



## The economic contribution of the muck dive industry to tourism in Southeast Asia



Maarten De Brauwer<sup>a,\*</sup>, Euan S. Harvey<sup>a</sup>, Jennifer L. McIlwain<sup>a</sup>, Jean-Paul A. Hobbs<sup>a</sup>, Jamaluddin Jompa<sup>b</sup>, Michael Burton<sup>c</sup>

<sup>a</sup> Department of Environment and Agriculture, Curtin University, Perth, Australia

<sup>b</sup> Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar, Indonesia

<sup>c</sup> School of Agricultural and Resource Economics, University of Western Australia, Perth, Australia

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### ABSTRACT

Scuba diving tourism has the potential to be a sustainable source of income for developing countries. Around the world, tourists pay significant amounts of money to see coral reefs or iconic, large animals such as sharks and manta rays. Scuba diving tourism is broadening and becoming increasingly popular, a novel type of scuba diving which little is known about, is muck diving. Muck diving focuses on finding rare, cryptic species that are seldom seen on coral reefs. This study investigates the value of muck diving, its participant and employee demographics and potential threats to the industry. Results indicate that muck dive tourism is worth more than USD\$ 150 million annually in Indonesia and the Philippines combined. It employs over 2200 people and attracts more than 100,000 divers per year. Divers participating in muck dive tourism are experienced, well-educated, have high incomes, and are willing to pay for the protection of species crucial to the industry. Overcrowding of dive sites, pollution and conflicts with fishermen are reported as potential threats to the industry, but limited knowledge on these impacts warrants further research. This study shows that muck dive tourism is a sustainable form of nature based tourism in developing countries, particularly in areas where little or no potential for traditional coral reef scuba diving exists.

### 1. Introduction

Nature-based experiences are an integral part of many tourism activities with participation gaining popularity, especially in developing countries [5]. Recent estimates of the global revenue created by nature-based visits to wildlife protection areas is as high as USD \$6 billion per year [6]. If managed correctly, nature-based tourism can lead to increased local incomes and improved standards of living, and decreased dependence on less sustainable livelihoods such as fishing [27,50]. In contrast, poor management can lead to conflict between resource users, severe habitat degradation, and leakage of revenue out of the local area [22,48,51]. These challenges highlight the need for a clear understanding of specific drivers of nature-based tourism to enable the development of efficient local management plans.

Participation in nature-based tourism can range from the occasional standardized daytrip during a larger, more general holiday, to entirely customised holidays, focused solely on the nature experience [2]. Nature-based holidays are considered to be a broad tourism niche, which can be divided into multiple narrower categories [37,40]. One such narrow niche is specialist animal watching with bird watching a

classic example, and one that has been steadily increasing in popularity for two decades [13,40]. While fewer visitors participate in niche tourism compared to more general tourism, its specialised attractions appeal to higher spending participants and it has repeatedly been shown to have a high economic value to the local community [37]. In Point Pelee, a small national park in Canada, expenditure on bird watching can be as high as USD\$5.4 million annually while in Costa Rica, 41% of the total tourism income is estimated to come from bird watchers, a value close to USD\$400 million per year [25,41]. Demographically, tourists participating in bird watching tend to be middle aged, have relatively high incomes and are well educated [13,25].

While research interest in nature-based tourism has focused primarily on the terrestrial environment, a number of recent studies have investigated the value of nature-based marine tourism [10,38,39,50]. When practiced in a sustainable manner, marine tourism offers an alternative income for fishing communities while simultaneously increasing conservation awareness for the local population and tourists visiting the region [9,47,50]. Scuba diving in particular has been shown to be a valuable segment of marine tourism with estimates for Southeast Asia alone as high as USD\$4.5 billion per year [39]. An examination of

\* Corresponding author.

species-specific scuba diving reveals the annual global value of diving or snorkelling with manta rays, for example, is approximately USD\$73 million [38] and for sharks between USD\$5.4 million to USD\$18 million per year, depending on the location and shark species [12,29,47].

Studies that have quantified the valuation of scuba diving mostly focus on regions with coral reefs, or on iconic megafauna such as sharks or whales [10,38,47]. Interactions with these species and ecosystems are mostly standardised package tourism and previous studies often do not account for other segments of the scuba diving market [2,20]. When placing a value on diving in tropical destinations these same studies assume diving activities only happen on or near coral reefs. As the dive industry matures, however, other types of diving in adjacent systems are being explored [15,26]. Inexperienced divers generally visit tropical destinations for a typical coral reef experience, but more experienced divers are often attracted to novel and specialised experiences [11,15,49].

