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Sea urchin utilisation in Eastern Indonesia

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Abstract

Sea urchins have long been an important component of gleaning invertebrate fisheries and are valued for their highly nutritious gonads. Sea urchin fisheries are often unreported and unregulated, despite increasing indications of overexploitation. Data on the post-harvest utilization of sea urchins are limited, particularly in the Indo-Pacific region. This study at 12 sites across four regions in Indonesia (Sulawesi, Moluccas, Nusa Tenggara, Papua) aimed to provide an overview of sea urchin utilization in eastern Indonesia. Data were collected from July to September 2020 using a questionnaire with a snowballing sampling method. There were 187 respondents (62.6% male and 37.4% female) ranged in age from 3-76 years old, and most had been collecting sea urchins for more than five years. Respondents mostly collected the sea urchins from coral reef or seagrass habitats. Four genera (Tripneustes, Diadema, Echinometra and Echinothrix) were identified. Mean catch ranged from 32 (Makassar) to 169 (Maluku Tengah) individual sea urchin per collection. Most respondents knew local names for sea urchins, especially those they collected. Almost 70% respondents used their catch mainly for home consumption, and only 4.8% respondents mainly selling their catch. Most urchins sold were whole or crudely de-spined, typically fetching IDR 500-1000 each. Additional post-harvest processing before sale included removing the gonads from the test and/or cooking, with a unit price of IDR 5,000-25,000/product. Commonly consumed raw, urchins were sometimes cooked (mostly barbecued). These data indicate a need for efforts towards socio-ecologically appropriate sea urchin conservation and fisheries management to address the widespread indications of increasing exploitation levels and declining sea urchin populations.

Keywords: *Diadematidae, Echinometra, gleaning fisheries, post-harvest processing, Tripneustes*

Introduction

Sea urchins have long been an important component of gleaning invertebrate fisheries (Dalzell, 1998; Amesbury and Hunter-Anderson, 2003; Harris and Weisler, 2017, 2018; Kaharudin, 2020; McKenzie *et al*., 2021). In the Talaud Islands to the north of Sulawesi, remains of shelled animals in human habitations dated to the Late Pleistocene included molluscs, crustaceans and sea urchins (Ono *et al*., 2009), while sea urchin consumption goes back around 40,000 years in Alor (Kealy *et al*., 2020). In recent decades, sea urchin gonads have contributed to the food security and livelihoods of coastal and small island communities (EC-PREP, 2005; Cruz-Trinidad *et al*., 2009; Cullen-Unsworth *et al*., 2013; Wagey and Bucol, 2016; Darius *et al*., 2018; Furkon *et al*., 2020; Sjafrie *et al*., 2021).

Sea urchin collection and utilization are widespread in the Indo-Pacific (Dalzell, 1998; Amesbury and Hunter-Anderson, 2003), including eastern Indonesia (Ono *et al*., 2009; Wainwright *et al*., 2018; Kaharudin, 2020; Ambo-Rappe, 2020; Kealy *et al*., 2020). However, there is a dearth of recent and detailed information on these and other small scale invertebrate fisheries (Nordlund et al., 2018). This knowledge gap is especially evident with regards to gleaning (Furkon *et al*., 2020). One reason for the lack of data is that such fisheries are often unreported and mostly unregulated, despite increasing indications of invertebrate

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overexploitation (Anderson *et al*., 2011), including gleaning fishery targets such as molluscs and sea urchins (Lawrence, 2013; Parvez *et al*., 2016; Moore *et al*., 2019b; Alati *et al*., 2020; Tamti *et al*., 2021; Jones *et al*., 2022).

In addition to fisheries and resource status, data are also limited on the post-harvest utilization of sea urchins collected in small-scale/gleaning fisheries, in particular in eastern Indonesia. This study aimed to provide an overview of sea urchin utilization by small-scale sea urchin collectors in eastern Indonesia.

Materials and Methods

This study was conducted in 12 sites across eastern Indonesia (Figure 1). The sites were selected purposively, based on the known occurrence of sea urchin collection and geographic spread, to provide an overview of sea urchin utilization in eastern Indonesia. These sites represent four widely recognized bio-ecological regions: Sulawesi (including its satellite archipelagos), the Moluccas, Nusa Tenggara and Papua.

