

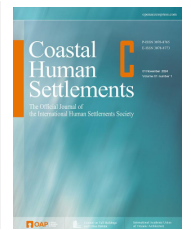


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Ocean Architecture: Disciplinary Connotation, Boundaries, and System Construction

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Abstract

As marine development accelerates, coastal urbanization increases, sea levels rise, and human activities expand from land to ocean, the built environment must adapt to dynamic marine conditions rather than stable land settings. Existing research covers floating architecture, offshore structures, resilient coastal cities, marine spatial planning, underwater habitats, and ecological restoration. However, these studies are scattered across fields like architecture, ocean engineering, marine science, environmental planning, and ecology. They have not yet formed a unified discipline capable of defining Ocean Architecture's objects, methods, knowledge, and education system. This paper aims to clarify what Ocean Architecture is, define its boundaries relative to related fields, and propose a systematic framework for its development. Methodologically, it combines literature review, comparative analysis, synthesis, and theoretical framework development. It defines Ocean Architecture as an interdisciplinary field focused on planning, designing, constructing, operating, and inhabiting marine environments. The core features include environmental adaptability, dynamic spatiality, human-centered habitation, ecological integration, technological coupling, and multi-scalar marine spatial organization. The paper distinguishes Ocean Architecture from traditional architecture, ocean engineering, and coastal science, emphasizing its focus on marine habitation and built environments rather than solely engineering or natural processes. It proposes a disciplinary system comprising a theoretical foundation, research objects, technical methods, practical applications, and talent cultivation. The paper argues that Ocean Architecture is an emerging but essential interdisciplinary discipline for land-sea integration. Its importance lies in expanding architectural theory beyond land-based assumptions and providing a human-centered, ecologically informed, and technologically grounded framework for future marine civilization.

Keywords Ocean Architecture; marine-built environment; marine spatial habitation; interdisciplinary discipline; coastal resilience; floating architecture

1. Introduction

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1.1 Research Background

The twenty-first century has been widely described as a maritime century in which oceans are no longer peripheral geographical margins but central spaces of resource extraction, logistics, habitation, climate regulation, and geopolitical competition. The intensification of coastal urbanization, the extension of offshore energy infrastructures, and the growing strategic importance of marine territorial governance have together transformed the relationship between human settlements and the sea. At the same time, rising sea levels, coastal hazards, and ecological degradation have destabilized the conventional assumption that urban and architectural development can continue to rely primarily on fixed terrestrial land^{[1][2][3]}. In this context, the built environment is being pushed simultaneously toward adaptation at the shoreline and toward expansion into marine space.

This transformation is not reducible to a single technical trend. It includes the redesign of coastal settlements under climate pressure, the proliferation of offshore platforms and logistics nodes, the revival of floating urban concepts, the emergence of amphibious and buoyant dwellings, the architecturalization of cruise and marine tourism infrastructures, and renewed interest in underwater environments as spaces of research, hospitality, and habitation^{[4][5][6]}. Historical visions of marine urbanization, once treated as speculative or utopian, have re-entered serious discussion because climate change, urban land scarcity, and maritime economic restructuring have altered the material conditions of feasibility^{[7][8]}.

The architectural implications of this shift are profound. Traditional architecture developed primarily through terrestrial assumptions: relatively stable ground, comparatively legible property boundaries, predictable infrastructural support, and climatic conditions treated as environmental modifiers rather than constitutive spatial agents. By contrast, marine space is hydrodynamic, corrosive, unstable, legally layered, ecologically sensitive, and operationally dependent on technological mediation. Designing for such conditions requires more than transferring land-based models seaward. It demands new understandings of structure, enclosure, circulation, material durability, spatial comfort, ecological reciprocity, and life-support systems. Floating houses on Lake Tempe, for instance, show that aquatic habitation is not merely futuristic imagery but also a vernacular adaptive logic shaped by seasonal hydrology and livelihood practice^[9]. Meanwhile, recent work on amphibious foundations and modular floating cities demonstrates that contemporary design research is already grappling with the built consequences of dynamic water environments^{[7][10]}.

The broader planning context also reinforces this shift. Marine spatial planning has matured as a framework for managing competing uses of sea space, yet its dominant formulations have focused on governance, zoning, ecosystem-based management, and sectoral coordination rather than on the architectural constitution of habitable marine environments^{[11][12][13]}. Coastal resilience literature has made clear that future adaptation cannot be limited to defensive infrastructure; it must include ecological design, spatial reconfiguration, and new modes of inhabiting coasts and waters^{[14][15][16]}. Ocean Architecture emerges precisely at this junction: where architecture can no longer remain land-exclusive, and where marine development can no longer be understood through engineering and governance alone.

Recent Chinese discussions have begun to articulate this emerging field under the name "Ocean Architecture," particularly from the perspectives of coastal habitation, land-sea integration, and disciplinary construction. These discussions are significant because they do not merely call for more marine projects; they call for a new knowledge system capable of interpreting the marine-built environment as a distinct domain of architectural inquiry. The present paper builds on that emerging discourse while positioning it within a broader international theoretical conversation.

1.2 Research Objectives and Significance

The first objective of this paper is definitional: to clarify what Ocean Architecture is as a discipline rather than as a loose thematic label for architecture near or on the sea. The second objective is boundary-making: to identify how Ocean Architecture differs from, while remaining connected to, traditional architecture, Ocean Engineering, coastal science, marine ecology, and spatial planning. The third objective is constructive: to propose a preliminary but systematic disciplinary framework that includes theoretical foundations, research objects, methodological tools, practical applications, and talent cultivation.

These objectives matter for at least three reasons. First, a discipline cannot mature without conceptual self-definition. Without a clear disciplinary core, marine-related architectural research remains fragmented across floating building design, offshore engineering support systems, coastal landscape adaptation, tourism infrastructure, and marine public works. Such fragmentation limits cumulative knowledge formation and weakens institutional recognition. Second, the systematic construction of Ocean Architecture is significant for architecture itself. It compels architectural theory to move beyond the stable ground paradigm and to confront fluidity, uncertainty, ecological interdependence, and hybrid technological-environmental systems as constitutive, not exceptional, design conditions. Third, it is significant for marine development because human-centered spatial quality, cultural expression, social use, and ecological responsibility cannot be derived automatically from engineering competence alone.

