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RESEARCH ARTICLE

Exploring sociodemographic and cultural characteristics of sea turtle take and use to support effective conservation strategies in Indonesia

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Abstract

1. Many sea turtle populations face severe declines in the Asia-Pacific region and, although threats are widely recognised, drivers are practically unknown, especially in Indonesia.
2. We surveyed 140 respondents at three sites in Sumatra, Indonesia (Padang, Mentawai, Nias) to identify how sociodemographic and cultural characteristics across these sites influence illegal turtle take (direct removal of turtles or their eggs from the wild) and use (utilisation of turtles or their products) and the purposes of use (subsistence, cultural, medicinal, religious).
3. Cultural and ceremonial hunting played a minor role in turtle capture, but cultural and religious traditions influenced which turtle parts were used (eggs, meat and by-products, carapaces). Use purposes varied significantly between the survey sites ($p < 0.001$): only medicinal use was found in Padang, all uses were reported in Mentawai, and subsistence, cultural and religious uses were recorded in Nias.
4. Although the odds of turtle take were highest among middle-aged Muslim males (36–55 years) with a lower level of education who worked in the primary sector, turtle use was most probable among unemployed middle-aged Christian males with a higher level of education. Furthermore, significant site differences were observed—while the highest odds of turtle take were found in Nias ($p < 0.001$), the highest odds of turtle use were found in Mentawai ($p < 0.05$). Most of the respondents (94%) were aware of the status of turtle protection in Indonesia, but widespread misconceptions persist that turtles deplete fish stocks.

5. The results identify the factors and drivers behind the illegal take and use of turtles. They can support the development of regional and national conservation policies and refine local management programs in Indigenous communities to provide alternative livelihoods and intervene in trade dynamics.

KEYWORDS
aquatic bushmeat, conservation, intentional take, sea turtle, threats, tortoiseshell, traditional use

1 | INTRODUCTION

Sea turtles face numerous threats, including habitat degradation, marine debris, overfishing, climate change and incidental capture (bycatch) (Wallace et al., 2011, 2023). A major threat is the overexploitation of turtles for various forms of utilisation (e.g. subsistence, cultural, medicinal and religious purposes), including commercial trade (Brander et al., 2021; CITES Secretariat, 2019; Miller et al., 2019; Senko, Burgher, et al., 2022). The primary target species are green turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) (Senko, Burgher, et al., 2022), listed globally on the IUCN Red List as endangered (Seminoff, 2023) and critically endangered (Mortimer & Donnelly, 2008), respectively. Large-scale sea turtle exploitation expanded during the colonial era (McClenachan et al., 2006; Miller et al., 2019) and the development of international markets in the 17th century (Bjorndal & Bolten, 2003). Despite global trade bans since 1975, illegal trade persists at likely unsustainable levels due to the erosion of traditional uses for subsistence, lack of enforcement and technological advancements (Ingram et al., 2022; Migraine, 2015). All parts of the turtle are used, including meat, viscera, blood, bones, fat, eggs and the hawksbill's tortoiseshell (CITES Secretariat, 2019). Meat and eggs are important sources of protein in rural areas (Ingram et al., 2022) and delicacies in urban areas (Gomez & Krishnasamy, 2019). Although some religions prohibit the consumption of turtle meat, eggs are ubiquitously consumed (Balazs, 1983; Barrios-Garrido, 2018; Frazier, 1980; Migraine, 2015). Beliefs in the health benefits and aphrodisiac properties of eggs led to extreme levels of exploitation in some regions (Campbell, 1998; Groombridge & Luxmoore, 1989). Fat, bones and blood are used in traditional medicine and rituals (Balazs, 1983; Barrios-Garrido et al., 2018; Fretey et al., 2007). Tortoiseshell has been a valuable decorative and jewellery material for centuries (Meylan & Donnelly, 1999; Miller et al., 2019; Parsons, 1972). This particularly applies to Southeast Asia (Miller et al., 2019; Nahill et al., 2020) which remains a significant turtle exploitation hotspot not only for tortoiseshell but also for other turtle species and parts (Gomez & Krishnasamy, 2019; Ingram et al., 2022; Migraine, 2015; Senko, Burgher, et al., 2022).

Indonesia has been repeatedly reported to have one of the highest levels of turtle exploitation in the region (Armstrong et al., 2023; Miller et al., 2019; Nahill et al., 2020; Senko, Burgher, et al., 2022). Historically, Indonesia was the main exporter of tortoiseshell to Europe and Japan (Dijk & Shepherd, 2004; Frazier, 1980; Miller et al., 2019). Records indicate that more than 2.5 million turtles were exported from Indonesia between approximately the 1920s and 2005 (Miller et al., 2019; Nahill et al., 2020). Despite international agreements and national legislation (Gomez & Krishnasamy, 2019; Ingram et al., 2022; Migraine, 2015; Senko, Burgher, et al., 2022) seizures and trafficking studies confirm ongoing international trade between Indonesia and Malaysia, the Philippines (Armstrong et al., 2023), China (Gomez & Krishnasamy, 2019; Migraine, 2015), Japan and Singapore (Dijk & Shepherd, 2004; Kinch & Burgess, 2009). Between 2003 and 2021, a total of 71 sea turtle seizures were recorded in the Sulu-Celebes region (Indonesia, Malaysia, the Philippines) (Armstrong et al., 2023). Although sea turtle exports from Indonesia have decreased in the past three decades, there are suggestions that imports have risen (Senko, Burgher, et al., 2022). Records indicate domestic exploitation is concentrated in Nias, West Sumatra, Bali, Papua (Dijk & Shepherd, 2004; Gomez & Krishnasamy, 2019; Nahill et al., 2020) and East Kalimantan (Migraine, 2015). Furthermore, there has been a shift from open domestic trade markets to clandestine markets (CITES Secretariat, 2019) and a rapid growth in online trade (Armstrong et al., 2023; Ingram et al., 2022; Nahill et al., 2020). Indonesia repeatedly ranked highest in online turtle trade, primarily on Shopee, Lazada and Tokopedia (Armstrong et al., 2023; Nahill et al., 2020).

Domestic turtle exploitation remains unmonitored and unabated due to limited resources and law enforcement capacity, highlighting the need for new research to understand levels of exploitation and drivers at the community level. Prior regional studies (Armstrong et al., 2023; Gomez & Krishnasamy, 2019; Migraine, 2015; Nahill et al., 2020) have mostly focused on describing trade patterns and volumes, with little information on socio-cultural drivers and purposes of use. However, understanding these aspects is crucial for establishing conservation measures, setting community-driven policies and addressing overexploitation and the illegal turtle trade. In this study, we conducted a socio-cultural survey in three communities (hereafter referred to as 'survey sites') in Sumatra, a major turtle exploitation hotspot (Dijk & Shepherd, 2004; Gomez & Krishnasamy, 2019; Nahill et al., 2020). Our study aims to investigate whether sociodemographic and cultural characteristics influence turtle exploitation—take (illegal direct removal of turtles or their eggs from the wild, including intentional and incidental capture, hereafter 'take') and utilisation (use of turtles or their products for various purposes including trade,

hereafter 'use'), the specific purposes of use and differences within survey sites. We also aim to provide conservation recommendations tailored to Sumatra, but relevant to Indonesia, in general, and the wider region of Southeast Asia.

