Fishers' local knowledge strengthens seagrass restoration planning

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Abstract

Seagrass restoration is increasingly guided by habitat suitability models, yet restoration outcomes depend on more than biophysical suitability alone. In coastal social-ecological systems, fishers and anglers hold fine-scale, time-integrated knowledge of habitat condition, human use, and local constraints that are rarely incorporated at the outset of restoration planning. Here, we tested whether fisher and angler knowledge could generate a spatially explicit basis for seagrass restoration site selection along the southern Welsh coastline, UK. Using participatory mapping and a Wisdom of Crowds approach, 33 coastal resource users identified locations perceived as suitable for seagrass restoration and areas where restoration should be avoided. Weighting responses by regional participation and converting them into kernel density surfaces, we tested whether participatory-derived suitability predicted independently observed seagrass occurrence and assessed stakeholder perceptions of seagrass benefits. Participatory mapping revealed coherent hotspots of perceived restoration opportunity in sheltered bays and estuarine environments, whereas avoidance areas clustered around ports, sediment-influenced estuaries, and high-use tourism locations, indicating that participants integrated both ecological opportunity and human-use constraints. Net suitability was a strong predictor of seagrass occurrence, demonstrating close correspondence between aggregated local knowledge and observed seagrass distribution. Perceptions of seagrass restoration were broadly positive, with strong agreement that seagrass benefits marine life and the wider environment. Our findings show that fisher and angler knowledge can generate spatially coherent and ecologically meaningful information for restoration planning. Rather than acting as a simple substitute for habitat suitability modelling, participatory mapping functions as a social–ecological diagnostic layer, identifying areas of opportunity, constraint, and potential conflict. Integrating local knowledge early in restoration planning can improve site selection, guide choices between protection, passive recovery and active restoration, and strengthen legitimacy, stewardship, and long-term support for seagrass recovery.

Keywords: Participatory mapping; Stakeholder engagement; Social-ecological systems; Knowledge co-production; Local ecological knowledge; Seagrass restoration; Restoration planning; Habitat suitability

Introduction

Environmental decision-making often proceeds under uncertainty, shaped by data scarcity, coarse spatial resolution, and incomplete understanding of ecological and social dynamics (Gregory et al., 2012; Milner-Gulland and Shea, 2017). Indigenous and Local Knowledge (ILK) is increasingly recognised as a critical evidence base for terrestrial and marine management, particularly where empirical data are sparse, costly, or spatiotemporally limited (Brook and McLachlan, 2008; Stern and Humphries, 2022; Jones et al., 2024). Across ecological disciplines, ILK has been used to infer species distributions, reconstruct historical baselines, and inform habitat suitability and species distribution models (Smith et al., 2007; Lopes et al., 2019; Early-Capistran et al., 2020). Participatory mapping and interview-based approaches with resource users have also been successfully integrated with spatial modelling frameworks, often improving predictions of habitat extent and ecological change (Stern and Humphries, 2022; Jones et al., 2024).

The “Wisdom of Crowds” provides a complementary theoretical foundation for this approach. Under the right conditions, aggregated estimates from diverse and independent individuals can match or exceed expert judgement (Surowiecki, 2004; Kattan et al., 2016; Wu et al., 2020; Turiel et al., 2021; Jones et al., 2025b). Applied to ecological systems, this suggests that experience-based knowledge, built through repeated interaction with natural environments, can generate robust insights into ecological structure, function, and change. In practice, structured elicitation and spatial aggregation of ILK have revealed patterns that are either consistent with, or entirely absent from, ecologically modelled outputs (Whitmore, 2016; Gray et al., 2020; Jones et al., 2025b).

Despite this potential, ILK remains unevenly integrated into formal spatial modelling and conservation planning. In marine systems, Habitat Suitability Models (HSMs) and Species Distribution Models (SDMs) are commonly driven by environmental covariates derived from remote sensing or interpolated datasets (Monk et al., 2011; Souza Oliveira et al., 2025). These approaches are powerful, but their reliability depends entirely on the resolution, availability, and assumptions of their input layers, with many models utilising open-source data. As a result, model reliability, robustness, and performance are constrained by the resolution, quality and ecological relevance of available predictors across space and time (Barry and Elith, 2006; Cushway et al., 2026). Furthermore, fine-scale heterogeneity, particularly in dynamic coastal environments, may be systematically underrepresented.

These limitations matter because HSMs are increasingly central to restoration planning. They are widely used to identify priority areas, guide site selection, and optimise intervention design (Questad et al., 2014; Yuen et al., 2023; Shyvers et al., 2024). Yet restoration is not simply an ecological intervention. In social–ecological systems (SES)(Ostrom, 2009), restoration outcomes emerge through interactions among ecological conditions, governance, knowledge systems, resource users, and local values (Tedesco et al., 2023). Knowledge acquisition, production, and implementation are therefore core components of restoration planning, rather than external inputs (Unsworth et al., 2026b), indeed as it should be (Di Sacco et al., 2021; Quigley et al., 2022; Unsworth et al., 2024). Seagrass meadows provide a compelling SES through which to explore these components.