In this sense, the disciplinary project of Ocean Architecture is not a terminological expansion but an epistemic and methodological necessity. It enables a transition from isolated marine projects to a coherent field concerned with how humans dwell, work, circulate, and construct meaning in oceanic space. Such a framework is indispensable if marine development is to become habitable, socially grounded, and ecologically accountable rather than merely extractive or infrastructural.

1.3 Literature Review

Existing scholarship relevant to Ocean Architecture can be grouped into at least six partially overlapping strands.

The first strand concerns floating architecture and amphibious design. Lin et al.^[5] provide one of the clearest reviews of floating architecture as a design field, synthesizing its functions, typologies, and technological constraints. Olthuis and Keuning^[17] frame building on water as a strategic response to congestion and climate pressure, while Naing et al.^[9] show that floating habitation can also be a vernacular adaptation rooted in local environmental cycles and livelihood systems. Recent studies extend this domain toward biomimetic amphibious design and modular floating urban configurations, demonstrating that floating settlement research is becoming more systematic, though still largely project- or technology-specific^{[10][7][18]}.

The second strand focuses on offshore structures and Ocean Engineering. Core works in offshore engineering have long addressed hydrodynamics, sea loads, structural reliability, platform systems, and material performance under marine conditions^{[19][20][21]}. More recent work on corrosion trends, digital twins, and maritime system intelligence further expands the engineering toolkit for operating in hostile ocean environments^{[22][23]}. This body of research is indispensable to Ocean Architecture, yet its primary concern is engineering performance, risk, and operational efficiency rather than architectural inhabitation, spatial experience, or cultural meaning.

The third strand addresses coastal resilience and climate adaptation. Sea-level rise, flood risk, and shoreline vulnerability have produced a major body of work on coastal urban futures^{[1][24][3]}. Studies on ecological engineering and ecosystem-based coastal defense demonstrate that adaptation requires hybrid solutions integrating physical protection, ecological restoration, and spatial planning^{[14][15][16]}. Work on shoreline hardening likewise warns that conventional defensive infrastructures often degrade nearshore ecological systems and reduce long-term resilience^[25]. This literature is highly relevant to Ocean Architecture because it redefines coasts as adaptive socio-ecological interfaces rather than static development fronts.

The fourth strand is marine spatial planning and ocean governance. Douvres^[11], Ehler and Douvres^[12], and Foley et al.^[13] establish marine spatial planning as a framework for ecosystem-based sea-use management. Their contributions are foundational for understanding marine space as governable, multi-use, and conflict-prone. Subsequent work has introduced more explicitly spatial, ethical, and political readings of marine planning, including analyses of rhythm, measurement, and environmental ethics in marine spatial planning practice^{[26][27]}. Even so, the architectural dimension of marine space remains underdeveloped in this literature.

The fifth strand involves marine urbanism and oceanic spatial thought. Beatley's^[4] notion of blue urbanism reconnects cities with oceans as ecological, cultural, and political systems, while Huebner^[8] traces the genealogy of marine urbanization through twentieth-century design imaginaries linking cybernetics, environmental adaptation, and offshore habitation. These studies are especially important because they move beyond the project scale and frame the ocean as an urbanizable, though not simply terraformed, domain. They offer critical conceptual resources for disciplinary positioning.

The sixth strand concerns marine ecology, deep-sea systems, and underwater space. Barbier et al.^[28] and Thurber et al.^[29] demonstrate the economic and ecological significance of coastal and deep-sea ecosystems, highlighting why marine construction cannot be ecologically neutral. Vannini^[6] broadens the discussion by reviewing underwater spaces as experiential, touristic, and potentially habitable environments. Such work indicates that marine-built environments must be theorized not only as technical artifacts but as ecological interfaces and lived spaces.

Taken together, these strands provide substantial knowledge relevant to Ocean Architecture. However, they do not yet add up to a mature and systematic disciplinary framework for Ocean Architecture as an independent discipline. What remains missing is a coherent structure that defines the field's core object, disciplinary legitimacy, internal categories, methodological system, educational pathway, and relation to neighboring disciplines. Existing studies often illuminate one dimension of the problem while leaving others unintegrated. This gap justifies the disciplinary-construction perspective adopted here.

1.4 Research Methods

This paper adopts four mutually supporting methods.

First, it employs literature review to identify the major research trajectories that currently inform discussions of marine habitation, floating architecture, offshore structures, coastal resilience, and marine spatial planning. Second, it uses comparative disciplinary analysis to distinguish Ocean Architecture from adjacent fields, especially traditional architecture, Ocean Engineering, and coastal science. Third, it applies inductive synthesis to organize dispersed concepts, typologies, and methods into an internally coherent disciplinary schema. Fourth, it uses theoretical framework construction to propose a preliminary system for the discipline, including its theoretical foundation, research object structure, technical methods, practical applications, and talent cultivation model.

The purpose of this methodological combination is not to produce empirical measurement but to establish conceptual clarity and framework coherence. As such, the paper is positioned as a foundational theoretical study for an emerging interdisciplinary field.

2. Core Connotation of Ocean Architecture

2.1 Definition of Ocean Architecture

Ocean Architecture may be defined as an interdisciplinary discipline concerned with the planning, design, construction, operation, and habitation systems of marine spatial environments. Its core task is to study and shape marine-built environments in ways that are structurally viable, environmentally adaptive, socially habitable, and ecologically integrated.

Several elements in this definition require emphasis. First, Ocean Architecture is not limited to buildings physically located at sea. It includes spatial systems across the land-sea interface, offshore domains, underwater environments, and deep-sea operational settings whenever architectural questions of inhabitation, spatial organization, environmental mediation, and human use become central. Second, it is not reducible to Ocean Engineering, because its object is not simply the structure as technical object but the marine-built environment as a habitable and meaningful spatial condition. Third, it is not reducible to coastal planning or marine governance, because its focus is not only the allocation of space but the architectural constitution of space.

Ocean Architecture therefore extends architecture from a discipline primarily organized around land-based settlement into one capable of theorizing, designing, and operating in fluid, dynamic, and ecologically entangled marine environments. If architecture has historically dealt with the artificial shaping of human dwelling in terrestrial place, Ocean Architecture asks how dwelling can be rethought when place itself becomes amphibious, floating, submerged, or offshore.