2 | METHODS

2.1 | Survey sites

The three survey sites are located in subdistricts within Padang and Mentawai (West Sumatra Province) and Nias (North Sumatra Province) (Figure 1). The sites were selected based on three criteria: (1) documented evidence of sea turtle take and use from scientific and grey literature; (2) a maximum distance of 70 km from the nesting/foraging habitat of sea turtles, reflecting the typical range of small-scale fishers they travel on fishing trips; (3) existing relationships between authors and local communities.

At all three survey sites, green turtles generally nest year-round, while hawksbill turtles nest predominantly from January to May and leatherback turtles (*Dermochelys coriacea*) from October to March. Several green and hawksbill turtle foraging grounds are also known in the region (Figure 1) (Groombridge & Luxmoore, 1989; Mast, 2024; Turtle Foundation, 2023; LKKPN Pekanbaru, personal communication, 16 August 2024). However, data on population sizes and demographic structure are lacking at these sites and, more broadly, in all sea turtle populations in Indonesia.

Padang (0°56′57.26″N, 100°21′15.37″E) is the capital of West Sumatra, predominantly inhabited by the Minangkabau ethnic group. The society is matrilineal, with Islam as the main religion (Abdullah, 1966). Within the Taman Wisata Perairan Pieh marine protected area, approximately 30 km from Padang, a nesting beach on Pandan Island recorded 137 green turtle nests and 20 hawksbill turtle nests in 2022. Olive ridley turtles (*Lepidochelys olivacea*) also nest sporadically (LKKPN Pekanbaru, personal communication, 16 August

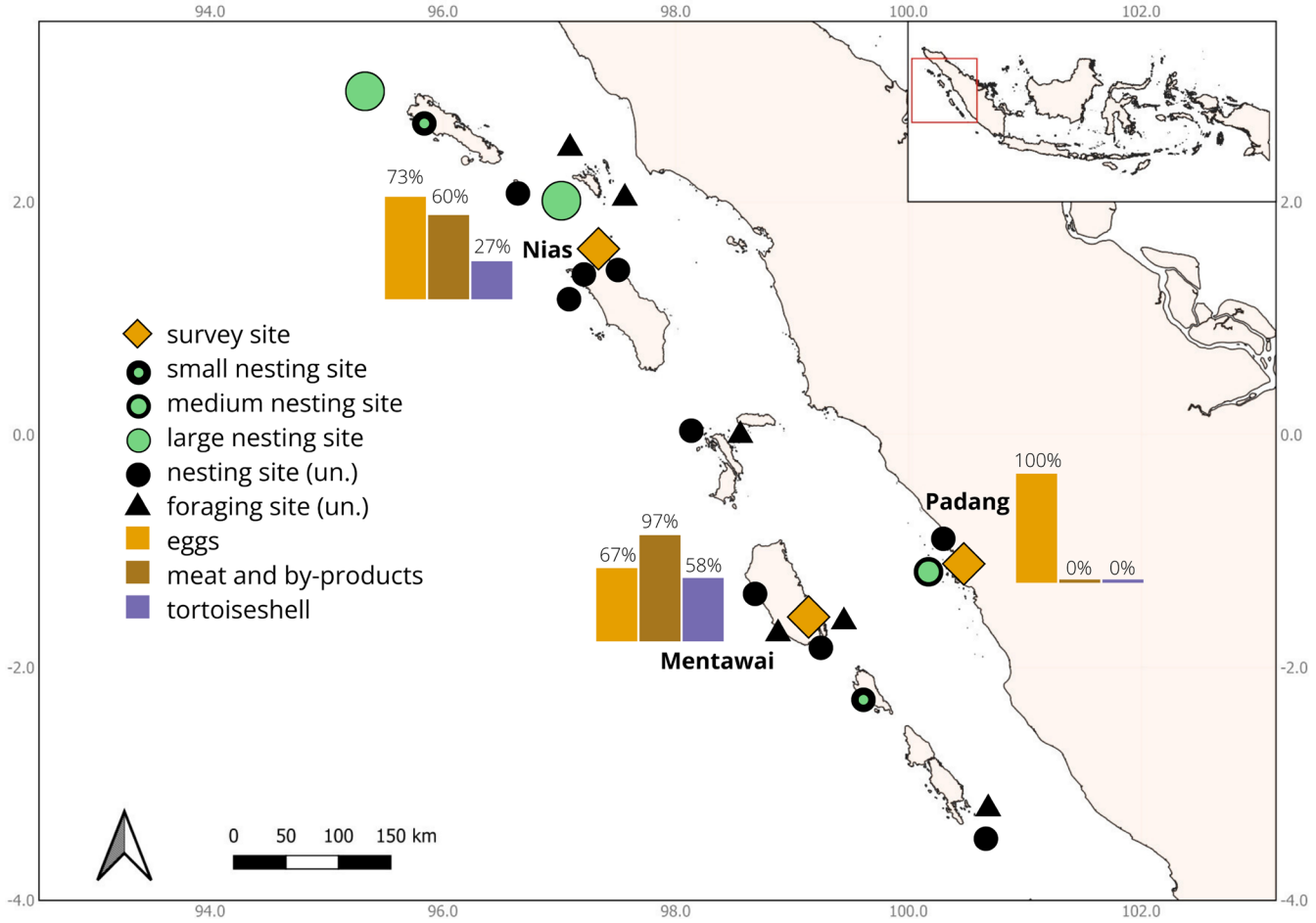

FIGURE 1 Map of survey sites (yellow diamonds), nearby sea turtle habitats, and respondent' reported use of turtle parts. Quantified sea turtle nesting sites are shown as green circles, with point size and black outline weight indicating relative abundance (small: 0–100 nests/year, medium: 101–500, large: >500). Black circles represent unquantified nesting sites. Black triangles indicate known but unquantified foraging grounds (Groombridge & Luxmoore, 1989; Hamann et al., 2021; LKKPN Pekanbaru, personal communication, 16 August 2024; Mast, 2024; Turtle Foundation, 2023). Bar charts display the percentage of respondents at each site who reported use of eggs, meat and by-products or tortoiseshell. As multiple responses were allowed, category totals may exceed 100%.

2024). Occasional nesting also occurs on Padang's beaches, though populations remain unquantified (Groombridge & Luxmoore, 1989).

Mentawai (1°35′48.46″ S, 99°12′49.8″ E) is an archipelago whose main islands include Siberut (survey site), Sipora, Pagai Utara and Pagai Selatan. The Mentawai people, one of Indonesia's oldest Indigenous groups, live in patrilineal clans and practice a mix of Christianity, Islam and traditional animism (Suzuki, 2013). Turtle nesting occurs in northwestern Siberut and on Karang Majat Island, south of Siberut. Sea turtles are also found in other parts of Mentawai: 32 leatherback and an unspecified number of green and olive ridley nests were recorded west of Sipora in 2022/2023 (Turtle Foundation, 2023), other sites (e.g. Sanding Island in South Pagai) remain unquantified (Hamann et al., 2021).