One such novel and yet-unstudied sector in scuba diving tourism is the so-called “Muck diving” (sometimes also called “Critter diving” or “Macro diving”) [31]. Muck diving has previously been defined as “diving in mostly gravel and mud areas with little or no coral reef or rocky outcrops” [31] (Fig. 1). Often sites will also feature man-made or natural debris, such as rotting vegetation [33], and may be at sites that are adjacent to coral reefs. Understanding what drives this sector requires determining why tourists choose to dive in these less attractive and previously avoided habitats. Muck diving is in many ways the marine equivalent of bird watching, in that it offers a unique opportunity to observe or photograph unusual, rare, or cryptic species that are not usually encountered on coral reefs. The key motivation of muck diving is locating rare species, with greater customer satisfaction recorded when this goal is achieved [32]. The species of interest are not limited to fishes (e.g. frogfishes, seahorses), but also include molluscs (octopuses, nudibranchs, etc.) and other invertebrates (e.g. harlequin shrimp, bobbit worms).

As with birdwatching, muck diving relies heavily on tourists observing and often photographing cryptic and rare species. The failure to see the animals of interest affects the number of tourists visiting a location, and therefore the incomes of communities dependent on them [49]. The species important to this type of diving are often rare and data deficient resulting in researchers having little awareness of their population size, distributions, critical habitats or conservation status. Due to this lack of information it is difficult to assess whether threats exists that could affect the abundance and distribution of these species, and the tourism industry that relies on them. Destructive uses of the environment where these species occur, such as trawling, mining, or fishing for the marine aquarium trade could have a significant impact, but data is lacking.



Fig. 1. A typical muck diving scene: a sandy bottom with few defining features. In the foreground an Estuary seahorse (*Hippocampus kuda*) holding on to algae (Photo by Dragos Dumitrescu).

While muck diving is practiced globally, the name originated in Milne Bay, Papua New Guinea [42] and it is currently most practiced in Southeast Asia [31]. Indonesia is one of the most important dive destinations in the world [23,51], but the importance of muck diving compared to general types of scuba diving is unknown. At present, the world's most popular muck diving sites are in Indonesia and Philippines, often in locations where other tourism activities are limited. Consequently, muck diving might provide a substantial alternative income for communities that otherwise depend on subsistence fishing or other extractive uses of the marine environment [21].

Since muck dive tourism is mostly practiced in developing countries, often in areas with limited alternative forms of income, there is a need to define the characteristics of the industry and quantify the value of this type of niche tourism. If muck diving is the marine equivalent of bird watching, it is to be expected that substantially larger revenues will be generated. To evaluate the sustainability of the muck diving industry, it is imperative to determine whether the money spent by dive tourists benefits the local population. Due to the heavy dependence on rare species and the lack of data on their conservation status, it is equally important to define which potential threats exist for the industry. This study has four goals:

1. Describe the demographics and attitudes of divers participating in muck dive tourism.
2. Identify the value of muck dive tourism in Indonesia and Philippines.
3. Describe the demographics and earnings of those employed (dive guides) in muck dive tourism.
4. Describe the main perceived threats to muck dive tourism.

## 2. Methods

### 2.1. Muck diving

For the purpose of this study, “Muck diving” is defined as: Scuba diving in soft sediment habitats with limited landscape features, with the explicit goal to observe or photograph rare, unusual, or cryptic species that are seldom seen on coral reefs. Taking photographs of these rare species is what makes muck diving especially popular with underwater photographers. While Southeast Asia is the region best known for muck diving it is frequently practiced in other regions, albeit without the same intensity [33].

### 2.2. Study area

The areas surveyed for this study are three of the most popular muck dive destinations in Southeast Asia. Two locations were surveyed in Indonesia and one was surveyed in the Philippines (Fig. 2).

#### 2.2.1. Indonesia

**2.2.1.1. North Bali.** Bali is Indonesia's most popular tourist destination, it was visited by more than 4 million people in 2015 [4]. The majority of visiting tourists remain in the south and centre of the island, but the north-east coast of Bali is a popular destination for scuba divers. The area with the best established scuba dive infrastructure is based around the village Tulamben (8° 15' S, 115° 36' E). The population of Tulamben mostly relies on subsistence fishing or tourism for their incomes. Dive tourism in Tulamben has long since been established around the site of the *USAT Liberty*-shipwreck, but in recent years, new dive centres have been built that specialise in muck diving on the nearby black sand slopes. In the high season the popular shipwreck-site can receive up to 300 divers per day (pers. comm. with local authorities). There are an estimated 14 dive centres and resorts in Tulamben, with an additional 40 in nearby villages. The area is also visited by operators from the south which organise daytrips to the wreck.