Globally, seagrass ecosystems underpin coastal productivity and resilience (Unsworth et al., 2022), sequestering carbon, stabilising sediments, attenuating wave energy, improving water quality, and providing vital habitat for a wide range of species. Critically, they underpin fisheries by providing nursery and juvenile habitat for numerous species of finfish and shellfish (Unsworth et al., 2018), linking ecosystem function directly to human livelihoods, particularly in subsistence fishery reliant communities (Jones et al., 2021; Jones et al., 2022b). In the UK, seagrass habitats support commercially and recreationally important fish species, such as Atlantic Cod (*Gadus morhua*)(Bertelli and Unsworth, 2014), and in other temperate systems, seagrass can nearly double cockle (*Cerastoderma edule*) feeding rates (Brun et al., 2009).

Despite their ecological and socio-economic importance, seagrass meadows are in global decline (Dunic et al., 2021), threatened by pollution, coastal development and climate change (Jones et al., 2025a). Restoration efforts have expanded in response (van Katwijk et al., 2016), but current approaches remain largely model-driven. Restoration site selection typically draws on HSM outputs, ground-truthing and experimentation (Stankovic et al., 2019; Bertelli et al., 2022; Grigg et al., 2025), with stakeholder engagement often introduced later to manage conflict, support implementation, or build local acceptance. This sequencing creates two limitations. First, it risks over-reliance on model assumptions and available datasets, which could lead to poor restoration outcomes when unsuitable sites are selected (Coals et al., 2025). Second, it misses opportunities to incorporate locally held ecological knowledge and social context early in the process (Smith et al., 2022). The result is not only a potential gap in ecological understanding, but also a risk of weakening community ownership, stewardship, and broader support (Dennis, 2025).

Fishers and anglers hold detailed, place-based knowledge accumulated through sustained engagement with coastal environments, often over decades and across generations (Jones et al., 2024; Mason et al., 2025). A potential benefit of this time-integrated knowledge is that it overcomes many of the problems associated with single time point datasets inherent in the creation of HSMs. Such knowledge is well positioned to support seagrass restoration planning because it can capture local ecological conditions, historical baselines, temporal change, and location-specific pressures that may be difficult to detect in conventional datasets (Berkström et al., 2019; Jones et al., 2022a). When systematically aggregated (Jones et al., 2025b), fisher and angler knowledge also reflects the principles of the "Wisdom of Crowds", offering a potentially robust and scalable source of spatial evidence for restoration planning.

However, spatial knowledge alone is insufficient for understanding restoration potential within an SES. Restoration also depends on how stakeholders perceive ecological benefits, resource benefits, and personal relevance. Such perceptions shape whether restoration is viewed as desirable, legitimate, and worth supporting, and they influence how resource users interpret what restoration is for (Matzek and Wilson, 2021; Löfqvist et al., 2023). Measuring these perceptions alongside spatial knowledge can therefore reveal whether mapped restoration opportunities are underpinned by broader social support, uncertainty, or contested values.

Here, we test whether aggregated fisher and angler knowledge can identify suitable seagrass restoration sites along the southern Welsh coastline, UK(Unsworth et al., 2026a). Rather than treating ILK as supplementary, we position it as an alternative, or complementary, approach to conventional HSMs. Specifically, we assess how participatory-derived site suitability maps compare with independently observed seagrass data, and how stakeholder perceptions of seagrass and restoration benefits align with these spatial patterns. In doing so, we evaluate whether experiential knowledge can meaningfully inform restoration planning within this SES. While inherently place-based, this approach provides a framework transferable to other local, regional and global systems where ecological conditions and knowledge contexts are comparable.

Methods

Study context

The study was conducted along the southern coastline of Wales, UK. This coastline, hereafter referred to as south Wales for simplicity, spans from Pembrokeshire in the west, to Monmouthshire in the east, and encompasses a continuum of estuaries, embayments, and shallow coastal systems that have undergone systematic anthropogenic induced change over a period of 300 years (Unsworth et al., 2026a). The study region also spans three ICES regional seas; Bristol Channel, Celtic Sea and Irish Sea (Moore et al., 2023). While regional definitions vary in policy and common usage, the south Wales framing reflects a semi-continuous social-ecological system linked by coastal processes, fisheries activity, and shared cultural identity.

The region supports a long-standing and diverse suite of coastal fisheries situated across three ICES regional seas; Bristol Channel, Celtic Sea and Irish Sea (Moore et al., 2023). The region remains characterised by active, highly engaged fishing and angling communities (Monkman et al., 2018; Silva and Ellis, 2019). It supports a mosaic of commercial, recreational, and traditional fisheries centred on estuarine and nearshore systems, most notably the Burry Inlet cockle fishery, which has operated for over a century and remains one of the most significant shellfisheries in Wales (Norris et al., 1998). These fisheries are embedded within local economies and livelihoods, with hand-gathering methods and management systems reflecting strong continuity across generations. More broadly, the south Wales coast sustains a range of small-scale and recreational fisheries that interact with dynamic coastal habitats, including estuaries and shallow embayments where seagrass meadows occur (Monkman et al., 2018). While some fisheries have declined or shifted in form over time, long-term monitoring and historical analyses indicate persistent ecological and socio-economic linkages between shellfisheries, environmental change, and coastal management in the region (Callaway, 2022).