Nias (1°23′41.67″ N, 97°10′7.44″ E) is the largest island of Sumatra and is known for its unique megalithic culture within a patrilineal society where Christianity and Islam predominate (Bonatz, 2002; Suzuki, 2013). Greens, hawksbills and leatherbacks nest in North Nias (Sifahandro, Afulu, Lahewa) and surrounding islands including South Nias and the Tello Archipelago (e.g. Simuk Island), but population sizes remain unquantified (Hamann et al., 2021). The largest nearby nesting site is Bangkaru Island (Aceh Province), with about 2000 green turtle nests annually (Mast, 2024). Other notable sites include Babi and Lasia Islands (80 green turtle nests), Along Beach on Simeulue Island (38 leatherback nests) and Selaut Island (18 leatherback nests and 679 green turtle nests in 2022/2023) (Turtle Foundation, 2023).

2.2 | Permissions and ethics statement

The study was carried out under the Indonesian National Research and Innovation Agency permit number 37/TU.B5.4/SIP/VII/2021. Additional permits were secured from the relevant provincial and district authorities, and prior consent was granted by local community representatives.

The questionnaire and study design were approved by the Ethics Committee of the Czech University of Life Sciences Prague. Only participants >18 years were allowed to participate in the survey. Given the illegality of turtle take and use and the need to maintain the anonymity of all respondents, informed consent to participate in the survey was obtained verbally prior to participation. Participation was entirely voluntary. Respondents were informed about their right to decline to answer or to withdraw from the survey at any time if they wished. No compensation was provided for participation.

2.3 | Socio-cultural survey design

Data were collected using a semi-structured questionnaire in Indonesian (English version in Supporting Information S1), based on a community-based socio-cultural turtle use and trade survey by the World Wide Fund for Nature (WWF) under the *Turtle Use Project* (Riskas & Madden Hof, 2020; WWF, 2019).

2.3.1 | Fieldwork and data collection

Fieldwork was carried out from September 2021 to April 2022. A 1-week pilot with 20 participants was conducted a month prior to the survey to ensure the clarity of questions, without making any changes to the questionnaire. Data were collected by the main researcher (AH, a long-time resident in Indonesia), an Indonesian research assistant from the Universitas Syiah Kuala, and a member of the local community (the key informant), who was different for each survey site. Contacts between the research team and key informants were established in early 2021 to build trust and address research-related issues.

Respondents were selected using nonprobability convenience sampling combining snowball and purposive techniques (Naderifar et al., 2017; Newing, 2010). Participants were required to be originally from, or have resided in, the site at least 10 years to ensure a shared socio-cultural context. If multiple members of the household were present, one was chosen by the household. Most households were headed by males, typically the income earners and spokespeople. Although this may have introduced a skewed gender balance, men were also less likely to be at home during daytime hours due to work (e.g. fishing), which meant that women were frequently selected as respondents. Importantly, women also play a crucial role in processing and using turtle products, and thus often have detailed traditional knowledge (Barrios-Garrido et al., 2018). We acknowledge this as a possible limitation and recommend that future studies adopt more explicitly gender-stratified sampling strategies.

To minimise bias and facilitate accurate reporting, the questionnaire was administered face-to-face in Indonesian or local languages, with responses recorded immediately (Abd Mutalib et al., 2013). Respondents were encouraged to elaborate on their answers to provide additional context if they desired. Unsolicited comments were noted and used to support the interpretation of structured responses when relevant. The questionnaire took between 20 and 40 min to complete.

A total of 140 respondents participated in the survey, representing 10% of the adult population (>18 years) in each subdistrict (Briceño et al., 2021), as obtained from the Indonesian Statistics Agency (BPS-Statistics Indonesia, 2023). Given the time-consuming field work, the respondents' reluctance to participate and the illegality of turtle take and use, we consider our sample size to be representative.

2.3.2 | Questionnaire structure

The 28-question survey was split into two parts. The first part included the sociodemographic characteristics (explanatory variables): (1) site, (2) gender, (3) age, (4) religion, (5) education, (6) employment. The second part gathered information (response variables): (1) turtle capture (number of individuals captured intentionally, incidentally or both, in the last year; species; capture techniques); (2) egg take (number of nests taken monthly; species);

(3) turtle use and trade (parts used—meat and by-products, eggs, tortoiseshell, fat, oil, blood, bones); (4) purposes of sea turtle use (subsistence = consumption for food, cultural, medicinal, religious) and self-perceived importance of these uses; (5) perceived changes in turtle populations over the past 5 years and conservation status. The questionnaire included open-ended and structured questions. To minimise misidentifications, respondents identified turtle species using images. The importance of turtle use, perceived population changes and conservation perceptions were measured on a five-point Likert scale (Ballesteros & Rodríguez-Rodríguez, 2018; Bergseth et al., 2015). A skip logic ensured respondents answered relevant questions only (De Vaus, 2002) and information was cross-verified for consistency (Abd Mutalib et al., 2013).

2.4 | Data analysis

Responses were coded numerically or by theme for categorical data (De Vaus, 2002). Responses 'Not applicable' were omitted from all analyses. The responses 'Do not know' and 'Prefer not to say' were summarised but omitted from the analyses. Selected sociodemographic variables (religion, education and employment) were each recoded into broader categories for analysis. Religion was grouped into two categories: Islam and Christianity (Catholicism, Protestantism). Education was grouped into two levels: lower (no formal education, primary education) and higher (middle, high, college/university degree). Employment was divided into three classes: no employment (housewife, student, non-employed, unemployed), primary sector (farming, fishing, harvesting, processing), secondary and tertiary sector (civil servant/officer, tourism, private business—vendor, private business—craftsman, private business—other). The turtle capture in the previous year and egg take in a typical month volumes were grouped into three intervals: 1–10, 11–50 and >51 turtles/nests, as none of the respondents selected 1–2 and >100. Likert scales on self-perceived importance of turtle use purposes were collapsed into two categories: 1 and 2 = Not important; and, 4 and 5 = Important (De Vaus, 2002). None of the respondents answered 3 = No opinion for these questions.