Unlike the south of Bali, the Tulamben area has few tourist

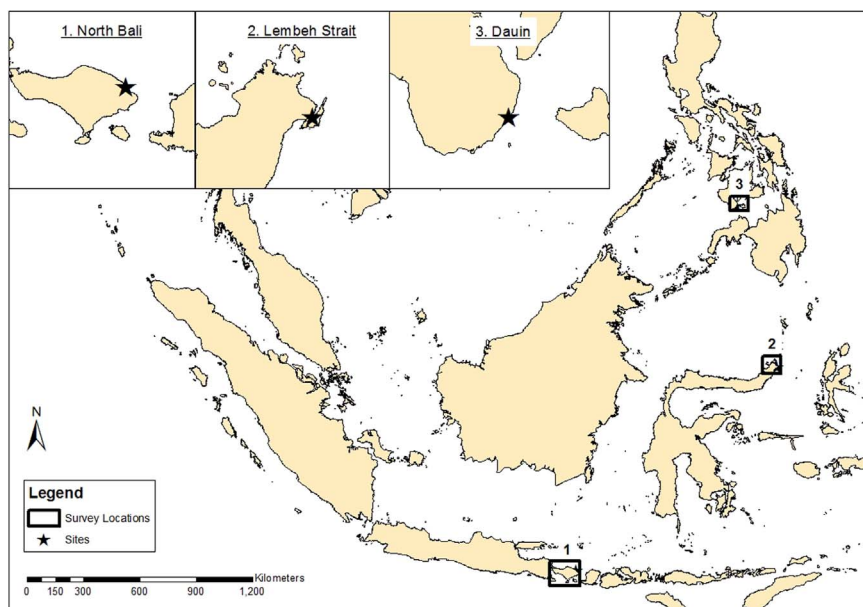


Fig. 2. Map of surveyed locations across Southeast Asia.

attractions other than scuba diving. Other popular dive destinations around Bali are Menjangan Island in the west of Bali and Nusa Penida, an island situated a short boat ride east of Bali. These locations predominantly offer coral reef diving and limited muck dive opportunities.

**2.2.1.2. Lembeh strait.** Lembeh is an island in North-Sulawesi, opposite the port town of Bitung with a population of 190,000 (1° 27' N, 125° 13' E). The strait between Lembeh Island and the main land is a busy shipping lane, but has also been widely considered an important muck dive location for more than fifteen years [14]. On Lembeh Island, there are multiple small villages, each with less than 1000 inhabitants. These villages are largely dependent on subsistence fishing and limited agriculture.

There are six dive resorts on Lembeh Island and seven dive resorts on the North-Sulawesi side of the Strait. While dive tourism has been established in Lembeh Strait for more than twenty years, there has been a substantial increase in the last six years, with new resorts and dive centres built each year. Lembeh Strait also receives divers from dive centres and resorts from nearby locations such as Bangka Island and Manado.

The North-Sulawesi region has two other main dive destinations: Bunaken National Park and Bangka Island. Both of these locations are coral reef dive destinations, unlike Lembeh Strait, which is known only for its muck diving. Other tourism activities in the region include visiting the Tangkoko National Park (rainforest), forest hikes, and cultural visits to local markets.

## 2.2.2. Philippines

**2.2.2.1. Dauin.** Dauin is a small village in Negros Oriental province, 20 km south of the province capital city Dumaguete (9° 11' 19" N, 123° 16' 10" E). The village has a population of 25,000 people which rely on fishing, agriculture and tourism for their income. Dive tourism in Dauin was originally focused on the coral reefs of nearby Apo Island, one of Philippines oldest and best known marine protected areas. In the last decade diving focus has increasingly shifted to muck diving off the beaches in Dauin, although daytrips to Apo Island are still frequently organised by all dive operators. Tourism in the area is increasing, and plans for the construction of a new international airport have recently been approved. As of late 2015 there were 16 dive centres and resorts operating in Dauin, with an estimated 10 additional operators in Dumaguete and nearby villages. New dive centres and resorts were being built at the time, so this number is likely to increase in the future.

Scuba diving and snorkelling are the main tourist activities in the Dauin region, though there are options for forest hikes, visits to waterfalls and cultural visits to local markets. Other scuba dive destinations are more than a day's travel away, but include coral reef locations such as Bohol, Malapascua and Cabilao.

