± 1070.2	1666.3 ± 872.7	511.7 ± 417.2	1070.2 ± 454.9	$P < 0.05$	MP to HF
Harvested fish richness (No species.1000 m^2)	14.5 ± 1.1	12.0 ± 2.8	3.5 ± 0.5	8.4 ± 1.3	$P < 0.001$	LF to HF MP to HF
Harvested fish standing stock (metric tons ha^{-1})	0.22 ± 0.06	0.004 ± 0.001	0.004 ± 0.002	0.06 ± 0.04	$P < 0.001$	MP to all sites
Harvested invertebrate abundance (No ha^{-1})	230 ± 56.3	390 ± 72.2	1340 ± 237.4	565.8 ± 112.3	$P < 0.001$	HF to all sites
Harvested invertebrate richness (No species.500 m^{-2})	5.3 ± 0.8	7.3 ± 0.9	9.3 ± 1.1	7.2 ± 0.5	$P < 0.05$	MP to HF

of this value, whereas in fished areas invertebrates contributed most value (Table 3).

The MPA had significantly higher value than the other sites ($F_{2,17} = 10.6$, $p < 0.001$) at US$ 136.7 ± 43.2 ha^{-1}, this is 66% higher than the value of the heavily fished site (Table 3). The lightly fished site had a value of US$ 109.1 ± 63.3 ha^{-1}. Values of the fish standing stocks varied significantly between sites ($F_{2,17} = 3.3483$, $p < 0.001$), but no significant difference was found between sites for the values of the invertebrate standing stocks.

Ten species accounted for 98.2% of the value of the fish standing stock, the most valuable of these was *Lethrinus harak* with a standing stock value across all sites estimated at US$ 18.4 ± 5.0 ha^{-1}. The high standard error highlights that the value of this species reached US$ 63.6 ± 25.1 ha^{-1} in the MPA and dropped to US$ 0.1 ± 0.1 ha^{-1} at the heavily fished site. The ten most valuable invertebrates represent 92% of the total value of the invertebrate standing stock, the most valuable of these is the sea cucumber *Holothuria scabra*, which is valued at US$ 20 ± 14 ha^{-1}.

Indonesia is estimated to comprise at least three million hectares of seagrass meadows (Kuriandewa et al., 2003). Extrapolation of values for unmanaged (mean of the heavily and lightly fished sites) seagrass meadows in WNP (US$ 77.9 ± 40.4 ha^{-1}) to a national Indonesian context reveals Indonesian seagrass fisheries to be worth a minimum of approximately US$230 million. This value equates to 0.06% of the value of Indonesia's proven oil reserves and 0.02% of its GDP [37].

Modelling of the spillover from Apo Island, Central Philippines [21] applied to WNP data provides a relationship of the value of the standing stock with distance from the MPA ($Y = 0.0002x^2 - 0.2567x + 98.394$, where Y = Monetary Value (US$) and X = Distance (m) away from the MPA) (Fig. 4). In order to utilise this relationship to estimate the value of any potential spillover from the WNP MPA, a value for each hectare surrounding the MPA was calculated on both sides of the reserve (see inset diagram within Fig. 4). The value of each hectare was determined based on the mid point of each hectare (e.g., the first hectares used 50 m, the second used 150 m etc) and the total value of these hectares to a maximum of 800 m from the MPA was determined for each side of the MPA. The potential benefit to the fishery at each side of the MPA is therefore estimated to be ≈US$611 (or US$38 ha^{-1} over 16 ha), resulting in a total benefit of ≈US$1222 to the local seagrass fishery (or US$38 ha^{-1} over 32 ha).

4. Discussion

This study provides the first direct assessment of the estimated potential financial value of the standing stock of a seagrass system, and suggests that with minimal protection the direct financial value of seagrass standing stock could triple from one under no protection. We provide an indication of the existing potential financial values of the current status of the seagrass fishery that can be reassessed temporally, and provide transparent information about the effectiveness of management policies. MPAs are often applauded for their ability to increase the biomass, diversity and abundance of fish assemblages [13,19,38], but this is the first study we are aware of to place these benefits into a direct financial context. Strategic fisheries management is urgently required to halt the declining fisheries of many areas of the Indo-Pacific, this is particularly the case within the Wakatobi National Park (WNP) [19,39,40]. The consideration of local socioeconomic factors and the development of locally appropriate adaptive regulations are essential if the capacity of natural resource management regimes to conserve resources is to be improved [15]. In the case of the WNP, small MPAs may be acceptable to local, culturally diverse fishers and stakeholder committees.