Data were collected from July to September 2020 using a questionnaire with a snowballing sampling method. The respondents were sea urchin collectors (Table 1.). At each site, once at least one collector had been identified, they were asked about other people who collected in their area. The questionnaire collected data on sea urchin collector profiles; what sea urchins were collected, how, how many, and where; the purpose of collecting (home consumption or for sale), sea urchin sale prices; sea urchin consumption patterns, including post-harvest processing. The respondents were also shown photographs of sea urchin species and respondents were asked to point out and name the species they collected.

Primary data from the questionnaire were tabulated in Microsoft Excel 365. Data analyses were performed and graphs were produced in Microsoft Excel 365. Data were tested for equal/unequal variance before t-test implementation. Statistical significance was evaluated at the 95% confidence level (α= 0.05).

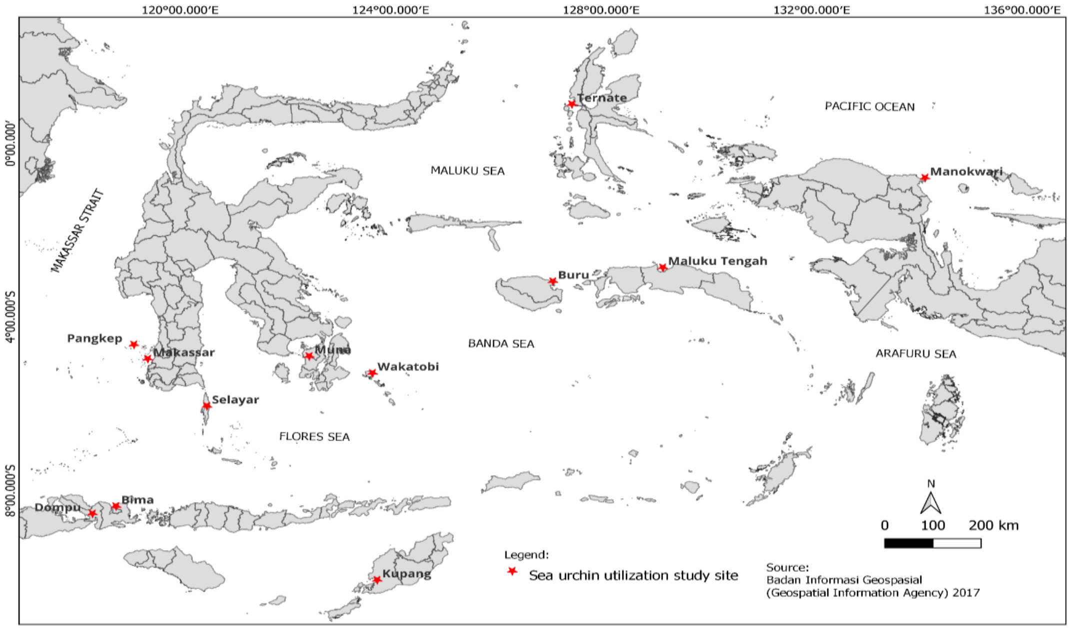

Figure 1. Map of Indonesia showing the twelve study sites in eastern Indonesia

Table 1. Sea urchin fishery respondents (N= 187) from twelve sites across four regions in eastern Indonesia

Region	City/District (Site)	Number of respondents	Region	City/District (Site)	Number of respondents
Sulawesi	Makassar	15	Moluccas	Maluku Tengah	10
	Pangkep	13		Buru	13
	Selayar	16	Nusa Tenggara	Bima	29
	Muna	15		Dompu	15
	Wakatobi	15		Kupang	16
Moluccas	Ternate	10	Papua	Manokwari	20

Result and Discussion

Sea urchin collector profiles

The respondents (n= 187) comprised more male (62.6%) than female (37.4%) collectors. The age range was 3-76 years old, with a mean ± standard deviation (SD) of 34±13 years. Collecting experience ranged from 1 to 51 years, with a mean of 16±9 years. There was no significant difference in age or experience between male and female collectors (t-test with equal variances, *P*> 0.05). Over a third (36%) began collecting urchins at pre-school or primary school age (3-11 years old), 29% at secondary school age (12-18 years old) and 35% when over 18. Of the 81 (43%) collectors who self-identified as fishers or in fisheries-related employment, 11 (13.6%) were female. Monthly income ranged from IDR 100,000 (some schoolchildren) to IDR 3 million (a farmer), with a mean of IDR 1.81 million (approximately US$ 121 at an exchange rate of 1US$= IDR 15,000). There was a significant difference (t-test with unequal variance, *P*< 0.001) in mean income between men (IDR 2.38 million) and women (IDR 0.87 million).