Statistical analyses were performed in R 4.2.0. (R Core Team, 2022). We fitted two binomial generalised linear models to test how the probability of turtle take and turtle use—a binary response with 1 (yes) and 0 (no)—varied with the sociodemographic predictors (site, gender, age, religion, education, employment). We used a non-informative prior distribution and the 'sim' function from the 'arm' package (Gelman, 2022) to compute Bayesian simulations, generating a sample of 10,000 simulated values for each model parameter (posterior distribution). The interval estimates of the coefficients from the models and the model predictions were calculated as Bayesian 95% credible intervals (CI) represented by the 2.5 and 97.5 percentiles of the posterior distribution of the 10,000 simulated values. The quality of the model was assessed using pseudo-R^2 and Variance Inflation Factor (VIF) (<3). The significance of the predictors of the models was evaluated using the Type II analysis of variance table. The corresponding VIF and ANOVA functions were used from the 'car' package (Fox & Weisberg, 2019). We used the packages 'stats' and 'rcompanion' in R (Mangiafico, 2022) to perform chi-squared tests and calculate Cramér's V to assess whether the probability of turtle use differed significantly between sites for each purpose (subsistence, cultural, medicinal, religious). The sample size provided 80% statistical power to detect medium effect sizes at a significance level of 0.05. Data and code are publicly available at OSF: https://osf.io/f9djw/?view_only=403d87aa09ae49c48320e55b1c46559a.

3 | RESULTS

3.1 | Respondent sociodemographics

Of the 140 respondents, most were from Padang (57%), followed by Mentawai (26%) and Nias (17%). The majority were males, 36–55 years old, who identified as Muslim. The levels of education were evenly balanced between lower and higher education. Half of the respondents worked in the primary sector (Table 1).

3.2 | Sea turtle take

Of all respondents, 32% reported taking sea turtles, 64% did not, and 4% preferred not to say (Table 1). Among those who took turtles, 52% ($n = 23$) captured them (intentional, incidental or both), 23% ($n = 10$) took eggs, and 25% ($n = 11$) did both. Of the captures, 47% were intentional (targeted capture), 53% were a mixture of intentional and incidental (bycatch) capture, and one respondent reported capturing turtles solely as incidental bycatch (Figure 2d). These patterns varied between sites. Only eggs were taken in Padang (9%). In Mentawai, 80% captured turtles and 28% took eggs. In Nias, 21% captured turtles and 17% took eggs (Table 1, Figure 2a). Most turtle takers were males (91%, $n = 40$), aged >56 years (50%, $n = 22$), Christian (59%, $n = 26$), with a lower level of education (82%, $n = 36$) and worked in agriculture and fishing (84%, $n = 37$).

3.2.1 | Capture specifics

Of the 34 respondents who reported turtle capture, 41% reported low (1–10 turtles) and 53% reported medium (11–50 turtles) capture volumes in the previous year (Figure 2b). Green and hawksbill turtles were the most commonly captured species (91% and 65%, respectively). One respondent reported the capture of leatherback turtles; no captures of olive ridley or loggerhead turtles (*Caretta caretta*) were reported (Figure 2c). Capture methods included nets (82%), direct hand capture on the beach (21%) and using spears (15%, barbed head attached to a short shaft with rope and retrieval system, thrown by hand from a boat). Underwater harpooning (barbed head, fired from a gun with line or rope and retrieval system) and free-diving hand

TABLE 1 Sociodemographic characteristics of respondents and reported incidence of sea turtle take and use pooled by survey site, with overall totals provided.

		Survey site			
		N (%)			
		Padang	Mentawai	Nias	Total
Variable	**Category**	**80 (57%)**	**36 (26%)**	**24 (17%)**	**140 (100%)**
Sex	Male	39 (49%)	33 (92%)	19 (79%)	91 (65%)
	Female	41 (51%)	3 (8%)	5 (21%)	49 (35%)
Age	18–35	34 (43%)	2 (6%)	12 (50%)	48 (34%)
	36–55	32 (40%)	11 (30%)	11 (46%)	54 (39%)
	>56	14 (17%)	23 (64%)	1 (4%)	38 (27%)
Religion	Muslim	80 (100%)	8 (22%)	15 (62%)	103 (74%)
	Christian	0 (0%)	28 (78%)	9 (38%)	37 (26%)
Education	Lower	23 (29%)	33 (92%)	14 (58%)	70 (50%)
	Higher	57 (71%)	3 (8%)	10 (42%)	70 (50%)
Employment	Agriculture and fisheries	21 (26%)	34 (94%)	16 (67%)	71 (51%)
	Small business and services	42 (53%)	0 (0%)	4 (16.5%)	46 (32%)
	No employment	17 (21%)	2 (6%)	4 (16.5%)	23 (17%)
Sea turtle take	Yes	7 (9%)	31 (86%)	6 (25%)	44 (32%)
	No	69 (86%)	4 (11%)	18 (75%)	90 (64%)
	Prefer not to say	4 (5%)	1 (3%)	0 (0%)	6 (4%)
	Capture turtles: yes	0 (0%)	29 (80%)	5 (21%)	34 (24%)
	Capture turtles: no	80 (100%)	6 (17%)	19 (79%)	105 (75%)
	Capture turtles: prefer not to say	0 (0%)	1 (3%)	0 (0%)	1 (1%)
	Take eggs: yes	7 (9%)	10 (28%)	4 (17%)	21 (15%)
	Take eggs: no	69 (86%)	25 (69%)	20 (83%)	114 (81%)
	Take eggs: prefer not to say	4 (5%)	1 (3%)	0 (0%)	5 (4%)
Sea turtle use	Yes	48 (60%)	35 (97%)	15 (63%)	98 (70%)
	No	31 (39%)	1 (3%)	8 (33%)	40 (29%)
	Prefer not to say	1 (1%)	0 (0%)	1 (4%)	2 (1%)

Note: The percentages are based on the number of respondents per survey site. 'Sea turtle take' refers to any involvement in either direct turtle capture (including intentional and incidental captures or both), egg take or both activities. 'Capture turtles' refers specifically to the direct capture of turtles, either on nesting beaches or at sea. 'Take eggs' refers only to the taking of turtle eggs. 'Sea turtle use' includes any use of turtle parts for subsistence, cultural, medicinal or religious purposes, including trade.

captures were not reported. Although not specifically asked, several respondents spontaneously mentioned damage to fishing gear caused by turtle bycatch. In terms of temporal changes, 56% of respondents ($n=19$) reported capturing fewer turtles, 12% of respondents ($n=4$) reported the same number, and one respondent reported capturing more turtles than they did 5 years ago. Finally, compared to when respondents began to capture turtles, 15% of respondents ($n=5$) reported capturing smaller turtles, 21% ($n=7$) larger turtles, 53% ($n=18$) did not know and 11% ($n=4$) did not answer.

3.2.2 | Egg take

Of the 21 respondents who took eggs, 95% ($n=20$) reported low (1–10 nests) egg take in a typical month. One respondent (5%) reported medium take (11–50 nests). No high take (>51 nests) was reported. Green and hawksbill turtle eggs were taken the most frequently (81%, $n=17$ and 52%, $n=11$, respectively). Olive Ridley egg take was reported in Padang and Nias (19%, $n=4$). Egg taking of other turtle species was not recorded.

