

Mussel Memories: An Interdisciplinary Overview of Bivalve (Mollusca) Gathering, Mariculture, and Other Culture Practices amongst Several Pre-Modern Communities on the Western Coasts of the Americas¹

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Abstract: I review pre-modern (prior to approximately 800 C.E.) approaches to bivalve gathering, use, mariculture, consumption, and celebration, as practiced by several societies on the western coastlines of the Americas. I also include a brief analysis of bivalves in global cultures and histories, as well as a discussion of contemporary applications of bivalve ecosystem services globally. Herein, I provide critical insights into ancient socioecological interactions that affected the health and well-being of local human and bivalve communities. These insights include the connections between bivalve trade and sociocultural developments, the role of the bivalve in shaping human identities, and the effects of bivalve ecosystem services on the well-being of those early human groups. The lessons were garnered from the use of an array of species of bivalves, including *Tivela stultorum*, the Pismo clam; *Leukoma staminea*, the littleneck clam; *Saxidomus gigantea*, the butter clam; *Spondylus crassisquama*, a spiny oyster; and *Mytilus californianus*, the California mussel. These lessons may be incorporated into modern-day ecology and sustainability studies, as well as contemporary coastal planning and solution-building. Important suggestions for modern-day sustainable coastal management systems include greater utilization of bivalve services in environmental planning and further inclusion of historical ecology, traditional ecological knowledge (TEK), and other elements of the historical record in such planning frameworks.

Resumen: Reviso los enfoques premodernos (antes de aproximadamente 800 E.C.) para la recolección, uso, maricultura, consumo y celebración de bivalvos, tal como lo practican varias sociedades en las costas occidentales de las Américas. También, incluyo un análisis breve de los bivalvos en las culturas e historias globales, así como una discusión de las aplicaciones contemporáneas de los servicios de los ecosistemas de bivalvos a nivel mundial. En este documento, analizo las antiguas interacciones socioecológicas que afectaron la salud y el bienestar de las comunidades locales de humanos y de bivalvos. Estos conocimientos incluyen las conexiones entre el comercio de bivalvos y los desarrollos socioculturales, el papel de los bivalvos en la configuración de las identidades humanas y los efectos de los servicios de los ecosistemas de bivalvos en el bienestar de esos primeros grupos humanos. Las lecciones se obtuvieron mediante el uso de una variedad de especies de bivalvos, incluyendo *Tivela stultorum*; *Pismo*, una almeja;

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Leukoma staminea, la almeja de cuello pequeño; *Saxidomus gigantea*, la almeja mantequera; *Spondylus crassisquama*, una ostra espinosa y *Mytilus californianus*, el mejillón de California. Estas lecciones pueden incorporarse en los estudios de sostenibilidad y ecología así como en la planificación costera contemporánea y en la creación de soluciones. Las sugerencias importantes para los sistemas de gestión costera sostenible modernos incluyen una mayor utilización de los servicios de bivalvos en la planificación ambiental y una mayor inclusión de la ecología histórica, el conocimiento ecológico tradicional (CET) y otros elementos del registro histórico en dichos marcos de planificación.

Key Words: Bivalvia, Mollusca, collecting bivalves, oyster mariculture, cultural practices involving bivalves, pre-modern human coastal communities, ancient socioecological interactions, western coastlines of the Americas, bivalve trade, shaping human identities, bivalve ecosystem services, *Tivela stultorum*, *Leukoma staminea*, *Saxidomus gigantea*, *Spondylus crassisquama*, *Mytilus californianus*, *Chione undatella*, traditional ecological knowledge (TEK), contemporary coastal planning, modern-day sustainable coastal management systems, environmental planning, historical ecology, sustainability studies, imaginal ecology

“A shell is a small thing, but I can exaggerate its size by putting it back where I found it on an expanse of sand. What I'll do is take a fistful of sand and observe the little that's left in my hand after almost all of it has run through the interstices between my fingers; I'll observe a few grains, then each grain, and not one of those grains will still seem a small thing; soon the form of the shell, this oyster shell or this miter shell, this razor clam, will impress me as an enormous monument, colossal and yet exquisite, something like the temple at Angkor, Saint-Maclou or the Pyramids, but much more mysterious than these all too incontestable human products.”

Francis Ponge, *Notes Towards a Shellfish*,
translated by C. K. Williams

Introduction

Human communities adjacent to any water source – be it freshwater, brackish water, or saltwater – have likely subsisted on molluscs at some point during their existence (Figure 1). Geologist Donald Prothero, for example, writes that “[n]early all prehistoric peoples who lived near the coast were big mollusc eaters” (Prothero 2020). Molluscs are a type of shellfish – a term for a motley collection of invertebrates that are not fish and are not necessarily molluscs. Shellfish have long played a key role in the preservation of human society and its diverse endeavors, which have included artistic exploration (Jue 2014, Weiss 2002), economic development (Khan and Liu 2019), decorative use (Marean 2010, Paulsen 1974), ritual practices (Marcos 1980), and culinary practices, such as community clam-bakes (Dupree 1996 and Figure 1).

Some shellfish, such as lobsters, crustaceans related to crabs and isopods, have experienced startling shifts from culinary pariahs to gourmet delicacies

(Luzer 2017). Others, such as several species of sea urchin, which are echinoderms related to sea cucumbers and sea stars, enjoy a popularity on many dining tables that, in countries such as the United States, has ebbed and flowed with the tide of cultural zeitgeists (Miller 2014). Certain classes of molluscs, such as cephalopods (which include octopuses and squids) and bivalves (which include oysters and scallops) also occupy a coveted place in the most epicurean of shellfish-oriented dining rooms (Khan and Liu 2019).

Many members of the mollusc class Bivalvia can be found in more accessible arrangements. Consider, for example, a warm cup of clam chowder or serving of clam pie on a crisp evening, or a mussel-laden seafood boil on a muggy afternoon; foods which are regarded fondly in many communities in the United States (Halweil 2005, Beard 2014, Wakefield 2020) and thus retain a hallowed place in regional recipe books (Dupree 1996).

The changing status of various species of molluscs, including bivalves, oscillating between subsistence food and gourmet pleasure, speaks to the amorphous nature of sociocultural functions globally, which are largely dependent on the nexuses of time, space, and human condition. Naturally, the use of bivalves is not restricted to culinary realms; they have been critical components of various trade networks and economies for centuries – refer to the use of *wampum* by Indigenous peoples on the eastern seaboard of what is now the United States (Becker 2008), or the circulation of *Tridacna* clamshell rings – and their ceramic imitations – in the western Solomon Islands (Richards 2010). Globally, bivalves can provide up to \$6.47 billion worth of ecosystem services per year in the non-food sector alone – and it is possible that this amount may be even greater (van der Schatte Olivier et al. 2018).



Figure 1. Winslow Homer's, *A Clam-Bake*. Watercolor, gouache, and graphite (1873). Public domain provided by the AMICA Library/ Cleveland Museum of Art via Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Winslow_Homer_-_A_Clam-Bake.jpg

In addition, bivalves are an oft-represented subject in visual artwork. Take Botticelli's *The Birth of Venus*, which depicts the newborn yet fully-grown goddess Venus, or Aphrodite as she is also known (Figure 2), standing in the center of a scallop. The Irish folk song, *Molly Malone*, as sublimely rendered by singer Sinéad O'Connor, and many others before and after her, has immortalized cockles and mussels – other types of bivalves – as well as their role in people's livelihoods.