The region also includes prominent seagrass restoration initiatives, most notably Dale in Pembrokeshire, widely recognised as the first large-scale seagrass restoration site in the UK (Unsworth et al., 2026b), as well as extensive historic seagrass meadows across the Milford Haven area and the Burry Inlet (Jones and Unsworth, 2016; Bertelli et al., 2018). The Welsh Government has also made a commitment to seagrass protection and restoration, investing in the National Seagrass Action Plan. As such, the region provides a relevant and timely context in which to evaluate alternative approaches to restoration planning, alongside ongoing national efforts to scale seagrass recovery.

Stakeholder engagement

An initial pilot study was conducted through an in-person, map-based workshop at two Seagrass Nursery Open Days in Laugharne, Carmarthenshire. Forty-two participants were invited to map known seagrass presence, identify areas they believed suitable for seagrass growth, and highlight locations where restoration should be avoided by identifying anthropogenic pressures such as pollution or conflicting activities (*i.e.*, bait digging). Participants were invited from a mixed stakeholder group, based on their interest in local seagrass restoration, and included members of local community science groups, regulatory bodies, NGOs and local businesses. This exercise was supported by a facilitated discussion on the ecological conditions required for seagrass establishment. Workshop outputs were subsequently digitised for analysis.

Several challenges, however, arose during the workshop. Participants varied in their familiarity with the coastline presented, and some lacked regular direct engagement with the areas in question. The in-person format also constrained stakeholder participation, excluding individuals unable to attend due to time or travel limitations, and was biased towards individuals with prior knowledge of seagrass restoration and/or whom had a level of interest sufficient to motivate attendance at a seagrass-related event. Additionally, the group setting may have introduced further bias, as participants could see and be potentially influenced by others' responses (O.Nyumba et al., 2018), limiting the independence necessary for robust knowledge aggregation.

To address these limitations, a structured online survey was developed, specifically targeting fishers and anglers, given their sustained interaction with marine and coastal environments and detailed local knowledge. The online format enabled broader geographic reach and greater participation flexibility, with surveys designed to be completed in a reasonable timeframe *i.e.* within 10–15 minutes. Rather than assuming seagrass knowledge *a priori*, all participants were provided with a clear description of seagrass morphology and ecology associated with *Zostera marina, Nanozostera noltii* and *Ruppia maritima* before taking the survey.

To capture social-ecological variation, the south Wales coastline was divided into sub-regions reflecting differences in seagrass species composition, geographic clustering and patterns of resource use (Figure 1). For example, some areas are characterised by intertidal *N. Noltii* and *R. maritima*, often associated with cockle beds and saltmarsh systems, while others are dominated by subtidal *Z.marina*, supporting fisheries targeting species such as crab and lobster. In the online survey, interactive maps for each sub-region allowed respondents to spatially identify up to five areas of perceived suitability and five areas of unsuitability, alongside questions to share their local insights and perceptions of seagrass restoration more broadly. Importantly, participants were asked which fishing region they visited most, and only that map was provided to participants.

The online survey was circulated during the winters of 2024/5 and 2025/6 across the south Wales area, with the intention of targeting commercial fishers, shellfish harvesters, aquaculturists, recreational anglers and spearfishers. To maximise diversity of responses, consistent with the logic of a Wisdom of Crowds approach, the survey was distributed through a multi-pronged recruitment strategy combining purposive, opportunistic, and snowball sampling. Recruitment routes included: QR-coded leaflets placed in bait and tackle shops, email circulation through fishing networks, paid social media advertisements, posts in fishing-related Facebook groups, word-of-mouth sharing, direct engagement with fishers and anglers, dissemination through local nature partnerships, and coverage in local press. Responses were then collated and analysed to investigate patterns in site selection, perceptions of the community, and to compare the sites selected through the surveys with those selected through habitat suitability modelling and ground-truthing.