2.2 Core Characteristics

The first core characteristic of Ocean Architecture is marine environmental adaptability. Marine environments are defined by tides, waves, currents, salinity, corrosion, humidity, storm exposure, and long-term climatic uncertainty. Architectural systems in such conditions cannot assume a stable environmental background. Instead, environmental variability becomes a primary design determinant. Adaptation here is not a supplementary performance target but a constitutive design logic^{[3][16]}.

The second characteristic is dynamic spatiality. Terrestrial buildings are generally founded on stable ground and framed by comparatively fixed coordinates. Marine-built environments, by contrast, may drift, oscillate, rise, submerge, or operate within mobile infrastructures. Even when fixed, they are exposed to constantly changing environmental forces. This produces a spatial condition in which stability must often be designed as controlled dynamic equilibrium rather than absolute fixity. Floating and amphibious structures exemplify this shift most directly^{[10][5]}.

The third characteristic is human habitation. Ocean Architecture is not primarily about occupying marine space instrumentally, but about making such space inhabitable. Habitation includes shelter, circulation, comfort, work, sociality, service provision, sensory experience, safety, and long-duration use. This is why cruise architecture, floating settlements, marine public facilities, offshore living modules, and underwater hospitality environments all fall within the field's scope: they transform marine space into lived space.

The fourth characteristic is ecological integration. Marine construction takes place within ecosystems of extraordinary sensitivity and systemic connectivity. Coastal habitats provide protection, biodiversity, nursery functions, and livelihood support, while deep-sea systems generate important ecological services yet remain poorly understood^{[14][28][29]}. Ocean Architecture must therefore incorporate ecological restoration, habitat compatibility, and lifecycle environmental reasoning. Its ambition cannot be to dominate oceanic nature by pure technical means; it must design with ecological processes and limits.

The fifth characteristic is technological integration. Marine-built environments are heavily dependent on engineering systems, materials science, digital simulation, monitoring technologies, and operational control. Corrosion-resistant materials,

hydrodynamic modeling, modular construction, energy systems, digital twins, and life-support systems are not external supplements but internal components of marine architectural practice^{[22][23]}. Ocean Architecture therefore requires a higher degree of technological coupling than most conventional building domains.

The sixth characteristic is multi-scalar marine spatiality. Ocean Architecture operates across scales ranging from the room or module to the platform, settlement, port-waterfront interface, coastal urban district, offshore cluster, and regional land-sea system. This multi-scalar condition means that the discipline must articulate architectural, infrastructural, urban, territorial, and ecological logics simultaneously rather than sequentially.

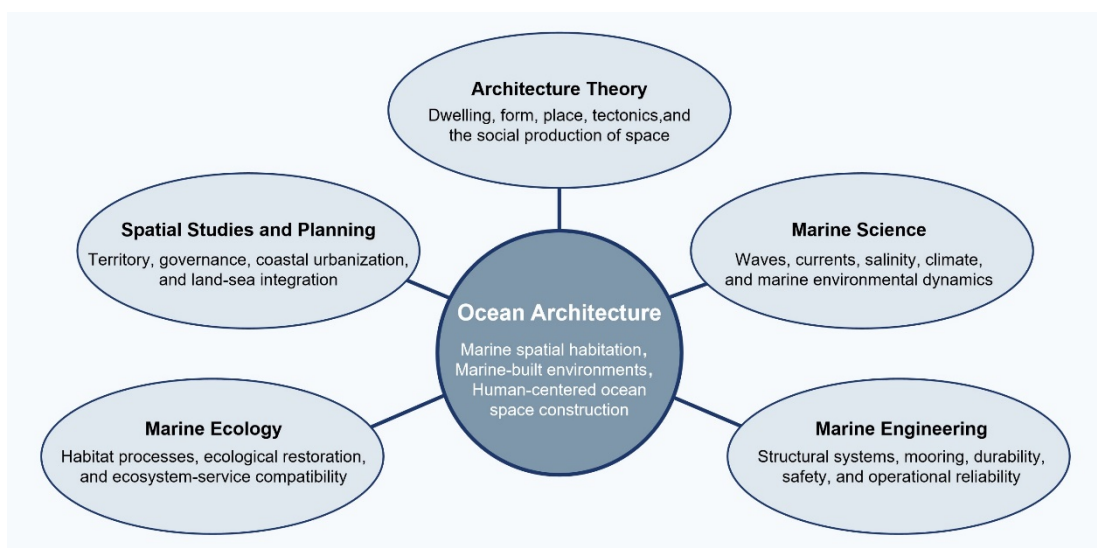


Figure 1. Disciplinary relationship diagram of Ocean.

Note. Conceptual diagram positioning Ocean Architecture at the intersection of architecture, marine science, Ocean Engineering, ecology, and spatial studies, with marine spatial habitation at the center. Source: author-generated schematic.

2.3 Research Objects

The research objects of Ocean Architecture can be grouped into seven major domains.

The first is coastal architecture, including waterfront public buildings, adaptive housing, coastal campuses, ports with strong civic or habitable functions, and transitional land-sea public spaces. These are not simply coastal versions of terrestrial types, because shoreline risk, saline exposure, seasonal inundation, and ecological edge conditions alter both program and form.

The second is offshore floating architecture, including floating dwellings, workspaces, leisure platforms, modular floating communities, and large-scale floating urban components. This domain is central because it concentrates many of the field's defining issues: buoyancy, motion, anchoring, modularity, utility integration, and social habitability^{[7][5][17]}.

The third is artificial islands and hybrid land-making systems. Here Ocean Architecture addresses not only land-creation technologies but also the spatial, ecological, and social logics by which reclaimed or newly constructed marine ground becomes a built environment. The discipline's concern lies less in the mechanics of fill than in the spatial consequences of inhabitable marine terrains.

The fourth is cruise architecture and marine tourism environments. Large passenger vessels, floating resorts, waterfront leisure complexes, and underwater hospitality spaces demonstrate that marine inhabitation already exists at substantial scale. They are valuable research objects because they integrate mobility, hospitality, safety, environmental control, and marine experience within bounded architectural systems.