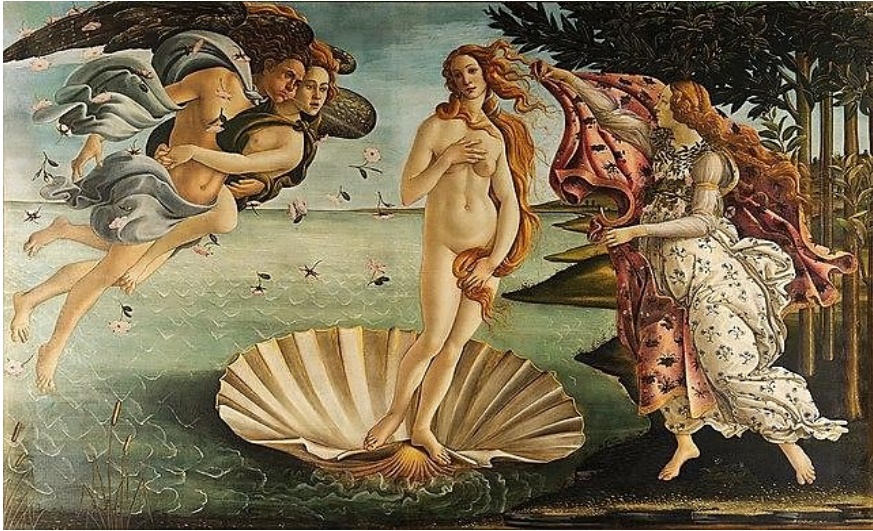


Figure 2. Sandro Botticelli, *The Birth of Venus*. Tempera on canvas (circa 1485). Public domain image provided by Google Art Project via Wikimedia Commons. [https://commons.wikimedia.org/wiki/File:Sandro Botticelli - La nascita di Venere - Google Art Project - edited.jpg](https://commons.wikimedia.org/wiki/File:Sandro_Botticelli_-_La_nascita_di_Venere_-_Google_Art_Project_-_edited.jpg)

Bivalve is a term that refers to filter-feeding molluscs with hinged shells (Morton 2020), that presently comprise “about 8,000 to 15,000 living species” (Prothero 2020) in Bivalvia, a taxonomic class within the phylum Mollusca. Their hinged nature is one prominent feature that distinguishes them from members of another, larger molluscan class, Gastropoda – or gastropods, the grouping of molluscs that includes snails and slugs (Prothero 2020).

Bivalves occupy a storied place in the realm of shellfish literature and mythos throughout history. For example, in the Venus/Aphrodite birth mythos, Venus/Aphrodite is ferried to shore by a scallop, which in Botticelli's depiction, is prominently featured. The scallop shell is a common motif for the goddess which symbolizes, according to various viewers, procreation (Leach 1974), sensuality (Ahn 1996) – and/or human female genitalia (Leach 1974). In fact, shellfish appear frequently in ancient Greek comedic works, serving as proxies for human genitalia and as representations of human sexuality (Shaw 2014).

The centering of the scallop in the Botticelli painting reveals its importance in Venus/Aphrodite's creation story, a poignant placement that might speak to our own overall relationship with shellfish – specifically bivalves. The noted classics scholar Eleanor Winsor Leach, in her article analyzing Roman playwright Plautus's comedy *The Rudens*, quotes a passage that displays the significance of the bivalve to humankind. Here, an enslaved man named Trachalio asks the goddess to aid two shipwrecked maidens:

“They say you were born from a mussel shell; take care how you spurn this pair of bivalves.”

Within the context of this passage, “bivalves” refers to the two unfortunate girls. It is notable that Trachalio appears to use Venus/Aphrodite's birth from the bivalve as a kind of leverage – perhaps implying that Venus/Aphrodite, the bivalve, and the girls are kin. The significance of the relationship between the bivalve, Venus/Aphrodite, and the girls is one of numerous affirmations of the indispensable roles that these animals have held in our societies since recorded history – and indeed, long before it (Minkel 2007).

Jorge Marcos, in his 1980 study of the trade of the bivalve genus *Spondylus* throughout South America, also writes “[t]radicionalmente las conchas marinas, particularmente las bivalves y los grandes gasterópodos han sido un símbolo sexual y de fertilidad” – “traditionally, seashells and large gastropods have been symbols of sexuality and fertility.” Indeed, prior to the European invasions of the Americas, bivalve species, such as *Spondylus crassisquama* (Lamarck, 1819; previously known as *Spondylus princeps* Broderip, 1833), also known as spiny oyster though it is not a true oyster, were revered as symbols of fertility and rain (Marcos 1980). Through these numerous connections between seafood, fertility, sexuality, and creation in ancient works, a theme begins to emerge: the strength of the human-bivalve relationship. Humans eat bivalves; humans use bivalves – and sometimes, it appears that bivalves have helped make us who we are.

Indeed, bivalves have played prominent roles in several creation myths from around the world. Sarah Bartlett writes that “[s]hells are important symbols of creation to many Oceanic peoples.” A Nauruan story tells of the spider deity Areop-Enap, who, while wandering around in the primordial darkness, stumbled upon a bivalve – sometimes identified as a *Tridacna* specimen (Dixon 1916) – that swallowed her whole (Bartlett 2009). Areop-Enap and a caterpillar named Rigi tussled within the clam, which eventually opened up. From the clam's two valves, Areop-Enap made the sky and the earth; its body became islands (Bartlett 2009).

The Haida people, whose lands are located off the western coast of Canada and the southern coast of Alaska, also tell a bivalve-centric creation story. This particular tale involves the trickster deity, Raven (Leeming 2010). Many eons ago, while wandering about, Raven encountered a small clam from which a curious

sound emanated. Within the clam were five little people – the first people (Leeming 2010), and from this humble little clam, they emerged into the world (Leeming 2010).

Whether a bivalve or ten-legged crustacean, globally, shellfish are an important component of our cultural memory and present. Indications of early shellfish consumption and use among the ancestors of modern humans, *Homo sapiens* Linnaeus, 1758, have been found. Joordens et al. (2015), for example, found evidence that the earlier hominin, *Homo erectus* (Dubois, 1893) used shellfish for tools, consumption, and engraving in what is now East Java, Indonesia, approximately 500,000 years ago. Additionally, Choi and Driwantoro (2006) documented evidence of *H. erectus* shellfish tool use in Central Java, Indonesia, between 1.6 and 1.5 million years ago.

While investigating a site in what is now coastal South Africa in search of the origins of symbolic thinking, a team of researchers, led by the paleoanthropologist Curtis Marean of Arizona State University, found evidence suggesting that modern humans (*H. sapiens*) have likely been eating shellfish for 165,000 years (Minkel 2007). Marean and his team found “a bowl’s worth of edible shellfish” (Minkel 2007), consisting of brown mussels (Minkel 2007), in addition to stone tools and signs of pigment production (Minkel 2007). The discovery of these shellfish remains speak not only to the emergence of a human relationship with shellfish, but possibly of the beginnings of symbolic thought that Marean’s team had been attempting to identify (Minkel 2007)

Symbolic thought, according to the American Psychological Association (c, n.d.), is “the ability to think about objects and events that are not within the immediate environment. It involves the use of signs, symbols, concepts, and abstract relations, as evidenced by language, numeracy, and artistic or ritual expression.” The pigment use was, according to Marean, a possible sign that peoples who had lived in the area 165,000 years previously had engaged in symbolic thinking (Minkel 2007). As the pre-modern community of the area increased, this population growth would have “increas[ed] the need for negotiations between individuals or social groups, which might have led to a system of decorative markings” (Minkel 2007). The advent of such a system would represent an enormously significant stage in the development of human cultures.

Marean would later write about his discoveries regarding this pre-modern community in coastal South Africa for *Scientific American* in 2010. This particular seaside area was rife with shellfish, providing ancient peoples with ample opportunity to harvest and eat (Marean 2010). A diet with a prominent shellfish component would have been rich in protein and omega-3 fatty acids and dense with calories (Marean 2010). According to Marean,

“...the readily available shellfish and other abundant foods provided a high-quality diet that allowed people to become less

nomadic, increased their birth rates and reduced their child mortality. The larger group sizes that resulted from these changes would have promoted symbolic behavior and technological complexity as people endeavored to express their social identity and build on one another's technologies."

Fittingly, the title of Marean's excellent piece is "When the Sea Saved Humanity." I might posit – half in jest – that he could have also titled his article "When Shellfish Saved Humanity."