## 2.3. Surveys

To determine the value of muck dive tourism, surveys were conducted between May 2015 and November 2015. The surveys consisted of three different questionnaires each designed for specific stakeholders: dive centre operators, dive guides and divers (questionnaires included in [Supplementary Materials](#)). A pilot survey was conducted with 19 divers in March 2015 to ensure adequacy of the questions, but data were not used in the analysis. Surveys were based on Vianna et al. [47] and adapted following the pilot study to ensure the goals of this study were addressed. Based on the pilot surveys, questions regarding expenditure and motivations for visiting dive locations were adjusted for clarity. The final surveys were distributed to dive centres and resorts considered representative of the industry. Sampled dive centres included both big and small businesses, locally owned and foreign owned businesses, low cost and high end businesses.

### 2.3.1. Divers

Self-administered, written questionnaires (in [Supplementary Materials](#)) for divers were distributed by the staff of 15 dive centres, and collected afterwards by the author (MDB). Guidelines for completing the questionnaires were provided with the questionnaire form. These guidelines included the goals of the study, author contact details and ethics information. Diver questionnaires were available in English, Chinese (Mandarin) and Japanese.

Diver questionnaires asked information about an individual's demographic, dive experience, motivation to visit the location, expenditure, and willingness to pay for environmental protection.

### 2.3.2. Dive guides

Staff surveys were distributed (by MDB) at 15 dive centres and collected a week after distribution. Written dive guide questionnaires were in English only, but explanations were provided to staff upon distributing questionnaire forms. Questions for dive guides focused on demographics, income and personal opinions about tourism in their region.

**Table 1**  
Education level, diver certification level and origin of scuba divers visiting muck dive locations. All values rounded to nearest whole number (N = 100).

Variable	Dauin	Lembeh	Bali	All
<b>Education Level</b>				
Secondary education	35%	8%	0%	15%
Technical / Vocational Training	12%	5%	0%	6.25%
Bachelor	27%	34%	50%	33%
Master	15%	39%	17%	31%
PhD	12%	14%	33%	15%
<b>Diver Certification Level</b>				
Open Water Diver	32%	20%	17%	23%
Advanced open Water Diver	36%	43%	17%	39%
Rescue Diver	14%	9%	0%	10%
Divemaster	4%	14%	0%	10%
Instructor	11%	9%	50%	12%
Not answered	4%	5%	17%	5%
<b>Origin</b>				
Europe	61%	47%	33%	50%
North-America	29%	30%	50%	31%
Asia	11%	9%	17%	10%
Australia	0%	9%	0%	6%
Africa	0%	3%	0%	2%
South-America	0%	2%	0%	1%

Wages of dive guides (obtained from questionnaires) were compared with local minimum wages using government data published online [36,44]. If monetary values were not provided in USD in surveys, currencies were converted to USD using the exchange rate [52] at the time surveys were collected.

2.3.3. Dive centre operators

Questionnaires for dive operators were done face to face with the managers of 16 dive centres. Interviews with dive centre operators included questions about visitor and staff numbers, strengths and threats to local dive tourism, prices charged, and costs and incomes of running the operation. For eight interviewed operators, completed surveys were returned by email. An additional email was sent to muck dive operators across Indonesia and Philippines that were not interviewed face to face. Thirty-eight additional operators were located after an internet search for dive centres in the following muck dive destinations: Ambon and Alor in Indonesia and Anilao in Philippines (Table in Supplementary Materials). This email asked three targeted questions concerning visitor numbers, staff numbers and the percentage of guests visiting primarily for muck diving. This data allowed for comparisons with the more in-depth surveys in the three focal locations. While attempts were made to survey dive operators who specialise on the Asian market segment, collecting data at any of these dive centres did not succeed.

All surveys were approved by the Curtin University Ethics Committee (RDSE-06–15) and followed the requirements of the Australian National Statement on Ethical Conduct in Human Research.

2.4. Estimating revenue

Financial revenue was used as an estimate for the value of muck dive tourism in Indonesia and Philippines [47]. The revenue (R) created by tourists visiting muck dive centres was calculated using the formula:

$$R = \left[ \sum_{i=1}^n V_i \times E \times P_m \right] \times \frac{Nm}{n}$$

- R = Revenue (rounded to nearest USD\$1000)
- $V_i$  = Total number of visitors at dive centre  $i$
- E = Average expenditure per visitor
- $P_m$  = Proportion visitors visiting with muck diving as main motivation
- $n$  = Number of dive centres sampled

$Nm$  = Total number of muck dive centres in Indonesia and Philippines as found in internet search

Costs of airfares were not included in the calculation, since these revenues created by muck dive tourism do not return to local communities. For the same reason the costs of equipment such as underwater cameras or scuba dive gear were not included in the estimate of expenditure. As these costs are considerable, the amount spent on camera equipment is provided separately from revenue.