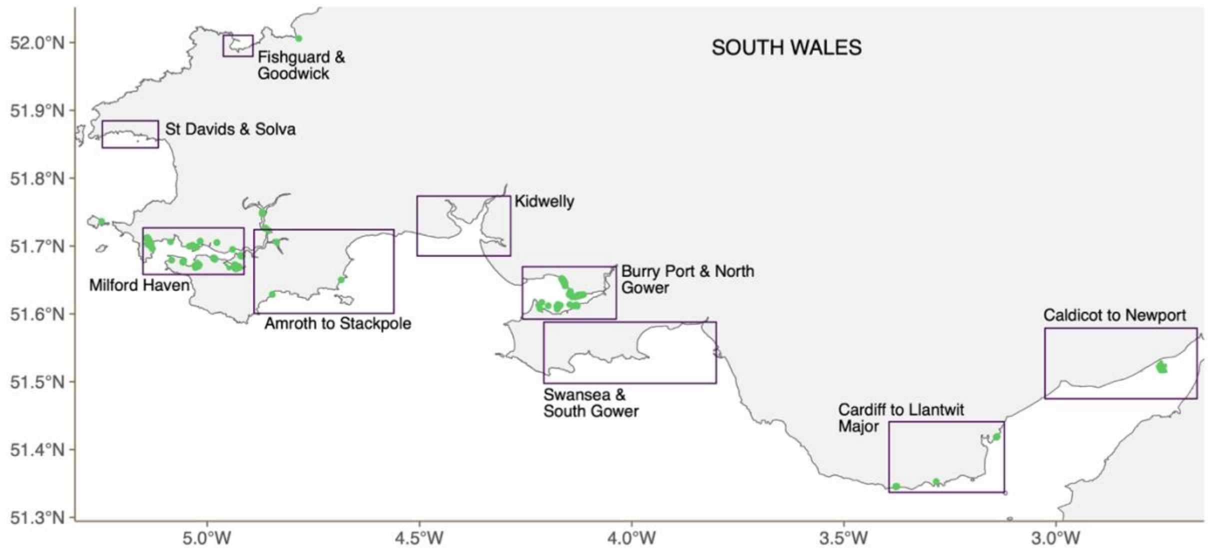

Figure 1. South Wales study region showing the nine coastal regions used in the participatory mapping survey. Purple boxes indicate the survey map areas presented to participants, while green points and polygons show existing seagrass records (Green et al., 2021; Rice et al., 2022; Jones et al., 2025a), including mapped meadows, point observations, and fragment sightings.

Responses from 33 of 42 participants were retained for analysis, based on either full survey completion or provision of sufficient spatial data. These responses generated a georeferenced dataset of participant-selected locations, classified as either suitable for seagrass restoration or areas where restoration should be avoided. These data were then used to produce spatial heat maps of perceived restoration opportunity and constraint across the study regions.

Data analysis

Survey data were imported and processed in R (R Core Team, 2026). For the mapping data, each respondent was assigned a unique *stakeholder_id*, and their reported primary fishing region was retained for subsequent weighting. Given spatial responses were originally stored as paired longitude–latitude coordinates across multiple ranked choices (*e.g.* “Suitable.Choice.1.x”, “Suitable.Choice.1.y”), these were reshaped to create two distinct datasets representing locations identified as suitable and those identified as unsuitable (avoid), which were subsequently combined into a single dataset with a categorical variable distinguishing response type. Records with missing coordinates were removed.

Next, to reduce spatial bias arising from uneven sampling effort across regions, responses were weighted inversely by the number of respondents per region. Specifically, each point was assigned a weight:

$$weight = \frac{1}{n_{region}}$$

This ensured that geographic areas with higher participation did not disproportionately influence the analysis.

Resulting point data were converted to a spatial object using the *sf* package for R (Pebesma, 2018), and projected into the British National Grid coordinate reference system (EPSG:27700) to allow for spatial analyses requiring metric distances, such as Kernel Density Estimation (KDE) (Baddeley et al., 2016). Projected coordinates were then converted into a planar point pattern object using the *spatstat* package, with point weights retained as marks (Baddeley et al., 2016).

Given that spatial responses were collected using a mobile-compatible map interface using Qualtrics, point locations were treated as spatially uncertain observations rather than precise coordinates. The extent of each map presented to respondents varied between regions (5–27 km), and responses were typically recorded on mobile devices (screen widths ~ 6.5–7.5 cm). To account for this, positional uncertainty was estimated by converting map extent to a spatial resolution (km per cm), and applying a conservative tap error of 0.5 cm, representing the approximate precision of a finger-based input. This produced region-specific uncertainty distances for each point. Rather than buffering points geometrically, these uncertainty estimates were incorporated directly into the KDE as smoothing bandwidths, allowing each observation to contribute a spatially diffuse signal consistent with its expected positional precision.

Weighted kernel density estimation was applied using Gaussian kernels, incorporating both respondent weights and spatial uncertainty (Diggle, 1985). Bandwidths were defined based on the median estimated positional uncertainty for each response type (suitable and avoid), ensuring that smoothing reflected the scale of input error rather than relying solely on data-driven optimisation. Edge correction was applied to reduce boundary effects.

Finally, each density surface was normalised independently by dividing by its maximum value, resulting in continuous surfaces scaled from 0 to 1. This standardisation was used to allow direct comparison between suitability and avoidance intensities.

We then derived a net suitability surface as:

$$\text{Net suitability} = \text{Suitability density} - \text{Avoidance density}$$

This produces a continuous index ranging from −1 to 1 where positive values indicate areas perceived as suitable, negative values indicate areas perceived as unsuitable, and values near zero indicate neutrality, or disagreement among respondents. We first normalised this to a scale of 0-1, then to improve interpretability, near-zero values (0.475 to 0.525) were set to missing, effectively masking areas of low consensus.

To evaluate the relationship between participatory suitability mapping and independently recorded seagrass occurrence, external presence data were obtained from SeagrassSpotter records (Jones et al., 2025a) and other published seagrass point data (Green et al., 2021). We extracted net suitability values at each seagrass observation location using the *terra* package. Next, to provide a baseline for comparison, we generated a set of randomly distributed background points across the study extent using spatial random sampling, and net suitability values were extracted for these locations using the same procedure.