The world is one's oyster – and cockle, clam, and scallop

There are numerous reasons to study ancient bivalve use, as evidenced by discussions of the role that shellfish have played in the emergence of symbolic thought, in the survival of human communities, and in the proliferation of various forms of media. Herein, I examine the significance of shellfish across multiple realms of pre-modernity, including economy, art, ritual, and aquaculture, in addition to exploring their importance in contemporary spaces. Much literature exists about the importance of shellfish, whether crustacean, mollusc, or echinoderm, which provides ample material for analysis and synthesis.

This literature review specifically seeks to explore the roles that a specific type of shellfish – bivalves, the grouping that includes oysters, clams, mussels, and scallops – have played in several pre-modern societies throughout the western coasts of the Americas. The areas of study extend from British Columbia in present-day Canada (Toniello et al. 2019) to California in what is now the United States (Erlandson 1988), through Manabí in modern Ecuador (Bauer 2007). Evidence of pre-modern shellfish use and consumption in these locales is numerous, and includes artisanal production (Erlandson et al. 2005, Bauer 2007, Martín 2010), ritual practice (Chicoine and Rojas 2013; Gamble 2017), aquacultural operations (Lepofsky et al. 2015), and shell middens, which are piles of discarded shellfish waste (Foster 1975).

In this overview, I assert that fragments from our past – whether they be the discarded remains of shellfish found at various shell middens up and down the coast of California, or whether they take the form of oral histories surrounding the use of *Spondylus* in ancient Ecuador - have profound implications for the role that bivalves can potentially play with regards to supporting modern coastal resilience projects. In order to interpret such evidence and implications, I argue for the increased utilization of historical ecology and traditional ecological knowledge (TEK) in academic spaces such as modern ecology, environmental, and sustainability studies, as well as within areas such as contemporary environmental planning and management. I also center the roles of narrative, memory, and the imagination in environmental solution-building.

Traditional ecological knowledge, a term that has been used interchangeably with names such as "Indigenous knowledge" and "traditional knowledge" (Whyte

2013), can refer to bodies of environmental knowledge and systems of knowledge-gathering and interpretation, as practiced by Indigenous peoples over centuries and generations (Whyte 2013). Whyte discusses various definitions of traditional ecological knowledge, depending on actor: they include TEK as a collaborative concept; as a kind of “archival” unit; as a continuous spiritual practice and participation that concerns the connections between all beings; and as a collection of knowledge that is often directly juxtaposed with Western science, amongst other meanings (Whyte 2013). Additionally, Pierotti and Wildcat (2000) write that “[t]raditional knowledge is based on the premise that humans should not view themselves as responsible for nature, i.e., we are not stewards of the natural world, but instead that we are a part of that world, no greater than any other part.” Further, they state that “[o]ne major theme of TEK is that all things are connected...that no single organism can exist without the web of other life forms that surround it and make its existence possible” (Pierotti and Wildcat 2000).

Historical ecology may be defined broadly as a field of study that is “concerned with the historical interconnectedness of nature and human culture” (Szabó 2015). Other applications of the historical record are equally valuable, such as the field of conservation paleobiology, a “sister discipline” to historical ecology that also concerns historical study of ecosystems (Dietl and Flessa 2011). The two fields may be distinguished in the following manners: historical ecology typically studies relatively recent events, such as those that occurred during the Pleistocene, while conservation paleobiology also considers events prior to the Pleistocene (Dietl and Flessa 2011). Additionally, conservation paleobiology, “in addition to ecological dynamics, concentrates on evolutionary dynamics (e.g., adaptive responses of species to changing climates or ecological interactions)” (Dietl and Flessa 2011).

Together, each of these systems of study, knowledge-gathering and interpretation, storytelling, and sociocultural practice form a rich and valuable array of resources with which we can experience our world – in its past, present, and future.

Bivalve aquaculture

Bivalve species, such *Tivela stultorum* (Mawe, 1823), known as the Pismo clam; *Leukoma staminea* (Conrad, 1837), the littleneck clam, the latter two members of the bivalve family Veneridae; and *Mytilus californianus* (Conrad, 1837, and Figure 3), the California mussel, a member of the Mytilidae, have been prominently featured in evidentiary remains such as shell middens or ancient clam gardens (Glassow and Wilcoxon 1988, Rick and Eliot 2013, Lepofsky et al. 2015). Bivalves weave critical threads in the fabric of coastal spaces around the globe in our dynamic present, as they have in our past. For example, D’Anna and Murray (2015) examine how shellfish aquaculture might affect the well-being of coastal communities in Baynes Sound, British Columbia, Canada, where shellfish

aquaculture lies at a complex intersection of sociocultural function, political action, and economic reality. Guyondet et al. (2015) explore how bivalve cultivation may aid in stopping environmental damage caused by nutrient loading, which is the accumulation of foreign nutrients in an ecosystem (Reid et al. 2005). Bauer (2007) argues “that the artistic production of *Spondylus* [spiny oysters] acts as a mechanism for anchoring contemporary identities [in Manabí province, Ecuador] to the precolumbian [sic] past despite significant changes in modes of production.” And Groesbeck et al. (2014) analyze how traditional management practices utilized in the ancient clam gardens of British Columbia can aid contemporary coastal management.



Figure 3. *Mytilus californianus*, the California mussel. Size: 10.9 cm (4.3 inches) x 6.5 cm (2.6 inches). Image provided and herein reproduced with permission by John T. Snow. Copyright of this image remains with John T. Snow.

These works, amongst other entries in the canon of bivalve study, provide critical insight and context into the beneficial roles that bivalves occupied within communities throughout the ancient western Americas – and provide suggestions as to how we may continue to work with bivalves to develop healthy and thriving coastal communities. Braje et al. (2007) write, for example, that “[h]istorical ecological studies of this type are of great value to resource managers and policymakers because they can provide deeper historical frameworks in which to evaluate modern historical impacts, along with a better understanding of the causes and consequences of human decision-making.” Toniello et al. (2019) assert that “[h]istorical ecology can provide insights into the long-term and complex relationships between humans and culturally important species and ecosystems, thereby extending baselines for modern management.” And Armstrong and Veteto (2015) state, with regards to historical ecology, that “[b]y extending the timescale of landscape change, it is possible to create a more historically situated

understanding of social-environmental interactions and patterns. Such patterns can be used to inform and initiate environmental conservation and social justice.”

My review of the bivalve canon has engendered a deeper understanding of the human-ecological condition and underscored the importance of our interactions with bivalves across time and space. I write this review to encourage further intensive study of historical human-bivalve relationships, and impress upon readers the necessity of an interdisciplinary knowledge-gathering practice that includes historical ecology and traditional ecological knowledge. Additionally, I strongly encourage readers, writers, students, and teachers of the natural sciences to boldly explore what can be termed *imaginal ecology* – ecology steeped in story, symbolism, memory, and endless possibilities, of what our relationships to environments and landscapes do and can look like if we are given the space to create and dream.

Merriam-Webster Dictionary defines the imaginal as “of or relating to imagination, images, or imagery.” To write is to tell a story, to bring thoughts, memories, and images from the realm of the *imaginal*, or the imagination, onto a more “tangible” surface (in this case, a Microsoft Word document). The power of the imagination is immense and often understated. I am reminded of when science-fiction author Ursula K. Le Guin accepted her National Book Award speech for her novel *The Farthest Shore*, saying “[f]or after all, as all great scientists have said and as all children know, it is above all by the imagination that we achieve perception, and compassion, and hope.”

I find this statement particularly moving, especially as it appears that we are situated within the Anthropocene. The Anthropocene has often been defined as our current geological epoch, in which our environments and ecosystems have been profoundly influenced by human activities (Lewis and Maslin 2015); in this anthropogenic age, many individuals are looking to traditional knowledge-holders, scientists and youth climate activists as stewards of positive change, as well as keepers and teachers of vital wisdoms and practices. I wholeheartedly believe that the imaginal realm is ever present, the kindling to fuel transformative fires. Reinsborough (2010) states beautifully that “[a]ll fights for true change begin with the ability to envision a different future...Radical imagination is the rocket fuel of social change.” In a sense, we live in an eternal now, consolidating events from our past and our present so that we may build towards the future. We gather stories to write new ones – and is that not a radical act of imagination – to look to the past in order to contextualize our present and dream for tomorrow?