The value for R is predicted to be an underestimate of the real value of muck diving in Indonesia and Philippines, as the following assumptions were made which are conservative by nature:

1. Our internet search for dive centres specialising in muck diving ( $Nm$ ) only showed those dive centres with an online presence. Dive centres without websites are therefore not represented in our results. Some local operators do not have an online presence, but rely on walk-in guests or word of mouth advertising, therefore  $Nm$  is very likely to be an underestimation.
2. The number of muck dive centres ( $Nm$ ) included only dive centres that specialise in muck diving and did not include the many dive centres that are more “general” dive operators. These dive centres usually offer muck dives in addition to normal coral reef dives, and as a consequence still gain income from the muck dives they organise.
3. Exclusive, remote locations such as Ambon or Alor in Indonesia are up and coming muck dive destinations which are generally more expensive than the locations surveyed in this study. Our value for the average expenditure per diver ( $E_i$ ) is likely to be an underestimate as it does not include data from these high-end locations

3. Results

3.1. Diver demographics and attitudes

One hundred diver surveys were collected. Diver questionnaires distributed in muck dive centres in Indonesia and Philippines revealed the average age of muck divers was 45.9 years (SE ± 4.6 years) old. An estimated 58.1% of respondents were male and 41.9% female. Approximately 79.2% of visitors held a university degree (Table 1) and the mean yearly income of respondents was USD\$88,514 (SE ± USD \$5592).

Divers visiting muck dive sites were experienced divers, with 71.7% holding a certification beyond entry level and 22.2% a professional dive certification (equivalent to Instructor or Divemaster). On average, visiting divers had conducted a total of 587 dives (SE ± 84 dives) in their life and 58 dives (SE ± 6 dives) during the previous year. A third of respondents were returning visitors to the location they were currently diving, though this varied strongly between sites (17.9% in Dauin, 33.9% in Lembeh, 100% in Bali). The majority of divers (73.5%) used some kind of underwater camera, with 41.5% of the cameras being the more expensive dSLR type. The average price of an underwater cameras used was USD\$4296 (SE ± USD\$517.2).

Respondents came from 21 countries, of which half were European and an additional 30.6% North-American (Table 1). Asian divers made up 10% of visitor numbers, though this number might in reality be much higher and reflect our inability to sample those dive centres focusing on the Asian market.

Muck diving is an important drawback to the regions that were surveyed, with 53.1% of visitors indicating they would not have visited if there was no muck diving available. This was even higher in Lembeh, where 74.2% of divers visited only because of muck diving. The majority of divers (89.69%) were willing to pay a fee to protect dive sites, although multiple respondents were concerned about possible corruption if such fees would be levied. Divers visiting Lembeh Strait were most willing to pay for such a fee (93.85%), with slightly lower

**Table 2**

Key values for muck dive tourism in Indonesia and Philippines in 2015. Values over USD \$1 million rounded to nearest thousand, values over 10,000 rounded to nearest ten.

Code	Variable	Value
V	Visitor numbers in surveyed dive centres	35,720
Vt	Total estimated visitor numbers for all muck dive centres	101,500
E	Average expenditure per diver	\$2133.65
Pm	Proportion visitors visiting mainly for muck diving	70.3%
n	Number of dive centres sampled	19
Tm	Total number of muck dive centres	54
R	Total revenue muck dive tourism	\$152,341,000
Sm	Total staff employed	2290
Pw	Percentage of dive centre revenue spent on wages	33.7%
Rw	Total local income in wages	\$51,339,000

willingness in Bali (83.33%) and Dauin (80.77%). When asked about how much divers would be willing to pay, the average amount was USD \$50.9. This number was similar in Lembeh and Bali (USD\$56.1 and USD\$55.6 respectively), but considerably lower in Dauin (USD\$28.6). Dauin is the only location where such a fee is currently in place, although many respondents were not aware of this.

### 3.2. Value of muck dive tourism

One hundred diver surveys and 16 operator surveys were collected. An additional four operators responded to our emailed survey. The visitor numbers from one operator survey showed an outlier with triple the number of visitors compared to similar sized dive centres, this outlier was removed prior to data analyses (summary dive centre statistics in [Supplementary Materials](#)).