The relationship between suitability and seagrass occurrence was first assessed visually using density plots. To formally test predictive performance, binomial logistic regression models were fitted with presence–background status as the response variable and suitability as the predictor. Model outputs were used to generate continuous prediction functions, and model performance was evaluated using the area under the receiver operating characteristic curve (AUC).

Results

Participatory mapping reveals spatially structured restoration opportunity

Local knowledge held by 33 fishers and anglers revealed a structured pattern of perceived opportunity for seagrass restoration across south Wales. The participatory-derived net suitability output showed strong spatial convergence in sheltered coastal bays and estuarine environments, where respondents consistently identified locations favourable for seagrass restoration (Figure 2). Distinct suitability hotspots were evident within the Milford

Haven waterway (including Angle Bay, Dale Bay and surrounding inlets), Fishguard Bay, the Burry Inlet, and Barry Island. These areas are characterised by low exposure, shallow subtidal environments, proximate to existing and historic *Z. marina* and *N. noltii* meadows (Unsworth et al., 2026a).

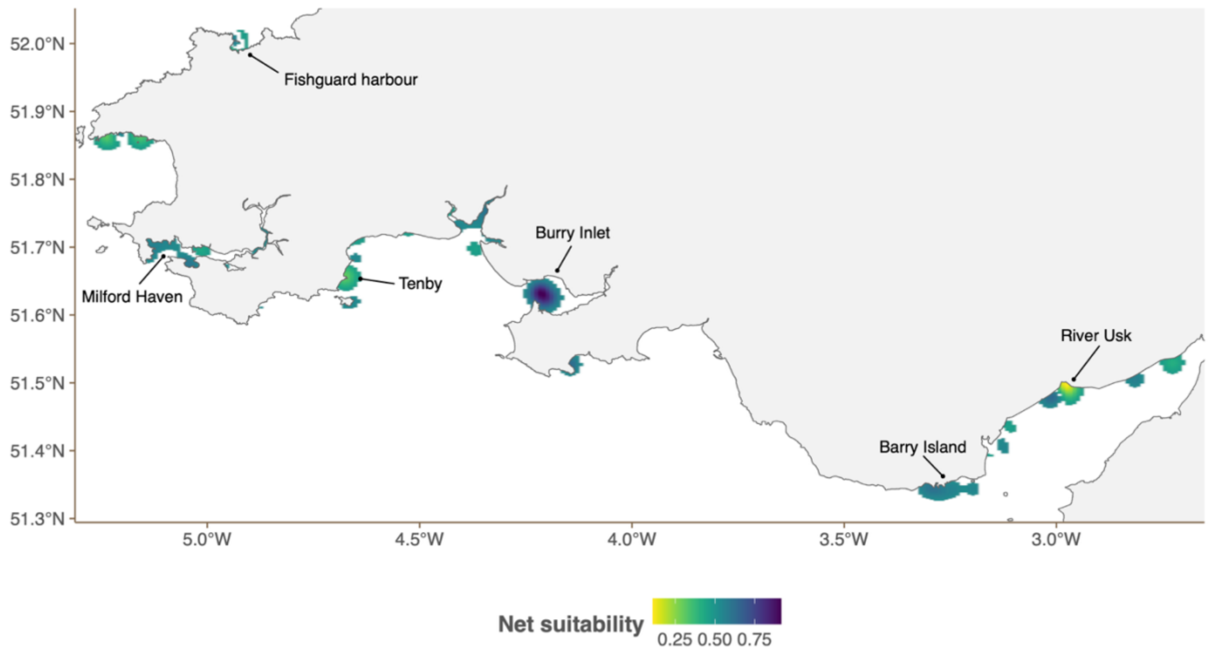

Figure 2. Participatory-derived net suitability for seagrass restoration in south Wales, UK. Kernel density surfaces of perceived suitable and unsuitable restoration locations were generated from stakeholder mapping responses and combined to produce a normalised net suitability output (0 being unsuitable and 1 being suitable).

In contrast, areas perceived as unsuitable for restoration (despite potential ecological suitability) were strongly associated with zones of high anthropogenic pressure, including port infrastructure in Milford Haven, sedimentary pressure in the River Usk estuary, and heavily visited tourism locations such as Tenby. This spatial contrast of net suitability (0= unsuitable, 1=suitable) indicates that perceptions of restoration potential are shaped not only by environmental conditions but also by patterns of human use and infrastructural constraint.

Participatory-derived suitability conforms with seagrass occurrence

Independent validation using seagrass occurrence data (Jones et al., 2025a) showed strong agreement with participatory outputs. Net suitability derived from participatory mapping was a strong predictor of seagrass presence, with a highly significant positive relationship ($\beta = 52.573 \pm 3.006$ SE, $p < 0.001$). The probability of occurrence increased sharply across the suitability gradient (Figure 3), and model performance was high (AUC = 0.89), indicating strong discrimination between observed seagrass locations and background points. Importantly, this correspondence emerges despite participants being explicitly asked to identify locations suitable for seagrass growth. This distinction is critical as it suggests that respondents are either implicitly conceptualising restoration as the enhancement of historically suitable seagrass environments or identifying areas of existing seagrass. In either case, the strong agreement between perceived restoration suitability and observed distribution indicates that local knowledge is closely coupled to present-day ecological conditions, even when elicited through a future-oriented framing.