The fifth is underwater architecture, including research habitats, underwater museums, submerged observatories, underwater hotels, and experimental subsea chambers. Vannini^[6] shows that underwater space has become a legitimate subject of spatial experience and habitation studies, even if still marginal in mainstream architecture. Underwater environments also force the discipline to confront enclosure, pressure, visibility, isolation, and life-support in radical form.

The sixth is subsea and deep-sea spatial systems. Although many deep-sea facilities remain primarily operational or scientific, they generate architectural questions whenever human presence, occupation cycles, service interfaces, and interior environmental mediation become significant. Ocean Architecture need not claim full jurisdiction over deep-sea engineering,

but it must recognize those subsea spatial systems where human use and built environmental quality matter.

The seventh is marine public infrastructure. This includes lighthouses, marine stations, ferry terminals, coastal emergency shelters, sea-based service hubs, offshore education facilities, and ecological monitoring platforms. Such infrastructures matter because they translate ocean space into a public realm of service, accessibility, and collective use.

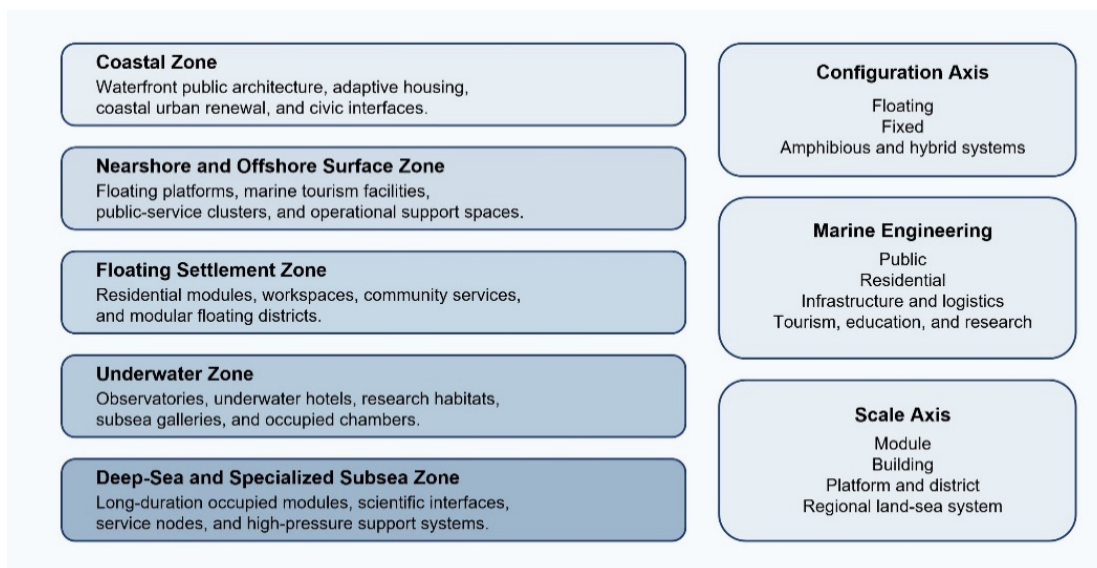


Figure 2. Marine spatial hierarchy of Ocean Architecture research.

Note. Schematic showing the nested relationship among coastal, offshore, underwater, and deep-sea domains, and the crossing typological categories of floating, fixed, public, residential, and infrastructural systems. Source: author-generated schematic.

3. Disciplinary Boundaries of Ocean Architecture

3.1 Boundary with Traditional Architecture

Ocean Architecture shares with traditional architecture a concern for human habitation, spatial order, material articulation, environmental mediation, and cultural expression. It therefore remains inseparable from the core architectural questions of dwelling, place, form, and social use. Yet its disciplinary object diverges significantly from that of traditional architecture because marine environments transform the assumptions under which these questions are posed.

Traditional architecture has been shaped by terrestrial conditions: ground-bearing stability, relatively durable parcel boundaries, clear distinctions between inside and outside, and environments in which fluid forces usually appear episodically rather than continuously. Even when architecture engages climate, topography, or landscape, the foundational premise is still largely geostatic. Ocean Architecture, by contrast, works in geographies where the medium itself is mobile and where the distinction between ground, infrastructure, and environment becomes unstable. A floating settlement, for example, cannot be understood through the same ontological assumptions as a land-based neighborhood, because its support, anchorage, movement, service distribution, and risk profile differ fundamentally.

This does not mean that Ocean Architecture abandons architectural theory. On the contrary, concepts such as dwelling, cultural form, and place remain essential, but they must be reformulated. Rapoport's emphasis on the cultural production of built form and Norberg-Schulz's notion of place are still relevant, yet marine environments demand that place be understood less as fixed locality than as an adaptive relation among environment, technology, and inhabitation^{[30][31]}. Similarly, Frampton's call for critical regionalism remains useful, but marine regionality cannot be confined to land-based climatic identity; it must include tidal rhythms, coastal ecologies, maritime labor, and sea-facing cultural imaginaries^[32].

In short, the boundary with traditional architecture is not one of complete rupture but of transformed object conditions. Ocean Architecture remains architecture, but architecture reconstituted under marine spatial premises.

3.2 Boundary with Ocean Engineering

The distinction between Ocean Architecture and Ocean Engineering is fundamental to disciplinary clarity. Ocean Engineering is primarily concerned with the technical realization, safety, durability, and operational performance of structures and systems in marine environments. Its central questions include hydrodynamic response, structural integrity, sea loads, mooring, fatigue, corrosion, materials degradation, propulsion, and operational risk^{[19][20][21][23]}.

Ocean Architecture depends on this knowledge but does not coincide with it. Its distinctive concern lies in how marine structures become habitable environments. It asks questions that engineering alone cannot resolve: How should spatial programs be organized in floating or submerged conditions? What forms of enclosure and transition produce psychological comfort in isolated marine settings? How should circulation, community, privacy, and publicness be rethought when architecture is buoyant, mobile, or submerged? How can built form accommodate both technical infrastructure and meaningful human experience?