Respondents collected sea urchins in seagrasses and/or coral reef ecosystems, mainly the reef flat and sometimes the crest and upper slope. They used simple collecting gear and mostly collected on foot at low tide, although some used boats (typically wooden canoes, with or without long-shaft outboard motors). Some (≈ 12%) used crowbars, a potentially destructive fishing gear. Most respondents collected sea urchins on a seasonal basis, with 2-12 collecting months per year (mean 6.3±4); there was considerable variation in collection season between sites and individuals within each site. Collecting activity lasted 0.5 to 5 h (mean 2.1±1.2, mode 2), with 1 to 30 sea urchin collection (mean 8±5) per collecting month.

The sea urchin collection methods used by respondents are similar to those reported previously from eastern Indonesia and elsewhere (Nurhasan and Rahim, 2011; Furkon *et al.*, 2019, 2020; Tamti *et al.*, 2021), with most collecting activity taking place at low tide in shallow coastal waters with simple tools such as tongs (especially for long-spined urchins) or no gear other than some form of receptacle. However, it is worrying that crowbars were used by some respondents in two regions (the Moluccas and one in Nusa Tenggara) and most respondents in Papua, especially when used to collect a variety of food and ornamental fish as well as invertebrates such as the boring clam *Tridacna crocea*, sea cucumbers, and abalone (*Haliotis* sp.) by breaking open or overturning the coral or other substrate, this tool can cause widespread and serious damage to the habitat where it is used, especially shallow reefs and reef flats (EC-PREP, 2005; UNEP, 2005; Lowe, 2006; Clifton *et al.*, 2010; Madduppa *et al.*, 2014; Lampe *et al.*, 2017; Yusuf and Moore, 2020), and also seagrass meadows (Sjafrie *et al.*, 2021).

Taxonomic diversity, volume and local names of sea urchins collected

The taxonomic diversity and mean volume (Table 2) of sea urchins collected varied between and within sites. The urchins collected belonged to at least three families and four genera: Diadematidae (*Diadema* and *Echinothrix*); Toxopneustidae (*Tripneustes*); and Echinometridae (*Echinometra*). In addition, some respondents said that they collected other urchins not on the identification sheets. These unidentified urchins and *Echinothrix* are not collected regularly so there are no volume data for these taxa in Table 2.

The most common local name for *Tripneustes* in Selayar, *tie-tie*, has also been recorded from other areas of South Sulawesi (Furkon *et al.*, 2020) and is very similar to the name *tia-tia* used in at least two other Sulawesian archipelagos (A.M. Moore, unpublished data). It is also similar to the name *tehe-tehe* used in Sabah, Malaysia (Nurhasan and Rahim, 2011). Interestingly, respondents from Wangi-Wangi in the Wakatobi and Muna in Buton used the name *tetehe*, while according to Toha *et al*. (2014) the names used in Tomia (Wakatobi) and in Bau-Bau (Buton) are *tihe* and *taeo*, respectively. Meanwhile the name *sarawaki* used by some respondents from Maluku Tengah is very similar to *salawaki*, a name used in the Philippines for *Tripneustes gratilla* (Wagey and Bucol, 2016). *Tayung* has been reported as a Bajo sea gypsy name for diadematid sea urchins, especially *Diadema* (EC-PREP, 2005; Moore *et al*., 2012), and likely indicates Bajo ethnic collectors in the study areas (Wakatobi, Muna, Ternate) where this name (including the variants *tayong, tayam*) is used, and possibly also *tajung* (Selayar), all of which are also similar to the name *tayum* widely used by Bajo communities in Sabah, Malaysia (Nurhasan and Rahim, 2011) and *tuyom* in the Philippines (Wagey and Bucol, 2016). These may be the respondents themselves or people interacting with Bajo neighbours or roving fishermen, as has occurred in Sabah, Malaysia (Nurhasan and Rahim, 2011).

