BUOYANT ECOLOGIES FLOAT LAB

The Buoyant Ecologies Float Lab is a prototype for a new kind of resilient coastal architecture. It merges expertise from design, advanced composites manufacturing, and marine ecology to imagine a floating architecture of the future that can exist productively with its surrounding environment. The project has developed through a multi-year partnership between academia and industry that serves as a model for expanding architectural agency beyond architecture's traditional disciplinary limits. Central to the project is a belief that architects and architecture schools must begin to develop these kinds of extra-disciplinary capacities in order to address the pressing ecological challenges of our time.

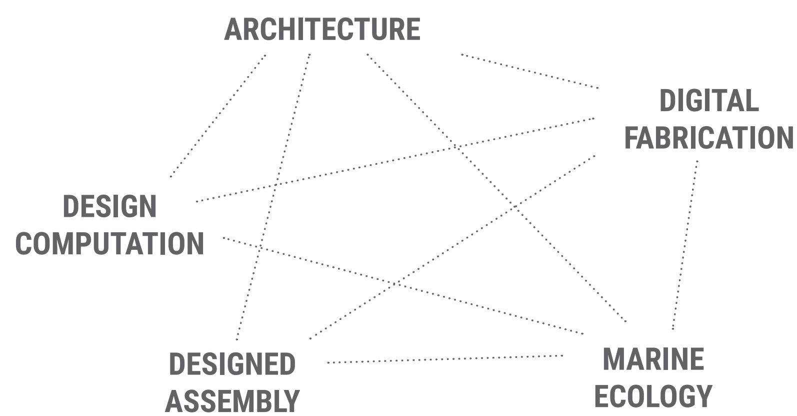
The project builds upon five years of applied research, prototyping, and monitoring led by the Architectural Ecologies Lab at California College of the Arts, and conducted by a collaborative team of architects, students, ecologists, and fiber-reinforced polymer (FRP) composites manufacturers. The Float Lab is a floating breakwater structure that incorporates a digitally fabricated, ecologically optimized FRP composite substrate with variable topographies that perform both above and below the water. The Float Lab was launched in Oakland, California in August 2019 for a three-year deployment to serve as both a public ecological demonstration project and a floating platform to further the research into ecologically productive substrates and floating breakwaters.

