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A framework for co-creating knowledge across the ocean humanities and sciences

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Ocean sustainability demands interdisciplinary knowledge. While interdisciplinary collaborations involving the natural sciences are common, few have also included the ocean humanities despite the entanglement of human culture and history with the ocean. We—a team of both ocean scientists and humanities researchers—outline a framework for integrating these disciplines. We show how this framework operates in practice by presenting a case study of the shifting baseline syndrome (SBS) in the intertidal of Monterey Bay, California, United States, as represented in historical ecological data and newspapers. We highlight such collaborations' potential to transform our knowledge of and potential actions in the ocean.

Background: vital but largely unknown oceans

Oceans are vital to human and planetary health yet uniquely difficult for humans to understand. Marine ecosystems are essential to sustaining human life both directly, providing the main source of animal protein for billions of people[1], and indirectly, through global ocean circulation[2] and the marine carbon pump[3]. From a socio-cultural perspective, humans today are oceanic creatures. The planetary community of present-day humanity arose through overseas voyages: millennia of Pacific sailing[4,5], north Atlantic overseas empires[6], Indian Ocean trading networks[7,8], and global maritime diasporas[9,10].

The link between oceans and humans has only become stronger with the accelerating impacts of anthropogenic processes: groups of people putting too much waste into the water and taking too many fish out. Recognizing the central role of oceans, the UN declared 2021-2030 the "Decade of the Ocean," with a vision to achieve "[t]he science we need for the ocean we want"[11].

Along with the many issues raised when deciding what "we want,"[12] the goal of finding the "science we need"—of knowing the oceans—runs into fundamental challenges. The oceans are vast[13,14], deep[15,16], dark[17,18], and dangerous[19,20] environments that intersect with a huge range of human groups and practices across the planet. Getting "the science we need" demands an all-hands-on-deck approach, involving many different people with many different knowledge systems. Working towards ocean sustainability means working together; and working together means rethinking the kinds of knowledge we value and how disparate knowledge systems can find common ground.

Need and opportunity: the transdisciplinary oceans

One persistent social challenge has been that in many current societies knowledge of the oceans can be siloed into different *disciplines* that struggle to communicate. Ocean science has confronted this problem by becoming increasingly interdisciplinary, especially across the natural sciences and reaching into the social sciences. Yet interdisciplinary collaborations across the ocean sciences and humanities remain comparatively absent.

Despite broad movements towards interdisciplinarity, at some universities, government agencies, and NGOs, the disciplinary structures of departments, programs, projects, and evaluations can continue to divide us from each other, reflecting a long history of disciplinary knowledge. Recall that oceanography became a discipline by focusing research on the undersea to working oceangoing ships, rather than the smaller "pleasure craft" that earlier naturalists and students (including women) had used[15]; and that philology splintered into distinct humanities fields during the nineteenth century as scholars "self-isolat[ed]" into separate professional societies[21]. In particular, disciplines block a more holistic perspective on oceans' relationship with humans. By contrast, traditional endeavors such as ethnobotany seamlessly combined knowledge from different areas (natural history, traditional use, oral history). These broader perspectives are especially necessary with increasing human impacts on the oceans and consequent vulnerabilities to sea level rise, extreme weather, and fisheries collapse.

Ocean users already encounter their marine environments as a disciplinary totality. For example, fishers across the planet combine cultural, biological, meteorological, and economic knowledge to make a living from

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the seas—without worrying that this knowledge is split across different university departments[22]. Ocean users show that understanding the oceans entails considering both human and more-than-human[23] dimensions and their complex interrelations.

There is already a strong record of working toward interdisciplinary collaboration in the ocean sciences that we can build on further. Biological, chemical, and physical oceanography, along with marine biology and ecology, have for decades collaborated, especially to study topics like ocean acidification that inherently entangle multiple disciplines[24]. Further, there have also been many efforts to work across the natural and social sciences, in both established disciplines, such as fisheries science[25], and emerging fields, such as coastal and marine socio-ecological systems[26], marine environmental history[27,28], and marine historical ecology (as discussed below). Ocean natural sciences have looked to non-academic expertise from Indigenous communities, as in marine conservation biology's engagement with traditional ecological knowledge[29] and Indigenous and local knowledge[30]. These examples of interdisciplinary work have had remarkable results, producing knowledge that no single discipline could have arrived at independently.