3.2.3 | Probability of sea turtle take

The probability of turtle take in both Mentawai (odds ratio [OR]:5.96, 95% CI: 1.06–33.02, $p<0.05$) and Nias (25.15, 5.49–112.28, $p<0.001$) was significantly higher than in Padang (Table 2). The highest probability of turtle take was predicted for males aged 36–55 who identified as Muslim, had a lower level of education and worked in the primary sector. For individuals with

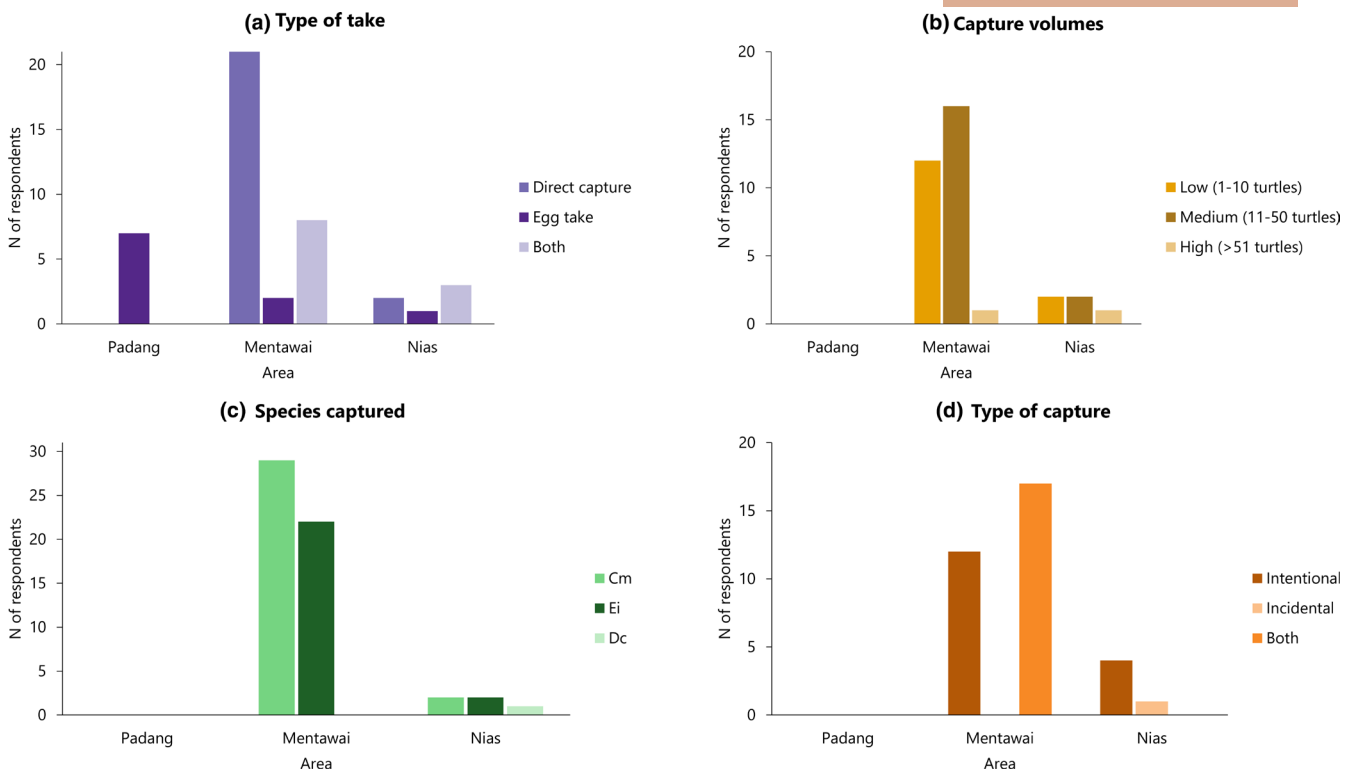

FIGURE 2 Specifics of sea turtle take at survey sites: (a) type of take; (b) capture volumes; (c) captured species: Cm, green turtle; Dc, leatherback turtle; Ei, hawksbill turtle; (d) type of capture.

this profile, the predicted probability was 25.48% (8.31%–53.88%) in Padang, 66.88% (33.23%–88.83%) in Mentawai and 89.46% in Nias (66.03%–97.34%). Conversely, the lowest predicted probability was for females over 56 years of age who identified as Christians, had a higher level of education and were not employed. In this group, the predicted probability was 1.87% (0.15%–19.26%) in Padang, 10.11% (1.26%–48.88%) in Mentawai and 32.12% (4.41%–83.76%) in Nias. The model explained 34.18% of the variability in turtle take.

3.3 | Sea turtle use

Across all sites, 70% of the respondents used turtles, 29% did not, and 1% preferred not to say (Table 1). The prevalence of turtle use and turtle parts used varied by site (Figure 1). Among those who reported turtle use, most were males (69%, $n=68$), 36–55 years old, Muslim (66%, $n=65$), with lower levels of education (55%, $n=54$) and were employed in agriculture or fisheries (57%, $n=56$). The products most commonly used were eggs (88%, $n=87$), followed by meat (45%, $n=44$). Tortoiseshell was used by 17% of the respondents ($n=17$). A total of 21% of respondents ($n=29$) acknowledged their involvement in the trade in sea turtles, with tortoiseshell being the product most traded (62% of traders, $n=17$). Apart from hawksbill (specifically preferred for tortoiseshell), no other species use preferences were reported.

3.3.1 | Probability of sea turtle use

The odds of turtle use were significantly higher in Mentawai than in Padang (26.31, 1.95–331.62, $p<0.05$, Table 2), the difference between Nias and Padang was not significant (0.89, 0.25–3.23). The highest predicted probability of turtle use was among males who were middle-aged, Christian, had a higher level of education and were not employed in Padang (86.85%, 42.73%–98.51%), Mentawai (99.41%, 91.92%–99.96%), Nias (85.42%, 43.53%–98.00%). The lowest probability was among females who were >56 years old, Muslims, had a lower level of education and worked in the primary sector in Padang (31.48%, 86.80%–69.49%), Mentawai (92.23%, 47.86%–99.36%), Nias (28.96%, 62.25%–71.89%). The model explained 15.86% of the variability in turtle use.

3.3.2 | Purposes of sea turtle use

The self-perceived importance of sea turtle use purposes (subsistence, cultural, medicinal, religious) varied significantly between the survey sites ($p<0.001$, Figure 3). In Padang, only medicinal use was reported, all involving turtle eggs (77%), which were believed to improve overall health and used as an aphrodisiac by some respondents. In Mentawai, all purposes were reported, with subsistence (66%) and cultural uses (83%) being the most common. Cultural use was linked to specific community celebrations, including the

TABLE 2 The effect of sociodemographic characteristics on turtle take.