In the 19 dive centres for which data were analysed, a total of 35,715 visitors were recorded for the year 2014 ([Table 2](#)). Extrapolating this number to the total number of dive centres specialising in muck diving ( $n = 54$ ), amounts to an estimated 101,505 divers visiting Indonesia and the Philippines to participate in muck dive activities. Mean diver expenditure per dive holiday differed between divers who booked a dive package (includes flights, accommodation, food and dives) or those who booked flights and accommodation separately. Once average cost of flights was subtracted from package deals, expenditure was very similar to the non-package expenditure: USD \$2293.95 compared to USD\$2133.65 after flight adjustments. The former is used in the following estimates. On average, divers spent 9 days ( $SE \pm 1$  day) in the dive location and conducted 21 dives ( $SE \pm 1$  dive) during their holiday. Operators indicated that an average of 73% of divers visited primarily for muck diving, compared to 67.68% of visitor indicating muck diving as main reason to visit the area. The average of those two numbers (70.3%) was used to calculate total revenue.

The revenue created by muck divers in Indonesia and Philippines is approximately USD\$ 152,341,000 annually. Depending on whether diver or operator motivation is used, this can range between USD\$ 146,580,000 and USD\$ 158,102,000. The total revenue created by muck dive centres when not taking in account the main reason for visits could be as high as USD\$ 216,578,000.

Operator surveys indicated 33.7% ( $SE \pm 4.3\%$ ) of their revenue is spent on wages, which amounts to USD\$ 51,339,000 being paid in wages annually across the region. Dive centres and resorts specialising in muck diving employ on average 42 staff ( $SE \pm 7$  people), the majority of these employees (95%) are local people. This totals to 2289 local people employed in muck dive centres in the study region.

### 3.3. Dive guide demographics and earnings

Dive guide surveys were collected in Lembeh and Dauin, but not in Bali. Questionnaires distributed to 44 dive guides showed that the average age of dive guides working in muck dive centres was 33.4 years

**Table 3**

Education level and diver certification level of dive guides in muck dive locations. All values rounded to the nearest whole number ( $N = 44$ ).

Variable	Dauin	Lembeh	All
<b>Education Level</b>			
No secondary education	15%	11%	14%
Secondary education	38%	56%	45%
Technical / Vocational Training	4%	6%	5%
Bachelor	31%	22%	27%
Not answered	12%	6%	9%
<b>Diver Level</b>			
Open Water	0%	11%	5%
Advanced Diver	0%	6%	2%
Rescue Diver	4%	39%	18%
Divemaster	31%	33%	32%
Assistant Instructor	4%	0%	2%
Instructor	35%	6%	23%
Not answered	27%	6%	18%

old ( $SE \pm 5.1$  year). The majority of the dive guides (90.1%) were nationals of the country they were working in, 9.9% of guides were international. In Indonesia none of the dive guides interviewed were foreign nationals. The majority of dive guides were male (90.5%).

Overall, dive guides are extremely experienced divers with an average of 3895 dives ( $SE \pm 594$  dives) and high diver certification level ([Table 3](#)). However, the general education level is relatively low with 14% not having completed secondary education ([Table 3](#)). A frequent comment of dive guides in the surveys was how they are proud to be working in the places they live, having the opportunity to show visitors their marine environment.

Wages were divided into three segments: salary, commission and tips. While dive guides are paid a basic salary, most operators pay extra commission per dive conducted or courses taught. The mean salary for guides was USD\$233.6 ( $SE \pm$  USD\$18.9) per month. When including commission and tips, the average income of dive guides in the Philippines and Indonesia was USD\$419.1 ( $SE \pm$  USD\$64.8). Mean salaries in the Philippines were higher than in Indonesia, but commission and tips in Indonesia were higher than in the Philippines, resulting in similar monthly incomes ([Table 4](#)).

Basic salaries for dive guides in both the Philippines and Indonesia were higher than the legal minimum income for workers employed in these regions (119.8% and 137.6% respectively). When commission and tips are included, guides employed in the muck dive industry can earn up to double (195.8%) the legal minimum wage of other workers in the Philippines or nearly triple (271.5%) the minimum wage in Indonesia ([Table 4](#)).

### 3.4. Threats to muck dive tourism

Because the threats to muck fauna have not been documented, dive centre operators and dive guides were asked an open-ended question on what they considered to be the potential pressures that could impact the industry. The three threats most mentioned were: overcrowding of dive sites and associated impacts of diver behaviour, pollution, and negative effects of fishing. Operators and guides in Lembeh were more worried

**Table 4**

Average monthly income in US dollars of dive guides working in muck dive tourism. "Minimum salary" indicates the legal minimum salary in the region for jobs with a similar education level, "Basic salary" is the average monthly salary for dive guides excluding tips and commission, "Full salary" is the average monthly salary of dive guides including tips and commission. All values rounded to the nearest whole number.