However, one interdisciplinary collaboration that remains missing is between the ocean sciences and humanities, across the divide of the "two cultures"[31]. The ocean humanities, also termed the oceanic humanities[32] or blue humanities[33], has emerged as an interdisciplinary formation in its own right. The ocean humanities study human interactions with oceans across an array of disciplines, including history[34], literature[35], anthropology[36], media studies[37], philosophy[38], ethnic studies[39] and especially Black studies[40], Indigenous studies, human geography[41], and law[42]. While there is no absolute line between the social sciences and humanities, one distinguishing factor is that where marine social science tends more towards the quantitative (e.g., in studying "determinants of human behavior")[43], the ocean humanities are primarily qualitative[44]. The ocean sciences and ocean humanities share common interdisciplinary tendencies, overlapping interests in the oceans, and an urgent need to better understand the human-ocean relationship in the context of accelerating human impacts on the oceans. Further, ocean science often touches on human culture[45] and history[46], while the humanities discuss bathymetry[47], optics[48], and organisms[49]. Yet little scholarship has reached across the divide separating the humanities and sciences in order to *co-create* knowledge, rather than use another discipline as a source of data which is then processed according to the concepts, methods, and goals of the other discipline[50].

We—an interdisciplinary team of ocean scientists and ocean humanities researchers—argue that the intersection of the ocean humanities and ocean sciences presents a major, largely untapped opportunity for interdisciplinary collaboration that can lead to surprising *propagative findings* and, potentially, to an *expanded solution space for addressing ocean challenges*. Disciplinary silos have made it difficult to formulate solutions that take both ocean health and human well-being into account. More limited collaborations can produce new answers and approaches to existing disciplinary questions. But a co-creative approach can enable a longer-term, wholescale rethinking of fundamental assumptions about what the oceans are and what our relationship with them should be, expanding the scope of possible actions we can pursue[51]. In other words, working across the humanities and sciences has an unusually strong potential to get beyond what "we already know"[52] about the oceans to explore new dimensions of ocean-human interactions and new possibilities for mobilization and action. Such knowledge is more crucial than ever for informing ocean sustainability.

We base this argument on our experience conducting collaborative interdisciplinary research. Such collaboration can be uniquely rewarding in part because it is also uniquely difficult to work together across disciplines that have very different communicative, epistemic, and social norms. As such, in the following sections, we set out a guiding framework for integrating these disciplines that can aid future collaborations. We explain that framework through a case study from our own collaborative research.

Framework for integration

Our framework for integrating the ocean sciences and ocean humanities is as follows (Fig. 1):

1. Cultivating *shared literacy*, the common ground that lets us communicate, through
   a. An open disposition to the other discipline
   b. Regular time-limited conversations
   c. Introducing disciplines to one another through presentations and readings
2. Building *integrative archives*, the materials over which we can connect, through
   a. Focusing on specific maritime spaces