A platform optimized for structural efficiency is not thereby an architectural environment. Likewise, an offshore habitat that is safe in engineering terms may still fail in architectural terms if it does not support legibility, comfort, sociability, environmental quality, or long-duration occupation. The distinction is therefore not between technical and nontechnical domains, but between performance as engineering adequacy and performance as marine-built habitability. Ocean Architecture translates Ocean Engineering from structure-centered problem solving into human-centered spatial construction.

3.3 Boundary with Coastal Science

Coastal science studies natural processes of the shore and nearshore environment, including erosion, sediment transport, shoreline morphology, tidal dynamics, estuarine processes, storm impacts, and habitat change. Its object is explanatory and analytical: to understand how coastal systems function and transform.

Ocean Architecture, by contrast, treats those natural processes as conditions and knowledge bases for spatial construction. It does not ask primarily how a coastline evolves in geomorphological terms, but how such knowledge can inform settlement, public space, building form, protective interfaces, ecological integration, and long-term inhabitation. Coastal science explains processes; Ocean Architecture applies and spatializes them in built form. The relationship is thus asymmetric but intimate.

This distinction is especially important for climate adaptation. Studies of coastal flood risk, shoreline change, and sea-level rise establish the environmental realities within which marine-built environments must operate^{[1][24][3]}. Yet the conversion of that knowledge into habitable and ecologically sensitive design requires architectural mediation. Similarly, ecosystem-based coastal defense literature demonstrates that ecological processes can and should inform spatial strategies, but the actual design of inhabitable hybrid interfaces remains an architectural problem^{[15][16]}.

3.4 Boundary with Naval Architecture

Naval architecture takes mobile maritime vehicles as its core object, including ships, submarines, and floating carriers. Its central tasks involve hull form, buoyancy, stability, seakeeping, manoeuvrability, structural strength, and propulsion systems, with the objective of ensuring navigation safety and transport efficiency. Ocean liners, cargo vessels, and yachts are first and foremost conceived as “ships”, with navigational function occupying the dominant position.

Ocean architecture, by contrast, takes habitable marine space as its core object, focusing on spatial layout, interior environment, landscape and form-making, residential comfort, and the construction of marine living scenarios. It proceeds not from navigation but from dwelling.

Large passenger cruise ships typically illustrate the intersection and division of labour between the two disciplines: the hull structure and navigation systems fall under the purview of naval architecture, whereas the design of guest rooms, retail areas, entertainment zones, and public spaces belongs to ocean architecture. More generally, the boundary between the two can be delineated as follows: any maritime carrier capable of free navigation and primarily intended for transport and mobility falls into the domain of naval architecture; any spatial environment that is fixed on the sea surface, floating but stationary, and primarily intended for habitation and recreation falls into the domain of ocean architecture. Cruise ships occupy the middle ground: their hulls and systems belong to naval architecture, while their spatial design belongs to ocean architecture.

In practice, the two disciplines are best approached through a boundary arrangement of “mutual reinforcement and division of labour”: naval architecture ensures maritime safety and navigational performance, while ocean architecture creates liveable, comfortable, and place-making marine spaces. The two are not in competition but are rather in a necessary collaborative relationship for the realisation of the marine human habitat.

3.5 Summary of Disciplinary Boundaries

From the preceding comparisons, Ocean Architecture can be identified as an independent interdisciplinary discipline centered on marine spatial habitation and marine-built environments. It draws from traditional architecture, Ocean Engineering, naval architecture, coastal science, ecology, planning, and digital technologies, but it is not reducible to any of them. Its legitimacy rests on a distinct object: the human-centered, ecologically informed, and technologically mediated construction of inhabitable space in marine environments.

Discipline	Primary Object	Central Question	Dominant Output
Traditional architecture	Terrestrial buildings, settlements, and urban spatial organization	How are human dwelling, form, space, symbolic meaning, and culture organized on relatively stable land?	Buildings, urban form, place-making, environmental design, and culturally meaningful terrestrial habitats
Marine engineering	Marine structures, equipment, and operational support systems	How can structures survive wave action, loads, corrosion, motion, and operational risk under marine conditions?	Safety, performance, reliability, operational efficiency, and structural serviceability in marine environments
Coastal science	Natural shoreline processes, sediment systems, and habitats	How do tides, erosion, sediment transport, storms, and ecological processes shape coasts through time?	Process explanation, hazard analysis, shoreline monitoring, and environmental assessment
Ocean architecture	Marine spatial habitation and marine-built environments	How can human-centered, ecologically integrated, and technologically viable marine environments be planned, designed, built, operated, and inhabited across dynamic ocean space?	Habitable coastal, floating, offshore, underwater, and service environments that combine spatial quality, social use, ecological compatibility, and technical feasibility

Figure 3. Boundary comparison of Ocean Architecture and adjacent

Note. Matrix comparing core research objects, dominant questions, and methods across traditional architecture, Ocean Engineering, coastal science, and Ocean Architecture. Source: author-generated schematic.

4. Construction of the Ocean Architecture Disciplinary System

4.1 Theoretical Foundation System

The theoretical foundation of Ocean Architecture must be explicitly composite. No single existing discipline provides a sufficient conceptual base for it.

The first component is architectural theory. Ocean Architecture inherits the architectural concern with habitation, environmental mediation, tectonics, morphology, and cultural meaning. It also inherits architecture's responsibility to make technology socially legible and spatially intelligible. Yet within Ocean Architecture these concerns must be reformulated in relation to dynamic, amphibious, and marine conditions.

The second component is marine environmental science. Knowledge of tides, currents, salinity, wave climate, sediment behavior, and offshore environmental loading is indispensable because marine space cannot be abstracted into a neutral site. Environmental science in this sense is not supplementary data but a constitutive layer of architectural reasoning.

The third component is marine ecology. Ocean Architecture must work with ecological processes, not only to avoid damage but to produce beneficial interfaces between built form and marine life. Coastal habitats supply protective and ecosystem-service functions, while deep-sea ecologies remind us that marine construction is always entangled with systems of value not fully captured by development metrics^{[14][28][29]}.

The fourth component is climate adaptation theory. The field must engage uncertainty, resilience, managed retreat, adaptive infrastructures, and hybrid ecological-technical systems. In this respect Ocean Architecture is inseparable from contemporary debates on coastal resilience and transformation^{[1][25]}.