It is my sincere hope that actors involved in the planning, management, and development of coastal spaces will synthesize the lessons from our past and present involvement with bivalves, in order to ensure a future rich in knowledge, health, and resilience; that they will bring the beautiful possibilities of imaginal ecologies, landscapes, and communities into corporeal spaces; and that the criticality of the human-bivalve relationship will be further acknowledged and explored, its story read with warmth.

En realidad lo mejor que coleccioné en mi vida fueron mis caracoles.
Actually, the best things that I collected in my life were my seashells.

Pablo Neruda

Mussel Methods

The focal point of my research are coastal spaces and their ecologies, geologies, and intersectional histories. I had become familiar with the significance of molluscs in sociocultural and economic settings through my education and personal research. In the winter of 2019, I read several articles, published by the Canadian Broadcasting Corporation (CBC) regarding clam gardens maintained by Indigenous coastal peoples of what is now British Columbia, Canada. Clam gardens – or walled beaches or sea gardens, as they are also known – are a tradition that is still practiced today; the Clam Garden Network (<https://clamgarden.com/>) is one dedicated community of individuals who research and contextualize the socioecological significance and histories of these structures and their associated practice and management.

I continued to read studies and articles on clam gardens by Clam Garden Network researchers such as Smith, Groesbeck, and Lepofsky, and also explored articles on California shell middens by researchers such as Erlandson, Gamble, and Rick. This early investigation into bivalve cultivation and consumption revealed many incidences of bivalve usage by pre-modern communities in the coastal regions of what are now the Americas. Thus, I decided to focus my studies on these spaces. These readings constituted the beginnings of my review process.

Mollusc eating and mariculture, as previously discussed, is common within coastal spaces globally (Figure 4). The presence of molluscs in various spaces lends itself to a plethora of artistic depictions, from ancient stone tablets to modern digital art. One type of mollusc commonly depicted in artwork is the cephalopod – a class of predatory, large-brained molluscs that enjoy quite a large degree of popularity (Wood et al. 2000).

However, I was not drawn to study octopi, or any cephalopod, despite my appreciation for their marvelous nature, and familiarity with the multifaceted spaces that they occupy globally. I suspect that I have always been much fonder of so-called “simpler” molluscs, like snails, scallops, and nudibranchs (though I will passionately argue, as I imagine many individuals would, that these creatures are not “simple” at all!).

Over the course of several months, beginning in February of 2020, I sought out articles regarding ancient bivalve mariculture and usage throughout various seaside cultures of the ancient Americas. In order to find these articles and resources, I primarily conducted literature searches, using several online academic repositories. Throughout the next several months, I reviewed literature across various disciplines, including ecology, archaeology, art history, classical studies, anthropology, culinary studies, media studies, and environmental science. The preservation of an interdisciplinary perspective throughout my research was a

critical endeavor; as the relationship between bivalves and humankind has not been limited solely to consumption, it was necessary that a review of the existing bivalve literature can be multi-dimensional.



Figure 4. Katsushika Hokusai, *Kuwana 4*. Ukiyo-e print, date unknown. Public domain image provided by the Kuwana City Museum in Kuwana, Mie Prefecture, Japan. <https://commons.wikimedia.org/w/index.php?curid=4407235>

After reviewing, discussing, and summarizing the selected articles, I synthesized my findings into a literature review, in which I argue that the manners in which the studied societies used bivalves in the past can aid in coastal planning and solution-building in the present, and that traditional ecological knowledge and historical and imaginal ecologies are critical practices with which to frame our ecological perspectives.

All art is autobiographical; the pearl is the oyster's autobiography.

Federico Fellini

Diving for Pearls of Wisdom

Commonly used species in Southern and Central California

Braje et al. (2011) write that “shellfish and other marine resources were an important part of ancient human subsistence economies in coastal areas around the world.” Accordingly, shellfish middens are common features found in ancient

coastal settlements. In California, for example, they have been found at various sites in what are now Santa Barbara County (Erlandson 1988, Rick and Eliot 2013, Glassow and Wilcoxon 1988, Kennett and Kennett 2000, Erlandson et al. 2005) and Orange County (Drover 1974). The shellfish remains at these sites include species such as *Mytilus californianus*, the California mussel (Colten 1989; Braje et al. 2011), *Tivela stultorum*, the Pismo clam (Colten 1989, and Figure 5), and *Chione undatella* (G. B. Sowerby I, 1835, and Figure 6), or wavy chione, a type of saltwater venerid clam (Drover 1974).



Figure 5. *Tivela stultorum*, the Pismo clam. Size: 12.3 cm (4.8 inches) x 9.6 cm (3.8 inches). Image provided and herein reproduced with permission by John T. Snow. Copyright of this image remains with John T. Snow.

Erlandson's (1988) hypothesis centers the notion that shellfish, including *Mytilus* species, played a critical role as a protein source for prehistoric peoples, based partly on a review of several prior studies of shellfish exploitation and studies of coastal archaeological sites in California. The diet of prehistoric peoples was often plant-based (Erlandson 1988), with shellfish at times functioning as a more accessible form of protein relative to the availability of other animal sources (Erlandson 1988). Erlandson writes that "The point...is not to imply that shellfish collection is universally an efficient and productive subsistence pursuit, but that under certain circumstances or during particular time periods shellfish exploitation may be an optimal strategy in relation to terrestrial alternatives" (Erlandson 1988). Erlandson notes examples of shellfish exploitation occurring in what is now coastal Southern California during the

Millingstone Horizon (Erlandson 1988), the period beginning approximately around 8,000 through 5,000 B.C.E. and concluding around 200 C.E. (a, n.d.). Human estuarine settlements that date back to this time period bear the classic sign of shellfish consumption – shell middens (Erlandson 1988). Notably, few tools that would have been used for hunting and fishing were found in the archaeological remains of these settlements (Erlandson 1988).



Figure 6. *Chione undatella*, the wavy chione. Size: 4.0 cm (1.6 inches) x 3.6 cm (1.4 inches). Image provided by John T. Snow and herein reproduced by permission. Copyright of this image remains with John T. Snow.

Erlandson suggests several reasons why shellfish might have been so prominent in Millingstone Horizon coastal groups. One factor is the relative abundance of shellfish beds in the estuarine environments (Erlandson 1988); another factor is the relative ease of access – specifically, the lessened need for tools and the lower risk associated with shellfish harvesting versus fishing or hunting (Erlandson 1988). The last factor named by Erlandson is the low human population density within these settlements, which may have played a critical role in preventing shellfish beds from becoming overexploited (Erlandson 1988).

Inevitably, environmental fluctuations changed the relationship that local prehistoric peoples had with the shellfish beds (Erlandson 1988). Erlandson writes that a stabilization of sea level approximately 6,000 years ago changed the composition of local estuaries, which experienced siltation, leading to a reduction in shellfish productivity (Erlandson 1988). Colten (1989) points to this period discussed by Erlandson as one that included “significant cultural changes on the

Santa Barbara coast.” These cultural changes appear to be linked with the changes in environment (Gamble 2017). As siltation occurred in the estuaries, the coasts continued to erode (Erlandson 1988), and local populations grew (Erlandson 1988). These critical changes in environment and human population, according to Erlandson, likely led to a decrease of shellfish consumption in coastal peoples living in what is now Santa Barbara, California (Erlandson 1988). This decline in shellfish consumption was followed by a rise in alternative methods of protein gathering, hunting, and fishing (Erlandson 1988). These events were succeeded by a significant development – the evolution of “the complex maritime culture of the historic Chumash Indians, to whom shellfish probably were a seasonally important but supplemental resource” (Erlandson 1988).

