frontiers | Frontiers in Sustainability

TYPE Original Research
PUBLISHED 07 October 2025
DOI 10.3389/frsus.2025.1650431

OPEN ACCESS

EDITED BY
Maria Alzira Pimenta Dinis,
University Fernando Pessoa, UFP, Portugal

REVIEWED BY
Giorgia Graells,
Pontificia Universidad Católica de Chile, Chile
Lota Creencia,
Western Philippines University, Philippines
Calyd Cerio,
Partido State University, Philippines

*CORRESPONDENCE
Kristian Q. Aldea
k_aldea@catsu.edu.ph

RECEIVED 19 June 2025
ACCEPTED 05 September 2025
PUBLISHED 07 October 2025

CITATION
Aldea KQ and Tumala ZMT (2025) Tidal flats' faunal resource utilization in Catanduanes Island, Philippines: gleaning, fishing, and their associated provisioning and cultural services. *Front. Sustain.* 6:1650431.
doi: 10.3389/frsus.2025.1650431

Tidal flats' faunal resource utilization in Catanduanes Island, Philippines: gleaning, fishing, and their associated provisioning and cultural services

Kristian Q. Aldea* and Zyra Mae T. Tumala

Catanduanes State University, Catanduanes, Philippines

Tidal flats are identified as a food-rich coastal zone, yet despite this recognition, information on food provisioning and its associated cultural services remains relatively understudied. To address these gaps, we first investigated the tidal flat species caught and their metrics (time spent, catch quantities, frequency of utilization, income), and second, explored the cultural benefits of gleaning and fishing through an explanatory sequential mixed-method design. The data were gathered through surveys, individual interviews, and focused-group discussions with the gleaners and fishers, the two main livelihood groups in the tidal flats. Our results suggest that tidal flats provide diverse species, reflecting utilization types and various gleaning/fishing methods, which generate food and income for coastal communities. Considering the current utilization schemes, it is inferred that the activities are sustainable, although assessments may be necessary to develop an informed policy framework while maintaining their livelihood value. Various cultural services evolved from the utilization linked to wellbeing, which includes the following: social cohesion and knowledge transfer, sense of place and connection, recreation and leisure, stress relief and social repair, and children's natural discovery learning. Personal and shared experiences associated with the tidal flats may thrive through narratives and intergenerational practices, potentially contributing to the preservation of cultural heritage in the coastal environments. Integrating the tidal flats' conservation is hereby recommended for coastal resource management in the island.

KEYWORDS

unvegetated tidal flats, tidal flat resources, gleaning and fishing, intertidal gleaning, intertidal fishing, intertidal environment, coastal ESs

Introduction

Tidal flats are important food-source areas (Koh and Khim, 2014; Lau et al., 2019), yet despite this recognition, information on food provisioning remains limited, with most studies on utilization and, perhaps, conservation efforts skewed toward more "vibrant" coastal ecosystems, such as mangroves, seagrass, and coral reefs. Although tidal flats' livelihood value is known to subsistence or marginalized groups (Aldea, 2022), limited information is partly due to their general public image as "barren wastelands," making them highly susceptible to human disturbances and alterations (Withers and Tunnell, 1998; Miththapala, 2013). Illustrating their benthic cross-sections, however, reveals a

rich network of species (Dittmann, 1995, 2008; Kinoshita et al., 2010; Dashtgard, 2011; Henmi et al., 2017; Dewenter et al., 2023; Shchepetkina et al., 2025), a stark contrast with what is observed from their unvegetated landscapes. These resident species facilitate nutrient cycling and augment organic matter (De Smit et al., 2021; Zhou et al., 2024), contributing to high intertidal biodiversity, of which many species are utilized as food by coastal communities.

In Catanduanes Island, earlier surveys of resource utilization at low tide showed gleaning activities, where catches typically consist of invertebrates such as gastropods, bivalves, and crustaceans (Aldea, 2022, 2023). Gleaning has been documented in several parts of the Philippines (De Guzman et al., 2019; Mahilac et al., 2023; Stiepani et al., 2023b; Molina et al., 2025; Sahidjan et al., 2025), but tidal flat gleaning is less explored than gleaning in other coastal habitats (e.g., seagrass, mangroves). It is also noted that the communities obtain different species through tidal flat fishing (Aldea, 2022), indicating two utilization strategies linked to the shifting tides. Information on fish assemblages and abundance in the tidal flats has been described in some studies (Reis-Filho et al., 2011; Murray et al., 2015); however, data on the utilization of these species by the community (tidal flat fishing) are limited. Tidal flat fishing is associated with high tides, which facilitates species migration (e.g., demersal fishes), hence the increased abundance of tidal flat species in general. Considering the biodiversity of the tidal flats (Volkenborn et al., 2009; Passarelli et al., 2014; Henmi et al., 2017; Yamakita et al., 2020; Chen et al., 2024), gleaning and fishing may provide rich food resources, providing livelihood support for coastal households (Aldea, 2022). Utilization activities reflected in the shifting tides demonstrate temporal harvesting strategies, potentially preventing simultaneous and intensive utilization pressures.

Due to its archipelagic nature, the Philippines boasts a diverse array of coastal landscapes, several of which are fringed with tidal flats. Current information about tidal flats in the country is generally embedded within the coastal biodiversity strategies and coastal protection framework [Biodiversity Management Bureau (BMB)—Department of Environment and Natural Resources (DENR), 2016; Jensen, 2018; BirdLife International, 2025; Gutierrez, 2025], with ecosystem services information interfaced with other coastal ecosystems. For example, the Las Piñas–Parañaque Wetland Park (LPPWP), which is predominantly covered by mudflats (partly by coastal vegetations such as mangroves), supports rich marine biodiversity and is linked to avian migration and eco-tourism [(Society for the Conservation of Philippines Wetlands, Inc. (SCPWI), 2025)]. Owing to their land-sea intersections, tidal inundation provides unique assemblages of fish and invertebrates (Murray et al., 2014), signifying biological productivity in the tidal flats. Diverse intertidal mollusks, for instance, are assessed in Davao Del Sur tidal flats, with several mollusks exhibiting high species importance values (Jumawan et al., 2015). Since intertidal species are relatively easily obtained, they could be a source of immediate supply of protein and other essential nutrient requirements for the fisherfolk [De Guzman et al., 2019; Department of Science and Technology—Food and Nutrition Research Institute (DOST-FNRI), 2020]. Aside from being a vital food and nutrient source, several families generate income from intertidal fauna, further expanding the provisioning services of the tidal flats for the coastal households.

Ecosystem services derived from coastal ecosystems are not limited to material benefits. This includes cultural services (Hahm et al., 2014), which, in part, encompass social cohesion and knowledge transfer, sense of place and connection, recreation and leisure, stress relief and social repair, and children's natural discovery learning. Cultural services are also associated with expressions of psychological wellbeing such as mental and physical health (Dadvand et al., 2016; van den Berg et al., 2016; Bratman et al., 2019; Stott et al., 2024). These potential benefits could diversify ecosystem services related to obtaining food resources in the area. For example, shared connections and collaboration have been exhibited by resource users in a type of forest utilization system (Raymond and Kenter, 2016). Further, traditional utilization and implements (e.g., fishing methods, social systems), as in the Dadohae region of Korea, are viewed with inherent cultural value, leading to spatial harmony and preservation of ecological balance through natural and sustainable practices (Hong, 2012).

Cultural services, unlike food and timber, are often overlooked, perhaps due to the unquantifiable or less available metrics for comparative assessments. Nonetheless, their importance is paramount when providing personal, family, and community wellbeing (van den Berg et al., 2016). These services capture the intricate and socially fragmented connections between wellbeing and the ecosystems (Grantham et al., 2020). Tidal flats, in particular, could potentially offer a quiet and serene aesthetic, relevant to psychological and mental decompression. Engagements with coastal ecosystems do not only offer material assets but also represent nature connections and quality of life (Grantham et al., 2021). For instance, a case by mangrove users in Ecuador exhibited personal attachments to mangroves in a reciprocal human-mangrove connection (Treviño, 2022). Further, biodiversity in the tidal flats may influence coastal communities' utilization practices through knowledge transfer. When communities maintain and share traditional knowledge, the deeply rooted values, many of which have been developed through generations, are intergenerationally linked (De Sousa et al., 2022; Zhao et al., 2024). Traditional ecological knowledge, for example, has been integrated into the collaborative process of coastal resource management, describing the importance of promoting community traditions (Fernández-Rivera et al., 2024). Tidal landscapes, despite their "blankness," may generate a sense of place that may be experienced either during gleaning and fishing or when they return to the place to relax and meditate. Biodiversity framework integrates with environmental stewardship, social cohesion, collaboration, and volunteerism toward the protection of the coasts (Petriello et al., 2025).

Studies on ecosystem's cultural services, in general, have been significantly increasing, perhaps partly due to the cross-cutting dimensions of the United Nations' Sustainable Development Goals in safeguarding cultural and natural heritage. However, cultural services in the tidal flats, particularly in a Philippine context, remain understudied. To address the identified gaps, we first investigated food provisioning in the tidal flats and second, their associated cultural benefits. Specifically, we elucidate the species caught during

gleaning and fishing, including time spent, catch, frequency, and income, and outline specific cultural benefits associated with the two utilization schemes.

Materials and methods

We employed an explanatory sequential mixed-methods design. This begins with obtaining information about the descriptive and quantifiable provisioning services, followed by a qualitative approach to elucidate the cultural services associated with gleaning and fishing. Providing a localized and deeper understanding of the services beyond the socio-economic data aims to create a broader perspective of the tidal flats' services in the coastal areas.

Study site

The tidal flat areas in the study are situated on the east, northeast, and southern parts of the island (Figure 1) with the following coordinates: Gigmoto Bay, 13.45′57″ to 13.46′55″ N and 124.23′42″ to 124.24′08″ E; Banquerohan wetlands (Oco river mouth basin), 13.53′40″ to 13.53′48″ N and 124.18′38″ to 124.18′48″ E; Balite coast, 13.32′48″ to 13.33′17″ N and 124.08′55″ to 124.09′30″ N. The tidal flats referred to in this study are generally unvegetated mudflats, sand, or rocks experiencing regular tidal inundation (Healy et al., 2002), including tidal areas in between. Descriptions of tidal flats in each location are presented in Table 1, and examples of the tidal flats are shown in Figure 2.

Initial identification of the study site was made in collaboration with local community members. Local communities (*barangays*), from which participants reside, are situated nearby: Gigmoto Bay (Biong, District I, District III, and San Vicente in Gigmoto Municipality), Banquerohan wetlands (San Jose Poblacion and Peña Francia in Viga Municipality, Santa Ana in Panganiban Municipality), and Balite coast (Balite in Virac Municipality). In 2020, the communities had a human population as follows: Biong (991), District I (778), District III (776), and San Vicente (608) in Gigmoto Municipality; San Jose Poblacion (827) and Peña Francia (380) in Viga Municipality; Santa Ana (423) in Panganiban Municipality; and Balite (939) in Virac Municipality (Philippine Statistics Authority, 2025). Some communities do not necessarily possess territorial jurisdiction over the tidal flats, recognizing the diverse spaces and nearby areas supported by the tidal flats' environments.

Sample characterization

A characterization of local community extraction activities was carried out. Preliminary surveys have identified gleaners and fishers in the area, which enabled us to determine the initial number of participants at 120 (63 gleaners, 57 fishers) through stratified random sampling based on proportion and residence (stations). We considered participants who were active gleaners and fishers, with at least one gleaning/fishing trip in the tidal flats in the last 3 months, although some initially identified participants were unable to participate due to availability and time constraints. Gleaners and fishers generally travel 10–500 m, but some may extend to tidal flats with >500 m from their households. We also included gleaners and fishers who utilize multiple coastal habitats, but we informed them to separate gleaning information obtained from the tidal flats by approximating relevant information (e.g., catch rates, frequency, income, etc.). Participants who actively engaged in both activities were excluded from the study.

We recognize gleaning and fishing under the general scope of fishing, but in this study, we separated them to obtain comparative analyses of their specific utilization. We mean gleaning when the activity is conducted in shallow waters or exposed substrates, typically with 0–30 cm depth, although other gleaners start when the water is still 50 cm deep or "knee level." Gleaners generally use bare hands or simple tools when catching species that primarily settle or are naturally trapped in the tidal pools/crevices during low tide. Fishing, on the other hand, is done during high tide or when the area is fully inundated with ≥50 cm depth ("knee-level" and above). Gears are used to catch fish species, taking advantage of the fish migration with the tidal currents. Fishers, however, may harvest catch during the shallower point of the ebbing/flooding tide or move the fishing gear to the shallower or exposed areas to harvest the catch. Time spent starts from the actual time they commence gleaning/fishing in the tidal flats (e.g., collecting bivalves, positioning their gears, etc.) and ends after placing or storing the last catch in the container (gleaning), or after the gears have been checked or packed-up (fishing) just before heading to their residences (excluding travel time to and from the tidal flats).