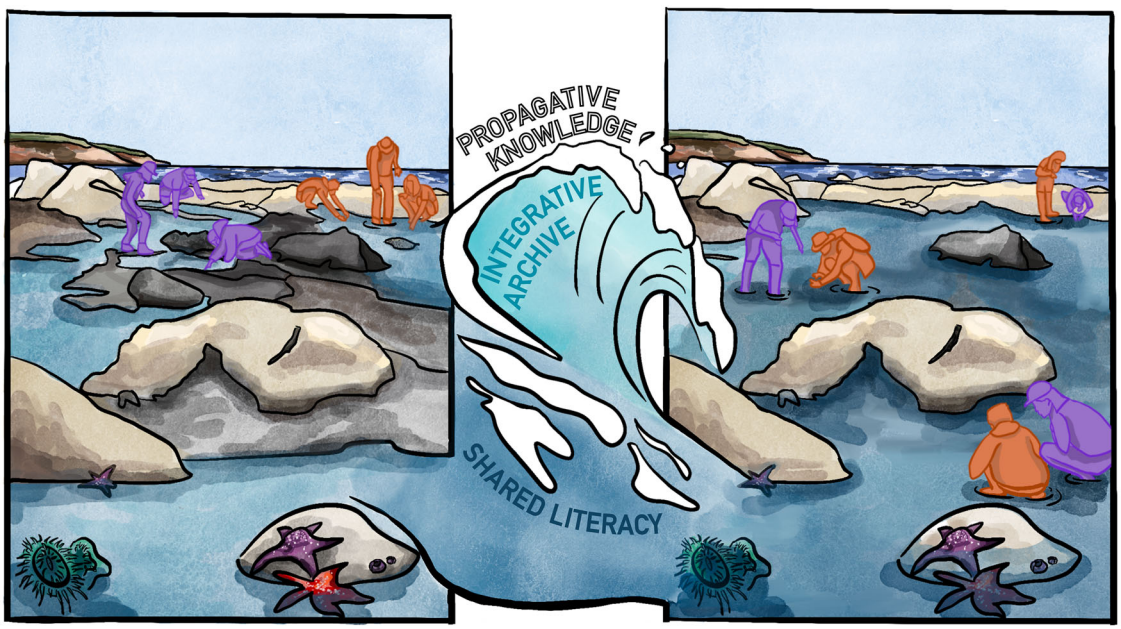

Fig. 1 | Illustration of our framework. In the left panel, ocean science and humanities researchers (depicted as purple and orange figures) engage with isolated tide pools at low tide. Through the rising of the tide and our framework for collaboration, shown as the central wave, the ecosystem becomes more interconnected. Researchers can then work together in new and generative ways.

   b. Taking advantage of digital file storage systems
   c. Using hybrid archival structures
3. Co-creating *propagative knowledge*, the results from analyzing these archives, through
   a. Approaching archives as both text and data
   b. Mixing interpretive and quantitative methods
   c. Reframing basic concepts in both disciplines

We developed this framework by conducting a pair of studies, namely on the media produced through oceanographic research cruises and on the shifting baseline syndrome (SBS) in the Monterey Bay littoral. Despite the disparate geographies, timescales, and goals of these studies—pelagic vs intertidal, contemporary vs historical, analyzing scientific practices vs recovering ecological information—we found that this shared framework was effective for both.

The key to this process is forming an integrative archive: a collection of data, artifacts, documents, and other objects that have both scientific and human meaning. While past work on interdisciplinary collaboration has touched on step 1 extensively and to varying extents step 3[53–55], it has not necessarily argued for the importance of the archive. Yet we found creating such archives to be the point where our collaboration gained real traction. Further, they are uniquely important to the interdisciplinary study of the oceans for reasons that we elaborate below.

We pictorially represent this protocol as a rising tide that causes separate pools of disciplinary knowledge to mix (Fig. 1). The human figures represent disciplinary experts, initially isolated in their disconnected tide pools. The tide, depicted as an incoming wave, represents the collaborative process. The integrative archive has a central place in the transition, making up the bulk of that wave, because of its pivotal importance. As the tide rises and this process of collaboration progresses, new possibilities emerge: the pools of disciplinary knowledge converge, creating a common zone across what had seemed to be separate systems, and the humans learn new, unexpected things together.

The implied ebb and flow of the tide represents the continued value of specialist knowledge. Specialists separate into disciplinary niches at low tide and then come together across disciplines at high tide, in a persistent back-and-forth movement, rather than either abandoning specialist knowledge or making rare interdisciplinary forays. While Fig. 1 directly depicts the movement from specialization to synthesis, our focus here, we chose the tidal metaphor because of this implied cyclical transition in and out of the disciplines.

The rising tide has an ambivalent significance. Optimistically, it registers upward movement towards greater integration; pessimistically, it alludes to increasing human impacts on the ocean (e.g., rising sea levels) that demand interdisciplinary integration. As the tide rises, all hands are called to deck.

The framework in action: fragmented baselines

Our group came together with the aim of integrating the ocean humanities and ocean sciences. We are experts in disciplines and subfields including fisheries science, literary studies, socio-ecological systems, digital humanities, marine ecology, film, and environmental science. We are cognizant of our group's bias towards biology and literature, even as we hold that our processes for collaboration can apply for other ocean disciplines.

Here, we present a narrative of a case study we conducted on the historical ecology of the Monterey Bay intertidal zone. We do so in order to show how our framework for collaboration works in action, moving along this sequence from literacy to archives and finally knowledge.