	(a) Sea turtle take model				(b) Sea turtle use model			
Predictors	**Estimate**	**2.5% CI**	**97.5% CI**	***p***	**Estimate**	**2.5% CI**	**97.5% CI**	***p***
Intercept	−2.504	−4.404	−0.582	*	0.185	−1.198	1.577	
Mentawai	1.785	0.054	3.497	*	3.270	0.668	5.804	*
Nias	3.225	1.703	4.721	***	−0.113	−1.399	1.172	
Female	−0.436	−1.750	0.862		−0.159	−1.098	0.795	
36–55 years old	0.136	−1.138	1.445		0.492	−0.429	1.377	
>56 years old	−0.057	−1.554	1.395		−0.580	−1.784	0.624	
Christian	−0.336	−1.690	0.987		0.829	−0.847	2.546	
Higher level of education	−0.618	−1.803	0.542		0.422	−0.518	1.339	
Employment in primary sector	1.269	−0.261	2.825		−0.183	−1.526	1.122	
Employment in secondary/tertiary sector	0.451	−1.378	2.299		−0.049	−1.242	1.119	
Pseudo-R^2	34.18%				15.86%			

Note: Shown are posterior estimates of effect sizes with 95 credible intervals (CI) from a posterior distribution of 10,000 simulated values generated by the 'sim' function in R. *p*, *p*-value: *<0.05, ***<0.001.

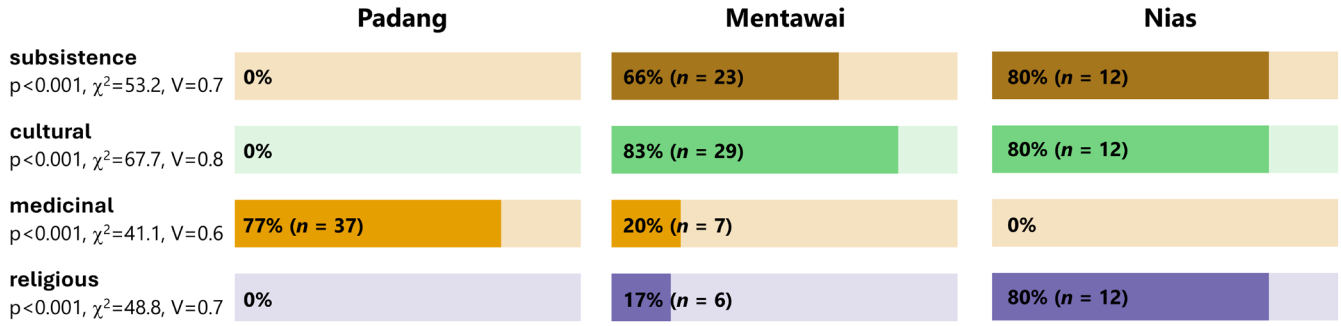

FIGURE 3 Self-perceived importance of sea turtle use purposes reported by survey site. Responses are shown as percentages, representing the percentage of respondents who perceived each purpose of use as important on a Likert scale. The sum of the percentages exceeds 100% because the respondents could select more than one purpose. Statistical results are reported as *p* (*p*-value) from the chi-square test (χ^2) and *V* (Cramer's *V*) as a measure of effect size (small: 0.07, medium: 0.21, large: <0.35; Kim, 2017).

completion of the house, transportation of wood from the forest for boat building and launching a boat into the sea. Turtle carapaces and skulls were also used to decorate tribal houses. Medicinal use was less frequent (20%) and included eggs, with beliefs similar to those of Padang, as well as turtle fat, which was used to treat rheumatism, support child growth and as traditional medicine for poultry. 17% of the respondents mentioned the use of turtle meat during religious celebrations, with preference attributed to its availability. In Nias, the subsistence (80%), cultural (80%) and religious (80%) uses were all high. Although cultural use was not related to specific events, turtle consumption was generally perceived as part of local tradition, and religious use was strongly associated with weddings and Christian Holy Days. Across all sites, no respondents reported non-consumptive purposes (e.g. cultural beliefs, ecotourism, aesthetics, ecology). Most respondents were aware of the protected status of sea turtles (94%, $n=132$), and 82% ($n=81$) perceived a decrease in turtle populations, while 18% ($n=18$) perceived an increase.

4 | DISCUSSION

4.1 | Sea turtle take

The type of turtle taken, and consequently its use, appeared to be strongly shaped by site-specific cultural and religious contexts (Figures 1 and 2a). In Padang, Muslim respondents reported that they did not eat turtle meat and only took eggs, a pattern consistent with Islamic dietary prohibitions documented in other regions (Chan, 2006; Frazier, 1980; Migraine, 2015). On the contrary, in Mentawai and Nias, turtle meat consumption was common among Muslim respondents (88% and 27%, respectively). This suggests that the religious prescriptions were moderated by deeply rooted cultural traditions. In Mentawai and Nias, Indigenous communities maintain subsistence practices and cultural uses of turtles, including the consumption of turtle meat. These practices are further reinforced by elements of animist belief systems that persist alongside formal religions, shaping attitudes and behaviours. For comparison, in Padang, the cultural

framework is more strongly influenced by Islamic principles, and traditional practices involving turtle meat have largely disappeared.

4.1.1 | Capture specifics

According to our findings, although the reported capture volumes were medium or low (Figure 2b), extrapolating the incidence (Table 1) from our survey indicates that the total number of turtles captured annually could reach several hundred. Furthermore, most turtle populations in Sumatra (Figure 1) have small to medium annual nesting volumes (Mast, 2024; Turtle Foundation, 2023), meaning relatively low contribution to the next generation. Data from foraging grounds are lacking, but historical records indicate long-term, extreme turtle and egg (up to 100%) take in some sites (Groombridge & Luxmoore, 1989). The demographic impacts of exploitation can take years to become apparent due to the delay in maturity of sea turtles, making sustained direct captures (particularly of juveniles and smaller adults) especially detrimental. Although we cannot quantify these effects on current population volume and demography, the combination of relatively small nesting volumes, historical exploitation and ongoing captures underscores the urgent need for targeted research to assess demographic impacts and inform conservation strategies. We also acknowledge that the reported captures may be conservative, as respondents may be reluctant to share actual volumes. In addition, captures in industrial fisheries were not included in our survey. Green and hawksbill turtles, the most common species in the region (Groombridge & Luxmoore, 1989; Halim et al., 2001), were also the most frequently reported captures in our survey (Figure 2c). Considering the hawksbill turtle's critically endangered status on the IUCN Red List (Mortimer & Donnelly, 2008), the loss of each individual poses a serious threat to the species' survival (Pheasey et al., 2021). We found no culturally specific techniques or ceremonial hunts typical of other Indigenous communities in Indonesia (Suarez & Starbird, 1995). Consistent with other studies (Alfaro-Shigueto et al., 2011; Hamilton et al., 2024; Peckham et al., 2008), intentional and incidental captures (Figure 2d) indicate that this turtle capture may be functioning as a small-scale fishery and may significantly impact turtle populations (Gautama et al., 2022; Lewison et al., 2014). Some respondents noted that incidentally captured turtles can damage nets, leading fishers to trade turtles to replace damaged gear. Self-comparisons of capture volumes may indicate population declines, with more than half of respondents reporting fewer captures than in the past. Although previous Indo-Pacific studies suggested long-term exploitation affects turtle demographics (Bell et al., 2020; Miller et al., 2019), our results could not confirm these effects. Although population declines and demographic changes are likely, we acknowledge the need for further research.