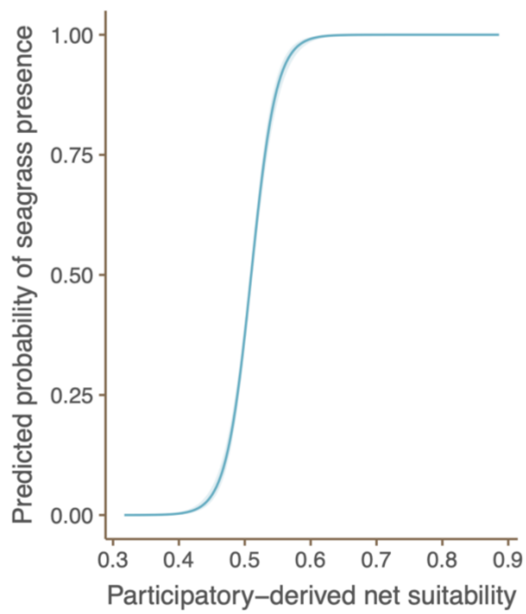

Figure 3. Predicted probability of seagrass occurrence across a participatory-derived net suitability gradient. The logistic regression curve shows the relationship between participatory-derived net suitability and observed seagrass presence, with the shaded area representing the 95% confidence interval. Higher net suitability values are associated with a greater predicted probability of seagrass presence (AUC = 0.89), indicating that aggregated participatory mapping (Wisdom of Crowds) captured spatial patterns consistent with observed seagrass occurrence.

Strong consensus on ecological benefits, with weaker perception of individual gains

Perceptions of seagrass meadows and its restoration potential were strongly positive across south Wales fishers and anglers (Figure 4). The vast majority agreed or strongly agreed that the presence of seagrass benefits the wider environment (85.3%) and marine life (82.9%), with similarly high agreement that seagrass restoration would benefit the wider environment (82.4%). Perceived direct benefits to targeted fishery resources were lower, but remained substantial, with 68.6% agreeing that the presence of seagrass meadows benefits the species they collect and 61.8% agreeing that restoration would enhance these resources. Perceived personal benefits were somewhat weaker, with 66.7% agreement for seagrass presence and 62.9% for seagrass restoration. Across all questions, disagreement remained low (11–15%), while neutral responses increased for questions relating to individual and resource-specific benefits (up to 25.7%), indicating greater uncertainty in how ecosystem recovery translates to direct outcomes for natural resource users.

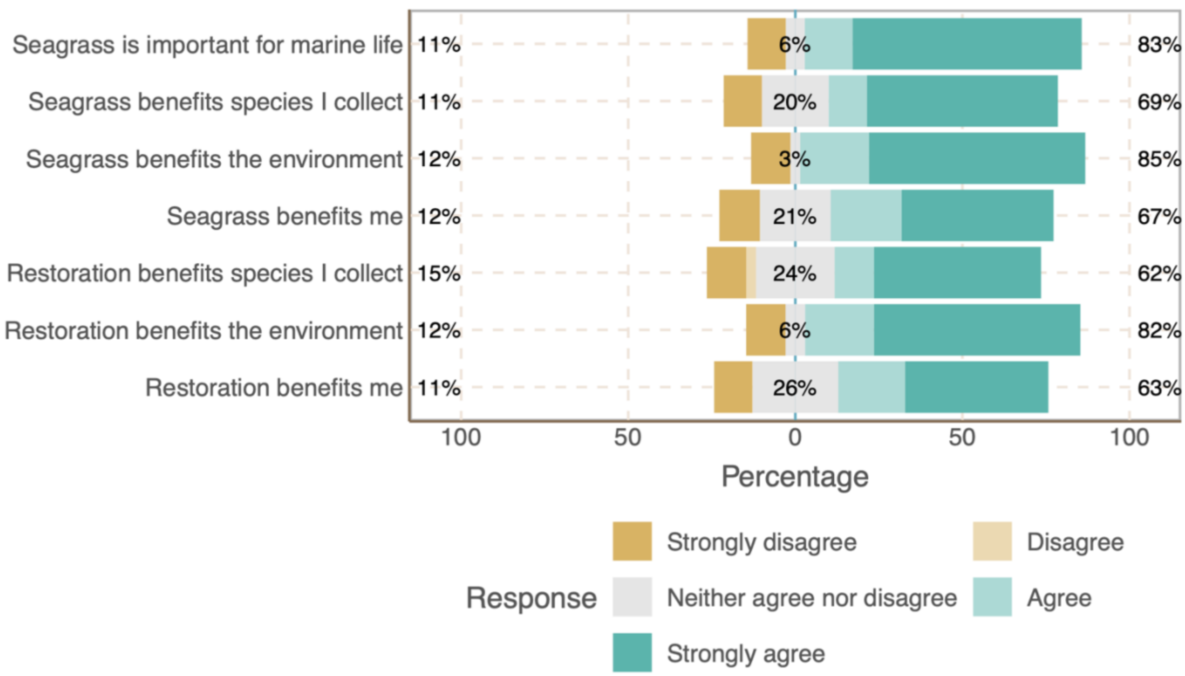

Figure 4. Stakeholder perceptions of seagrass ecosystem benefits and restoration outcomes across south Wales, UK. Diverging stacked bar charts show the distribution of responses (strongly disagree to strongly agree) for statements relating to (i) the ecological importance of seagrass and (ii) perceived benefits of seagrass restoration. Bars are centred on the neutral category to illustrate the balance of agreement and disagreement.