A total of 109 main participants took part in the study (gleaners, $N = 55$; fishers, $N = 54$). Gleaners comprised 35 women, 14 men, and six children, while fishers comprised 41 men and 13 women. Gleaners' age ranges were 24–71 in women (Mean, 50.8; SD, 11.47), 24–61 in men (Mean, 42.79; SD, 11.02), and 10–16 in children (Mean, 12.67; SD, 2.16). Among fishers, age ranges were 19–61 in men (Mean, 39.15; SD, 9.57) and 24–63 in women (Mean, 42.85; SD, 11.35). The 17 participants during the qualitative phase are part of the 109 total participants.

Measurement instruments

Before the main data gathering, we conducted semi-structured interviews in a preliminary visit with a small group of gleaners and fishers ($N = 11$ gleaners, $N = 10$ fishers). This enabled us to revise questions when participants perceived them as ambiguous or needing further modifications. Aside from beginning questions about personal profile, questions about tidal flat utilization included the following: (1) the faunal groups caught; (2) average percentage of the faunal groups caught per trip; (3) average total kilograms caught, per trip; (4) gear/tool/method used; (5) specific destination; (6) average depth preference (starting and finishing time); (7) average hours spent per trip; (8) average frequency (times) of trip per month; and (9) average monthly income. These questions aimed to answer provisioning services, primarily focused on the species caught and their socio-economic values. The semi-structured questions during the qualitative phase included the

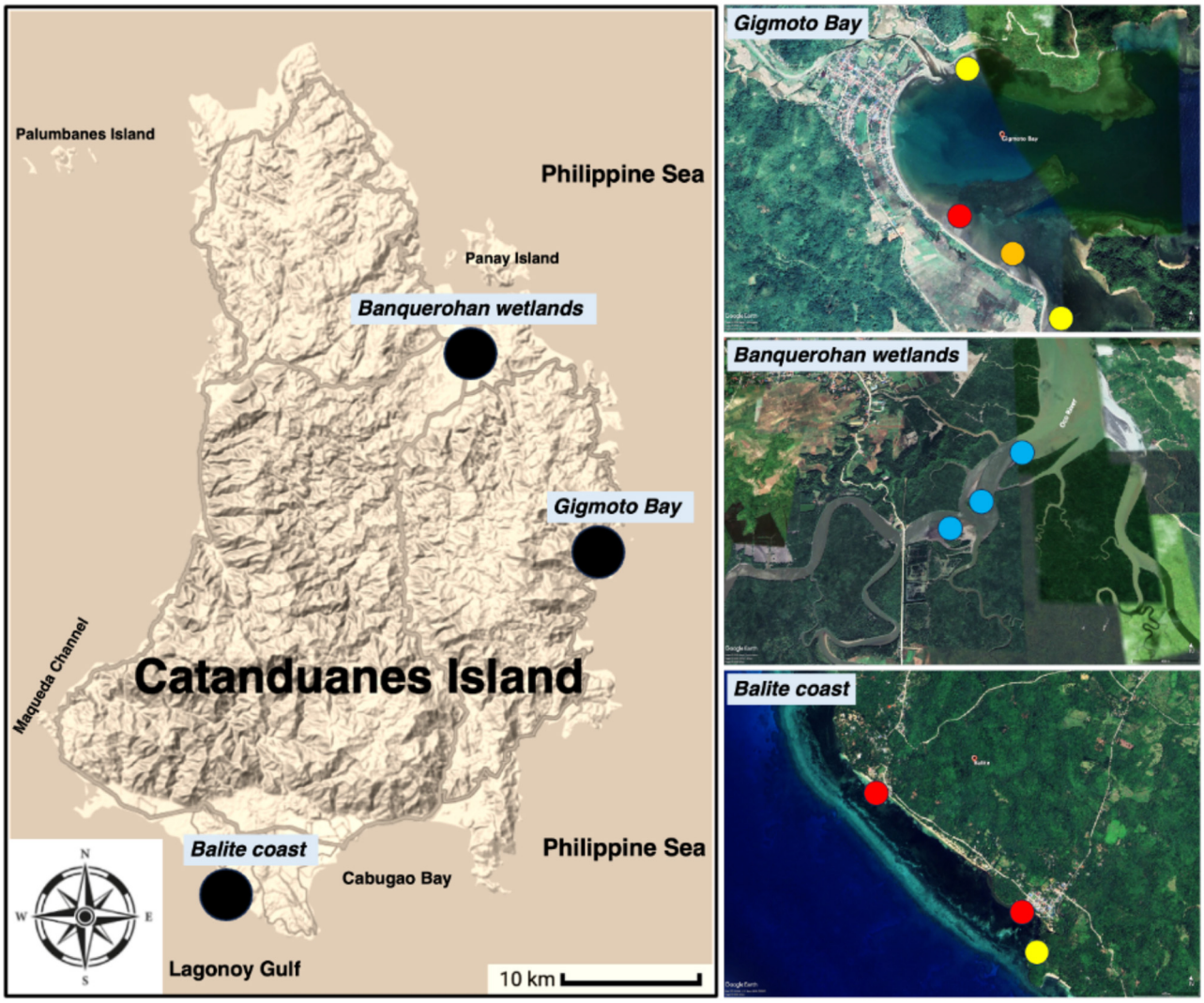

FIGURE 1
Location of Catanduanes tidal flats in the study: Gigmoto Bay, Banquerohan wetlands, and Balite coast. Except for the Banquerohan wetlands, which lie along the main river channel-estuaries, all areas are seaward or parallel to the coasts (adjacent to or facing the sea). Legend for small colored circles: yellow, predominantly pebbled/rocky substrate; orange, mudflats with sparse to no pebble cover, surface high burrow density; red, mudflats with sparse to no pebble cover, surface with distinct ripple marks; blue, generally mudflats with low to moderate pebble cover, riverine.

following: (1) cultural benefits obtained from the tidal flats; and (2) a follow-up question about their feelings (or emotions) when gleaning/fishing on the tidal flats; these two questions aimed to elucidate cultural services obtained from the tidal flats.

The instrument was then subjected to content review from one natural resource professional and two senior practitioners (one gleaner and one fisher). Reliability tests for the quantitative section were employed (gleaners, $N = 37$; test-retest, $R^2 = 0.84$; fishers, $N = 32$; test-retest, $R^2 = 0.89$). Thematic analysis for the qualitative section ($N = 11$ gleaners, $N = 10$ fishers) was performed as part of the preliminary interviews. Informed consent was obtained from the participants before the data collection, including personal consultations with community chieftains (*barangay captains*). During the survey/interview, the children gleaners were facilitated by their parents or guardians (informed consent obtained from parents or guardians), who were also participants in the study. Several terms vary among communities, while others have no direct English translations; thus, data gathering was facilitated by focal persons. Likewise, as many local terms associated with gleaning and fishing may be changed depending on the target species, interviewing was contextualized during the survey administration/interview, or if participants needed clarification. Participants were informed that they could refuse to participate at any time without needing an explanation or without facing conditions or demerits. Actual data collections (surveys and interviews) were conducted in September 2023, November 2023, May–June 2024, and March–May 2025.

Data analysis

The quantitative data obtained from the 109 participants were analyzed using both descriptive (e.g., means, standard deviation)

as well as inferential statistics (*t*-test). We calculated the Shapiro-Wilk Test for the assessment of data normality. For homogeneity of variance, we applied a logarithmic transformation. Histograms were illustrated based on the raw data, but inferential analyses were based on the log-transformed data. All statistical analyses were done using SAS-JMP Statistical Software.

Information on the cultural benefits was gathered through interviews (9 participants: gleaners, $N = 5$; fishers, $N = 4$) and Focused-Group Discussions (FGDs) (8 participants: gleaners, $N = 4$; fishers, $N = 4$), comprising a total of 17 participants (a portion of the total number of participants in the study). As part of data elucidation, participatory spatial and visual elicitation was employed simultaneously with interviews and FGDs. During the participatory spatial and visual elicitation, two questions were asked: (1) specific types of tidal flats they usually utilize, and (2) the fauna caught in the tidal flats type, wherein illustrations, if possible, were solicited. This enabled us to draw the summation of tidal flat species in the area. During the FGD, participants could suggest the placement of the items in the spatial-conceptual illustration. We have not provided pre-suggestions to the participants to avoid influencing their answers, but we responded to queries if they needed clarification. Finished illustrations were shown to participants for confirmation purposes and were revised until all suggestions were complied with. Illustrations were aided by Affinity Designer (Product 1.9.2) on iOS 14.4.2 Operating System. Further, we systematically categorized the qualitative information obtained during the interviews and FGDs to reveal the underlying themes that emerged from the participants' narratives (particularly identifying the mentioned benefits). Our concept of cultural services includes the non-material benefits obtained from the tidal flats.

On the groups of marine fauna, the following were referred to: bivalves, cephalopods, crustaceans, fishes, and gastropods. In some cases when participants request clarifications or references, we discussed the general morphology of each group, including

TABLE 1 Tidal flats' descriptions.

Location	Description of the tidal flats
Gigmoto Bay	Gigmoto Bay has tidal flats parallel to the coasts, approximately 0–175 m from the shoreline, with a discontinued area (subtidal) near or within the pier site. Predominantly pebbled tidal flats with mixed sediments beneath the surface are found in the innermost part of the bay, and in the outermost area passing Macalanhog Island. Mudflats with firm ripple marks are present in the middle portion, while in the lower middle part, tidal flats are composed of mudflats with high burrow density. Tidal flats in Gigmoto Bay are generally adjacent to seagrass meadows, although small patches of mangroves are present.
Banquerohan wetlands	Banquerohan wetlands have riverine tidal flats within the Oco river-estuary basin, with a generally mudflat substrate (low to moderate pebble cover). Tidal flats in the area are situated within the main river channel, adjacent to dense mangrove forests, with the tidal flats located approximately 0–100 m from the edge of the mangrove forests from the southern direction.
Balite coast	A strip of narrow tidal flats is present on the Balite coast, consisting of mudflats and pebbled-rocky flats, approximately 0–50 m from the shoreline. The site is generally adjacent to seagrass meadows with a small but established mangrove forest. Coastal areas of Balite lie in Lagonoy Gulf, an inlet of the Philippine Sea.

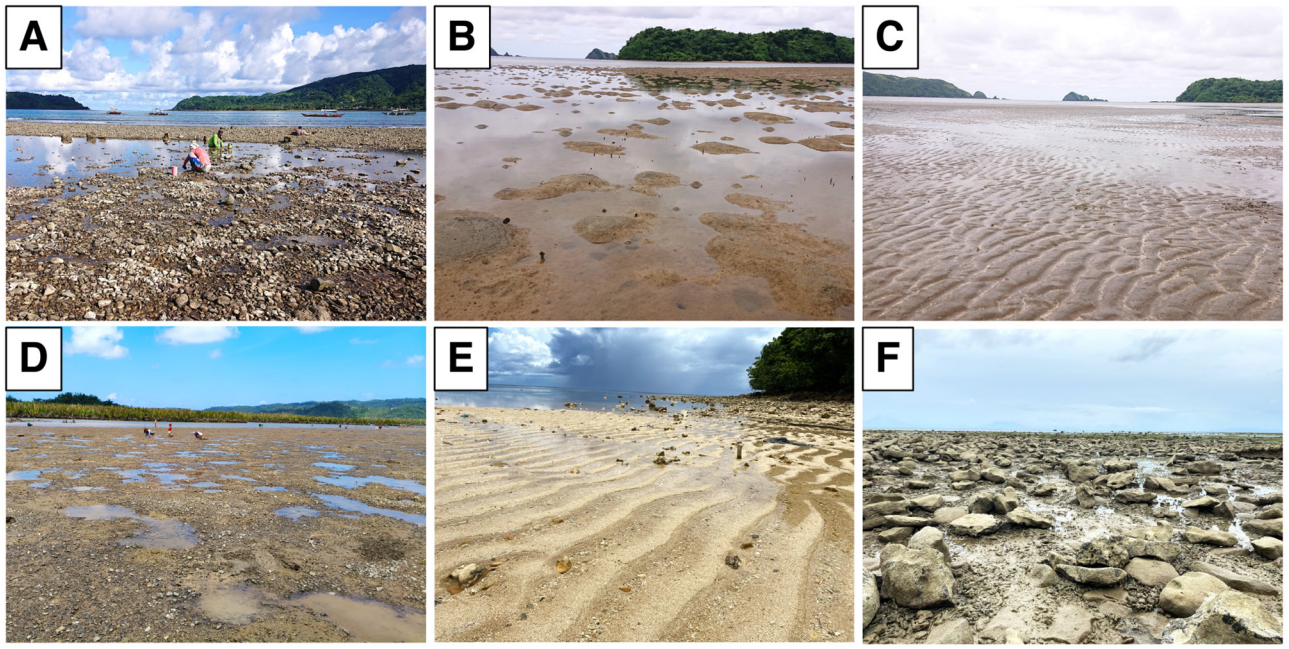

FIGURE 2
Examples of the tidal flats: Gigmoto Bay **(A–C)**; Banquerohan wetlands **(D)**; and Balite coast **(E, F)**.