The fifth component is regional marine culture. Marine-built environments are not only technical responses to water; they are embedded in maritime livelihoods, ritual practices, regional identities, and coastal settlement traditions. The vernacular logic of floating and stilted habitation demonstrates that marine architecture has cultural genealogies as well as technological futures^[9].

The sixth component is land-sea integrated planning. Ocean Architecture must move beyond the old split between terrestrial urbanism and marine governance. Internationally, marine spatial planning scholarship offers a powerful

framework for understanding sea space as a structured, contested, and governable domain^{[11][12]}.

Taken together, these six components form a theoretical foundation system in which architecture is neither dissolved into ocean science nor insulated from it. The discipline requires what might be called marine relational thinking: a mode of architectural reasoning that begins from interdependence among human occupation, environmental process, technological mediation, and ecological consequence.

4.2 Research Object System

For Ocean Architecture to become a discipline rather than a topic cluster, its research objects must be structured systematically. A useful approach is to classify them along three intersecting dimensions: environmental domain, spatial configuration, and social function.

By environmental domain, research objects may be divided into coastal, offshore, underwater, and deep-sea systems. Coastal systems include tidal-edge housing, resilient waterfront public architecture, harbor districts, and amphibious interfaces. Offshore systems include floating platforms, marine campuses, seaborne tourism environments, and energy-support habitation units. Underwater systems include submerged hospitality spaces, laboratories, observatories, and heritage-display environments. Deep-sea systems include highly specialized human-occupied modules and service environments connected to research or subsea operation.

By spatial configuration, objects may be distinguished as floating or fixed. Floating systems depend on buoyancy, modularity, anchorage, and dynamic balancing. Fixed systems may include piles, caissons, reef-integrated structures, or other forms of static anchorage in marine conditions. Between them lies a hybrid category of amphibious or periodically adaptive structures that shift between grounded and buoyant states.

By social function, objects may be divided into public, residential, productive, service, tourism, research, and infrastructure systems. Public systems include sea-facing civic spaces, ferry nodes, maritime museums, and public emergency facilities. Residential systems include floating houses, marine dormitories, and longer-duration offshore living environments. Productive systems include fishery-related habitation, offshore work modules, and logistics-support spaces. Research and education systems include marine laboratories, field stations, observatories, and experimental teaching infrastructures.

This matrix-based approach is important because it allows Ocean Architecture to integrate typology with environment and use. It also provides the basis for future database construction, case comparison, curriculum design, and standards development. Rather than listing isolated project types, the discipline can describe an internally coherent universe of research objects.

4.3 Technical Method System

If the theoretical foundation system defines why Ocean Architecture exists, the technical method system defines how it operates. At least seven method clusters are essential.

The first is adaptive marine architectural design. This includes hydrodynamically informed form generation, buoyancy-based design, amphibious foundation systems, flexible interface strategies, and environmental response mechanisms. Adaptive design treats motion, fluctuation, and uncertainty as active design parameters rather than disturbances to be eliminated.

The second is materials and durability science. Corrosion, biofouling, salt crystallization, ultraviolet exposure, humidity, and cyclic loading significantly affect marine-built environments. Material choice in Ocean Architecture therefore requires a far deeper integration of marine degradation knowledge than ordinary building design. Research on offshore and subsea corrosion trends is directly relevant here because architectural permanence in marine settings depends on materials strategy as much as on form^[23].

The third is digital marine architecture. Building information modeling, environmental simulation, sensor integration, and digital twin systems can substantially improve the lifecycle management of marine-built environments. In marine settings, digital twins are especially important because they allow continuous monitoring of structural behavior, environmental loads, energy performance, and maintenance needs under dynamic conditions^[22]. Ocean Architecture should therefore treat digital systems not merely as documentation tools but as operational companions to design.

The fourth is modular construction and prefabrication. Because offshore and floating environments often impose logistical constraints on transport, assembly, maintenance, and expansion, modularity becomes both a construction strategy and a spatial logic. Recent work on modular floating city configurations suggests that modularity can support not only technical efficiency but also phased growth, reconfiguration, and scenario-based planning^[7].

The fifth is resilient systems design. This includes flood adaptation, redundancy, evacuation logic, emergency support, climate uncertainty planning, and long-term transformability. Marine-built environments cannot rely on single-failure

assumptions; they require systemic resilience at the levels of structure, service, occupancy, and governance^{[1][18]}.

The sixth is ecological restoration and habitat-compatible design. Research on ecological engineering, living shorelines, and shoreline hardening effects shows that built interventions can either degrade or enhance marine ecosystems^{[15][25][16]}. Ocean Architecture should therefore include methods for designing ecologically porous edges, habitat-supporting surfaces, water-quality-sensitive systems, and restorative marine public works.

The seventh is human-factors and experiential assessment. Habitation in marine space raises questions of comfort, motion sensitivity, psychological security, confinement, visual connection, and environmental cognition. These are architectural questions that cannot be solved by engineering metrics alone. Underwater environments make this especially clear, since inhabitation depends simultaneously on life-support technology and on spatial experience^[6].