4.1.2 | Egg take

The lower incidence of egg take compared to turtle capture is likely related to conservation efforts at larger nesting sites (Mast, 2024; Turtle Foundation, 2023; LKKPN Pekanbaru, personal communication, 16 August 2024) as the presence of night patrols on the beach automatically increases surveillance and potentially deters illegal egg take (Pheasey et al., 2021). Given that small to medium-sized nesting sites remain unprotected (Groombridge & Luxmoore, 1989; Hamann et al., 2021), opportunistic take is more likely. This is consistent with our findings, where 95% of respondents reported low volumes of take (<10 nests per month). However, the impact of opportunistic egg take should not be underestimated. Extrapolating the incidence (Table 1) and the volume of taken turtle nests suggests that egg take could affect hundreds of nests annually. Although nesting is seasonal for hawksbill and leatherback turtles, green turtles in Sumatra are reported to nest year-round (Groombridge & Luxmoore, 1989; Mast, 2024; Turtle Foundation, 2023; LKKPN Pekanbaru, personal communication, 16 August 2024), which extends egg availability for much of the year. Many nesting sites remain unquantified (Figure 1), adding uncertainty to the potential scale of long-term overexploitation in unprotected areas. Similarly to capture, the eggs of green and hawksbill turtles were taken mainly. Despite confirmed captures of leatherback turtles at sea, egg take has not been documented in our study. We attribute this to the fact that leatherbacks nest in low numbers and only seasonally in the region and/or ongoing conservation efforts on leatherback nesting beaches (Mast, 2024; Turtle Foundation, 2023).

4.1.3 | Probability of sea turtle take

The odds of turtle take in Padang were significantly lower than in Mentawai and Nias (Table 2). As a city, Padang offers better education and employment opportunities. Previous studies have shown that education reduces poverty and dependence on natural resources, including sea turtles (Abd Mutalib et al., 2013; Barrios-Garrido et al., 2020; Hamann et al., 2021; Ingram et al., 2022; Moneron et al., 2020). Similarly, in Padang, people are less likely to work in the primary sector and to take natural resources (Poti et al., 2021; Shalehin et al., 2022). Furthermore, turtle take in Padang may be lower, since only egg take has been recorded there, and larger nearby nesting sites are protected (Figure 1).

Nias had the highest odds of turtle take, which we attribute to the high trade in tortoiseshell (Dijk & Shepherd, 2004; Nahill et al., 2020). This illegal trade creates a strong incentive for turtle capture, linked to local cultural practices (Figure 3). Similarly, the high odds of turtle take in Mentawai reflect the dependence on subsistence use and cultural practices (Figure 3) (Gomez & Krishnasamy, 2019). Although factors such as gender, age, religion, education level and employment may influence turtle take, these sociodemographic factors are likely site specific and may be masked by the site effect in our model.

4.2 | Sea turtle use

Consistent with findings from other regions (Campbell, 1998; Chan, 2006; Mejías-Balsalobre et al., 2021), eggs were the most

commonly used part of the turtle (88%). Hawksbill turtles, in addition to being used for eggs and meat, were exclusively targeted for tortoiseshell, the most traded product in our study (62%), with the highest trade reported in Nias. Half of the traders also captured hawksbills themselves, indicating a direct harvester–consumer link within local networks (Pheasey et al., 2021; Phelps et al., 2016). At the same time, anecdotal reports point to broader trade connections, including turtles transported from Aceh to Nias, open tortoiseshell craft stores and stalls in Nias (Gunungsitoli, Teluk Dalam, Sorake, Bawomataluo) and online vendors on shopping platforms advertising products originating from Nias (Nahill et al., 2020). These findings show that tortoiseshell exploitation is not limited to subsistence but is also embedded in wider trade networks (Armstrong et al., 2023; Nahill et al., 2020). However, we suggest the ongoing trade is more likely to be supply-driven. Captures appear to depend largely on the local availability and accessibility of hawksbills, with trade occurring as an outcome of these captures, whether initially motivated by subsistence or trade. Previous studies have shown that turtle trade can provide modest, but rapid income, which may be significant for small-scale fishers (Mejías-Balsalobre et al., 2021; Pheasey, 2020). This underscores the need for strategies that deter or reduce illegal turtle take at the point of capture (Pheasey et al., 2021).

4.2.1 | Purposes of sea turtle use

Significant differences in the purposes of use between survey sites (Figure 3) highlight the influence of socio-cultural factors (Migraine, 2015), traditional and religious beliefs (Barrios-Garrido, 2018; Barrios-Garrido et al., 2018; Ingram et al., 2022) on turtle use, critical for future management.

Subsistence use in Nias and Mentawai was motivated by basic dietary needs, protein intake and taste preferences, consistent with findings from similar studies (Fendjalang et al., 2019; Hamilton et al., 2024; Suarez & Starbird, 1995). In our case, the respondents preferred turtle meat to pork and beef because of its lower cost and greater accessibility. The Mentawai respondents further explained that raising livestock is both time-consuming and expensive, while turtle take aligns with their traditional lifestyle of harvesting and hunting, making turtle meat a more practical and culturally embedded option. Furthermore, even though some respondents highlighted the taste of turtle meat, the preference was not linked to particular turtle species, which is in contrast to reports from the Caribbean where the meat of green turtles was largely preferred (Garland & Carthy, 2010; Pheasey et al., 2021). It is also noteworthy that the respondents reported fatal poisoning events in their communities after turtle meat consumption. Although the possible toxic effects of turtle meat consumption are known (Frías-Espericueta et al., 2006; Rothamel et al., 2021), respondents were not familiar with the possible toxicity of turtle meat, but attributed the poisoning to the bad cooking process.

Cultural practices involving sea turtles are common among Indigenous communities (Álvarez-Varas et al., 2020; Barrios-Garrido et al., 2018; Hamilton et al., 2024; Suarez & Starbird, 1995), as confirmed in Mentawai and Nias (Figure 3). In Mentawai, turtle meat was required for specific cultural celebrations, while in Nias consumption was regarded more broadly as part of cultural tradition. At both sites, turtle meat was preferred during Christian Holy Days and weddings, not because it was religiously mandated, but because of its availability. This reliance on availability may suggest an economic dependence on turtle meat, particularly where capture occurs on a subsistence basis. These findings highlight the importance of improving economic opportunities in Indigenous communities and fostering dialogue around alternative protein sources to reduce pressure on turtle populations. Contrary to other studies (Álvarez-Varas et al., 2020; Campbell, 2003; Frazier, 2003, 2005; Luna, 2003), no evidence of sea turtles as cultural symbols was found.