Knowledge base reflects diverse and experienced coastal users

The strength of these spatial and perceptual signals is underpinned by a diverse and multifunctional knowledge base consistent with a “Wisdom of Crowds” structure (Jones et al., 2025b). Thirty-four coastal resource users contributed spatial information, representing a broad range of fishing and harvesting practices. Recreational fishing dominated (76.5%), but substantial overlap with shellfish gathering (41.2%) and bait collection (23.5%) indicated multi-use engagement with coastal systems.

Access methods varied, with most respondents operating on foot (79.4%), alongside vessel-based fishing (32.4%) and freediving (26.5%). Nearly one-third reported multiple access modes. Respondents also demonstrated broad ecological knowledge, reporting a wide range of harvested taxa including crabs, lobsters, mussels, oysters, scallops, and cockles. Experience levels were somewhat skewed toward long-term engagement, with 58.8% reporting more than 10 years of experience and only 11.8% reporting less than two years. Spatially, knowledge spanned multiple coastal systems, including Milford Haven, the Burry Inlet, Swansea Bay, Pembrokeshire, and the Severn Estuary, with many respondents operating across multiple regions.

Discussion

Site selection is a crucial part of seagrass restoration planning that often defines success when compared with other variables (van Katwijk et al., 2016; Unsworth et al., 2024; Coals et al., 2025; Pansini et al., 2025). Amongst scientists and practitioners, Habitat Suitability Modelling (HSM) has emerged as the de facto way to predict potentially favourable sites, despite limitations (Bertelli et al., 2022). For seagrass systems, these approaches overlook the knowledge held by resource users, despite their long-term engagement with the coastal environments that may be targeted for restoration. This contrasts with suitability models on land, where local knowledge integration is somewhat more commonplace (Stern and Humphries, 2022). Here, we set out to test whether local knowledge held by fishers and anglers could support an alternative approach for seagrass restoration planning.

Participatory mapping revealed a coherent spatial structure and with clear areas of consensus for restoration opportunity. In some areas, these participatory suitability “hotspots” aligned closely with known seagrass distribution or areas of historic presence (Unsworth et al., 2026a). Further tests revealed that participatory-derived suitability outputs were strong predictors of independently observed seagrass occurrence.

Restoration is interpreted differently across knowledge systems

An unexpected outcome of this study is that many of the locations identified as suitable for restoration already contain seagrass meadows. This exposes a conceptual mismatch between participatory restoration mapping and assumptions embedded within conventional HSM and applied restoration practice. Conventional restoration planning, particularly when guided by HSM, is often oriented toward novel establishment; identifying new areas where seagrass could be introduced through active interventions such as seeding or transplanting. In contrast, stakeholder responses suggest a framing of restoration that is more closely aligned with enhancement, protection, or recovery of existing systems.

This aligns with a broader body of social science literature demonstrating that restoration is a socially constructed and contested practice. While scientific approaches often prioritise recovery towards a reference condition, local and Indigenous perspectives frequently frame restoration as the maintenance or improvement of functioning, lived landscapes (Weng, 2015; Robinson et al., 2021). In this context, we suggest that fishers and anglers are not only identifying *empty* space for restoration, but also recognising seagrass as an existing, valuable habitat that may be degraded, vulnerable, or in need of intervention.

Rather than identifying new sites for seagrass establishment, the spatial clustering emerging from stakeholder knowledge aligns more closely with an *intervention* perspective, where restoration is directed toward known seagrass locations that may be perceived as degraded, vulnerable, or in need of recovery. This is particularly important in the context of applied restoration methods, which typically refers to active planting of seeds or transplants into bare sediment. The alignment between participatory outputs and existing seagrass distribution potentially suggests that respondents are not only engaging with restoration as habitat creation in new areas, but also as enhancement or recovery of already recognised fishery assets.

This divergence highlights a limitation in a direct comparison between participatory suitability outputs and HSMs. While the latter are designed to identify biophysical potential for establishment in unoccupied space, the former may be capturing a management-oriented knowledge system that prioritises familiar, already-vegetated locations where perceived intervention is needed. As a result, the agreement between participatory mapping and observed seagrass distribution should not be interpreted as validation, but as evidence that local knowledge is oriented towards potentially different restoration ontologies focused on improving existing seagrass systems rather than expanding their spatial footprint through new introductions.

Implications for restoration planning and site selection

Our findings have direct implications for how restoration planning is structured. Current approaches typically follow a linear sequence involving model-driven site identification, site assessments and restoration trails, followed by stakeholder engagement to resolve conflicts or support implementation, if included at all. We believe this sequence to be suboptimal, particularly for restoration of social-ecological systems like seagrass meadows.