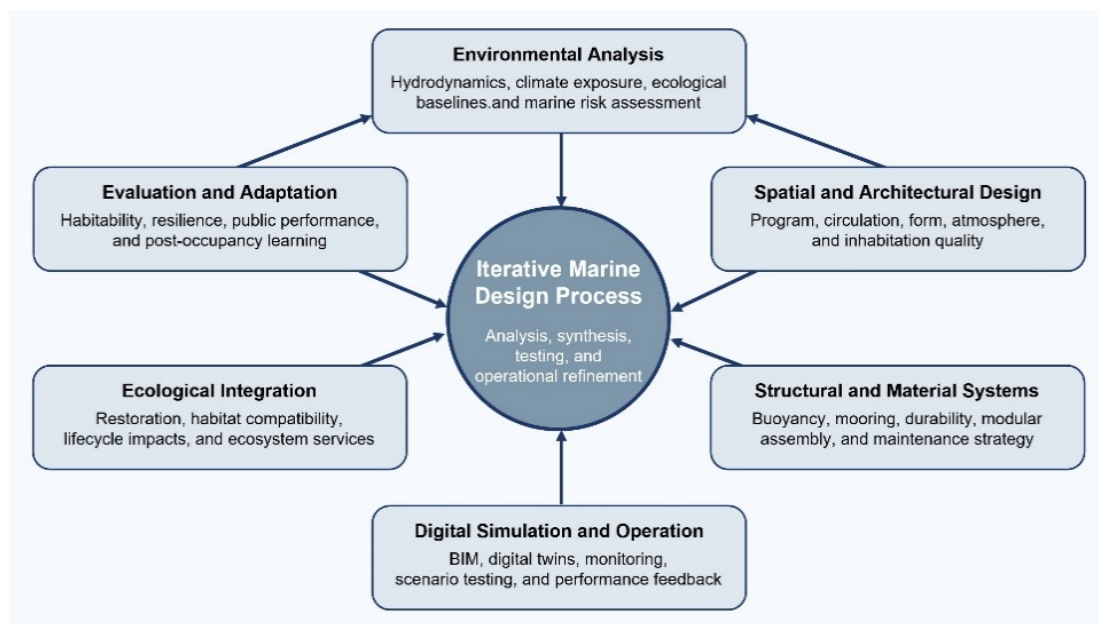


Figure 4. Technical method framework of Ocean Architecture.

Note. Diagram linking environmental analysis, architectural design, structural engineering, digital systems, material strategy, resilience assessment, and ecological restoration into an iterative workflow. Source: author-generated schematic.

4.4 Practical Application System

A discipline gains reality through application domains. For Ocean Architecture, five application fields are especially important.

The first is coastal urban renewal. Many waterfronts and coastal districts are under pressure from sea-level rise, aging infrastructure, shoreline hardening, and redevelopment demand. Ocean Architecture can support the transformation of these areas through amphibious public facilities, adaptive housing, hybrid ecological edges, marine mobility nodes, and resilient civic spaces. In this field, the discipline complements coastal engineering by addressing not only protection but also urban quality and long-term habitability.

The second is floating city and floating district development. While the phrase "floating city" can easily become speculative, recent research suggests that modular floating systems can be approached analytically rather than rhetorically^{7[7]}. Ocean Architecture should evaluate such projects through the combined lenses of structural feasibility, spatial livability, governance, energy systems, ecological compatibility, and social viability. Its role is to prevent floating urbanism from collapsing into either engineering determinism or promotional futurism.

The third is marine tourism architecture. Cruise terminals, floating leisure platforms, sea resorts, underwater hotels, and marine interpretation centers are already among the most visible forms of marine-built environment. Ocean Architecture can contribute by improving environmental performance, user experience, cultural interpretation, and ecological integration rather than treating tourism as a purely commercial typology.

The fourth is underwater facilities. Research habitats, submerged observatories, and underwater cultural venues remain relatively specialized, but they are invaluable laboratories for the discipline because they intensify questions of enclosure,

perception, maintenance, life-support, and environmental interface. Underwater architecture also expands the conceptual reach of the discipline beyond the surface bias of most architectural thinking.

The fifth is marine public service and ecological architecture. This includes offshore clinics, educational facilities, disaster-response units, fisheries service hubs, ecological monitoring stations, and habitat-supportive marine infrastructure. These applications are especially important for demonstrating that Ocean Architecture is not restricted to iconic projects but can address everyday public needs and ecosystem care.

4.5 Talent Cultivation System

No disciplinary system can develop without a corresponding educational system. Ocean Architecture therefore requires a deliberate talent cultivation model rather than ad hoc exposure through elective design studios.

First, it requires interdisciplinary education. Students must gain competence in architecture while acquiring foundational literacy in marine science, offshore systems, coastal ecology, and marine policy. The aim is not to turn architects into engineers or oceanographers, but to produce professionals capable of meaningful collaboration and concept integration.

Second, marine architectural studios should be established as core pedagogical platforms. Unlike generic waterfront design studios, such studios would focus specifically on marine spatial habitation, floating systems, underwater environments, offshore service architectures, and land-sea interface design. They should train students to work with environmental data, marine operational constraints, and scenario-based adaptation.

Third, engineering collaboration must be institutionalized. Joint teaching with naval architecture, offshore engineering, marine environmental science, and digital systems programs can create the collaborative habits needed by the field. Ocean Architecture is unlikely to mature within disciplinary isolation.

Fourth, digital technologies must become standard educational tools. Simulation, BIM, digital twins, GIS-based marine spatial analysis, and environmental modeling are not optional skills in this field. They are foundational instruments of design reasoning and lifecycle management.

Fifth, experimental teaching systems are needed. These may include floating prototype labs, coastal field observatories, material-weathering stations, hydrodynamic model workshops, and real-world living laboratories at waterfront campuses. Such platforms would help bridge theory and practice, which is one of the key weaknesses in current marine-related architectural education.

Recent Chinese discussions on Ocean Architecture have already identified the need for disciplinary framework design and talent cultivation reform. The next step is to convert that recognition into curriculum architecture, institutional partnerships, and pedagogical infrastructure.

5. Existing Problems and Development Paths

5.1 Existing Problems

Despite its growing relevance, Ocean Architecture faces several structural problems.

The first is immature disciplinary theory. The field currently lacks widely accepted definitions, conceptual categories, and theoretical propositions capable of distinguishing it clearly from adjacent domains. Many discussions remain at the level of project advocacy, technological possibility, or general marine strategy.

The second is fragmented research. Studies relevant to Ocean Architecture are distributed across architecture, Ocean Engineering, tourism studies, coastal planning, ocean governance, and ecology. This distribution has produced knowledge, but not yet disciplinary cohesion. As a result, research accumulates unevenly, and many issues, especially those concerning habitation and spatial quality, are repeatedly reinvented rather than systematically developed.

The third is the lack of standards. While offshore engineering and marine operations often possess mature technical codes, Ocean Architecture lacks architectural standards for floating dwellings, marine public buildings, underwater habitability, ecological integration, and lifecycle spatial performance. This makes evaluation difficult and weakens professional legitimacy.

The fourth is a shortage of talent. Few educational programs provide systematic training at the intersection of architecture and marine systems. Most practitioners therefore enter marine-related projects from only one side of the knowledge divide.

The fifth is the lack of textbooks and teaching resources. Without core textbooks, case databases, and methodological handbooks, the field cannot easily reproduce itself across institutions. This shortage also hinders the formation of common disciplinary language.