Beliefs in the health benefits of turtle use are widespread globally (Balazs, 1983; Barrios-Garrido et al., 2018; Campbell, 2003; Fretey et al., 2007; Hamann et al., 2006; Mejías-Balsalobre et al., 2021; Poti et al., 2021). This was also evident in our survey (Figure 3), although reported medicinal uses were relatively limited, involving only eggs and fat. In contrast, in Latin America and Africa, the uses extend more broadly to blood, genitalia or powdered bones (Barrios-Garrido, 2018; Fretey et al., 2007). In both Padang and Mentawai, turtle eggs were believed to improve stamina, appetite and blood pressure, consistent with reports from Malaysia (Poti et al., 2021), likely reflecting shared socio-cultural traditions between West Sumatra and Malaysia. In Padang, some respondents also attributed aphrodisiac properties to eggs, a belief also documented in Latin America (Barrios-Garrido, 2018; Campbell, 1998, 2003). The medicinal use of turtle fat was reported in Mentawai, particularly to treat rheumatism; this parallels practices in Guinea, where rheumatism was also treated with turtles, although blood rather than fat was used there. Unlike in parts of Africa (Fretey et al., 2007), however, no ritualistic medicinal practices involving turtles were found in our survey.

Additionally, we suggest that persistent turtle exploitation may also arise from misconceptions that turtles prey on fish, negatively impacting fish stocks and fishers' economies. This may explain the high exploitation rates despite strong conservation awareness (94%). Unlike other regions where sea turtles are valued for ecotourism and ecological importance (Hart et al., 2013; Poti et al., 2021; Ribeiro et al., 2022; Wilson & Tisdell, 2001), such perceptions were absent in our survey, possibly due to fewer ecotourism programs in Indonesia and prevailing misconceptions.

4.2.2 | Probability of sea turtle use

The site was the only significant predictor in the turtle use model, with the odds of use significantly higher in Mentawai compared to Padang and Nias (Table 2). We attribute this to the traditional lifestyles of Mentawai Indigenous communities, characterised by widespread subsistence and cultural uses (Figure 3). As with the turtle take model, we suggest sociodemographic factors were masked by

site effects. We acknowledge the influence of these factors on turtle use, as described in other studies (Hamann et al., 2021; Hancock et al., 2017; Poti et al., 2021; Rajakaruna et al., 2009; Shalehin et al., 2022). This includes the positive effect of education or age, with younger people more likely to adopt less traditional lifestyles and rely less on natural resources.

5 | RECOMMENDATIONS

Given the significant differences in turtle take and use between sites and the growing concerns about sea turtle declines across Indonesia (Ingram et al., 2022; Migraine, 2015), we recommend a set of tailored conservation strategies to reduce threats and local dependence on turtles in Sumatra.

Captures at sea and on nesting beaches require both stronger law enforcement and surveillance, but demand different approaches. At sea, where enforcement is logistically challenging, incidental captures can be reduced by implementing bycatch mitigation measures (e.g. LED net illumination) (Gautama et al., 2022; Senko, Peckham, et al., 2022) and by negotiating gear-use agreements with fishers, who are motivated to avoid gear damage. Engaging fishers in participatory monitoring and community-based surveillance at sea can further improve compliance, particularly when paired with income opportunities. On nesting beaches, ranger and community patrols, together with ecotourism schemes where communities benefit financially from protecting turtles rather than taking them may provide effective incentives. Volunteer programs can also support limited government and NGO capacity by ensuring daily patrols and nest protection (Pheasey et al., 2021).

Our results indicate that subsistence consumption is not essential for food security and that awareness of turtle protection status alone does not reduce exploitation. Efforts to change dietary preferences should be supported by mariculture projects and sustainable fisheries that provide accessible protein alternatives and alternative livelihoods. Collaboration with local leaders can help identify culturally appropriate substitutes for turtle use in cultural, religious and medicinal practices and dispel myths about the health benefits of turtle products (WWF Indonesia, 2005). Targeted education campaigns should emphasise both the ecological roles of turtles and the health risks of turtle meat consumption.

Reducing supply-driven tortoiseshell trade requires strong incentives. These should focus on enhanced surveillance and law enforcement targeting both fishers and traders, including online vendors, and on providing alternative livelihoods to fishers (McNamara et al., 2016; Pheasey et al., 2021). Promoting substitutes for handicrafts (e.g. coconut shell, cattle horn) can also help reduce customer demand for tortoiseshell.

Finally, stronger scientific baselines are essential to inform management. Further research should document understudied nesting and foraging sites, quantify the impacts of small-scale fisheries and integrate local ecological knowledge into management planning. Additionally, we recommend genetic studies (Madden Hof & Jensen, 2022; ShellBank, 2023) to assess population structure, connectivity and the origins of turtles taken or traded. This information will support enforcement and ensure that conservation measures prioritise the most vulnerable populations.

6 | CONCLUSION

Our study demonstrates that socio-cultural factors strongly shape turtle exploitation in Sumatra. We documented site-specific differences in types of turtle take, parts used, purposes of use and sociodemographic drivers. These findings indicate that broad, generalised conservation measures are unlikely to succeed. Instead, we emphasise the need for locally tailored approaches that integrate religious and cultural traditions, economic realities and are implemented in partnership with Indigenous communities. By providing one of the first comparative assessments of turtle exploitation in Sumatra, our study contributes new evidence to inform both national policy and international conservation frameworks. The replicable survey design (in line with the Turtle Use project) also offers a tool for investigating turtle (and other wildlife) exploitation beyond the region, helping to build the evidence base needed to strengthen management and enforcement under existing conventions. Looking ahead, future research should focus on understanding the ecology of understudied nesting and foraging sites and local ecological knowledge. Equally important is refining the conservation strategies by exploring alternative sources of livelihood and protein and addressing other threats such as bycatch, to ensure that management is ecologically effective and socially just, balancing the needs of Indigenous communities with the long-term survival of sea turtles.

AUTHOR CONTRIBUTIONS

Adela Hemelikova, Teuku Reza Ferasyi, Awaluddin, Nur Fadli, Widya Sari, Christine Madden, Kimberly Riskas and Jiri Vojar were all involved in the conceptualisation of the study. Adela Hemelikova, Petr Chajma, Christine Madden, Kimberly Riskas and Jiri Vojar developed the methodology of the study. Adela Hemelikova and Petr Chajma handled the software, validation, formal analysis and data curation and visualisation. Adela Hemelikova, Teuku Reza Ferasyi, Awaluddin, Nur Fadli and Widya Sari participated in the project administration and supervision. Adela Hemelikova collected the data. Adela Hemelikova led the writing of the manuscript. All authors critically contributed to the drafts and gave their final approval for publication.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

Data and code from this study are publicly available at OSF: https://osf.io/f9djw/?view_only=403d87aa09ae49c48320e55b1c46559a.

INCLUSION STATEMENT

Our study brings together authors from multiple countries, including scientists based in the country where the study was carried out. All authors were actively engaged from the early stages of research and study design, ensuring that the diverse perspectives they represent were integrated from the outset. Whenever possible, we engaged and discussed with local stakeholders to seek feedback on the research questions and methodological approach. Whenever relevant, literature published by scientists from the region was also cited; efforts were made to consider relevant work published in the local language.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Data S1.

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