This study did not collect data on the ethnic origin of respondents; however, it is likely that at several sites the respondents included indigenous local people as well as people from other regions or ethnic groups who might be temporary residents, first generation in-migrants, or their descendants. One example would be the sea cucumber fishers working on boats based in the Spermonde Archipelago (Nadiarti *et al*., 2021), while others could include civil servants (teachers, government staff, etc), and some entrepreneurs or traders (EC-PREP, 2005). The variety of names recorded for each of the species or genera in Table 3 could reflect ethnic or cultural diversity within the human population at some sites; conversely, shared or similar names could reflect cultural/ethnic ties between sites. In addition, local names can be an indicator of local ecological knowledge (LEK) (Aswani *et al*., 2020). LEK is an important but often overlooked resource that can reflect

Table 2. Taxonomic diversity and mean volume per trip of sea urchins collected at 12 sites in eastern Indonesia

Site		Mean number of sea urchins collected per trip by genus					
No	Region	*Tripneustes*	*Diadema*	*Echinometra*	*Echinothrix*	Other	Total
1	Makassar	28	4	0	No	No	32
2	Pangkep	59	19	3	Yes	No	81
3	Selayar	72	7	2	No	No	81
4	Muna	10	29	1	Yes	No	40
5	Wakatobi	61	21	0	No	No	82
6	Ternate	35	16	3	Yes	Yes	55
7	Maluku Tengah	47	107	16	Yes	No	169
8	Buru	22	20	0	No	No	42
9	Bima	40	24	24	Yes	No	88
10	Dompu	26	23	23	Yes	Yes	73
11	Kupang	44	1	1	No	No	47
12	Manokwari	7	14	14	Yes	No	36
Overall mean ± SE (n = 187)		36±3	23±4	10±2			69±6
Number of sites		12	12	10	7	2	
Number of collectors		157	113	74	22	3	

Note: Numbers rounded to nearest integer.
Generic names applied to sea urchins included the widespread terms *bulu babi* and *duri babi* (both meaning pig bristles); *garandang* (Pangkep); *saroa/soroa* (Ternate), *siroa/sirowa* (Dompu and Maluku Tengah); *sunggiang* (Maluku Tengah); *taju* and *rui wawi* (Bima); and *tiowek* (Kupang). Local names for specific sea urchin taxa (one or more genera) were used at one to three sites (Table 3), although in some cases, the names used at different sites were very similar.

Table 3. Local names for sea urchin species collected at 12 sites in eastern Indonesia

No.	Local Name	Sites	No.	Local Name	Sites
	Tripneustes			*Diadema*	
1	*Asarwai*	Manokwari	1	*Asasinai*	Manokwari
2	*Bulu pendek*	Dompu	2	*Ne'e*	Buru
3	*Cie-cie*	Buru	3	*Sunggiang*	Maluku Tengah
4	*Di'i*	Bima	4	*Taju/taju hitam*	Bima, Dompu
5	*Faesponu*	Kupang	5	*Tajung*	Selayar
6	*Garanda bukuh-bukuh*	Pangkep	6	*Tayam*	Ternate
7	*Garandang baku'-baku'*	Makassar	7	*Tayong/tayung*	Muna, Wakatobi
8	*Garandang*	Pangkep	8	*Teerombo*	Manokwari
9	*Insarwai*	Manokwari		*Echinometra*	
10	*Kaombai*	Manokwari	1	*Andanyang*	Manokwari
11	*Katiri*	Bima, Dompu	2	*Babaka*	Manokwari
12	*Salawaku*	Buru	3	*Lena*	Ternate
13	*Sarawaki*	Maluku Tengah	4	*Salaobang*	Muna
14	*Sowe*	Ternate	5	*Sarawaki batu*	Maluku Tengah
15	*Tek*	Kupang	6	*Sunggiang jarum*	Maluku Tengah
16	*Tetehe*	Muna, Wakatobi, Ternate	7	*Taeyo*	Manokwari
17	*Teyoe/tioe*	Kupang	8	*Taju*	Bima, Dompu
18	*Tie-tie*	Selayar	9	*Tajung batu*	Selayar
19	*Tiye-tiye*	Pangkep	10	*Tajung tedong*	Selayar
	Echinothrix			*Echinothrix*	
1	*Garanda buri*	Pangkep	4	*Tayong*	Muna
2	*Sarawaki batu*	Maluku Tengah	5	*Tee*	Manokwari
3	*Sunggiang bunga*	Maluku Tengah			

changes as well as the status-quo in social-ecological systems (Jones *et al*., 2022) and could be explored in more depth by future research programs.