Designation of MPAs should consider associated social and economic impacts to ensure that they do not exceed the ability of resource-users to adapt, and hence resource protection be maximised through high compliance rates [41]. MPA development can also benefit from an adaptive progression that integrates changing fishers' practices and requirements [42–44].

The financial value of an MPA, although important in representing its standing stock, remains effectively zero to its local stakeholders unless that MPA has spillover and can have a positive financial benefit on adjacent fisheries. Our predicted financial benefits of spillover from an MPA to adjacent seagrass fisheries of ≈US$1222 (or US$38 ha^{-1} over 32 ha) is high when placed into the context of the mean local WNP fisher annual income of US$ 701 ± 177 [24], and is particularly important given the limited current use of no-take MPA management within the locality. If such

Table 3
Direct financial value (Mean ± SE) of harvested fish and invertebrate standing stocks (those species known to have commercial or subsistence harvesting importance) within seagrass beds at three sites (MPA, Lightly fished, Heavily fished) within the Kaledupa sub-district of the Wakatobi Marine National Park, Indonesia calculated from the extrapolation of current financial value data recorded in local markets to current *in situ* populations estimated from ecological census techniques. Unmanaged sites refer to the mean of the heavily and lightly fished sites.

	Units	MPA	Lightly fished	Heavily fished	All sites	Unmanaged sites
Harvested invertebrates	US$ ha^{-1}	23.5 ± 11.6	86.8 ± 53.5	44.8 ± 16.8	51.7 ± 27.3	65.8 ± 35.1
Harvested fish	US$ ha^{-1}	113.1 ± 31.6	22.2 ± 9.8	1.9 ± 0.7	45.8 ± 14.1	12.1 ± 5.3
Total (all species)	US$ ha^{-1}	136.7 ± 43.2	109.1 ± 63.3	46.7 ± 17.5	97.5 ± 41.4	77.9 ± 40.4

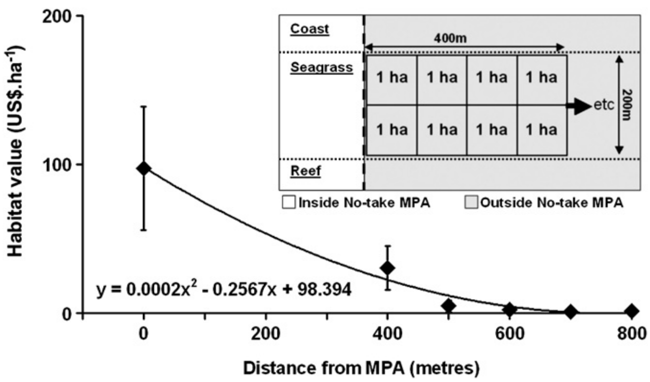

Fig. 4. Hypothetical model of spillover from the Hoga MPA. This was developed from a relationship between fish biomass and area (ha) from the MPA (solid line) (derived with data from Russ et al., 2003). Inset diagram illustrates the use of this relationship to calculate the hypothetical value of potential spillover.

findings were presented to stakeholders, MPAs as a resource management strategy may have a greater chance of success. Financial benefits could also result in improved incomes for local fishers struggling to assure their livelihoods.

This study also outlines the importance of seagrass meadows to Indonesia. Such estimates of value can be important at a government level in terms of planning and justifying future spending on fisheries and conservation as a proportion of the economy. The scale of these values in terms of GDP highlights that governments of many nations could be vastly under estimating the direct financial value of seagrass resources due to the limited national level conservation management currently provided to these habitats around the world [3]. Values calculated in the WNP are estimates, and may actually be an underestimation, as in many areas where large commercial seagrass shrimp fisheries are present (e.g. Aru Islands, Moluccas [45]) or where seagrass has remained unexploited, this value per hectare could be much higher. Additionally, seagrasses have many other values not considered here such as nursery ground function, carbon sequestration, coastal defence and nutrient cycling. We recognise that seagrass meadows in many areas are highly exploited, however, in our example, the value of a heavily fished site extrapolated to a national scale equates to a value of US$140 million (0.01% of GDP).