Cultivating shared literacy: the shifting baseline syndrome

After longer initial meetings to introduce our disciplines to each other through presentations, our group began meeting weekly to brainstorm about possible projects. At these weekly meetings, we consciously remained open to any topics that came up yet strictly limited the time. This format was simpler and more effective than more infrequent but longer conversations. At a sequence of meetings, we assigned and discussed short works from the other discipline. Openness to the other discipline was essential: we overcame institutional distrust of other units and insular disciplinary skepticism about other ways of knowing.

Team members from the humanities found Daniel Pauly's groundbreaking paper on SBS in fisheries[56]—a gradual change in what ecological conditions are considered normal, due to generational change and lost cultural memory—extremely compelling because of its rich humanities undercurrents. Further, we were intrigued by the interdisciplinary field of marine historical ecology[57–62] and by how SBS was not already widely-discussed in the ocean humanities. Conversely, the scientists wanted to better understand the human factors behind SBS, since the primary focus of studies has been reconstructing past baselines rather than understanding the drivers, awareness, and perception of baseline shifts. We therefore decided to use this concept as the starting point for a collaborative project.

Building integrative archives: the Hewatt-Sagarin transect and newspaper accounts of the Monterey Bay intertidal

Our initial scoping review of research on SBS showed that it did partially integrate the sciences and humanities, specifically ecology and history, yet researchers have noted how the disciplines are not co-creating knowledge[50,63]. Our study aimed to correct that imbalance.

We decided a specific study site, rather than a purely theoretical paper, would be more effective in this goal[53]. We did so because we noticed our more theoretical conversations gravitating towards separate disciplinary preoccupations. But discussions about a specific, concrete place pushed us out of our conceptual comfort zones and towards real collaboration.

Our institution is located by Monterey Bay[64] and the Hewatt-Sagarin transect, an extraordinary baseline for intertidal invertebrates going back to 1931[65–68]. Our team also has several experts in coastal marine biology in Monterey Bay. We therefore decided to study SBS in the Monterey Bay intertidal by comparing scientific records of coastal ecology to cultural records, as this environment is also extensively documented across media. We hoped to integrate these biological and cultural accounts of the environment in order to form a broader, more nuanced, and holistic historical baseline.

The integrative archive is particularly important to interdisciplinary ocean study because the oceans are primarily *known through mediated representations*. Direct access to these vast, dangerous environments is at best difficult, expensive, temporary, and partial; humans have long responded by depicting the oceans in their own terms. The abundance and primacy of such representations—from the "the lists, ledgers, and commodities" of the Middle Passage[69] to the "data tsunami" of contemporary ocean science[70], and epitomized in how ROV pilots model their work on science fictional films about the ocean[71]—means that they have a paramount role in our understanding of the sea. Again and again, we found ourselves saying that "we just need some data" and "we just need some texts" to work on together. Making such an archive was time-consuming, in both the discovery and collection phases, but extremely worthwhile. Once we formed such a collection of data/texts responsive to both disciplines, we quickly arrived at surprising insights.

We found that newspapers were a promising source of cultural representations of marine ecosystems, consistent with past work in marine historical ecology[72]. In addition to mentions of intertidal organisms scattered across newspapers, we found a column wholly dedicated to representing the Monterey Bay coast, "Along the Waterfront," which ran in the *Monterey Peninsula Herald* from 1934 to 1942[73,74]. Using keyword searches and manual review of digitized microfilm at the Monterey Public Library[75], we compiled 371 articles from the column into a digital database, forming an integrative archive responsive to humanities and scientific questions and scales. The affordances of digital archives and skills from the digital humanities were crucial here in locating, moving, labeling, and organizing page scans into an accessible, indexed database.