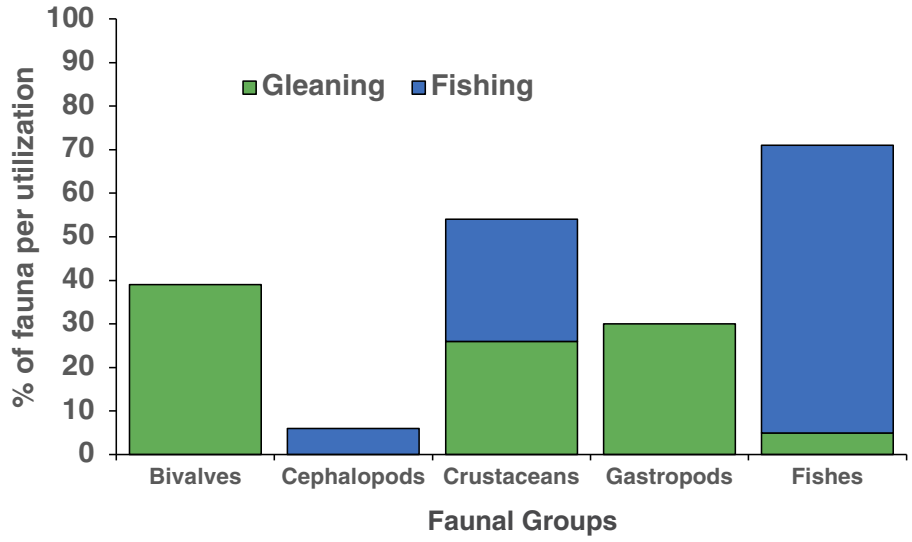

FIGURE 3
The faunal groups caught during gleaning and fishing in the tidal flats.

showing photos (printed books/field guides/checklist/collection report) from Voss (1963), Motoh and Kuronuma (1980), Edwards (1981), Gonzales (2013), Hombre et al. (2016), Olaño and Lanzuela (2016), Motomura et al. (2017), Subang et al. (2020), as well as referring to the databases World Register of Marine Species (WoRMS) (see https://www.marinespecies.org) and FishBase (see https://www.fishbase.se/Country/CountryChecklist.php?resultPage=1&&showAll=yes&what=list&trpp=50&c_code=608&cpresence=present&sortby=alpha&ext_pic=on&vhabitat=all2), which were presented through iPAD Pro (Version 14.4.2, 18D70). Participants were asked about the tools or gear they used during gleaning and fishing, including their preferred water depth.

The CPUE (calculated as kg/h/person) was used to "standardize" the comparison between gleaning and fishing, considering activity duration per person in the tidal flats. This metric allowed a direct comparison of the catch rates between the two types of utilization schemes despite their different methods and/or gears.

$$CPUE = \frac{\text{Total Catch (kg)}}{\text{Gleaning/Fishing Time} \times \text{Number of Gleaners/Fishers}}$$

Frequency of trip means days per month (day/month), and monthly catch is the sum of all catches in kg per month (kg/month); catch means raw and whole (uncleaned, or in their shells if shellfish). The monthly income was personally reported and includes both personally initiated selling and unintentional selling, such as when a random buyer approaches. For gleaners and fishers who usually extend their activities to other adjacent ecosystems during mixed-site activity, we asked them first about the catch in the tidal flats and the approximate income generated from those catches. On the other hand, we mean cultural benefits as those values gained from the activities that further support emotional, social, and mental wellbeing, as well as communication and knowledge transfer with the community.

Results

Provisioning services

Marine fauna caught and catching methods

Gleaners mostly catch invertebrates such as bivalves (clams, mussels, etc.) (39%), gastropods (neritid snails, limpets, etc.) (30%), crustaceans (crabs, shrimps, etc.) (26%), and sometimes may also catch fishes (gobies) (5%) (Figure 3). Species associated with gleaning are usually found in animal burrows or tunnels (bivalves, gastropods, benthic crustaceans), on the substrate's surface (gastropods), or in shallow water or tidal pools (crustaceans, gobies). Gleaned fishes are usually unintentionally caught, although some gleaners may simultaneously aim for them when looking for clams and burrowing invertebrates. Fishers' catches are composed of fishes (jacks, mullets, etc.) (66%), crustaceans (crabs, shrimps, etc.) (28%), and sometimes, cephalopods (squids, octopuses, etc.) (6%) (Figure 3). Crustaceans are co-target species (aside from fish) during fishing. Some bottom-dwelling fish (e.g., flounders) are also caught with fishing gear (e.g., nets) and thus were included in the catch during fishing.

The following fauna were identified during the participatory spatial and visual elicitation about the tidal flat environments (Figure 4). As gleaners and fishers noted, the microsites support a variety of invertebrates and fishes; many species are site-specific (e.g., gastropods, bivalves), while others are found in multiple sites (e.g., fishes). Most are target species, while some are incidental catch (e.g., gobies, squids, etc.). Microsites were characterized based on the presence of pebbles, sediments, or rocks on the surface area, as these have implications for utilization. For instance, fishing is mostly practiced on less pebbled/rocky areas or pure muddy-sandy areas (as pebbled or rocky surfaces may damage fishing nets), while gleaning is typically on partly or predominantly pebbled/rocky areas. Presence of the species is subjective only to the general catch components of the gleaning/fishing trips, recognizing

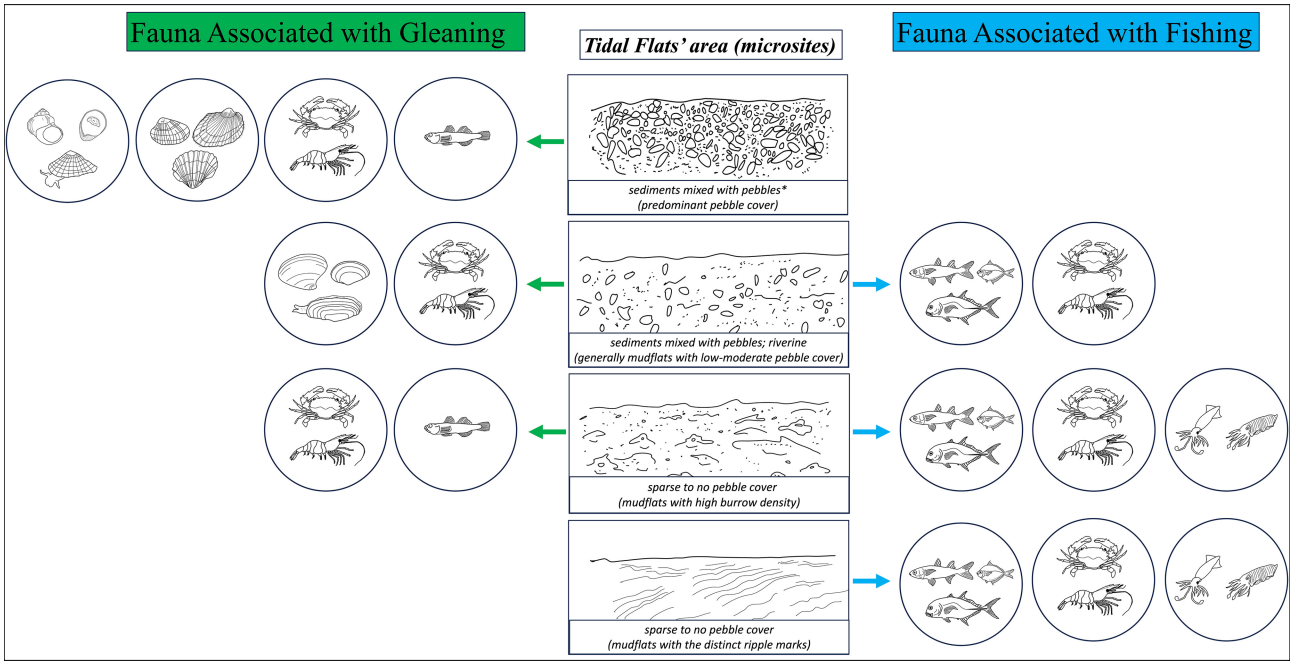

FIGURE 4
Faunal representatives identified during the participatory spatial and visual elicitation about the tidal flat environments. Most are target fauna, but fishes during gleaning, and cephalopods during fishing are incidental catches (non-target). Gleaners and fishers classify the tidal flats according to substrates (pebbles and sediments), such as the local terms *kak-ayan*, *hunasan*, or *kabatuhan sa hunasan* for areas with predominant pebble cover, and *balombon, bonbon,* or *lamdok* for mudflats or muddy-sandy areas with no to moderate pebble cover. Pebbled surfaces, nevertheless, also have muddy or sandy substrates underneath. Burrow means visible crustacean burrow on the tidal flats' surface. *Large rocks are also observed (together with pebbles) in some locations on the Balite coast.

the possibility of other non-reported fauna that may inhabit the area.

A simple tool, such as a small metal, plastic, or coconut shell, serves as a shovel or digger when obtaining bivalves from pebbled areas. Some gleaners use their feet to locate bivalves in muddy areas. Most gastropods are hand-picked, but some gleaners use bolo or metal rods for gastropods found in rocks and crevices. Fishes (primarily gobies) trapped in the burrows or tidal pools are caught by gleaners with bare hands or using a small net. Most fishers, on the other hand, use non-stationary fishing gear, primarily fishing nets (e.g., gill nets or *pangki*, seine nets, small scoop nets) when catching fish, shrimp (which may sometimes catch small squids). Crab lift nets (*bintol*) (another non-stationary gear) are used to catch mud crabs and other portunid species. Except using *bintol,* which may take 1–4 h (including soaking time), non-stationary fishing generally takes 20–40 min from the deployment of fishing nets to completion of retrieval/harvesting. Fishers, composed of usually 2–5 persons, repeat the activity 3–4 times per trip. Moreover, we also noted that a few were fishing with stationary gears (fish trap) stationed in the tidal flats (most stationary fish traps in the area are located in subtidal zones, and thus were excluded from the study). We mean stationary if a gear is placed or anchored in a specific location, for more than a day (>24 h). Fishing with the stationary gears had 2–3 h of operation per activity. Figure 5 shows examples of catches from gleaning and fishing.

Most gleaners prefer to glean when the water depth is ≤30 cm, with those gleaning for clams typically requiring exposed substrates or very minimal water depth (0–10 cm). Several gleaners ($N = 23$) would start gleaning when water is still a little deeper (50 cm) (ebb tide), but still finish during the low tide peak (exposed substrate) or when the flood tide is still ≤30 cm after the low tide peak. This makes most of the time engaged by all gleaners at ≤30 cm water depth. Participants mentioned that gleaning is highly synchronized with spring low tide, with most gleaning conducted within 5 days of the shallowest tides (the day of the spring low tide and 2 days before and after). However, the number of gleaning schedules varies among gleaners. Fishers, on the other hand, generally fish when the water depth is ≥50 cm ($N = 54$) and usually station their gear manually by wading (or walking), swimming, or using a non-motorized boat (*banca*) during or near high tide peaks with ≥100 cm water depth.