The cultural developments in pre-modern Santa Barbara County are somewhat reminiscent of those that Marean and his team studied in coastal South Africa. Here, as in the South African example, the availability of shellfish was followed by an increase in human population and certain sociocultural developments. Critically, Braje et al. (2011) write:

“In our view, shellfish use did not remain static through time and they were not a primary catalyst of sociopolitical changes in Chumash society. However, we view them as a reliable resource that could be harvested predictably, and by a wide cross-section of society, especially women, children, and the elderly who may have been less involved in more demanding subsistence pursuits such as offshore finfishing or marine mammal hunting. In this regard, shellfish may have been part of an increasing division of labor among more hierarchical Late Holocene peoples... In addition to being used for food, Late Holocene Chumash peoples also used many of the shells...to make fishhooks, beads, and other ornamental or functional items, where they were important tools for obtaining higher trophic foods or were part of the prestige economy (beads, etc.)”

Other pre-modern cultural applications of bivalves (and other shellfish) in the Southern California area have been noted. There is evidence, for example, to suggest that shell middens may have been used ritually (Gamble 2017). Gamble argues that a certain shell mound (another term for shell midden) used by the Chumash was an important space for ritual and ceremonial practices, including feasting and burial (Gamble 2017). This shell midden is called “El Montón” (“The Mountain”) and is located on Santa Cruz Island, in Santa Barbara County, California (Gamble 2017). Remnants of *M. californianus* specimens are present at El Montón, in addition to other shellfish, such as red abalone, barnacles, and sea urchin (Gamble 2017). Of the bivalve remains found at the site, *M. californianus* predominates (Gamble 2017, see also Figures 7 and 8).



Figures 7 and 8. A California mussel, *M. californianus*, bed in Laguna Beach, California. Photographed by the author on September 12, 2020.

Gamble writes that El Montón is a “place of social memory”; here, the dead were celebrated and buried, which imbues the mound with a particular poignancy and allows it to act as an anchor to historical traditions, identities, and narratives. A “place of social memory” is a feature of the landscape characterized by its sociocultural significance and accumulation of knowledge and stories of the past (Gamble 2017). Through El Montón, I note here the appearance of the imaginal, and reiterate the criticality of narrative and memory to humankind. Gamble writes of these places that:

“They may be repeatedly visited, modified, and interpreted, often reinforcing social relationships (Pauketat 2008) and creating links to the past and the ancestors (Meskell 2003, 2007; Yoffee 2007). Memory of the past is preserved in these links, negotiated, reinterpreted, and commemorated in rituals and public events, some associated with the deceased, others with more quotidian activities; practices of remembrance emerge from repeated actions and performances (Meskell 2007:224).”

Gamble’s hypothesis regarding El Montón speaks to the multi-faceted use of bivalves in the Southern California region – where they have acted as notable food sources, in addition to playing specific roles in sociocultural and economic contexts. The versatility of bivalves, of course, is not endemic to solely this area; they have been utilized in similarly diverse functions in Ecuador and Perú as well.

Bivalve influences in Ecuadorian and Peruvian societies

As reiterated, the usage of bivalves is not restricted to solely consumption. The Manteño civilization of southern Ecuador and the Moche civilization of northern Perú, for instance, are noted to have used bivalve material in various contexts (Martín 2010). Paulsen (1974), for instance, writes about the storied role that the bivalve genus *Spondylus*, or spiny oysters, played in the sociocultural and sociopolitical development in pre-modern Ecuador and Perú, alongside the gastropod genus *Strombus*. Additionally, Martín (2010) notes the inclusion of pearl oyster material, specifically *Pteria sterna* (Gould, 1851) and *Pinctada mazatlanica* (Hanley, 1856), in coastal Ecuadorian trade goods. This section will focus particularly on *Spondylus* use in pre-modern Ecuador and Perú.

The genus *Spondylus* is found throughout the world in tropical waters (Marcos 1980). *Spondylus* specimens were first gathered on the southern coast of Ecuador; given their propensity to enjoy reef habitats “20 to 60 feet below the surface of the ocean” (Paulsen 1974), *Spondylus* could not be gathered by combing the seashore, but could only be accessed by divers (Paulsen 1974). After collection, the *Spondylus* specimens were then exported to mountainous regions of Ecuador; this trade network eventually expanded to Perú (Paulsen 1974). It appears that this *Spondylus* export network may have begun as early as 100 B.C.E.

(Paulsen 1974). In fact, *Spondylus* artifacts appear to have been endemic throughout the Early Horizon (Paulsen 1974), the period between 900 and 200 B.C.E. in pre-Columbian Peru that was characterized by remarkable cultural developments (Helmer and Chicoine 2015). Paulsen notes that both *Spondylus* and *Strombus* material signified elite status in certain Andean ceremonies and burials during the Early Horizon (Paulsen 1974).

The beauty and relative hardness of *Spondylus* specimens lent themselves to a variety of uses, ranging from the decorative (Paulsen 1974) to the ritual (Marcos 1980; Paulsen 1974) to the practical (Paulsen 1974). While *Spondylus* was used to make items such as jewelry and figurines (Paulsen 1974), it was also represented in other media; Paulsen notes examples of Peruvian pottery that appears to depict *Spondylus* (Figure 9), as well as *Strombus* (Paulsen 1974). Martín additionally writes about the incidence of *Spondylus* material in Moche tombs and at sites such as the Tello Obelisk (Martín 2010). Specifically, Paulsen states that a deity called the “Smiling God,” as depicted on the Tello Obelisk, appears to hold a *Spondylus* specimen in his left hand; a gastropod *Strombus* specimen appears in his right (Paulsen 1974).



Figure 9. A depiction of *Spondylus* in the pottery of the Moche people of Perú, circa 200 CE. Image provided by the Larco Museum via Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Spondylus_Moche_pottery_Larco_museum.jpg

A testament to an unbroken chain of past reverence and present appreciation for *Spondylus* can be found in coastal Ecuador, where Bauer (2007) conducted an ethnographic study into contemporary applications of *Spondylus*, as informed by their historical use in pre-Columbian periods. Bauer specifically focuses on *Spondylus limbatus* (G. B. Sowerby II, 1847; also known as *S. calcifer* Carpenter, 1857, Figure 10) and *S. crassisquama*, two beautiful species exemplifying the visually captivating genus *Spondylus*.



Figure 10. *Spondylus limbatus* G. B. Sowerby II, 1847 or Donkey Thorn Oyster. Size: 5.8 cm (2.3 inches) x 5.3 cm (2.1 inches). Image provided and herein reproduced with permission by John T. Snow. Copyright of this image remains with John T. Snow.

Pre-Columbian sites throughout coastal Ecuador bear clear signs of *Spondylus* use (Bauer 2007), and numerous archaeological inquiries have confirmed their importance in regional pre-Columbian trade networks (Bauer 2007). Critically, Bauer argues that the appreciation and usage of *Spondylus* did not end with the invasion of what is now Central and South America by Europeans, but rather, retains a kind of spiritual successor within the modern folk art industry of coastal Ecuador, where artisans can still be found working *Spondylus* specimens into traditional crafts (Bauer 2007). Bauer argues that “[t]he

artistic production of *Spondylus* acts as a mechanism for anchoring contemporary identities to the precolumbian [sic] past despite significant changes in modes of production.” Certainly, *Spondylus*, specifically *S. crassisquama* and *S. limbatus*, whose ranges encompass the coasts of Southern California and Baja California and terminate in southern Ecuador (Bauer 2007), played a significant role in regional pre-Columbian society (Bauer 2007). But how has its rich past extended into southern Ecuador’s cultural present?