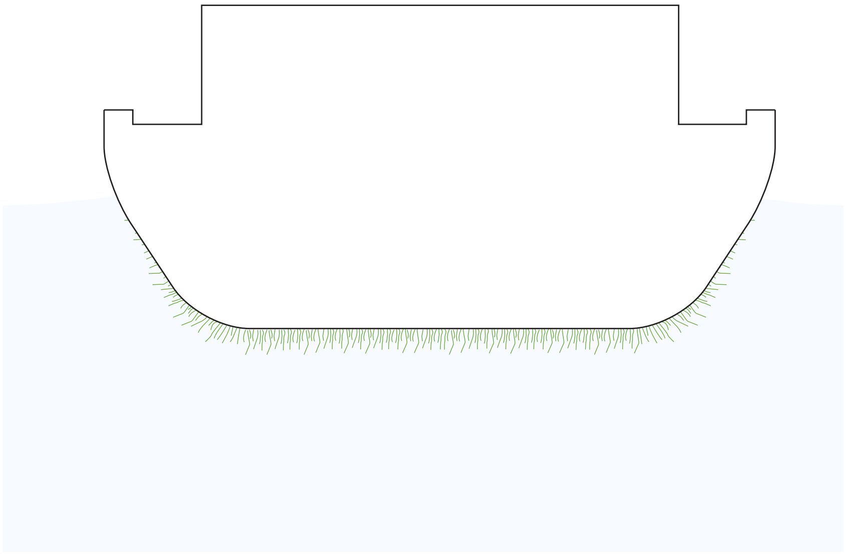





INTERDISCIPLINARY COLLABORATION

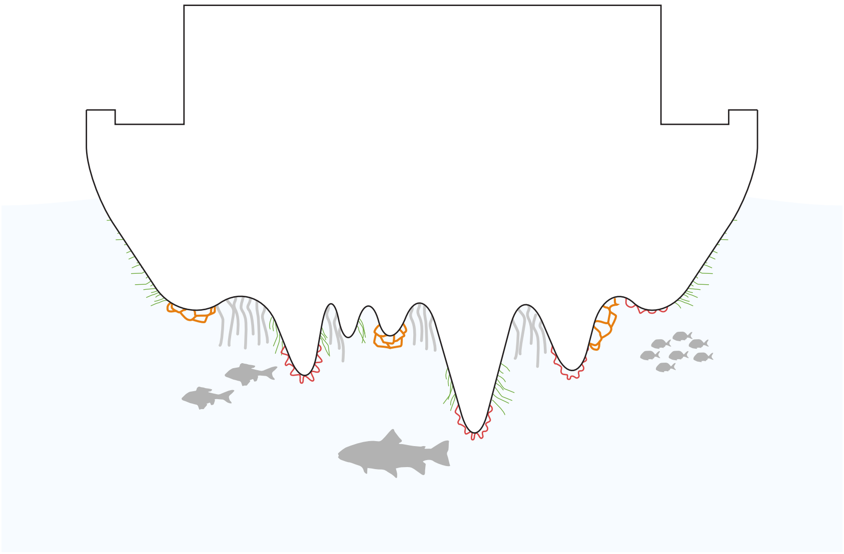
The project is a joint effort by faculty at the Architectural Ecologies Lab at California College of the Arts, marine ecologists at the Benthic Lab at Moss Landing Marine Laboratories, and fabricators at Kreysler & Associates. The collaborative structure allows for a process of iterative feedback between design ideas, scientific knowledge, and advanced digital fabrication techniques. The synthesis of these three areas of expertise provides a capacity for proof-of-concept that would be impossible without the contributions of each of the project partners.





FLAT BOAT BOTTOM

- Fouling communities are uniform and homogeneous, typically consisting of the most dominant invasive species.
- Fouling communities are often seen as a nuisance for boats and other waterfront structures, requiring regular cleaning and maintenance.



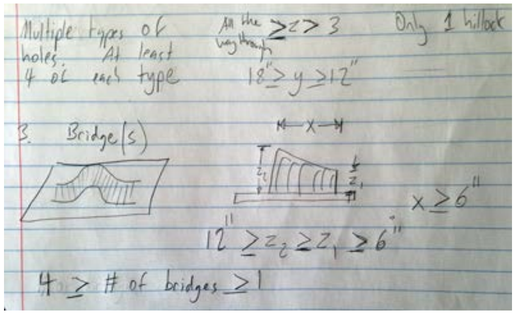
OPTIMIZED UPSIDE-DOWN BENTHOS

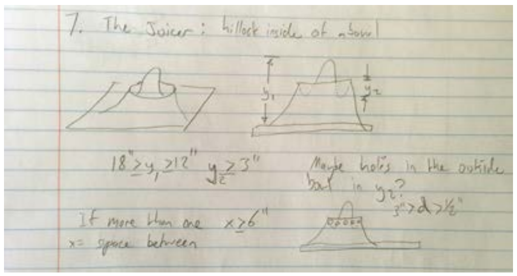
- Increased surface area provides more “real estate” for fouling communities to thrive.
- The fouling communities are more diverse, as smaller valleys provide refuge from predators for smaller species.
- Greater ecological diversity supports the food chain and enhances the broader ecosystem.
- Controlled growth of invertebrates perform as wave-attenuating “sponges,” reducing the effects of waves and coastal flooding.