Time spent, catch, CPUE, frequency, monthly catch, monthly income

The time spent in the tidal flats by gleaners and fishers had a Mean of 2.86 h^{-1} $trip^{-1}$ $gleaner^{-1}$ (SD = 0.72 h^{-1} $trip^{-1}$ $gleaner^{-1}$) and 1.41 h^{-1} $trip^{-1}$ $fisher^{-1}$ (SD = 0.39 h^{-1} $trip^{-1}$ $fisher^{-1}$), respectively ($t = -13.26$; DF = 105.48; $p < 0.01$). Catch per trip recorded a Mean of 4.54 kg (SD = 1.79 kg) for gleaners and 2.33 kg (SD = 1.80 kg) for fishers ($t = -7.44$; DF = 99.37; $p < 0.01$). Meanwhile, the catch rate (CPUE) of gleaners had a Mean of 1.7 kg h^{-1} $gleaner^{-1}$ (SD = 0.75 kg h^{-1} $gleaner^{-1}$), while fishers' catch rate had a Mean of 1.65 kg h^{-1} $fisher^{-1}$ (SD = 0.86 kg h^{-1} $fisher^{-1}$) ($t = -0.50$; DF = 106.43; $p = 0.62$). Gleaners' and fishers' frequency

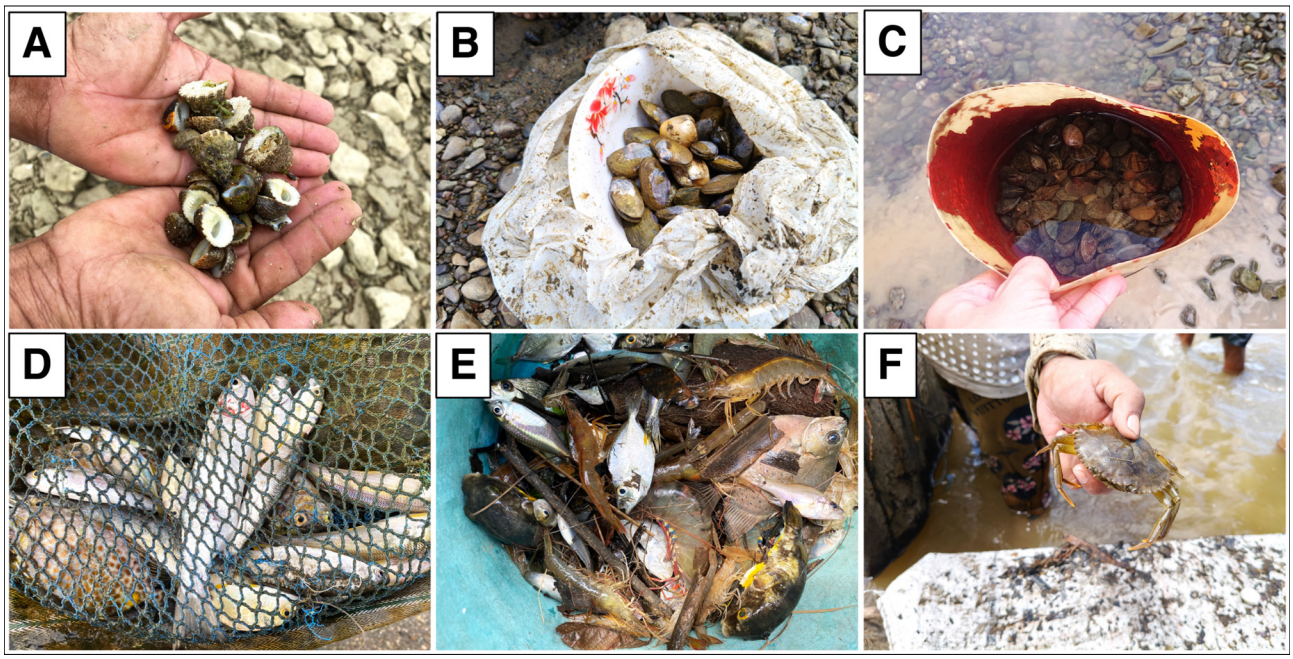

FIGURE 5
Examples of marine fauna caught. Gastropods, as shown by a gleaner on-site **(A)** and bivalves **(B, C)**, were obtained from predominantly pebbled or partly pebbled tidal flats. Fishes **(D)** and mixed catch (fishes and crustaceans, unsorted) **(E)** are obtained from mudflats; a mud crab is shown by a fisher on-site **(F)**.

of trip (day/month) had a Mean of 4.32 (SD = 3.10) and 11.96 (SD = 10.18), respectively ($t = 7.35$; DF = 100.82; $p = 0.01$). In the monthly catch (kg), gleaners had a Mean of 20.94 kg (SD = 19.62), while fishers had a Mean of 26.84 kg (SD = 28.07) ($t = 1.65$; DF = 103.88; $p = 0.10$). Gleaners' and fishers' monthly income (USD) had a Mean of USD 19.19 (SD = USD 18.64) and USD 22.33 (SD = USD 22.90), respectively ($t = 0.36$; DF = 49.75; $p = 0.72$). Figure 6 shows these general socioeconomic data. The results of the *t*-tests were obtained from log-transformed data. Most catches in the two activities are allocated to family consumption, although some may sell their catch by chance when a buyer is encountered along the way, going to their residences.

Cultural services

Various cultural benefits obtained from the tidal flats were mentioned during the interviews and FGDs, which generated the following themes of the general cultural services (Figure 7): social cohesion and knowledge transfer (e.g., gleaning/fishing strategies, information about a project collaboration), sense of place and connection (e.g., contemplation, nature-driven satisfaction), recreation and leisure (e.g., pastime, relaxation), stress relief and social repair (e.g., emotional regulation in times of anxiety or anger). The benefits under the general cultural services recorded 56–100% mentions (majority to totality) among gleaners and fishers. In addition, children's natural discovery learning (e.g., children learning with aquatic fauna) was drawn from the narratives of most gleaners as another cultural service obtained from the gleaning activity. The general outline of these cultural services is shown in Figure 8.

Social strengths are central to gleaners/fishers, which may result in their understanding of the community and the tidal flats' environment. This may be obtained when people communicate and collaborate in activities (potentially leading to strengthened social bonds) and provide inter-generational exchange of information. The following are narratives about group dynamics that demonstrate social cohesion and knowledge transfer:

> *I feel a sense of belongingness and appreciation of my work when I communicate with the group at the site, such as during discussions about the types of species, catching methods, as well as possible projects and initiatives in the community that we may engage with.*
>
> *"During my younger years, older fishers taught me specific zones where jacks and other fish would naturally be found, including information on the tidal time when they are most abundant. I kept that information and would teach it to younger generations because I am already old."*

Engagement with the tidal flats is perceived to offer calmness and a place for contemplation. These narratives related to a sense of place and connection were obtained from the gleaner and fisher, respectively.

> *"I feel a therapeutic effect when I see the tidal flats' serenity. This includes the satisfaction when I fill my bucket with clams and snails. It becomes even more satisfying when I come home and see my family gather around and investigate my catch."*
>
> *"I go to the area to fish but also to contemplate at the same time. The calmness of the area helps to stimulate my thinking and helps me decide on my plans."*

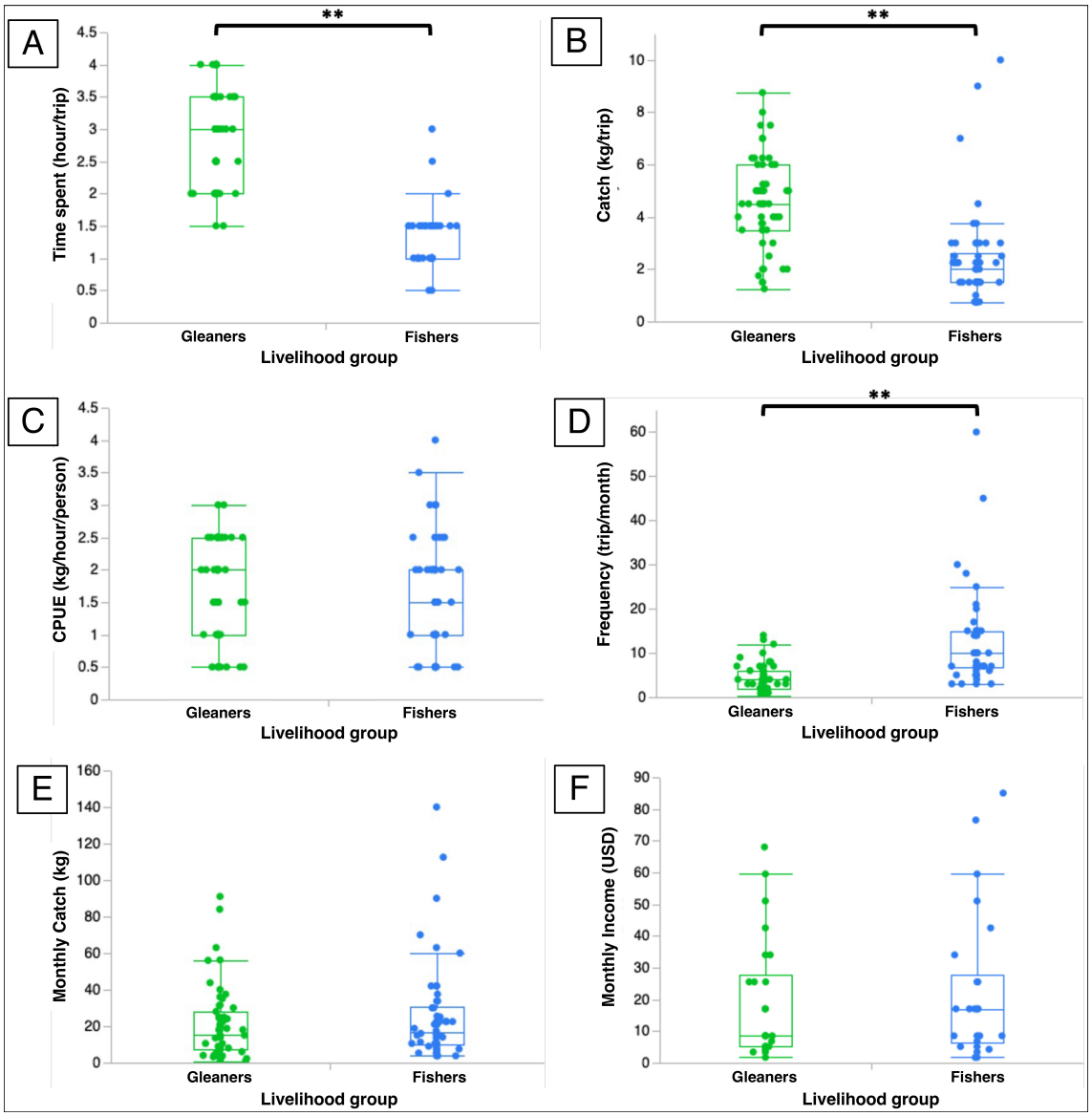

FIGURE 6
Socioeconomics of tidal flat gleaning and fishing. Time spent **(A)**, catch **(B)**, catch per unit effort **(C)**, frequency **(D)**, monthly catch **(E)**, and monthly income **(F)**. Gleaners, $N = 55$; Fishers, $N = 54$. **At the 0.01 level of significance.

Recreation and leisure is also indicated by the participants, as follows:

> *"Gleaning is not only for collecting invertebrates but also for relaxation. It has been my pastime, so I feel unwell if I cannot glean for weeks or months."*
>
> *"When fishing with peers or family members, sometimes we engage in simple fishing contests, providing us with relaxation and friendly competition."*

Many fishers and gleaners visit the area to regulate emotions, such as during conflict or disagreement. In most cases, a solution (or reconciliation) is achieved as reflected in these statements:

> *"Tidal flats help me to control emotional difficulties and struggles with other people in the community. For example, the simple happiness and contentment of other gleaners I observed at the site remind me to be mindful and considerate of people's feelings."*
>
> *"When I have disagreements with my spouse, I sometimes go to the tidal flats for a while and catch fish (high tide). Tidal flats are easily accessible due to their proximity to the coasts. When I come home, tensions are often eased when I present the catch. Sometimes, my catch may not be enough for a meal, but I still gain reconciliation, perhaps because my spouse acknowledges my effort."*