The sixth is weak integration between theory and practice. A considerable portion of available discourse is either highly

conceptual or strongly technical. What remains underdeveloped are demonstrative pilot projects, long-term post-occupancy evaluations, and prototype-based knowledge feedback capable of turning marine architectural experimentation into generalized disciplinary knowledge.

5.2 Optimization and Development Paths

To address these problems, Ocean Architecture needs a staged but coordinated development strategy.

First, interdisciplinary collaboration must be institutionalized rather than left to project contingencies. Permanent research platforms should connect architecture, naval architecture, Ocean Engineering, ecology, digital systems, coastal planning, and social sciences. The aim is not only collaboration but the production of common conceptual and evaluative frameworks.

Second, academic alliances should be strengthened. The International Alliance for Ocean Architecture (IAUOA) is especially important in this regard because disciplinary construction requires a networked rather than solitary institutional model. Alliances can organize shared terminology, thematic conferences, case archives, standard-setting dialogues, and international doctoral workshops.

Third, international cooperation is essential. Ocean Architecture addresses conditions that vary by hydrography, climate regime, legal framework, and maritime culture. Comparative work across deltas, island states, megacities, archipelagic communities, and offshore industrial regions can prevent the discipline from being shaped by a single geographic paradigm. It can also help distinguish universal principles from regional adaptations.

Fourth, textbook development and curriculum construction should be prioritized. The field needs introductory texts, thematic readers, design method handbooks, and typological atlases. Curriculum-wise, Ocean Architecture should include at least five teaching modules: marine environmental fundamentals, marine spatial planning and ecology, floating and amphibious design, offshore and underwater spatial systems, and digital marine architecture.

Fifth, experimental platforms are indispensable. Universities and research institutes should establish floating prototypes, coastal field laboratories, marine materials test stations, and design-build pilot programs. Experimental platforms are especially important because many questions in Ocean Architecture cannot be settled through abstraction alone. They require iterative testing under real marine conditions.

Sixth, industry-academia integration must be deepened. Collaboration with shipyards, coastal development agencies, marine technology firms, tourism operators, environmental organizations, and public authorities can support prototype realization, data acquisition, and professional standard formation. Industry collaboration should not subordinate the discipline to commercial logic; rather, it should ensure that research frameworks remain practice-relevant.

Seventh, standards and evaluation systems should be progressively developed. These should include not only structural and operational safety criteria, but also marine habitability, ecological compatibility, lifecycle adaptability, and public-service performance. The field will remain conceptually weak if its evaluative instruments are borrowed entirely from other disciplines.

In strategic terms, the development of Ocean Architecture should proceed through a dual path: conceptual consolidation and demonstrative experimentation. Conceptual consolidation gives the discipline its identity; demonstrative experimentation gives it institutional credibility and societal relevance.

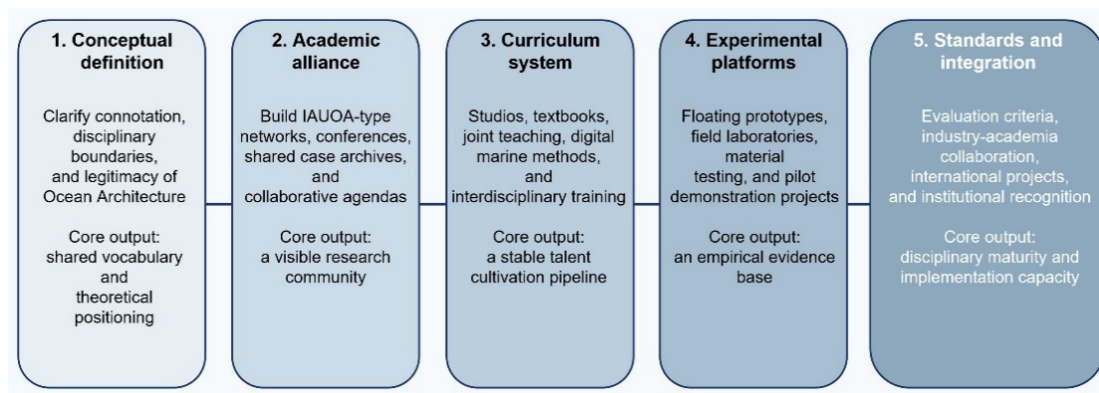


Figure 5. Disciplinary development path for Ocean Architecture

Note. Roadmap showing the interaction among theory building, academic alliance formation, curriculum design, experimental platforms, standards development, and industry-academia integration. Source: author-generated schematic.

6. Conclusions and Future Prospects

Ocean Architecture should be understood as an emerging interdisciplinary discipline concerned with marine spatial habitation and marine-built environments. Its rise is driven by converging pressures and opportunities: coastal urbanization, sea-level rise, the expansion of offshore infrastructures, renewed interest in floating and underwater spaces, and the inadequacy of purely terrestrial architectural assumptions in the age of land-sea integration. This paper has argued that the field possesses disciplinary legitimacy because its central object, the construction of habitable, meaningful, and ecologically informed space in marine environments, is not fully contained within architecture, Ocean Engineering, coastal science, or marine governance alone.

The main theoretical contribution of this paper is fourfold. It clarifies the core connotation of Ocean Architecture; it defines its boundaries in relation to neighboring disciplines; it proposes a disciplinary system composed of theoretical foundations, research objects, technical methods, practical applications, and talent cultivation; and it identifies the structural obstacles and development paths necessary for institutional maturation. In this sense, the paper aims not simply to describe a new research topic, but to help articulate the knowledge architecture of a new discipline.

Future research should move in at least five directions: typological taxonomy of marine-built environments; environmental and social performance evaluation; digital-twin-enabled lifecycle management; ecological design standards for marine architecture; and comparative studies across coastal, offshore, underwater, and deep-sea contexts. Equally important is the development of pilot projects and post-occupancy studies that can convert experimental marine environments into robust disciplinary evidence.

If architecture historically accompanied the making of terrestrial civilization, Ocean Architecture may become one of the disciplines through which future marine civilization is spatially articulated. Its task is not to romanticize expansion into the ocean, but to ensure that when marine space is built, it is built with ecological restraint, technological rigor, and genuine concern for human habitation.

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