In 2002, Bauer undertook a fieldwork expedition at the village of Salango in southern Ecuador’s Manabí province (Bauer 2007). This particular site has a prehistoric tradition of *Spondylus* usage that occurred as early as 3,500 B.C.E (Bauer 2007), and, as Bauer notes, *Spondylus* continues to play a critical part in the site’s economy. Bauer interviewed around 40 local divers and artisans – who, in several instances, were one and the same – in order to assess its sociocultural and economic impact and value among the local population (Bauer 2007). Interviews with these local divers and artisans, studies of community events that replicated other pre-Columbian traditions, and observations of the embedding of *Spondylus* into local community functions were among the factors that led Bauer to conclude that “[Bauer’s] research indicates that local conceptions of the unique community of Salango are largely informed by knowledge of the Indigenous past.”

This conclusion is further illustrated by Bauer’s 2005 interview with Marcos Ayola, a commercial *Spondylus* diver and collector of *Spondylus* clams (Bauer 2007). Ayola discusses the role that *Spondylus* usage has played in bridging the tangible present and the storied past:

“We do what our ancestors did.... Diving is something that was done in the past, and we continue that tradition in the present.... When I dive, I am able to see what my ancestors saw. We dive in the same locations as our ancestors.”

Bauer also quotes an interview with the diver Mario Valdez, who stated:

“*Spondylus* is a symbol, a symbol of our community. Salango is full of culture. The people who lived here thousands of years ago lived for *Spondylus*. It was very important. It was a symbol of the Inca Empire during that time and it is still an important symbol for the people of Salango. In Salango is one of the best known places for *Spondylus* in all of Ecuador if not all of the world.”

I note that Valdez refers to *Spondylus* as a symbol – an entity that exists in both the realm of the imaginal and our tangible world. It is evident from Bauer’s research endeavors that *Spondylus* use is an inextricable layer in the cultural

traditions of Salango and has been for thousands of years – a status reminiscent of the vital role that various bivalve species have played in other communities. In this context, the past is almost indistinguishable from the present; as Bauer argues, *Spondylus* usage and production provides a creative and much-loved tether between ancient and contemporary identities; between ancestral traditions and modern ones. Once again, the strength of the human-bivalve kinship is apparent; “people...lived for *Spondylus*,” as Valdez states. And the pre-modern memory of *Spondylus* lives, lovingly preserved in the present – fittingly, Bauer titles his article (emphasis added) “The *Reinvention* of Tradition: An Ethnographic Study of *Spondylus* Use in Coastal Ecuador.”

As evidenced by the writings of researchers such as Bauer (2007), Marcos (1980), Martín (2010), Paulsen (1974), and Pillsbury (1996), the pre-modern artistic and ritual usage of bivalves (particularly the oyster genus *Spondylus*) throughout coastal Ecuador through the highlands of Perú have informed specific sectors of local and regional cultural development up through the present-day. Some parallels may be made between the continuous lineage of bivalve use in Ecuador to the use of bivalves in coastal South Africa, as discussed by Minkel (2007) and Marean (2010), given the reiterated relationship of bivalves to certain progressions of human sociocultural development.

It is also evident that bivalves have been treated as beloved objects of ornamentation and worship in certain cultural traditions (Bauer 2007, Marcos 1980, Paulsen 1974, Pillsbury 1996). The exploitation of bivalve beds and other ecological events have also informed human relationships with the coastline (Erlandson 1988), precipitating a chain of events that eventually resulted in further transformations of cultural tradition and practice. These memories from the past provide numerous lessons in solution-building for contemporary coastal societies to consider – pre-modern stories are also contemporary ones.

The clam gardens of British Columbia

In coastal northwestern North America, clams have occupied a particularly storied space in local cultural traditions (Toniello et al. 2019). Here, memories of pre-modern clam usage can be found not only in the abundance of coastal shell middens, but also in the presence of seashore structures that are commonly called clam gardens (Toniello et al. 2019). The Kwakwaka'wakw people use the term *loxiwey* to refer to these human-made structures and refer to natural clam beds as *ixstawiis* (Deur et al. 2015).

According to Lepofsky et al. (2017), clam gardens are “walled intertidal terraces constructed to increase bivalve habitat and productivity” for bivalve species such as *S. gigantea*, or the butter clam (Toniello et al. 2019 and Figure 11), and *L. staminea*, the littleneck clam (Smith et al. 2019) which are members of the molluscan family Veneridae. In addition to clams, they have also provided homes for other molluscs and crustaceans, such as whelks, barnacles, and limpets (Smith et al. 2019).

Since pre-modern times, these structures have formed an important part of Indigenous maritime traditions on the northwest coasts of North America (Toniello et al. 2019); in particular, they have been utilized by Indigenous peoples on the northwest coast of what is now Canada for thousands of years. Smith et al. (2019) studied nine clam gardens on northern Quadra Island in British Columbia, Canada, which is located within “the traditional territories of the Laich-Kwil-Tach and northern Coast Salish peoples” (Smith et al. 2019). Through the utilization of radiocarbon dating, Smith et al. found that clam gardens on Quadra Island have been used for 3,500 years. Additionally, Toniello et al. (2019) have examined historical records of human-clam relationships within the Kanish and Waiatt Bays of Quadra Island, a relationship that spans the course of 11,500 years.



Figure 11. *Saxidomus gigantea* (Deshayes, 1839) as depicted by Charles H. Edmondson (1923) on *Shellfish Resources of the Northwest Coast of the United States*. Image provided by Wikimedia Commons. https://commons.wikimedia.org/wiki/Category:Saxidomus_gigantea#/media/File:FMIB_34739_Shell_of_Saxidomus_giganteus.jpeg

The story of the human and clam on Quadra Island provides various examples of a meaningful, cultivated coastal management practice that has spanned centuries and generations. Though clams were harvested extensively from these sea gardens, Toniello et al. (2019) found evidence that indicates that the clam gardens on Quadra Island prospered throughout the later part of the Holocene; overharvesting appears to have been avoided through the successive construction of clam gardens by Indigenous peoples over generations (Toniello et al. 2019). According to Toniello et al. (2019), clam garden construction decreased the slope of the beach, allowing for easier human access to clams. Toniello et al. also write that, within their focal area, continuous construction of clam gardens “increas[ed] the viable clam habitat.” A similar conclusion was echoed by Jackley et al. (2016). Jackley et al. (2016), who focused on a body called Kwakshua Channel on the central coast of British Columbia, state that “[b]y reducing the beach slope, clam gardens in Kwakshua Channel expanded optimal clam habitat to increase both the abundance and biomass of clams.” An experiment conducted by Groesbeck et al. (2014) also found that juvenile *L. staminea* specimens grew 1.7 times more quickly when situated in a clam garden versus a non-walled beach.

The construction of these clam gardens – and general availability of clams as a food source – have provided the impetus for numerous developments in local environments and human culture, and may offer critical lessons on how to avoid the specter of shellfish bed exploitation while also improving and maintaining positive health and well-being amongst human communities. Groesbeck et al. (2014) for example, state that “[a]ncient clam gardens and their governance by coastal communities are an example of an adaptive strategy that likely enhanced regional food security and thus conferred resilience to these coupled human-coastal ocean ecosystems.” Toniello et al. (2019), further discuss how clam gardens have acted as a vehicle for “enhancing a reliable and productive food source and trade item and in turn, by allowing for the increasingly larger human population and complex social relations.” Additionally, Deur et al. (2015) also write that the anthropogenic clam garden, or *loxiwey*, “appears to have helped facilitate large and stable populations as reported from the period before the first Europeans arrived.”

The creation of the walled habitat also had the effect of establishing sedimentary surfaces where other creatures, such as red rock crabs and snails, could thrive (Toniello et al. 2019). Jackley et al. (2016) reiterate the role of clam gardens in increasing coastal productivity, discussing evidence that strongly indicates that “greater butter clam biomass exists in clam gardens compared to nonwalled beaches.” While other food sources, such as salmon, were undoubtedly available, Deur et al. (2015) write that clams were a “key and complementary resource, contributing significantly to the stability and food security of Kwakwaka’wakw and other coastal communities even from the earliest times.”