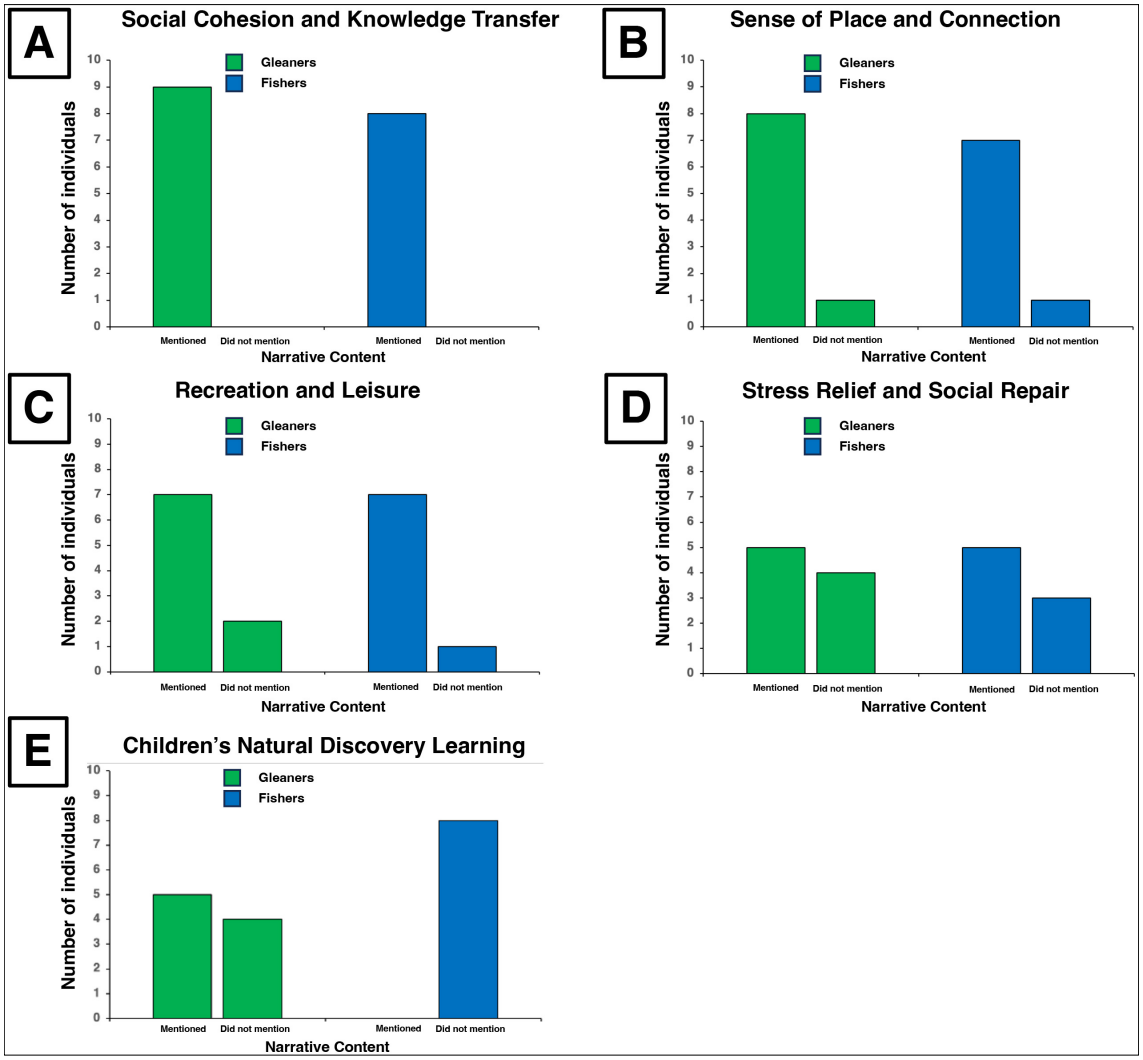

FIGURE 7
Cultural services associated with the tidal flats. Social cohesion and knowledge transfer **(A)**, sense of place and connection **(B)**, recreation and leisure **(C)**, stress relief and social repair **(D)**, and children's natural discovery learning **(E)**. Gleaners, $N = 9$; Fishers, $N = 8$.

Meanwhile, gleaners observed that the activity offers a natural discovery learning scheme for their young children (non-gleaning children) as they engage with play-based curiosity in the tidal flats. This was not mentioned by fishers, as younger children are typically not accompanied during fishing. Emphasizing the child's learning and social development, a gleaner expressed:

> *"During gleaning, my 6-year-old child sometimes accompanies me, which I allow due to the vicinity and relative safety of the tidal flats at low tide. We bring a large umbrella or headwear, water, and food to protect ourselves from the heat. At the same time, I can watch him while he investigates and learns educational concepts with the tiny animals in the tidal flats."*

Some settings are provided in Figure 9 (communications and group dynamics), which are viewed as instrumental in shaping and preserving cultural services provided by the tidal flats.

Discussions

Provisioning services

Marine fauna caught and catching methods

Catches vary between gleaning and fishing, primarily depending on the water level of the shifting tides. As most invertebrates have limited mobility, they are easily obtained by gleaners during low tide. Nonetheless, benthic invertebrates are probably still present in the area during high tide, but due to tidal currents and deeper water levels, they may be difficult to obtain. Most catch groups, such as bivalves and gastropods, are less motile than fish and thus are easily obtained by gleaners (Aldea, 2022, 2023). On the other hand, the catches during tidal flat fishing are obtained when the area is inundated. Tidal flats serve as shelter (by burrowing benthos), foraging, and breeding grounds for many species (Dittmann, 1995; Withers and Tunnell, 1998; Kinoshita et al., 2010; Dashtgard, 2011; Murray et al., 2015; Henmi et al., 2017; Chen et al., 2024), potentially supplying species associated

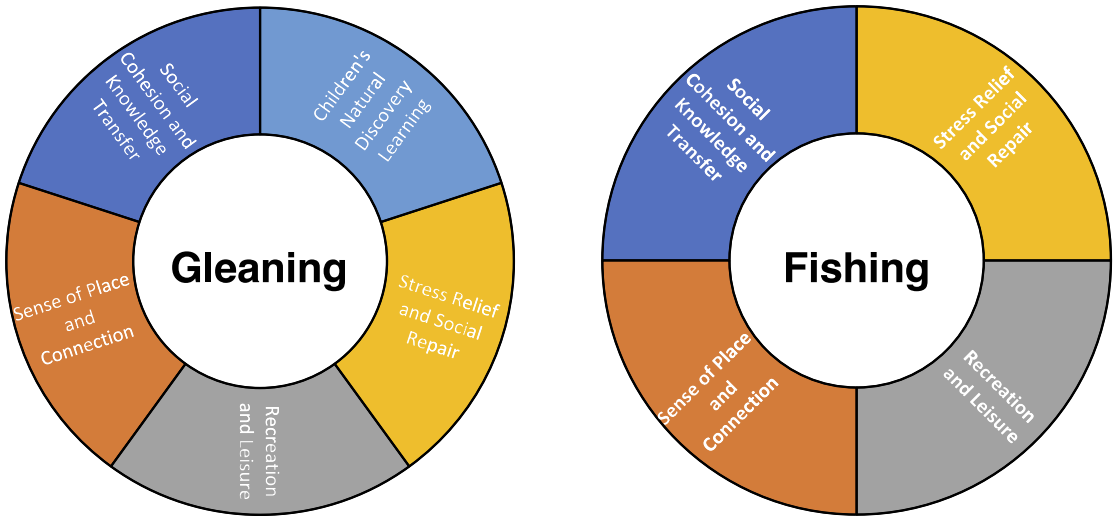

FIGURE 8
Outline of the cultural services derived from each utilization. All cultural services were noted in both gleaning and fishing, except for children's natural discovery learning, as young children are typically not accompanied during fishing.

FIGURE 9
Examples of on-site settings associated with cultural services. Gleaners and fishers (families or friends) travel in groups to reach the tidal flat area, often cooperating and communicating with each other **(A)**; a woman gleaning bivalves with her friend, other gleaning groups shown at a distance **(B)**; a fisher with her catch- a jack species which commonly occur at specific zones and certain seasons, an information that she teaches to her children and local youths **(C)**.

with gleaning and fishing. Bioturbation enhanced by tidal flat residents amplifies nutrient cycles and productivity in the tidal zones, augmenting species distributions (Brückner et al., 2021; De Smit et al., 2021).

Gleaners generally glean on pebbled or partly rocky tidal flats (Figure 4), likely due to most gleaned species being associated with these substrates, as represented by burrowing bivalves (e.g., clams) and gastropods (e.g., limpets, neritid and turbinid snails, etc.). On the other hand, fishers generally frequent mudflats, which may be due to fishes (e.g., jacks, mullets, ponyfish, rabbitfish) and crustaceans (e.g., shrimp and crab) foraging in these areas or partly due to relatively smooth surfaces that are less likely to damage their gear. Fishes caught during gleaning and cephalopods during fishing are usually non-target species. Further, it is important to note that tidal flats on the island are adjacent to other coastal habitats (e.g., seagrass and/or mangroves), whose proximity potentially provides synergistic effects on species abundance, given the comparable productivity and interconnectedness of these habitats (Skilleter et al., 2017; Worthington and Spalding, 2018). For instance, seagrass and mangrove fishes, such as snappers (Bastos et al., 2022) and siganids (Honda et al., 2013), are also reported by tidal flat fishers in the current study. It has been described that many species use multiple adjacent coastal ecosystems (Aldea et al., 2014; Bloomfield and Gillanders, 2005), suggesting the contributory role of these zones to the species distribution in the tidal flats. Variations in the species generally caught in the two activities may serve as resource-utilization options for coastal communities. It should be emphasized, however, that species groups are summed in all sites based on the reports of the current gleaners and fishers. Thus, future studies on specific sites and with larger samples of gleaners and fishers may show different compositions of species in the tidal flats.

As most of the catch is allocated for family consumption, gleaning and fishing provide an outright source of food. This augments nutritional requirements for coastal families. Seafood is an excellent source of protein, fatty acids, and other nutrients essential for human health (De Guzman et al., 2019; Hicks et al., 2019; Shalders et al., 2022). Among Filipinos, seafood is an important protein source, accounting for 42.2% of animal protein intake [Department of Science and Technology—Food and Nutrition Research Institute (DOST-FNRI), 2020], which is probably much higher in small islands and coastal communities. Considering that many of the coastal families are economically challenged (Aldea, 2023), this provides nutrient-rich yet easily accessible food for the fisherfolk, in contrast to other related but expensive food in the mainstream market. In addition, tidal flats are generally safer and accessible, even during the rough season, thus providing food and economic support when offshore fishing or farming is difficult or temporarily non-operational.

Gleaners use their bare hands or simple tools when catching tidal fauna. This is similar to gleaning activities in other areas, where generally simple tools or traditional methods are used to collect intertidal species (Furkon et al., 2019; Stiepani et al., 2023a,b). Most coastal gleaners (including those gleaning in other coastal ecosystems) believe that their methods have no or have only negligible damage to the ecosystems (Aldea, 2023), primarily associating the general subsistence nature of utilization. Tidal flat fishing similarly exhibits this trend due to the simple fishing gear and the general allocation of catch for the family, although selling may follow in some surplus catches. An earlier study about gleaning in the area (including other coastal ecosystems) found that utilization frequencies are strongly positively correlated with the increase of catch (Aldea, 2023), suggesting sustained services despite the increasing utilization rates. Further, the shifting activities (gleaning-fishing) associated with tides may divert resource utilization at times, thus potentially reducing pressures on target species in the tidal flats; shifting tidal actions influence and enhance activities of tidal migratory species (Reis-Filho et al., 2011; Murray et al., 2015), which may increase resource stock availability for the community. Nevertheless, while these utilization patterns suggest sustainable practice, assessment may be needed to ensure the long-term viability of the tidal flats and their subsistence fisheries. To date, there is no other information on fishing activities (and pressures) in the tidal flats in the area, with most observed fish in the market caught from offshore waters or coral-seagrass areas.

Gleaning in tidal flats is generally practiced in shallow waters or exposed areas, which agrees with earlier studies about gleaning in coastal ecosystems (Del Norte-Campos et al., 2005; David et al., 2024). Meanwhile, fishing is conducted in relatively deeper intertidal areas associated with tidal movements, where migratory fauna is expected to enter (or re-enter) the tidal zone, as shown by Reis-Filho et al. (2011) on fish captures being caught with the changing tides. Both activities indicate the importance of resuming or coordinating the activity (if in groups) associated with tidal fluctuations, marking the inundating tidal cycle as an important attribute of resource utilization in the tidal flats.

Time spent, catch, CPUE, frequency, monthly catch, monthly income

Time spent in the tidal flats is higher in gleaning, which can be explained by many gleaners utilizing the area most of the time (in contrast to fishers who mostly utilize mixed sites for fishing, aside from the tidal flats). The difference in the catch per trip is detected, demonstrating a higher catch (kilogram) among gleaners. Catch rates of gleaning and fishing, however, show a similar extent of operation (non-significant difference in catch rates). Aldea (2023) found a non-significant difference in the gleaning catch rates of the tidal flats compared with other coastal ecosystems on the island, suggesting their resource viability relative to other habitats. Complex organism interactions play in the tidal spaces (Dittmann, 2008; Kinoshita et al., 2010; Dashtgard, 2011; Hill et al., 2021), facilitating species richness, which may be relevant to obtaining gleaning-associated resources. On the other hand, many fishes utilize tidal flats as part of their life history (Franco et al., 2006; Nagelkerken, 2009; Siliprandi et al., 2019), which may boost fishing catch rates. Unfortunately, there is limited information on tidal flat fishing catch rates in the Philippines for comparison. Future studies on catch rates focusing on specific gear and utilized area, including using the more complex CPUE definitions between fishing and gleaning (e.g., area placed by net/time spent during netting, area walked/time spent during gleaning, etc.), may be conducted to fully describe the associated CPUE and perhaps explain the CPUE concept at species levels.

The frequency of trips is significantly higher among fishers, partly due to additional schedules (fishing at night and during neap high tides). This may have corresponded to a non-significant difference in the monthly catch between gleaning and fishing (higher daily catch in gleaning but higher frequency of trips for fishing). This is further supported by incomes from both activities, which were not significantly different, demonstrating economic importance (with relatively similar scales) for coastal households involved in both activities. Food resources associated with the tidal flats are generally described in other coastal communities (MacKinnon et al., 2012; Murray et al., 2015, 2019), highlighting possibilities for income-generating ventures. Like gleaning (De Guzman et al., 2019), fishing in the tidal flats is also linked with subsistence provisioning, although several fishers may sell their catch in the neighborhood (small-scale, similar to gleaning), especially with abundant catch. In general, gleaning and fishing in the tidal flats reflect a subsistence nature (though some individuals or households gain modest financial benefits) and are potentially vital components of the economics of many coastal families.