Sea urchin utilisation

The respondents all utilized at least some of the sea urchins they collected for home consumption, even there were nine collectors who did not cite home consumption as a reason for the sea urchin collecting. A substantial minority of respondents sold part of their catch. Urchins collected for both subsistence and income were most often, but not always, consumed or sold uncooked (Table 4.).

In addition to human consumption, respondents reported three other uses of sea urchins by people in their area (Table 4.). These were: feed for aquaculture (lobster grow out, Pangkep); medicinal use (Muna), and crafts/ornamental use (Bima). The medicinal use of sea urchins in Muna was not specified; but in Sabah, Malaysia sea urchins are used to treat convulsions and seasickness (Nurhasan and Rahim, 2011). In addition to the urchins reported here, other readily collected invertebrates such as tridacnid clams also recently began to be used as feed for panulurid lobsters in the Spermonde Archipelago (Yusuf and Moore, 2020), indicating that lobster fishery and grow-out could have considerable negative impacts on shallow coastal water invertebrate resources and ecosystems.

This study adds to the growing number of known instances of the use of sea urchins as feed in aquaculture and/or husbandry of wild-caught high-value fish and invertebrates destined for the life reef food fish trade, such as in the Banggai Archipelago (Ndobe *et al*., 2018; Moore *et al*., 2019b), including Napoleon wrasse *Cheilinus undulatus* (Moore *et al*., 2012). The use of sea urchins as bait for fish traps has been reported from the Philippines (Wagey and Bucol, 2016) and Tonga (Malm, 2009). The use of sea urchins in crafts and for ornamental purposes in Bima was not specified, but sea urchin spines have been used as tools in Micronesia (Amesbury and Hunter-Anderson, 2003).

The most common ways of preparing sea urchins were cleaning and eating the gonads direct from the test or removing the gonads from several urchins and placing them in a cleaned empty test or in some other form of container (plastic bottles and bags or jars). By far the most popular cooking method was barbecuing (45% of respondents), while several respondents (22%) also mentioned frying the gonads, and 64% cooked the urchins in other (unspecified) ways. Frying was especially popular in Papua (70% of respondents). More than half (58%) of respondents prepared urchins in more than one way, raw and cooked and/or using more than one cooking method. The number of sea urchins per serving varied from 1 to 30 (Figure 2.). These data highlight a weakness in the survey instrument, as some respondents appear to have interpreted the question as urchins per person, others as urchins prepared for one meal (therefore dependent on household size).

Sea urchin trade

The respondents selling sea urchins included similar numbers of male and female collectors, aged 10 to 76 years old. The selling patterns, prices for unprocessed (whole, fresh, often with partial de-spinning of the longer-spined taxa) or processed urchins, and perception of price trends varied between and within sites (Table 5).

Socio-economic importance of sea urchin utilisation

Shallow-water gleaning fisheries in tropical coastal ecosystems such as coral reefs and seagrass meadows are increasingly recognised for their social and economic importance (Nordlund *et al*., 2018; Jones *et al.,* 2022). The estimated mean income from

Table 4. Main motivation for collecting sea urchins, consumption and processing of sea urchins

No	Use of Catch	Unit	Sulawesi	Moluccas	Nusa Tenggara	Papua	All
1	Number of respondents	n	74	60	33	20	187
2	Mainly for home consumption	%	48.6	78.8	48.3	95.0	65.8
3	Mainly to sell	%	4.1	0.0	10.0	0.0	4.8
4	Home consumption and to sell	%	47.3	21.2	21.7	5.0	29.4
5	Typical serving	Urchins	7	11	9	12	9
6	Consumed/sold raw	%	52.7	42.4	30.0	90.0	47.6
7	Consumed/sold cooked	%	97.3	72.7	95.0	100.0	92.5
8	Most popular cooking method	method	barbecued	fried	barbecued	fried	barbecued
9	Use other than human consumption	type	Feed Medicinal	-	Ornamental	-	