	Dauin (USD\$)	Lembeh (USD\$)	All (USD\$)
Minimum salary	\$206	\$161	\$183
Basic salary	\$247	\$220	\$234
Salary + tips + commission	\$404	\$435	\$419

about crowding of dive sites and pollution, whereas dive professionals in Philippines were more worried about the effects of fishing near dive sites and destructive behaviour of divers while interacting with marine life. While questions about threats were not in the diver surveys, informal conversations with divers indicated a similar trend. Most divers seem to be worried about pollution on dive sites and an increase in the numbers of divers on sites.

#### 4. Discussion

Nature-based tourism can be a sustainable way to use marine resources and alleviate poverty in developing countries [27,50]. This study has shown that the developing niche market of muck diving is a highly valuable tourism industry in Indonesia and Philippines that attracts experienced divers and employs thousands of local people on a salary well above the national minimum wage. Since this type of diving does not require coral reefs, it offers potential for the development of tourism in areas that were previously considered unattractive to scuba dive tourism.

The tourists participating in muck diving tend to be very experienced, middle aged divers who are well educated and have a high income. The interests of experienced divers tend to differ than those of novice divers. As divers gain experience, they become more interested in smaller or rare animals, and often try to develop new skills such as underwater photography [11,26]. The demographic profile of the divers visiting muck dive sites is strikingly similar to that of birdwatchers. The birders described by Hvenegaard et al. [25], were around 49 years old (46 years in this study), 62.4% had a university degree (79.2% in this study) and their annual income was considerably higher than the national average. Due to various limitations (e.g. language barriers and lack of information received from Asian-based dive centres), it is likely that our study did not adequately survey the growing Asian segment of the muck dive tourism market. Interviews with management indicated a similar demographic profile for the Asian divers. Dive operators consider the Asian market segment as the segment with the largest growth potential for muck dive tourism. Therefore, gaining a better understanding of the demographics and attitudes of this group is important for the future management of muck dive tourism.

The profile of the divers visiting muck divers explains the high value of the industry as a whole. Experienced divers are usually willing to spend more on diving holidays that will guarantee the experience they are looking for [15,29]. While searching for rare marine species is a highly specialised niche market, it attracts a large number of divers to Southeast Asia. Other well-known, valuable marine tourism destinations such as Bonaire, Moorea, Palau all attract fewer divers on an annual basis [12,45,47]. Furthermore, muck dive tourism is nearly always the dedicated purpose of a holiday, which is why divers stay longer in one location and conduct more dives than divers visiting other destinations, leading to a higher expenditure [29]. For instance, tourists doing shark diving in Palau and South Africa spent between 4 and 6 days diving (9 days in this study), with shark divers in South Africa doing an average of 2 dives during their stay (21 dives in this study) [16,47]. Other types of marine tourism have shorter stays as well; 3–4 days for turtle and whale watching tourism, and two days or less for tourists visiting dolphin watching sites in Australia [43,50]. The specialised nature of muck diving also involves extra equipment such as expensive cameras and necessitates divers to do multiple dives in order to find a maximum of rare species, making it a tourism niche that is only accessible for those with a high expendable income.

Another consequence of the importance of finding rare or cryptic species, is the need for well-trained dive guides to spot the animals. The success of any given muck dive heavily depends on whether or not species were spotted. Therefore the dive guides working in this industry tend to be highly experienced, strongly service-oriented and comparably well paid. While many of the dive guides working in muck dive centres have had limited education, they frequently make up to twice or

more than what is considered to be the local minimum wage. Most guides indicated they were proud to be working in the muck diving industry as they considered it gave their region a good image and it brought employment to their villages. This study did not investigate the magnitude of financial leakage to other countries. While the leakages might be substantial [48], the dive centres surveyed in this study had strong links to the host communities and the benefits of muck dive tourism to local communities meet the social objective of sustainable tourism [19].