Cultural services

Responses about cultural services associated with the tidal flats are diverse and encompass beneficial effects on self, family, and community. All cultural services were noted in both gleaning and fishing, except for children's natural discovery learning (only associated with gleaning) (Figure 7), as small children are not usually accompanied during fishing. The outline of the cultural services (Figure 8) depicts the whole cultural

benefits, illustrating the holistic picture of cultural benefits derived from both gleaning and fishing. These suggest the integral connections of the tidal flats in social cohesion (which is highly associated with traditional knowledge transfer), natural beauty appreciation, and benefits related to emotional and social wellbeing. It has been described that resource utilization provides livelihoods and potentially improves the wellbeing of coastal folks (Koh and Khim, 2014; Lau et al., 2019; Grantham et al., 2020).

Utilization of tidal flat spaces engages resource users in communications and collaborations within the community. Related perspectives are exhibited in a forest utilization scheme in the Solomon Islands through a collective activity, emphasizing shared cultural connections and community cooperation (Raymond and Kenter, 2016). Likewise, ecosystem engagements offer natural inspiration to communities, which enhances communication and understanding with the public (Daniel et al., 2012; Fish et al., 2016; Lumber et al., 2017; Grantham et al., 2020). Narratives of information sharing (e.g., new communal activities and community projects) as they glean/fish in the tidal flats highlight feelings of belongingness and appreciation, which may enhance the sense of community wellbeing, leading to further community engagements. Stuart (2022) emphasized engagement and collaboration as fundamental to a community's organizational framework. For instance, in coastal areas of Louisiana, USA, community engagement helped to identify nature-based solutions and played a crucial role in coastal restoration projects (Baustian et al., 2020). Through communication and collaborative monitoring by the community (thus, enabling social cohesion), other cases of related local initiatives, such as mangrove projects, exhibited several productive outcomes (Vargas and Asetre, 2011; Aldea, 2024; Vargas-Sapico et al., 2024).

On-site tidal flat activities also highlight the transfer of traditional ecological knowledge (as embedded in cultural services), providing real-time experiences, such as information on fishing methods and fishing grounds, as well as information on poisonous or venomous species. While a transfer of some information is also possible at home, on-site communications and discussions can be more facilitating due to actual observation and mentorship in the tidal flats' natural settings. Naming systems and resource use practices (e.g., species and their information) are part of traditional ecological knowledge (Secretariat of the Convention on Biological Diversity, 2014; Fernández-Rivera et al., 2024), which are integrated with the cultural services of resource utilization in the tidal flats (Hong, 2012). Fundamental to their activities are strategies passed through generations (Ovung et al., 2022), enabling them to utilize coastal resources, thereby promoting the continued cultural identity of the coastal zones. Demonstrating effective strategies from experienced individuals is often requested by peers, likely due to its direct implications on catch rates. Gleaning and fishing strategies include elaborate practices that may be enhanced through teaching and learning with family members and the coastal communities. In connection, the conservation and management of ecosystems have been highlighted with the role of traditional ecological knowledge transfer (De Sousa et al., 2022), indicating the importance of these cultural service aspects in tidal flat conservation.

Spending time with nature can promote mental and physical health benefits (Bratman et al., 2019; Rueff and Reese, 2023; Stott et al., 2024). This perspective permeates gleaners and fishers' narratives on the obtained calmness and therapeutic effects of tidal flats engagements, an expression drawn from a sense of place and connection. Psychological wellbeing, which encompasses, in part, the influences of mental attributes, social systems, and vitality, has been linked with natural ecosystems, such as green spaces (Dadvand et al., 2016; van den Berg et al., 2016) and coastal environments (Ke et al., 2022). Wellbeing has also been related to ecosystems when people perceive happiness and a strong connection with nature and environmental issues (Grabowska-Chenczke et al., 2022), demonstrating the beneficial effects of contact with natural ecosystems (Kondo et al., 2018; Corazon et al., 2019). Further, a sense of place has been associated with community benefits, such as the case in George Town and Melaka, Malaysia, where person-place bonding has been viewed to contribute to sustainable intangible cultural tourism (Tan et al., 2018), a potential for communities associated with tidal flats in the current study. Meanwhile, leisure and recreation are closely related to a sense of place and connection, wherein people obtain relaxation and quality time (in free time or scheduled recreational engagement) personally or with family and friends. Related engagements in nature-based recreation have been suggested to positively influence health and wellbeing (Rosa et al., 2024). Korean tidal flats, for example, are popular leisure areas (e.g., fishing, sea bathing, resting, sightseeing), recognizing the place where people and nature exist in harmony (Kim, 2013). While in other regions, recreational services may generate revenues (Kreitler et al., 2013), the tidal flats on the island, to date, provide non-monetary recreational values and currently focus on vital local traditions of obtaining leisure with nature.

It is interesting to note that emotional regulations also play a part in the psychological wellbeing of some individuals, suggesting that tidal flats serve as a space for processing emotions and channeling potentially destructive behaviors to productive outcomes. Although less documented in other studies, these may have a specific symbolic meaning tied to the tidal flats' environment. Natural environments are known to reduce stress (Bratman et al., 2019; Coventry et al., 2021), depression, and anxiety (Chun, 2017). However, studies explicitly pointing to the roles of the ecosystems in reducing domestic anger and family tensions are limited, especially in the tidal flat context. Nevertheless, offering the catch obtained from the tidal flats after disagreement with a family member (the case in the narratives) indicates the cultural service's role in emotional regulation and social repair. On the other hand, cultural services potentially extend to younger children's natural discovery learning, as young children play and "discover" on the tidal flats, taking advantage of the relative safety of the tidal flat for young learners. These are non-gleaning children (4–8 years old) who accompany their parents or guardians during their free time, such as weekends or when there is no class schedule. Children's curiosity may lead to learning through basic observation of aquatic fauna, as collaborative play with other children is encouraged. It has been suggested that cognitive development, among others, is enhanced through interactions with nature (Summers et al., 2019). Coastal environment affordance has been associated with the supportive approach in outdoor pedagogy on a Scotland beach

(Barrable and Barrable, 2022), accentuating parallel opportunities in tidal flat pedagogy, which may be explored in future studies. All these intangible cultural services are central to the identity associated with the tidal flats. Personal or shared experiences learned within the tidal flats' context may thrive through narratives, ensuring continuity through oral traditions and practice.

Conclusions and recommendations

Tidal flats provide diverse species through gleaning and fishing, which supports the critical roles of tidal flats in providing provisioning services. These utilization schemes generate food and income, which could augment household economics in the coastal areas. At least considering the current utilization schemes, this suggests that the activities are sustainable, although future assessments may be needed for long-term trend analysis. Beyond the provisioning affordances, this study emphasizes indispensable cultural services associated with the tidal flats. Various cultural services are connected with the utilization, providing a sense of personal and community wellbeing. As these benefits are typically communicated or practiced in groups, this may promote intergenerational knowledge transfer, potentially contributing to the preservation of coastal cultural heritage. Given these perspectives, integrated coastal management should include tidal flat conservation in the policy frameworks, promoting coastal land-use strategies designed to avoid or mitigate future anthropogenic drivers of change (e.g., reclamation, human-induced habitat conversion, other forms of coastal development), while maintaining the ecosystem's livelihood value. Further, we acknowledge that several people in the coastal areas may be engaged in multiple livelihoods (e.g., actively gleaning and fishing in a given period); hence, the limitations to capturing perspectives of the mixed livelihood systems. We did not include these individuals to isolate the influences of each activity and draw straightforward comparisons between gleaning and fishing. Future research should consider the inclusion of these groups to further describe the dynamics of the gleaning and fishing activities in the tidal flats.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

Author contributions

KA: Conceptualization, Validation, Formal analysis, Methodology, Visualization, Funding acquisition, Writing – original draft, Resources, Supervision, Writing – review & editing, Project administration, Software, Investigation. ZT: Writing – original draft, Methodology, Visualization, Resources, Investigation, Conceptualization, Writing – review & editing, Funding acquisition.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. The research was partly supported by the Partnerships in Environmental Management for the Seas of East Asia (PEMSEA) through a funded travel grant during the "PEMSEA Learning Exchange on Good Practices in Implementing Biodiversity Conservation-Focused Ecosystem and Area-Based Management Approaches" in Seoul, South Korea in 2023 and during "Training on Integrating Blue Carbon into the ICM Framework" in Chonburi, Thailand in 2025, wherein initial results of the study were presented and discussed.

Acknowledgments

We thank the people and organizations who facilitated and cooperated with this study. It is noteworthy to mention Dr. Yumi Henmi of Kyoto University, Japan, for providing the printed copy of the book of Motomura et al. (2017) (we observed that participants greatly appreciate books or field guides being shown during species discussion), and Dr. Gyo Itani of Kochi University, Japan, for the version of the Statistical Software SAS-JMP. We are also grateful to the village chieftains (*barangay captains*) who were instrumental in our data gathering. We extend our thanks to Catanduanes State University through its former president, Dr. Patrick Alain Azanza, the Officer-in-Charge, Dr. Roberto B. Barba Jr., the vice presidents, Dr. Gemma G. Acedo (VPAA), Dr. Rosana S. Abundo (VPREPA), and Engr. Benjamin Hannycel T. Nuyda (VPAFA), the Research and Development Services, and the Internationalization unit of the university, for the facilitation and logistics. It is also noteworthy to mention the NRCP Team led by its Executive Director, Dr. Bernardo N. Sepeda, for the additional input and constructive remarks (including perspectives on ecosystem services) during their visits, as part of engagements between NRCP and CatSU. We are also grateful to Mr. Rowel Salvador and his family, Mr. Paul Amman Ogena, Mr. Larry Aldea, and other focal persons, including volunteers from youth groups and the Philippine Tidal Flats Foundation (local community-based group), who assisted our ocular visits in the area.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

References

Aldea, K. Q. (2022). "The unvegetated tidal flats in Catanduanes Island, Philippines: current and future trends," in *Interdisciplinary Studies for Integrated Coastal Zone Management in the Region Along the Kuroshio: Problem-Based Approach by the Kuroshio Science*, eds. T. Shinbo, S. Akama, and S. Kubota (Kochi: Research Center of Integrated Coastal Zone Management by Kuroshio Science, Kochi University; Kouda, Kochi: Livre Publishing Co., Ltd.), 76–82.

Aldea, K. Q. (2023). Macroinvertebrate gleaning in coastal ecosystems: utilization, pressures, and implications for conservation. *AACL Bioflux* 16, 1331–1345. Available online at: https://bioflux.com.ro/docs/2023.1331-1345.pdf (Accessed June 2, 2023).

Aldea, K. Q. (2024). Citizen science in the Philippines: coastal biodiversity engagements on a small island. *J. Mar. Island Cultures* 13, 153–172. doi: 10.21463/jmic.2024.13.1.09

Aldea, K. Q., Morales, M. I., and Masagca, J. T. (2014). Coastal marine ecosystems and biodiversity of the Kuroshio region: intertidal and mangrove-associated gastropods in Catanduanes Island, Philippines. *Paper presented at the 8th International Symposium on Kuroshio Science on September 12–13, 2014, Kochi University, Kochi Prefecture, Japan*.

Barrable, D., and Barrable, A. (2022). Affordances of coastal environments to support teaching and learning: outdoor learning at the beach in Scotland. *Education 3-13,* 52, 416–427. doi: 10.1080/03004279.2022.2100440

Bastos, R. F., Lippi, D. L., Gaspar, A. L. B., Yogui, G. T., Frédou, T., Garcia, A. M., et al. (2022). Ontogeny drives allochthonous trophic support of snappers: seascape connectivity along the mangrove-seagrass-coral reef continuum of a tropical marine protected area. *Est. Coast. Shelf. Sci.* 264:107591. doi: 10.1016/j.ecss.2021.107591

Baustian, M. M., Jung, H., Bienn, H. C., Barra, M., Hemmerling, S. A., Wang, Y., et al. (2020). Engaging coastal community members about natural and nature-based solutions to assess their ecosystem function. *Ecol. Eng.* 143:100015. doi: 10.1016/j.ecoena.2019.100015

Biodiversity Management Bureau (BMB)—Department of Environment and Natural Resources (DENR) (2016). *Philippine Biodiversity Strategy and Action Plan (2015-2028): Bringing Resilience to Filipino Communities*. Ed. C. Cabrido. Quezon: BMB-DENR, United Nations Development Programme – Global Environment Facility, Foundation for the Philippine Environment.