The values for the fisheries standing stocks quantified within the present study represent the current supply and demand. Processes such as ‘seasonality’ and ‘ability to catch stock’ are likely to affect these values. Economic theory dictates that should the fish stock collapse then market values will rise as supply decreases, resulting in a positive impact upon the value of individuals in the depleted stock. However, should stocks collapse in the WNP and prices rise it is likely that the number of fishers operating would increase to ‘chase-the-last-fish’ and utilise previously unexploited species. For example, in Indonesia during the financial collapse of the 1990s, many people returned to subsistence fishing due to its virtual zero cost [46]. Experience within the WNP (pers obs.) has shown that the total local collapse of individual species fisheries such as nearshore tuna, lobster and beche-de-mer has not resulted in price increases but instead in fishers exploiting new species within other habitats and within other trophic levels of the food web. This suggests that although the values calculated within the present study would be subject to seasonality and weather, they are likely realistic in the short-term with regards to the economic consequences of overexploitation. However, if the present values are considered in terms of total local fisheries collapse, the value of the fish stock should be higher based on the concept of a replacement value [47], such values are not considered in the present research.

This study adds to the evidence of the fisheries benefits of using MPAs for the protection of seagrass habitats [48]. By protecting seagrass fish assemblages, MPAs provide an additional role in protecting coral reef fish through the high connectivity that exists between seagrass meadows and nearby coral reefs [49,50]. Fish abundance, species richness and biomass were all found to be higher in the seagrass MPA than in the adjacent lightly fished and heavily fished areas, indicating that the refugia status of the MPA supports increased abundance and fish maturation.

Invertebrate gleaning within seagrass meadows is a significant fishery in the WNP, and therefore an important source of protein locally [24]. Standing stocks supporting gleaning are potentially high in value, however we present evidence that these fisheries are not benefiting from MPA protection. The reasons for this are not clear and require further investigation; however invertebrate fisheries have previously been found to remain unaltered by MPA protection in other locations and this may reflect processes in reproduction, development or population dynamics [51]. Excess sewage-based nutrient enrichment from the adjacent village could be an important factor in increasing the productivity of algal and detritus feeding invertebrates at the heavily fished site.

Direct financial values provide a useful measure and a directly applicable management tool that will be understood and regarded as important locally, nationally and internationally. However, some financial values will not highlight the importance of low market value species as subsistence foods that provide essential protein for local people. Additionally, many people in the WNP never purchase fish; being financially unable or preferring either to catch their own or eat excess catch from friends or family. In addition, many people who have relatively high incomes and do not need to fish, choose to fish in a recreational and often subsistence fashion.

The reliance of the majority of fishers in the present study on seagrass meadows, rather than coral reefs as a fishing ground in a tropical coastal environment, contradicts the emphasis of management, monitoring and conservation efforts placed primarily on coral reef habitats. Biodiversity and conservation measures often give only secondary consideration to seagrass habitats. This is despite evidence from many tropical regions that finds seagrass meadows to be an important subsistence fishery ground [2,5,52]. This is an important consideration in future management of these ecosystems; but managers should also consider the importance of seagrass meadows in light of the growing body of evidence for seagrass meadows as fish nursery and feeding grounds on a daily or ontogenetic basis [49,50]. As a result of processes of connectivity, unsustainable fishing practices within seagrass meadows may also severely impact upon adjacent coral reef fish assemblages [50,53].

In conclusion we find seagrass meadows in a small tropical island community to be of a high subsistence and financial value to local fishers. We also find the national seagrass resource may be vastly under estimated in relation to the limited national level conservation management currently afforded seagrass habitats. This research demonstrates for the first time the potential financial benefits of a small MPA on the value of a fishery standing stock and the financial implications of MPA spillover.

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