Note: Processed products typically include gonads from several sea urchins

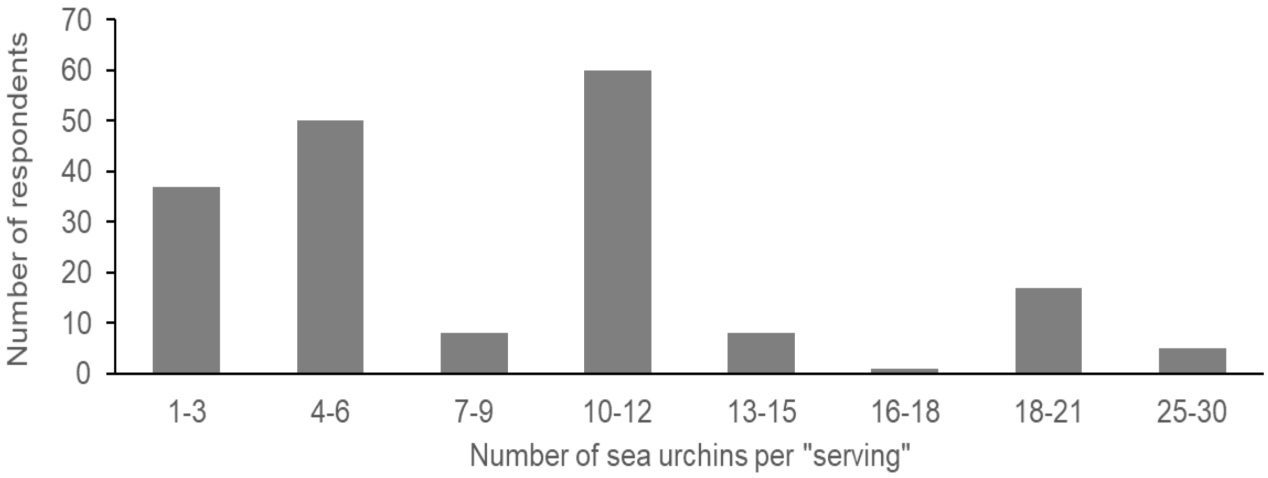

Figure 2. Histogram of the number of sea urchins per "serving"

Table 5. Sea urchin sales patterns and prices by region

Parameter	Unit	Sulawesi	Moluccas	Nusa Tenggara	Papua	All
Respondents selling	n	47	9	21	1	78
sea urchins	%	64	27	35	5	42
Where collectors sold sea urchins (percentage of respondents providing an answer)						
No. respondents	n	37	8	24	1	70
To neighbours	%	73	25	83	100	46
On a market	%	27	100	238	0	70
To trader/other	%	3	0	4	0	3
Sea urchin product type sold (percentage of respondents providing an answer)						
No. respondents	n	36	8	13	0	57
Unprocessed	%	64	50	69	0	63
Processed	%	39	50	46	0	42
Sea urchin price range						
No. respondents	n	16	8	31	1	
Unprocessed	IDR per urchin	500-2,000	100-3,000	500-1,000	1000	100-3,000
No. respondents	n	22	8	2	0	32
Processed	IDR per product[a]	5,000-15,000	5,000-25,000	5,000	-	5,000-25,000
Respondent perception of sea urchin price trends (percentage of respondents providing an answer)						
No. Respondents	n	47	12	51	1	111
Decline	%	0	0	2	0	1
Stable	%	53	8	65	0	53
Unstable	%	15	83	27	100	29
Increase	%	32	8	6	0	17

[a] Processed products typically include gonads from several sea urchins; [b] Estimated by dividing the estimated volume of catch sold by the number or urchins per serving given by the respondent

selling unprocessed sea urchins across the study sites was IDR 1.94 million per collecting month. Processed urchins were mostly sold in units containing a certain (mostly unspecified) number or weight of gonads, making it difficult to determine the price per urchin, while some respondents selling unprocessed urchins may have given the price per sale unit (possibly more than one urchin) rather than per urchin; therefore, the mean income of IDR 1.46 million per collecting month for processed urchin sales is only a rough estimate. Some respondents gave several answers to one question; conversely, some respondents did not answer all questions. In addition, several respondents who did not say they sold sea urchins were aware of local prices and/or price trends. Therefore, in some cases the total responses per site in Table 5 add up to more or less than 100, and the number of respondents per site and overall vary between questions. The estimated gross income per collecting month from selling unprocessed sea urchins typically ranged from around IDR 300,000 to IDR 4 million, with outliers as low as IDR 20,000 and as high as IDR 7.6 million.