BirdLife International (2025). *Manila Bay*. Available online at: https://datazone.birdlife.org/site/factsheet/manila-bay (Accessed April 18, 2025).

Bloomfield, A. L., and Gillanders, B. M. (2005). Fish and invertebrate assemblages in seagrass, mangrove, saltmarsh, and nonvegetated habitats. *Estuaries* 28, 63–77. doi: 10.1007/BF02732754

Bratman, G. N., Anderson, C. B., Berman, M. G., Cochran, B., de Vries, S., Flanders, J., et al. (2019). Nature and mental health: an ecosystem service perspective. *Sci. Adv.* 24:eaax0903. doi: 10.1126/sciadv.aax0903

Brückner, M. Z. M., Schwarz, C., Coco, G., Baar, A., Boechat Albernaz, M., and Kleinhans, M. G. (2021). Benthic species as mud patrol - modelled effects of bioturbators and biofilms on large-scale estuarine mud and morphology. *Earth. Surf. Process. Landf.* 46, 1–17. doi: 10.5194/egusphere-egu21-200

Chen, W. J., Chang, A. Y., Lin, C. C., Lin, R. S., Lin, D. L., and Lee, P. F. (2024). Losing tidal flats at the midpoint of the East Asian-Australasian flyway over the past 100 years. *Wetlands* 44:59. doi: 10.1007/s13157-024-01814-7

Chun, M. H, Chang, M. C, and Lee, S. J. (2017). The effects of forest therapy on depression and anxiety in patients with chronic stroke. *Int. J. Neurosci.* 127, 199–203. doi: 10.3109/00207454.2016.1170015

Corazon, S. S., Sidenius, U., Poulsen, D. V., Gramkow, M. C., and Stigsdotter, U. K. (2019). Psycho-physiological stress recovery in outdoor nature-based interventions: a systematic review of the past eight years of research. *Int. J. Environ. Res. Pub. Health.* 16:1711. doi: 10.3390/ijerph16101711

Coventry, P. A., Brown, J. V. E., Pervin, J., Brabyn, S., Pateman, R., Breedvelt, J., et al. (2021). Nature-based outdoor activities for mental and physical health: systematic review and meta-analysis. *SSM Pop. Health*. 16:100934. doi: 10.1016/j.ssmph.2021.100934

Dadvand, P., Bartoll, X., Basagaña, X., Dalmau-Bueno, A., Martinez, D., Ambros, A., et al. (2016). Green spaces and general health: roles of mental health status, social support, and physical activity. *Environ. Int.* 91, 161–167. doi: 10.1016/j.envint.2016.02.029

Daniel, T. C., Muhar, A., Arnberger, A., Aznar, O., Boyd, J., and Chan, K. M. A. (2012). Contributions of cultural services to the ecosystem services agenda. *Proc. Natl. Acad. Sci. U.S.A.* 109, 8812–8819. doi: 10.1073/pnas.1114773109

Dashtgard, S. (2011). Linking invertebrate burrow distributions (neoichnology) to physicochemical stresses on a sandy tidal flat: implications for the rock record. *Sedimentology* 58, 1303–1325. doi: 10.1111/j.1365-3091.2010.01210.x

David, A. D., Fadzil, K. S., Amri, A. Y., and Ooi, J. L. S. (2024). Gleaners, gleaning activities, and livelihoods in Peninsular Malaysia. *JATI-J. SE. Asian Stud.* 29, 99–142. doi: 10.22452/jati.vol29no2.5

De Guzman, A. B., Sumalde, Z. M., Rance, G. M. S., Colance, M. D. B., and Ponce, M. F. V. (2019). Contribution of gleaning fisheries to food security and nutrition of poor coastal communities in the Philippines. *J. Env. Sci. and Manag.* SI-1, 58–71. doi: 10.47125/jesam/2019_sp1/06

De Smit, J. C., Brückner, M. Z. M., Mesdag, K. I., Kleinhans, M. G., and Bouma, T. J. (2021). Key bioturbator species within benthic communities determine sediment resuspension thresholds. *Front. Mar. Sci.* 8:726238. doi: 10.3389/fmars.2021.726238

De Sousa, W. L., Zacardi, D. M., and Vieira, T. A. (2022). Traditional ecological knowledge of fishermen: people contributing towards environmental preservation. *Sustainability* 14:4899. doi: 10.3390/su14094899

Del Norte-Campos, A. G. C., Campos, W. L., and Villarta, K. A. (2005). A survey of macro-invertebrate gleaning in the Banate Bay intertidal area, Eastern Panay Island. *Paper presented during the 8th National Symposium in Marine Science, Palawan State University, Puerto Princesa, Palawan, on October 20–22, 2005*.

Department of Science and Technology—Food and Nutrition Research Institute (DOST-FNRI) (2020). *Philippine Nutrition Facts and Figures: 2018 Expanded National Nutrition Survey (ENNS)*. Taguig City: DOST-FNRI.

Dewenter, J., Yong, J., Schupp, P. J., Lõhmus, K., Kröncke, I., Moorthi, S., et al. (2023). Abundance, biomass and species richness of macrozoobenthos along an intertidal elevation gradient. *Ecol. Evol.* 13:e10815. doi: 10.1002/ece3.10815

Dittmann, S. (1995). Benthos structure on tropical tidal flats of Australia. *Helgol. Meeresunters* 49, 539–555. doi: 10.1007/BF02368381

Dittmann, S. (2008). *Biodiversity and Habitat Characteristics of Intertidal and Estuarine Mudflats of the Fleurieu Peninsula and Gulf St. Vincent. Report for the DEH and AMLNRM*. Adelaide, SA: School of Biological Sciences, Flinders University, 56pp.

Edwards, R. L. (1981). *Common Edible Molluscs of the Philippines: A Field Guide*. Iloilo: Aquaculture Department, Southeast Asian Fisheries Development Center.

Fernández-Rivera, M. F, Torre, J., Cuevas-Gómez, G. A, Amador-Castro, I. G., Velázquez-Castillo, M. A., and Espinoza-Tenorio, A. (2024). Inheriting wisdom: transfer of traditional, scientific, and ecological knowledge in fishing communities in Mexico. *Front. Sustain.* 5:1386259. doi: 10.3389/frsus.2024.1386259

Fish, R., Church, A., and Winter, M. (2016). Conceptualising cultural ecosystem services: a novel framework for research and critical engagement. *Ecosyst. Serv.* 21, 208–217. doi: 10.1016/j.ecoser.2016.09.002

Franco, A., Franzoi, P., Malavasi, S., Riccato, F., Torricelli, P., and Mainardi, D. (2006). Use of shallow water habitats by fish assemblages in a Mediterranean coastal lagoon. *Est. Coast. Shelf Sci.* 66, 67–83. doi: 10.1016/j.ecss.2005.07.020

Furkon, N. N., Ambo-Rappe, R., Cullen-Unsworth, L. C., and Unsworth, R. K. F. (2019). Social-ecological drivers and dynamics of seagrass gleaning fisheries. *Ambio* 49, 1271–1281. doi: 10.1007/s13280-019-01267-x

Gonzales, B. J. (2013). *Field Guide to Coastal Fishes of Palawan*. Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security (CTI-CFF) Secretariat, Coastal and Marine Management Office, Protected Areas and Wildlife Bureau, Department of Environment and Natural Resources, Quezon City, Philippines.

Grabowska-Chenczke, O., Wajchman-Switalska, S., and Wozniak, M. (2022). Psychological well-being and nature relatedness. *Forests* 13:1048. doi: 10.3390/f13071048

Grantham, R., Alvarez-Romero, J. G., Mills, D. J., Rojas, C., and Cumming, G. S. (2021). Spatiotemporal determinants of seasonal gleaning. *People Nat*. 3, 376–390. doi: 10.1002/pan3.10179

Grantham, R., Lau, J., and Kleiber, D. (2020). Gleaning: beyond the subsistence narrative. *Marit. Stud.* 19, 509–524. doi: 10.1007/s40152-020-00200-3

Gutierrez, G. L. (2025). *Las Piñas-Parañaque Wetland Park Key Stopover for Migrating Birds*. Philippine Information Agency. Available online at: https://pia.gov.ph/las-pinas-paranaque-wetland-park-key-stopover-for-migrating-birds/ (Accessed June 7, 2025).

Hahm, H., Jeong, S., Jeong, M., and Park, S. C. (2014). Cultural resources and management in the coastal regions along the Korean tidal flat. *Ocean Coast. Manag.* 102(Part B), 506–521. doi: 10.1016/j.ocecoaman.2014.07.011

Healy, T., Wang, Y., and Healy, J. (2002). *Muddy Coasts of the World: Processes, Deposits, and Function*. Amsterdam: Elsevier Science.

Henmi, Y., Fujiwara, C., Kirihara, S., Okada, Y., and Itani, G. (2017). Burrow morphology of alpheid shrimps: case study of *Alpheus brevicristatus* and a review of the genus. *Zool. Sci.* 34, 498–504. doi: 10.2108/zs170055

Hicks, C.C., Cohen, P.J., Graham, N.A.J., Nash, K. L., Allison, E. H., D'Lima, C., et al. (2019). Harnessing global fisheries to tackle micronutrient deficiencies. *Nature* 574, 95–98. doi: 10.1038/s41586-019-1592-6

Hill, N. K., Woodworth, B. K., Phinn, S. R., Murray, N. J., and Fuller, R. A. (2021). Global protected-area coverage and human pressure on tidal flats. *Conserv. Biol*. 35, 933–943. doi: 10.1111/cobi.13638

Hombre, S., Gonzalez, J., Baguinbin, D., Balisco, R. A., and Dolorosa, R. (2016). Preliminary checklist of marine gastropods and bivalves in the Kalayaan Island Group Palawan, Western Philippines. *Philipp. J. Syst. Biol*. 10, 15–34. doi: 10.26757/pjsb.201610007

Honda, K., Nakamura, Y., Nakaoka, M., Uy, W. H., and Fortes, M. D. (2013). Habitat use by fishes in coral reefs, seagrass beds and mangrove habitats in the Philippines. *PLoS ONE* 20:e e65735. doi: 10.1371/journal.pone.0065735

Hong, S-K (2012). Tidal-flat islands in Korea: exploring biocultural diversity. *J. Mar. Island Cultures* 1, 11–20. doi: 10.1016/j.imic.2012.04.001

Jensen, A. E. (2018). *Internationally Important Waterbird Sites in Manila Bay, Philippines*. The Netherlands: Wetlands International and IUCN National Committee of the Netherlands.

Jumawan, J. H., Tripoli, F. F. D., Boquia, E. E. S., Niez, K. L. M., Veronilla, J. A. H., Dellomes, S. A, Udtie, R. M., et al. (2015). Species diversity and spatial structure of intertidal mollusks in Padada, Davao del Sur, Philippines. *AACL Bioflux* 8, 301–309. Available online at: https://bioflux.com.ro/docs/2015.301-309.pdf (Accessed August 14, 2024).

Ke, G.-N., Utama, I. K. A. P., Wagner, T., Sweetman, A. K., Arshad, A., Nath, T. K., et al. (2022). Influence of mangrove forests on subjective and psychological wellbeing of coastal communities: case studies in Malaysia and Indonesia. *Front. Public Health* 10:898276. doi: 10.3389/fpubh.2022.898276

Kim, J.-E. (2013). Land use management and cultural value of ecosystem services in Southwestern Korean islands. *J. Mar. Island Cultures* 2, 49–55. doi: 10.1016/j.imic.2013.06.002

Kinoshita, K., Itani, G., and Uchino, T. (2010). Burrow morphology and associated animals of the mud shrimp *Upogebia yokoyai* (Crustacea: Thalassinidea: Upogebiidae). *J. Mar. Biol. Assoc. U.K.* 90, 947–952. doi: 10.1017/S0025315410000214

Koh, C.-H., and Khim, J. S. (2014). The Korean tidal flat of the Yellow Sea: physical setting, ecosystem and management. *Ocean Coast. Manag.* 102(Part B), 398–414. doi: 10.1016/j.ocecoaman.2014.07.008

Kondo, M. C., Jacoby, S. F., and South, E. C. (2018). Does spending time outdoors reduce stress? A review of real-time stress response to outdoor environments. *Health Place* 51, 136–150. doi: 10.1016/j.healthplace.2018.03.001

Kreitler, J., Papenfus, M., Byrd, K., and Labiosa, W. (2013). Interacting coastal based ecosystem services: recreation and water quality in Puget Sound, WA. *PLoS ONE* 8:e56670. doi: 10.1371/journal.pone.0056670

Lau, J. D., Hicks, C. C., Gurney, G. G., and Cinner, J. E. (2019). What matters to whom and why? Understanding the importance of coastal ecosystem services in developing coastal communities. *Ecosyst. Serv*. 35, 219–230. doi: 10.1016/j.ecoser.2018.12.012

Lumber, R., Richardson, M., and Sheffield, D. (2017). Beyond knowing nature: contact, emotion, compassion, meaning, and beauty are pathways to nature connection. *PLoS ONE* 12:e177186. doi: 10.1371/journal.pone.0177186

MacKinnon, J., Verkuil, Y. I., and Murray, N. J. (2012). "IUCN situation analysis on East and Southeast Asian intertidal habitats, with particular reference to the Yellow Sea (including the Bohai Sea)," in *Occasional Paper of the IUCN Species Survival Commission No. 47* (Gland and Cambridge: IUCN).