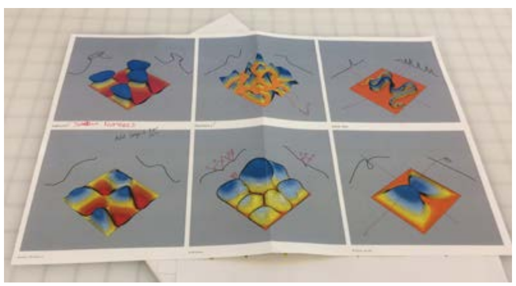
PREMISE: ECOLOGICALLY OPTIMIZED SUBSTRATE

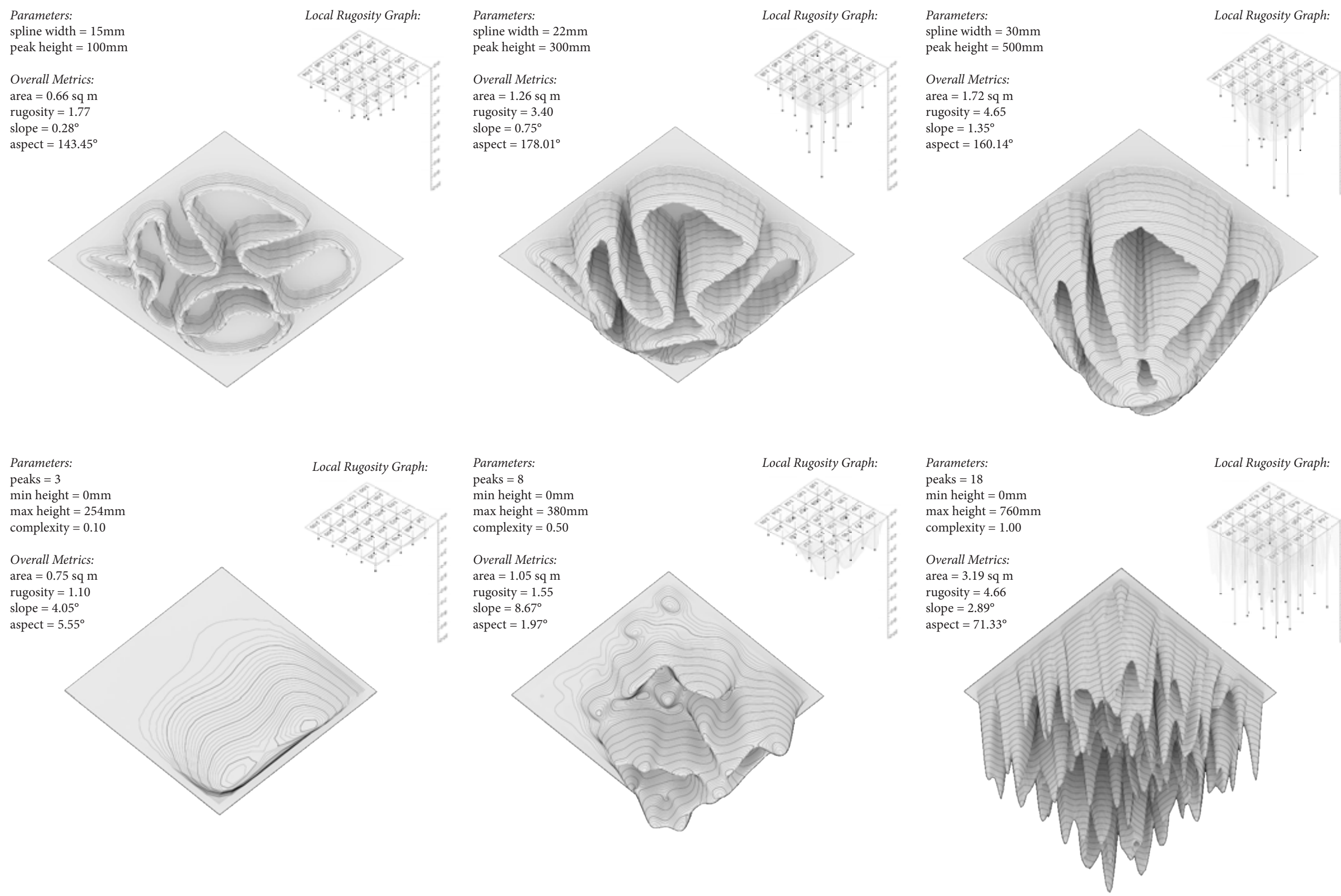
The research challenges conventional notions of “biofouling”—the unwanted accumulation of marine life on the underside of floating structures—and instead proposes controlled upside-down habitats for nonhuman animals as an ecological resource. Water flowing along this underwater landscape brings plankton and other nutrients into variably sized crevices and valleys, which protect smaller animals from larger predators. This helps to promote ecological diversity and support biological growth that in large quantities can help attenuate wave action. In this regard, ***the project explores how innovations at the micro scale of material substrates can initiate vectors of change that will have impacts at the macro scale of coastal ecology and resilience***.