Although respondents mostly sold their sea urchin catch on local markets or to neighbours/people within their village, the trade patterns varied considerably both between and within sites, including the trade volume, selling price, buyers and the level of pre-sale processing. The sea urchin taxa collected by respondents who sold all or part of their catch included all taxonomic groups. However, sales data were not disaggregated by taxon and data on the relative value of sea urchin taxa were not collected. Based on the limited data available from other regions, variations in demand and/or price between species could be present or arise at the study sites. A study in the Philippines reported prices for diadematid sea urchins (*Diadema* and *Echinothrix*) substantially (40-75) higher than for *Tripneustes* (Wagey and Bucol, 2016). Conversely a study in Sabah, Malaysia found that, although sea urchin prices varied considerably between areas, *Tripneustes* typically sold for around 25 more than *Diadema* (Nurhasan and Rahim, 2011).

The seasonality of sea urchin collection accords with other studies on gleaning in eastern Indonesia (EC-PREP, 2005; Furkon *et al.*, 2020). This means that the income estimates for sea urchin sales per collecting month by respondents in this study cannot be scaled up to annual income, as the number of collecting months varied from one to twelve. Overall, the data indicate that in some cases sea urchin collection is more of a hobby, a way of obtaining a preferred (but not necessary) food or a secondary occupation, while for others this activity is an important source of nutrition and/or income. Comparing the declared monthly income and estimated income from sea urchin sales for respondents selling a substantial proportion of their catch indicates that, during collecting months, this income can be comparable to or even exceed their income from other sources.

Given the reported nutritional content and value of sea urchin gonads (Parvez *et al.*, 2016; Murzina *et al.*, 2021; Baião *et al.*, 2022), the catch volumes used for household consumption were mostly large enough to make a significant contribution to the food security and nutrition of the collectors and their families. Thus, sea urchins likely make a considerable in-kind contribution to household budgets and welfare, saving on the purchase of other forms of protein and/or improving the nutritional quality of collector's diets. Gleaners of school age and describing their occupation as pupil or student as well as elderly people indicate that sea urchin fisheries may make significant contributions to their protein intake and hence the health of the rising generation, while also benefitting older people with likely inadequate or no pension income. One example of the latter was a 76 years old housewife with an average income well below the poverty line who collected *Tripneustes* for home consumption and to sell the gonads (raw or cooked, packed in an emptied test) on the market.

Sustainability of sea urchin utilisation

Several respondents expressed their concern that increasing numbers of collectors was causing or could lead to a decline in sea urchin abundance. Such a decline has been reported from the Banggai Archipelago (Moore *et al*., 2019a,b; Wiadnyana *et al*., 2020). In 2004, Bajo communities were the main consumers of diadematid sea urchins in the Banggai Archipelago, while other ethnic groups (including upland farmers) only collected sea urchins as part of multispecies gleaning (especially sea urchins and sea anemones) during periods of hardship such as occurred in 2007, resulting in a sharp decline in sea urchin densities compared to 2006 (EC-PREP, 2005; Moore *et al*., 2012). However, the extent and intensity of collection had increased by 2011-2012 (Moore *et al*., 2012) and by 2016 commercial exploitation had begun (Moore *et al.*, 2017). Surveys in 2016-2019 found extensive depletion of sea urchin populations associated with increased sea urchin collection and consumption (Moore *et al*., 2017; Ndobe *et al*., 2018; Wiadnyana *et al*., 2020). Factors influencing this increase in exploitation levels included a decline in the availability of fish (e.g. from overfishing; sale rather than consumption of finfish catch; shift to seaweed farming leaving less time for fishing other than collecting invertebrates in and close to seaweed farms, etc.); an increase in the awareness of the high nutritional value of sea urchin gonads and/or rumours of their aphrodisiac qualities; and new uses (e.g. feed for carnivorous fish in floating net cages). At one site, new market opportunities attracted collectors from outside traditional gleaning communities, with diadematid urchins collected by the truckload, generally twice a month at spring neap tides, and sold at IDR 15,000 for ten urchins (Moore *et al*., 2019a). In this study, a small number of collectors (male and female) accounted for the majority of sea urchins collected at two sites (Muna, Bima). This indicates that even small increase in the numbers of such collectors could have a major impact on sea urchin exploitation rates.

Conclusion

Overall, the results of this study indicate that, although mostly unrecorded in fisheries statistics, the small-scale and predominantly gleaning sea-urchin fisheries in eastern Indonesia are, indeed, "too big to ignore", in terms of their importance for human welfare as well as their potential impact on coastal ecosystems and resources. There is an urgent need for appropriate, site-specific and culturally sensitive management to avoid overfishing and, where necessary, promote the recovery of depleted sea urchin populations.

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