Presently, researchers like Toniello et al. (2019) note that the beaches that serve as habitats for clams appear to be less productive than they were in the late

Holocene, an effect that many coastal First Nations peoples and Toniello et al. attribute to the decrease in traditional management practices within these spaces. As humankind progresses further into the age of the Anthropocene and observes further instances of environmental degradation alongside contemporary processes, the integration of traditional ecological management and traditional ecological knowledge, as practiced for thousands of years, re-emerges as both a sacred and tangible tool of environmental preservation.

The role of resilience and remembrance

The historical record of the western coasts of the Americas is rife with instances of bivalve usage, as the examples from British Columbia, California, and Manabí demonstrate. It is evident that bivalves have been critical tools in community building, and traditional Indigenous management practices like that of the clam garden have been successfully deployed over generations. The bivalve has not only served as a productive food source but has also been an important factor in the lives of humankind in various manners. In many ways, the bivalve has been a great contributor to ecological resilience, which, according to Gunderson (2000), was defined by the famed Canadian ecologist C. S. Holling as “the amount of disturbance an ecosystem could withstand without changing self-organized processes and structures.” The phrase “ecological resilience” is often repeated in the study of ecosystem dynamics; I would also argue that it can be applied to the multi-layered – often, in the age of the Anthropocene, destructive – nature of the human-ecological condition. The resilience of human communities and ecological landscapes are often the responses to the suffering and violence presented by marginalization.

Inferences on the resilience of communities and ecosystems can be derived from numerous places, such as studies of ecological productivity and economic development; surveys of attitudes towards topics such as environmental degradation and conservation; observations of sociocultural practice; examinations of the effects of ecosystem services; and studies of *well-being*, a critical dimension in community planning. D’anna and Murray (2015), surveyed communities in Baynes Sound, British Columbia, Canada, on attitudes and perceptions regarding shellfish aquaculture, and examined how shellfish aquaculture may affect local well-being. The survey included individuals inside and outside the aquaculture industry.

D’anna and Murray (2015) state that “[w]ithin the aquaculture industry, molluscan and shellfish aquaculture is viewed as a particularly attractive adaptation to coastal change and is a ‘green industry.’” They found that most survey participants perceived that shellfish aquaculture provided positive effects for the local economy, though perceptions of its environmental effects tended to be negative or uncertain (D’anna and Murray 2015). Community and individual perceptions and attitudes can be powerful drivers of planning and policy efforts; indeed, D’anna and Murray’s study not only underscores the importance of such

beliefs to coastal management frameworks, but also emphasizes the crucial nature of cultural and place-based memory in such planning efforts.

Critically, they write that “[m]any of the themes of lived experience were related to connection to place. Interviewees recognized that shellfish farming is a way of life in Baynes Sound that connects to local history and identity. Clams and oysters were considered an indelible part of the landscape” (D’anna and Murray 2015). In Baynes Sound, as in Salango and other spaces, bivalve use has provided an anchor, a bridge between the tangible and the imaginal, and a lifeline between present identities and past lives. As Gamble (2017) writes, “[t]hrough memory of place and the reuse and reinterpretation of it, landscape is connected to the identity of its inhabitants.” Indeed, for these coastal communities, bivalves are an enduring feature of the environments in which they live.

Identity – and the capacity to be resilient – are often inextricably connected to environmental features and local landscapes; the presence of clam or oyster beds can not only signal layers and lifetimes of poignant memories for both community and individuals, but can also provide numerous ecosystem services that can aid in restoring and rebuilding habitats and communities for humans and animals alike.

Ecosystem services provided by bivalves

The ecosystem services provided by bivalves are numerous. For example, Beseres Pollack et al.’s (2013) study of the Eastern oyster, *Crassostrea virginica* (Gmelin, 1791) discusses its nitrogen removal abilities and its importance to the Mission-Aransas Estuary environment in Texas. The harvest of this economically valuable oyster species “can remove approximately 21,665 kg N per year” (Beseres Pollack et al. 2013), thus aiding in water quality improvement (Beseres Pollack et al. 2013). Gagnon et al. (2020) also write about the restorative potential of bivalve-plant interactions in aquatic ecosystems, depending on factors such as temperature and light. Plants, such as seagrasses and mangroves, offered bivalves such benefits as protection from predators and physical disturbances (Gagnon et al. 2020). Bivalves, in turn, provided services such as nutrient enrichment and sediment stabilization (Gagnon et al. 2020). Gagnon et al. amply cite instances where such interactions appear to have positive, restorative effects in aquatic habitats. In seagrass meadows, oysters can assist in facilitating growth of seagrasses through mechanisms such as water filtration (Gagnon et al. 2020). In salt marsh habitats, the presence of oysters can also reduce turbidity and stabilize sediment (Gagnon et al. 2020). Additionally, salt marsh mussels such as *Geukensia demissa* (Dillwyn, 1817) and *Geukensia granosissima* (G. B. Sowerby III, 1914) guard against erosion and provide nutrient enrichment for cordgrass, which in turn provide shade for the mussels (Gagnon et al. 2020). These studied interactions offer insights into how bivalves might be increasingly incorporated into effective coastal planning and environmental management initiatives.

One coastal planning technique that is increasingly employed is the “living shoreline” approach. Davis et al. (2015) define living shorelines as “a type of estuarine shoreline erosion control that incorporates native vegetation and preserves native habitats;” the employment of such biogenic factors aids in increasing coastal resiliency, while also providing critical ecosystem services for the surrounding environment (Davis et al 2015). Bivalves are utilized in living shoreline approaches through constructs such as biogenic reefs (Scyphers et al. 2011). Bivalve reefs can act as breakwaters (Scyphers et al. 2011) while also supporting other animal communities – some of particular economic value. For example, Scyphers et al.’s (2011) coastal Alabama study of several experimental reefs made of loose oyster shells found that the presence of the reefs enhanced marine species such as the blue crab, *Callinectes sapidus* (Rathbun, 1896) and red drum, *Sciaenops ocellatus* (Linnaeus, 1766).

Van der Schatte Olivier et al. (2018) also discuss a litany of ecosystem benefits shouldered by the bivalve, which include reef-building and carbon sequestration, two processes which can aid in preserving biodiversity (van der Schatte Olivier et al. 2018). In addition, bivalves have also been used to replace more “industrial” operations; for example, van der Schatte Olivier et al. (2018) also refer to a case in Denmark where the nutrient removal prowess of bivalves has been employed as an alternative to sewage infrastructure improvements.

However, the filter feeding nature of bivalves is a double-edged sword that can both aid in nutrient removal and assist in harmful nutrient accumulation in spaces where water quality is particularly poor (van der Schatte Olivier et al., 2018); Gagnon et al. also refer to the negative effects of high-nutrient spaces. As some bivalves, such as oysters and clams, have the ability to shoulder a buildup of environmental toxins and harmful pathogens, van der Schatte Olivier et al. (2018) suggest that “bivalves could possibly be used as sacrificial beds to regulate and safeguard shellfish/finfish production locations, coastal waters and bathing beaches by accumulating pathogens before they reach them.” To this end, Vaughn and Hoellein (2018) discuss instances where bivalves, such as the Asian clam, *Corbicula fluminea* (Müller, 1774) and Yesso scallop, *Mizuhopecten yessoensis* (Jay, 1857) have been used to filter and remove harmful metals that may enter an ecosystem due to mining or aquacultural operations (Vaughn and Hoellein 2018). Of the Yesso scallop, Vaughn and Hoellein (2018) write that it “bioaccumulates cadmium in the hepatopancreas [molluscan digestive gland]...The hepatopancreas is hazardous waste, but new methods can remove the accumulated cadmium for reuse in manufacturing and recycle the processed tissue as fertilizer” (Vaughn and Hoellein 2018).

The myriad of ecosystem services provided by bivalves also includes biomonitoring. The ability of the bivalve to bioaccumulate and the relative ease with which bivalves can be collected and sampled allows them to be excellent gauges of marine pollution (Vaughn and Hoellein 2018). In addition to the metals previously discussed, there is evidence that bivalves could also be used as

monitors for microplastics in marine spaces (Vaughn and Hoellein 2018) which have the potential to negatively affect human and animal health (Barboza et al. 2018). As previously stated, the ecosystem services provided by bivalves are many, with much potential to enhance or support human, animal, and environmental health, well-being, and *resilience*; however, a more complete list of such services, with appropriate discussion and analysis, is beyond the scope and length of this paper.