Fouling on the underside of boats and other waterborne structures is unavoidable and typically seen as a nuisance.









OPTIMIZATION & PARAMETRIC DESIGN

The project utilizes advanced design computation workflows to integrate ecological criteria into digital, parametric models than can be used to iterate and simulate how the substrate will perform as a diverse marine habitat. Through monitoring and documenting the proof-of-concept prototypes, the marine ecology team members establish precise parameters such as shape, dimension, slope, and spacing that are input directly into a digital model that translates these constraints into optimized topographic landscapes.

PERFORMANCE-DRIVEN DIGITAL FABRICATION

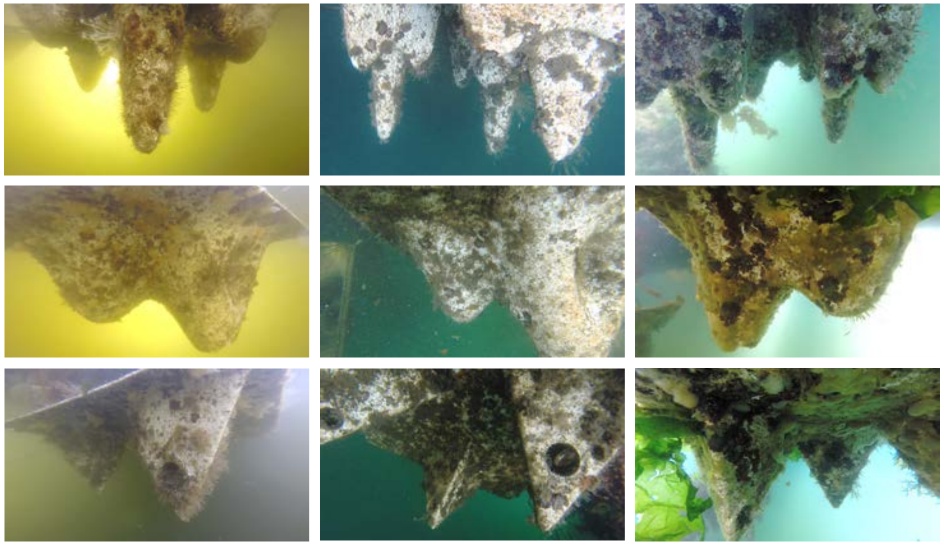
By utilizing computer numerically controlled (CNC) and robotic machines in the production of the ecological substrate, the project embraces file-to-factory workflows that are now common in architectural practice and industry. But it marries the paradigm of mass-customization with very precise performance-driven criteria derived from the ecological parameters of the optimized substrate. The project thus resists the more capricious and exuberant impulses that often inform contemporary approaches to digital fabrication in architecture, and instead insists on the use of computation to bridge ecological and material performance.