While social objectives might be met in muck dive tourism, little is known about the state of the environment and species muck diving depends on. A frequent comment from management, dive guides and divers was the fear of overcrowding on dive sites, and adverse impacts of diver behaviour on popular species and their habitat. Overcrowding is known to make protected areas less attractive to tourists and could potentially lead to declining visitor numbers [5]. The high prevalence of cameras, specifically DSLRs might be cause of concern, as photographers are known to cause higher impacts than know photographers, and flash photography could have a potential impact on animals [24,45]. Alternatively, the growing popularity of muck diving could be seen as an opportunity to develop muck dive tourism in other locations. Intrusive diver behaviour such as intentionally touching marine fauna was frequently reported, but impacts are unknown. The effects of other potential threats such as climate change, or harvesting of animals for the marine aquarium trade are similarly unknown [17,34]. Our research shows that nearly all divers participating in muck diving are willing to protect the environment, as long as conservation measures are transparent and well communicated. It has previously been shown that entry fees for marine parks have little impact on the total number of divers visiting a site [3,39]. For interactions with wildlife, visitors have been shown to accept management rules that might decrease proximity of wildlife interactions, provided it improved animal welfare [3]. It is crucial that management rules are transparent communicated clearly, as many of the respondents voiced concerns about potential corruption or inefficient management.

For future sustainability of muck dive tourism, the importance of its focal species needs to be emphasized. A large majority of respondents would not have visited the region if muck diving was not possible. This number was even higher than other valuation studies, 21% of scuba divers visiting Palau named sharks as the main reason visit, compared to 67% that named cryptic species critical for muck diving ([47], this study). The importance of muck diving is therefore much higher for local communities than in other types of dive tourism. Rarity of the species observed plays an equally important role for muck diving as it does for birdwatching [8]. This high reliance on rare species could make muck dive tourism more vulnerable to potential impacts. However, at present it is unknown which species are most important to the industry, and which threats could have the biggest impacts. The inherent problem with rare species is that little is known about their ecology, abundance or conservation status [28,30,34]. To effectively manage muck diving, more research is needed into the ecology of soft sediment ecosystems, the impacts of diver behaviour and underwater photography, and to determine the diver carrying capacity of popular sites [7]. Future research and management could potentially benefit from the high percentage of camera use in muck diving by establishing citizen science projects. Similar successful initiatives already exist for rare birds, and for marine megafauna and charismatic marine species [1,18,35].

The muck dive sites surveyed in this study were limited to Indonesia and Philippines, however the real scope and thus value of the industry is much larger. Within the Coral Triangle region, multiple well-known muck dive sites exist in Malaysia and Papua New Guinea [31,33]. The total number of specialised muck dive centres in the Coral Triangle area could be as high as 100 dive centres, which would nearly double the value described in this study. In 2013, 8.8 million people visited Indonesia, accounting for USD\$49.3 billion in expenditure, or 3.1% of the

GDP [23,46]. Scuba diving tourism makes up a small percentage of visitor numbers, but has a high economic value. The non-market use value of scuba dive tourism in Southeast Asia is estimated to be close to USD\$4.5 billion per year [39]. Muck diving is a small, yet very valuable niche of this industry that makes an important difference to the livelihoods of the local communities involved in it, especially since it is often practiced in regions where other tourist attractions and industries are limited. The muck diving niche is not limited to Southeast Asia, sites exist across the world, but are often not marketed this way. Therefore the global value of cryptic, soft sediment species deserves the attention of management and conservation organisations alike. Like bird-watching, viewing and photographing rare or cryptic marine species can be a sustainable form of tourism that benefits local communities, marine conservation and potentially scientific research [13].

## 5. Conclusion

Our research has shown that muck diving in Indonesia and Philippines is a very valuable niche tourism industry, combined it is worth over USD\$150 million per year. Muck dive tourism can be a sustainable form of nature based tourism in developing countries, especially in coastal areas where little or no potential for traditional coral reef scuba diving exists. The divers participating in this form of scuba diving tend to be highly experienced, well-educated and have a high annual income. This form of tourism creates thousands of jobs in rural areas where limited other sustainable livelihoods are available. The niche's high dependence on a limited number of rare species makes it vulnerable to future impacts, particularly as very little is known about the major threats to the species important to muck dive tourism. The effects of too many divers was suggested as an important threat to the industry, as was pollution and conflicts with fishermen. At present limited or no protection exists for the species on which this valuable tourism industry depends. However, our results show that muck divers are overall willing to pay for the conservation of the species they come to see, provided management strategies are transparent. The diver's willingness to pay for conservation and the kind of threats facing the industry highlight the possibilities of positive conservation outcomes, if suitable management strategies are employed. More research is needed to guide management policies and in deciding which species are most important and how they would benefit most from conservation actions. The high value of cryptic, soft sediment species illustrates how poorly studied species can support sustainable livelihoods, however, research and conservation efforts on these ecosystems are currently deficient.

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## Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.marpol.2017.05.033>.

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