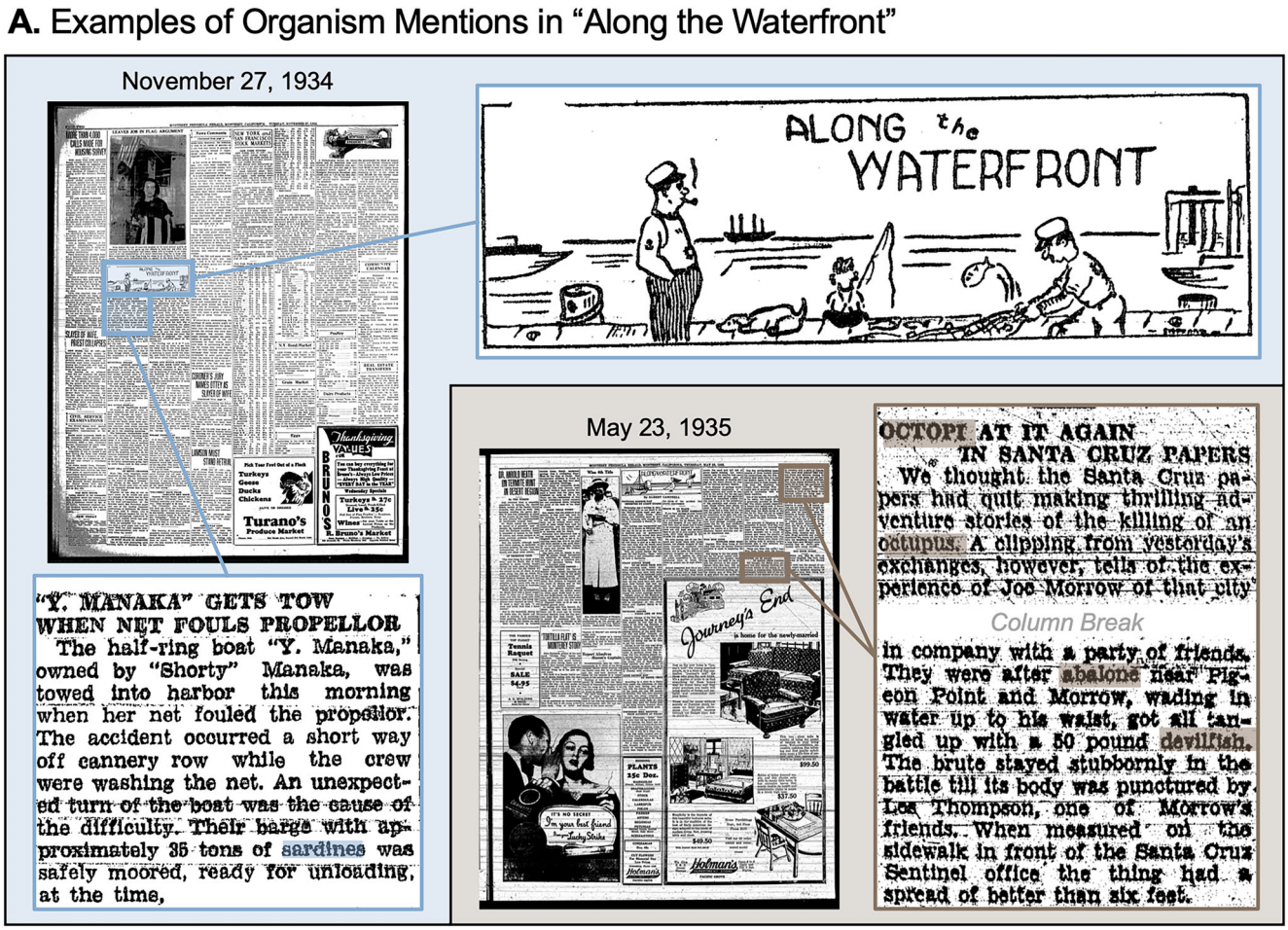

Fig. 2 | Data on marine species mentioned in the historical newspaper column "Along the Waterfront". A Examples of digitized articles highlighting the organisms mentioned there. **B** The most mentioned organisms across all articles. Newspaper images from: Campbell, A. Along the Waterfront, 27 November 1934. *Monterey Peninsula Herald* 2[83]; Campbell, A. Along the Waterfront, 23 May 1935. *Monterey Peninsula Herald* 3[77]. Accessed via https://monterey.gov/services/library/education___research/historical_newspapers.php.

Co-creating propagative knowledge: missing, biased, educational, and misaligned baselines

We analyzed this integrative archive through a biological presence-absence survey of columns in "Along the Waterfront," recording which marine organisms were mentioned in each column, the name used, and which genus or species it corresponded to (Fig. 2A). That survey also helped to focus our reading on SBS in the intertidal. (See the "Data availability" statement for a link to our survey data.) Attempting to merge scientific and humanities methods, rather than treating "Along the Waterfront" just as data to be crunched or text to be interpreted, helped us see basic epistemological issues in SBS.