We suggest that Incorporating ILK at earlier stages can identify ecologically suitable areas that may be missed or underrepresented in models, highlight fine-scale constraints and pressures (e.g. infrastructure, tourism, localised disturbance) not captured in environmental layers, reveal areas where intervention is socially acceptable or contested and align restoration objectives with stakeholder priorities, improving legitimacy and long-term stewardship.

Critically, participatory approaches may also help distinguish between different intervention pathways, including protection of existing meadows, passive recovery through pressure reduction and active restoration in suitable but currently unoccupied areas. This is particularly important given the high cost and variable success of active seagrass restoration. In many systems, improving environmental conditions and reducing pressures may yield far greater returns than planting alone (Ward et al., 2025).

Participatory mapping as a social–ecological diagnostic tool

Rather than viewing participatory outputs as direct analogues to HSMs, they may be better understood as social–ecological diagnostic layers. The net suitability output generated here integrates ecological knowledge, historical experience, and perceptions of human pressure into a single spatial product. The distinction between suitability and avoidance is especially informative. While suitable areas aligned with known seagrass habitat, avoidance areas were strongly associated with anthropogenic pressures, including ports, sedimentation, and high-use recreational zones. These patterns highlight constraints that are often poorly represented in HSMs but are critical for restoration success. As such, participatory mapping provides insight not only into where seagrass *could* occur, but where restoration is feasible, acceptable, and likely to persist in the long term.

These findings sit within an emerging body of seagrass research showing that local knowledge and participatory approaches can generate spatially explicit, policy-relevant ecological information. Across diverse contexts, these approaches are increasingly used not only to complement conventional mapping, but to strengthen ecological inference and decision-making. For example, combining satellite imagery with stakeholder interviews has revealed long-term seagrass decline trajectories in Brazil and identified locally specific drivers that would have remained undetected using remote sensing alone (Magalhães et al., 2026). In the eastern Aegean Sea, Greece, fisher knowledge has been shown to map *Posidonia oceanica* meadows with high accuracy, even under low-participation conditions, and in some cases outperform official seagrass maps (Alexopoulos et al., 2025). Participatory approaches are also being extended beyond seagrass habitat mapping into applied site selection. In Indonesia, community mapping was used to identify suitable sea cucumber grow-out sites in seagrass-associated systems, integrating both ecological and socio-economic criteria (Ainin et al., 2025). Our study builds directly on this trajectory, but extends it from mapping and habitat assessment into restoration planning.

Caveats and future refinement

There are several caveats that should guide interpretation. First, the participatory maps were necessarily presented at broad regional scales. While this was appropriate for identifying spatial patterns and areas of consensus, it was less suited to identifying precise boundaries. Therefore, the points should be interpreted as areas of perceived opportunity or constraint, not as perfect sites. In-person follow-up workshops, targeted interviews, and site-level site assessment would help refine these outputs, identify specific restoration zones, and clarify whether respondents were referring to active planting, passive recovery, protection of existing meadows, or pressure reduction.

Participation was voluntary and notably uneven across regions and user groups. Although responses were weighted by region to reduce spatial sampling bias, the sample was still dominated by recreational fishers and anglers, with limited representation from commercial fishers. Because different user groups may hold different knowledge, priorities, and concerns, this does present some bias. For example, the identification of the Burry Inlet as suitable for restoration may not fully capture the perspective of the commercial cockle fishery, highlighting the need for targeted engagement with disenfranchised and underrepresented groups before moving from spatial identification to restoration implementation.

Finally, mobile-based mapping introduces positional uncertainty. Some points were likely affected by screen size, zoom level, or user error, and obviously erroneous locations were removed. Future applications could improve precision by combining online mapping with facilitated in-person validation, clearer scale controls, and iterative feedback with local users.

Implications for restoration and management

Despite minor caveats, the approach offers clear practical value for seagrass restoration practitioners. Participatory mapping is scalable, relatively low-cost, and suitable for local communities, smaller NGOs, and restoration partnerships that may not have the resources to develop bespoke HSMs. It also brings fishers and anglers into the restoration planning process from the outset, rather than after sites have already been selected. Early involvement can strengthen trust, legitimacy, stewardship, and long-term support, while also helping avoid mistakes caused by selecting sites that are ecologically plausible but socially or operationally difficult. Such mistakes are costly, both for practitioners and funders.

We are quick to highlight that participatory mapping should not replace HSMs or field assessment entirely. Instead, it can act as an early social–ecological screening layer to identifying where local knowledge converges, where pressures or conflicts are expected, and where further site-level assessment should be prioritised.

To conclude, here we show that fisher and angler knowledge generates spatially coherent and ecologically meaningful information vital for seagrass restoration planning. Participatory-derived suitability did not simply replicate existing HSM but captured different and highly relevant signals that integrating ecological familiarity, human use, perceived pressure, and restoration feasibility. In doing so, it identified both areas of opportunity and areas where intervention may be socially or practically constrained. For seagrass restoration, this latter point is highly relevant. Successful restoration depends not only on whether seagrass can grow, but whether interventions are appropriate, supported, and likely to persist within lived coastal systems. Integrating local knowledge early in restoration planning can therefore improve site selection, guide decisions between protection, passive recovery and active restoration, and build stronger relationships with the communities who know and understand these systems best.

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