Guillotreau et al. (2017) critically examine examples of community and ecological resilience fomented by the relationship between Anthropocene-era human societies and bivalve populations, the latter of whom have experienced massive mortality events due to the consequences of anthropogenic climate change and other stressful occurrences (Guillotreau et al. 2017). For example, Beseres Pollack et al. (2013) write that “[s]hellfish (including oyster) reefs, are the most imperiled marine habitats on earth, with an estimated 85% lost in relation to historic levels.” The relationship between human and bivalve, as noted by Guillotreau et al (2017) and authors, such as Deur et al. (2015), is one of countless examples of the inextricable connections humans have with animals, land, plants, and water – things that both provide for our material world, but somehow lay just beyond them; as entities rich in economic value and cultural memory and, in some cultural traditions, possessed of their own agency. In the following beautiful excerpt, Deur et al. 2015 quote co-author Adam Dick, “*Kwaxsistalla*, Clan Chief of *Qawadiliqalla* (Wolf Clan) within the Tsawataineuk (*Dʼawada ʔenux*”) tribe of the Kwakwakaʼwakw (‘Kwakiutl’) Nation”:

“In the cosmology of the Kwakwakaʼwakw and other indigenous peoples of the Northwest Coast, clams have been regarded as having families and societies equivalent to those of humans, and with their own abilities and needs. As *Kwaxsistalla* expressed it, ‘We had the same voice at the beginning of time - all the animals, the people.’ Thus, humans maintained and enhanced the habitats of culturally-preferred species, influenced not only by general knowledge of the species and ecosystems, but guided by notions of reciprocity and responsibility to the species on which they depended.”

In my assessments of bivalves, and the numerous services they provide, much emphasis is placed on what *they* can do for *us*, which might speak to how embedded our continuous centering of humankind in the entirety of our global ecological system really is. My hunch is that we are moving towards a decentering of humankind in our global space and approaching a recognition of how inextricably linked we humans are to virtually all other beings on this planet – bivalves included.

Each one is a small life, but sometimes long, if its place in the universe is not found out. Like us, they have a heart and a stomach; they know hunger, and probably a little satisfaction too. Do not mock them for their gentleness, they have a muscle that loves being alive. They pull away from the light. They pull down. They hold themselves together. They refuse to Open.

Mary Oliver, *Clam* (2002)

Concluding Thoughts

I have had the opportunity to learn about rich traditions as well as practices surrounding bivalves that date back thousands of years, and which speak to the varied spaces that bivalves have occupied in many cultural spheres. Unlike many species, the sociocultural value of bivalves has not been evaluated on a large scale (van der Schatte Olivier et al. 2018). However, a review of the canon of bivalve literature centered on several societies on the western coasts of the Americas alone provides numerous examples of instances where bivalves have played remarkable roles in supporting cultural development and community-building. Bivalve use has been endemic throughout the coasts of the western Americas for much of recorded and pre-recorded history. The sociocultural, economic, and environmental importance of these deceptively “simple” creatures reverberates throughout time and space, meandering back and forth over the chasm of our past and present at the same time it is used to lay the foundations of our common future.

Bivalves, like humans, occupy a critical space in the eternal now, where past, present, and future are connected through the passage of knowledge and tradition and the fluid dimensionality of time and space. And yet, our relationship with them, at times, may seem understudied in certain aspects. Although much literature exists about bivalve contributions to the food industry and ecosystem health, I reiterate van der Schatte Olivier et al. (2019), who write that “there is little evidence on the cultural services per year of bivalve aquaculture, but [the authors] argue that these cultural values are broad ranging, although difficult to quantify.” While it may be presently difficult to quantify the annual value of the cultural services that bivalves provide, it is evident that the contributions that bivalves have made to cultural development globally have been impactful and enduring.

The various examples of human-bivalve interactions recorded throughout history bolster the need to incorporate historical ecologies and traditional ecological knowledge into not only our contemporary environmental and ecological planning practices, but also into our ecological and environmental teachings. While, for example, Armstrong and Veteto (2015) state that “historical ecology has been underutilized by ethnobiologists as a productive research

program, with notable exceptions” they also beautifully discuss shifting paradigms within the fields of modern anthropology and geology: “the ‘ontological turn’ that challenges Western nature-culture dualisms and sees humans and landscapes as inseparable and interrelated wholes (Latour 2014)” (Amstrong and Veteto 2015). I am hopeful that similar paradigm shifts continue to blossom, as conceptualizing humankind as deeply integrated into our environments, rather than a connected entity existing just outside of them, is, I believe, a much more truthful depiction of the human-ecological condition.

To this end, Toniello et al. (2019) state “[e]xamining the deep and specific history of human–species relationships, such as that between people and clams, is requisite for understanding and better managing our resources and ecosystems today.” Such history encompasses the present, as well as thousands of years into the past, and unimaginable years into the future. It has been reiterated many times that the story of humans and bivalves is a fruitful one with ancient roots – ancient roots that considered future blossomings. In this story, imaginal landscapes become real ones; concepts and plans nurtured by one generation become tangible in their present, with the hope or expectation that they will endure into the future. Smith et al. (2019) critically wrote:

“When investigating any traditional marine management system, researchers should be cognizant that Indigenous traditional ecological knowledge systems often incorporate a long-term view of resource management... Although some ecological benefit was accrued by those first wall builders, the full benefit of clam gardens (i.e., increasing clam productivity up to fourfold) was not experienced until many generations later. This kind of future-focused management practice, that ensures food security for generations to come, stands in sharp contrast to the short-sighted way that many of our natural resources are managed in today’s industrial age.”

For these societies of the western coastal Americas, whether contemporary or pre-modern, bivalves are artistic endeavors; they are the building blocks of community and critical contributors to local and regional economies; they live alongside humankind in ecosystems continuously challenged by never-before-seen consequences of anthropogenic climate change. Elsewhere in the world, bivalves are similarly treasured and embedded into the fabrics of many cultures (van der Schatte Olivier et al. 2018), serving as recurring motifs in art and literature (Leach 1974) and delicious impetuses for community gathering (Dupree 1996); they are bridges between the imaginal and corporeal. These hinged molluscs have, for centuries, provided humankind with sources of food, stories, money, and often, simple delights. Mussels – and clams, scallops, and oysters, and the many other bivalves that have played a storied role in the human condition

– are memories, our present and our future. Memories are stories; stories are memories; stories allow us to reaffirm who we are.

During the process of writing this review, I was asked several times why I found it appropriate to include discussion of art, literature, and community-building in what was, ostensibly at first, a paper “solely” focused on reviewing the canon of bivalve ecology literature. My response was that, as ecology is the study of the relationships between beings; it is, by definition, the study of stories – the stories of how creatures or entities interact with each other in their respective environments. Once again, we return to the imaginal; here, as humankind has always done, we weave the threads of scientific imagination and socioecological memory into a *story*.

Because the rich history of humanity and its relationship with bivalves is precisely that – a chronicle of how we have built communities in tandem with these marvelous molluscs; a collection of stories gathered over thousands of years and in many different places; a collection of stories to be told.

I go down to the edge of the sea.
How everything shines in the morning light!
The cusp of the whelk,
the broken cupboard of the clam,
the opened, blue mussels,
moon snails, pale pink and barnacle scarred -
and nothing at all whole or shut, but tattered, split,
dropped by the gulls onto the gray rocks and all the moisture gone.
It's like a schoolhouse
of little words,
thousands of words.
First you figure out what each one means by itself,
the jingle, the periwinkle, the scallop
full of moonlight.

Then you begin, slowly, to read the whole story.

Mary Oliver, *Breakage* (2003)

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