We found that "Along the Waterfront" said very little about intertidal ecosystems despite its ostensible proximity to the shore. As shown in Fig. 2B, the most common organisms mentioned in the articles were typically not intertidal inhabitants: 176 out of 371 articles mentioned sardines. In contrast, few organisms that utilize intertidal ecosystems appeared in the top 10% of mentions, and those that did—such as abalone, octopus, and crab—were not unambiguously intertidal. More characteristically intertidal invertebrates, such as hermit crabs and nudibranchs, were mentioned infrequently across the column. The baseline for the intertidal was missing. The absence has implications not only for ocean science but also our understanding of human history and culture in Monterey Bay. By the early twentieth century, the intertidal and nearshore are where Monterey's Chinese residents fished and gleaned, following a series of conflicts with Portuguese, Italian, and Japanese fishermen that worked in pelagic environments[76]. The geographic and ethnic division is represented and reinforced in "Along the Waterfront"[77,78] and other period documents[79].

The one exception came in columns about science education, where marine biology courses taught the author of "Along the Waterfront" to notice intertidal species[80]. Even these columns depicted ecological conditions at generalized or unspecified scales, rather than at specific points as in transect data—a geographic challenge that makes it persistently difficult to align baselines across sources.

As a result, the overall ecological intertidal baseline of Monterey Bay was fragmented according to the priorities and social divisions among human groups. The most available records are those matching the priorities of dominant social groups (e.g., the commercially valuable sardine fishery and associated canning industry)[64,81], with consequences for reconstructing historical baselines. Seemingly unified ocean sites, like Monterey Bay, can divide into non-overlapping biological and human segments whose representations are incomplete and biased. In essence, when the question of historical baselines comes up, we must first ask who observes that baseline, where it covers, how it was encountered, and what cultural factors shape these perceptions.

Rather than finding an ecological dataset comparable to the Hewatt-Sagarin transect data, we came to appreciate the extraordinary value of these data, distinct from other historical records, and we saw some of the social conditions that enabled and preserved these data. Conversely, if we had not had the transect data from the 1930s but only these newspapers, we may not have known how diverse and densely populated the Monterey Bay shoreline was or even noted its absence in the newspapers. This disconnect urges general caution in treating historical records as ecological information. The absence of evidence for species in such records—and especially the absence of coastal invertebrates that may be undervalued and overlooked by dominant groups—is not evidence of absence. However, "Along the Waterfront" does show the importance of science education in making people become conscious of intertidal ecosystems at their feet. The fragmented baselines of Monterey Bay underline that coastal marine stations and educational institutions are a key contributor to helping people observe, monitor, and document the intertidal.

More broadly, our case study shows that integrating the ocean sciences and humanities can achieve surprising results that propagate at unexpected angles towards fundamental conceptual and methodological issues. We label these results "propagative" in a nod to wave propagation, to flag how they expand outwards in multiple dimensions across our existing knowledge of the ocean. Our conclusions have implications for many areas of research on SBS, illuminating basic problems in how we know the ocean. It helps us see that "the baseline" is a multidimensional problem and that there is a corresponding need to corroborate baselines not just across space and time but also human dimensions.

Implications: expanding the solution space

Our findings have some concrete implications for ocean knowledge and solutions. We advise that future work in marine historical ecology could be more attentive to archival bias and thus seek out records from an array of social groups, especially those that might be harder to find, in order to reconstruct various baselines. When setting conservation targets, we recommend taking into account who knows what about which ecosystems, since inaccurate baselines unreflective of diverse ocean users may undermine management and conservation[82].

More generally, we propose that collaborative integration of ocean sciences and humanities, by calling attention to basic challenges in human understanding of the ocean, widens the scope of possible actions we might take. Propagative findings from the interdisciplinary integration of ocean sciences and humanities expand the solution space by helping us consider how we know the oceans, what our assumptions are, what knowledge counts, and what we believe might be possible. We come to those findings by developing shared literacy and, crucially, by building archives together. Expanding collaborations across disciplines leads us to expand the scope of our data, methods, knowledge, and potential action—an expansive outlook that is essential to understanding and sustaining ocean ecosystems, including the people in them.

Data availability

Our survey of "Along the Waterfront" is available at https://doi.org/10.5281/zenodo.15054031.

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Author contributions

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Competing interests

The authors declare no competing interests.

Additional information

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