Mahilac, H. M. O, Tandingan, J. P., Torres, A. G., Amparado, R. Jr., and Roa-Quiaoit, H. A. (2023). Macroinvertebrate assessment in seagrass ecosystem in Sinacaban Municipality, Misamis Occidental, Philippines. *Biodiversitas* 24, 5586–5597. doi: 10.13057/biodiv/d241040

Miththapala, S. (2013). "Tidal flats," in *Coastal Ecosystems Series*, Vol. 5 (Colombo: IUCN), iii + 48.

Molina, J. R. H., Muda, J. R., and Dela Cruz, R. C. (2025). Community structure of benthic macroinvertebrates in JoseAbad Santos, Davao Occidental, Philippines. *Davao Res. J.* 16, 130–142. doi: 10.59120/drj.v16i2.395

Motoh, H., and Kuronuma, K. (1980). Field Guide for the Edible Crustacea of the Philippines. *Aquaculture Department, Southeast Asian Fisheries Development Center*. Iloilo, Philippines. Available online at: https://repository.seafdec.org.ph/bitstream/handle/10862/152/ediblecrustacea.pdf;jsessionid=33BF1C1771F83E1F14867754922423E6?sequence=1 (Accessed, September 15, 2023).

Motomura, H., Alama, U. B., Muto, N., Babaran, R. P., and Ishikawa, S. (eds.) (2017). *Commercial and Bycatch Market Fishes of Panay Island, Republic of the Philippines*. Kyoto: The Kagoshima University Museum, Kagoshima, University of the Philippines Visayas, Iloilo, and Research Institute for Humanity and Nature, 246 pp, 911 figs.

Murray, N., Ma, Z., and Fuller, R. (2015). Tidal flats of the Yellow Sea: a review of ecosystem status and anthropogenic threats: status of Yellow Sea tidal flats. *Austral Ecol*. 40, 472–481. doi: 10.1111/aec.12211

Murray, N. J., Clemens, R. S., Phinn, S. R., Possingham, H. P., and Fuller, R. A. (2014). Tracking the rapid loss of tidal wetlands in the Yellow Sea. *Front. Ecol. Environ.* 12, 267–272. doi: 10.1890/130260

Murray, N. J., Phinn, S. R., DeWitt, M., Ferrari, R., Johnston, R., Lyons, M. B., et al. (2019). The global distribution and trajectory of tidal flats. *Nature* 565, 222–225. doi: 10.1038/s41586-018-0805-8

Nagelkerken, I. (2009). "Evaluation of nursery function of mangroves and seagrass beds for tropical decapods and reef fishes: patterns and underlying mechanisms," in *Ecological Connectivity Among Tropical Coastal Ecosystems*, ed. I. Nagelkerken (Dordrecht: Springer), 357–399. doi: 10.1007/978-90-481-2406-0_10

Olaño, V. L., and Lanzuela, N. S. B. (2016). *Guide in Identifying Common Fishes in Lagonoy Gulf and Sorsogon Bay*. Tabaco: Department of Agriculture, Bureau of Fisheries and Aquatic Resources, National Stock Assessment Program Regional Office, 123p.

Ovung, E. Y., Kithan, L. M., Brearley, F. Q., and Tripathi, S. K. (2022). Indigenous community fishing practices in Nagaland, Eastern Indian Himalayas. *Sustainability* 14:7049. doi: 10.3390/su14127049

Passarelli, C., Olivier, F., Paterson, D.M., Meziane, T., and Hubas, C. (2014). Organisms as cooperative ecosystem engineers in intertidal flats. *J. Sea Res.* 92, 92–101. doi: 10.1016/j.seares.2013.07.010

Petriello, M. A., Redmore, L., Sène, A. L., Katju, D., Barraclough, L., Boyd, S., et al. (2025). The scope of empowerment for conservation and communities. *Conserv. Biol.* 39:e14249. doi: 10.1111/cobi.14249

Philippine Statistics Authority (2025). *Philippine Standard Geographic Code (PSGC): Province of Catanduanes*. Available online at: https://psa.gov.ph/classification/psgc/citimuni/0502000000 (Accessed April 18, 2025).

Raymond, C., and Kenter, J. O. (2016). Assessing and applying transcendental values to the management of ecosystem services. *Ecosyst. Serv*. 21, 241–257. doi: 10.1016/j.ecoser.2016.07.018

Reis-Filho, J. A., Barros, F., Nunes, J. A. C. C., Sampaio, C. L. S., and De Souza, G. B. G. (2011). Moon and tide effects on fish capture in a tropical tidal flat. *J. Mar. Biol. Ass. U.K.* 91, 735–743. doi: 10.1017/S0025315410001955

Rosa, C. D., Larson, L. R., Collado, S., Geiger, S. J., Profice, C. C., and Menuchi, M. R. T. P. (2024). Associations between well-being and nature-based recreation: a cross-sectional study among adults in the United States, Brazil, and Spain. *J. Environ. Psychol.* 99:102438. doi: 10.1016/j.jenvp.2024.102438

Rueff, M., and Reese, G. (2023). Depression and anxiety: a systematic review on comparing ecotherapy with cognitive behavioral therapy. *J. Environ. Psychol.* 90:102097. doi: 10.1016/j.jenvp.2023.102097

Sahidjan, N. I. U., Pedrosa-Gerasmio, I. R., and Tatil, W. T. (2025). Density and species composition: an initial record of the marine macroinvertebrates in Malamawi Island, Isabela City, Basilan Province, Philippines. *AACL Bioflux* 18, 1105–1118. Available online at: https://bioflux.com.ro/docs/2025.1105-1118.pdf (Accessed July 10, 2025).

Secretariat of the Convention on Biological Diversity (2014). *Global Biodiversity Outlook 4*. Montréal, QC: United Nations Environment Programme.

Shalders, T. C., Champion, C., Coleman, M. A., and Benkendorff, K. (2022). The nutritional and sensory quality of seafood in a changing climate. *Mar. Env. Res.* 176:105590. doi: 10.1016/j.marenvres.2022.105590

Shchepetkina, A., Drago, T., Santos, J., Alberto, A., Fatela, F., and Freitas, M. D. C. (2025). Neoichnology and sediment distribution in tidal flats of the mud-dominated mesotidal Mira River estuary (Portugal). *Sedimentology*. doi: 10.1111/sed.70035

Siliprandi, C. C., Tuset, V. M., Lombarte, A., Farré, M., and Rossi-Wongtschowski, C. L. D. B. (2019). Optimal fishing samplers to reveal the morphological structure of a fish assemblage in a subtropical tidal flat. *Neotrop. Ichthyol* 17:e170168. doi: 10.1590/1982-0224-20170168

Skilleter, G. A., Loneragan, N. R., Olds, A., Zharikov, Y., and Cameron, B. (2017). Connectivity between seagrass and mangroves influences nekton assemblages using nearshore habitats. *Mar. Ecol. Prog. Ser.* 573, 25–43. doi: 10.3354/meps12159

Society for the Conservation of Philippines Wetlands, Inc. (SCPWI) (2025). *The LPPWP (formerly LPPCHEA) Wetland Center*. Available online at: https://www.wetlands.ph/projects/lppchea-wetland-centre-complex/ (Accessed June 3, 2025).

Stiepani, J., Jiddawi, N., and Mtwana Nordlund, L. (2023a). Social-ecological system analysis of an invertebrate gleaning fishery on the island of Unguja, Zanzibar. *Ambio* 52, 140–154. doi: 10.1007/s13280-022-01769-1

Stiepani, J., Sandig, A., and Blicharska, M. (2023b). The Where, the How, and the Why of the gleaning fishery: livelihoods, food security, threats and management on the island of Malalison, Philippines. *Ocean Coast. Manag.* 244:106806. doi: 10.1016/j.ocecoaman.2023.106806

Stott, D., Forde, D., Sharma, C., Deutsch, J. M., Bruneau, M. Jr, Nasser, J. A., et al. (2024). Interactions with nature, good for the mind and body: a narrative review. *Int. J. Environ. Res. Public Health*. 21:329. doi: 10.3390/ijerph21030329

Stuart, P. (2022). From the archives: Jesse Frederick Steiner assess community organization in 1922. *J. Commun. Pract.* 30, 1–9. doi: 10.1080/10705422.2022.2140999

Subang, B. P. Jr., San Juan, R. G., Ventura, G. F. C., and Aspe, N. M. (2020). An annotated checklist to the commonly harvested crabs (Crustacea: Decapoda) from marine and brackish water ecosystems of Palawan, Philippines. *J. Environ. Aquat. Resour.* 5, 61–82. doi: 10.48031/msunjear.2020.05.05

Summers, J.K., Vivian, D. N., and Summers, J. T. (2019). The role of interaction with nature in childhood development: an under-appreciated ecosystem service. *Psychol. Behav. Sci.* 8, 142–150. doi: 10.11648/j.pbs.20190806.11

Tan, S.-K., Tan, S.-H., Kok, Y. S., and Choon, S.-W. (2018). Sense of place and sustainability of intangible cultural heritage – the case of George Town and Melaka. *Tourism Manage.* 67, 376–387. doi: 10.1016/j.tourman.2018.02.012

Treviño, M. (2022). "The mangrove is like a friend": local perspectives of mangrove cultural ecosystem services among mangrove users in Northern Ecuador. *Hum. Ecol.* 50, 863–878. doi: 10.1007/s10745-022-00358-w

van den Berg, M., van Poppel, M., van Kamp, I., Andrusaityte, S., Balseviciene, B., Cirach, M., et al. (2016). Visiting green space is associated with mental health and vitality: a cross-sectional study in four European cities. *Health Place* 38, 8–15. doi: 10.1016/j.healthplace.2016.01.003

Vargas, S. R., and Asetre, A. V. (2011). Conservation practices at Agoho marine park and sanctuary in Catanduanes, Philippines: convergence of initiatives for ecogovernance. *Paper presented during the 13th Biennial Conference of the International Association for the Study of the Commons, 10–14 January, Hyderabad, India*.

Vargas-Sapico, S. R., Azanza, P. A. T., and Aldea, K. Q. (2024). Coastal resource governance in Catanduanes Island, Philippines. *Kuroshio Sci.* 18, 107–117. Available online at: https://jglobal.jst.go.jp/detail?JGLOBAL_ID=202502215554344005 (Accessed December 5, 2024).

Volkenborn, N., Robertson, D. M., and Reise, K. (2009). Sediment destabilizing and stabilizing bio-engineers on tidal flats: cascading effects of experimental exclusion. *Helgol. Mar. Res.* 63, 27–35. doi: 10.1007/s10152-008-0140-9

Voss, G. L. (1963). Cephalopods of the Philippine Islands. *Bull. U.S. Natl. Museum* 234, 1–180. doi: 10.5479/si.03629236.234.1

Withers, K., and Tunnell, J. W. Jr. (1998). *Identification of Tidal Flat Alterations and Determination of Effects on Biological Productivity of These Habitats within the Coastal Bend*. Corpus Christi, TX: Corpus Christi Bay National Estuary Program. Publication CCBNEP-26. Available online at: https://www.cbbep.org/publications/virtuallibrary/cc26.pdf (Accessed June 28, 2025).

Worthington, T., and Spalding, M. (2018). Mangrove restoration potential: a global map highlighting a critical opportunity. *Apollo Univ. Cambridge Repository*. doi: 10.17863/CAM.39153

Yamakita, T., Yamada, K., Yokooka, H., and Kanaya, G. (2020). Traits database of tidal flat macrobenthos along the Northwest Pacific coast of Japan. *Ecol. Res.* 35, 1062–1072. doi: 10.1111/1440-1703.12183

Zhao, Y., Han, Z., Zhang, C., Wang, Y., Zhong, J., and Gao, M. (2024). Coastal cultural ecosystem services: a bridge between the natural ecosystem and social ecosystem for sustainable development. *Land* 13:1352. doi: 10.3390/land13091352

Zhou, Z., Grandjean, T. J., De Smit, J., van Belzen, J., Fivash, G. S., Walles, B., et al. (2024). Sediment dynamics shape macrofauna mobility traits and abundance on tidal flats. *Limnol. Oceanogr.* 69, 2278–2293. doi: 10.1002/lno.12669