FIBER-REINFORCED POLYMER COMPOSITES

The material focus of this research is fiber-reinforced polymer (FRP) composites, commonly known as fiberglass. FRP is extremely durable and entirely resistant to corrosion, which explains its long history of use in maritime applications. The composite material is manufactured by applying layers of resin and glass fiber to molds and formwork. Project partner [name removed] is a global leader in FRP manufacturing, and their expertise with digital workflows and robotic fabrication enables a high degree of customization and surface variation without the added expenses often associated with this kind of work.

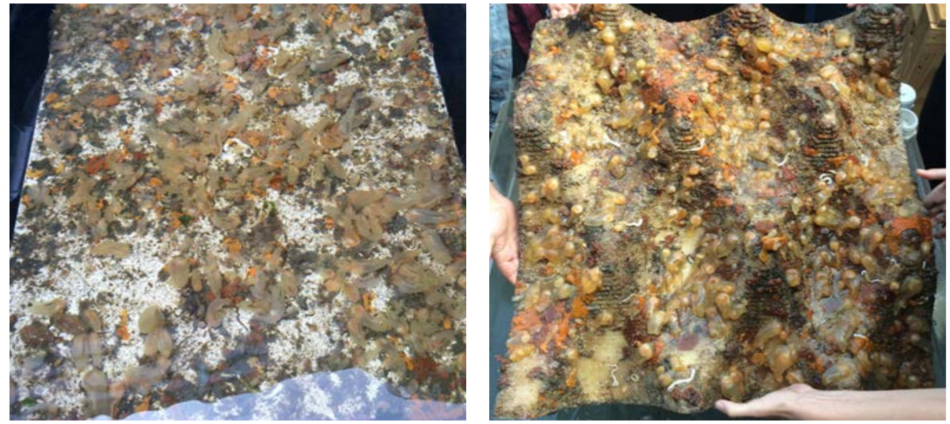
PROTOTYPING, TESTING, AND MONITORING

Since 2014, nearly two dozen full-scale FRP prototypes have been produced for testing and monitoring different surface geometry, slopes, and dimensional parameters for the "hillocks" and "valleys" along the substrate. The Benthic Lab team has installed duplicates of the prototypes in locations in Monterey Bay and San Francisco Bay to compare how the substrates perform in different environments.



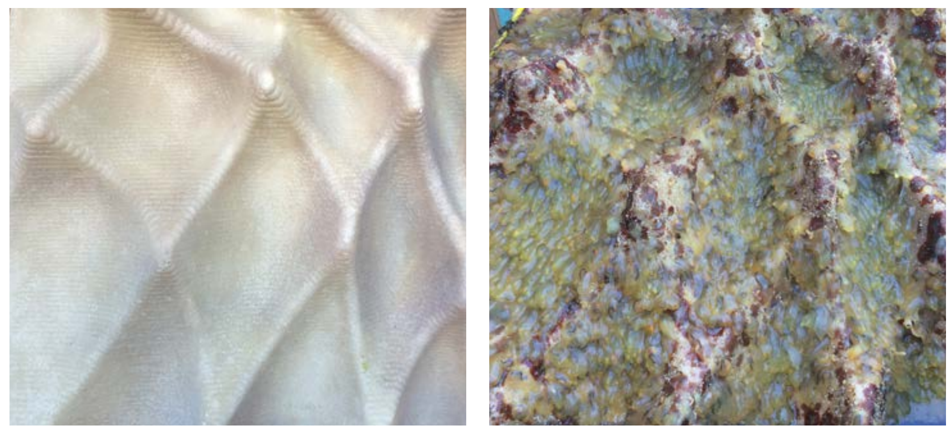
RECRUITMENT SUCCESS

Regular monitoring and observation has confirmed that the substrates perform remarkably well as upside-down habitats for a diverse range of invertebrate species, including bryozoans, tube worms, sponges, crabs, nudibranchs, tunicates, crustaceans, mollusks, and sea urchins.



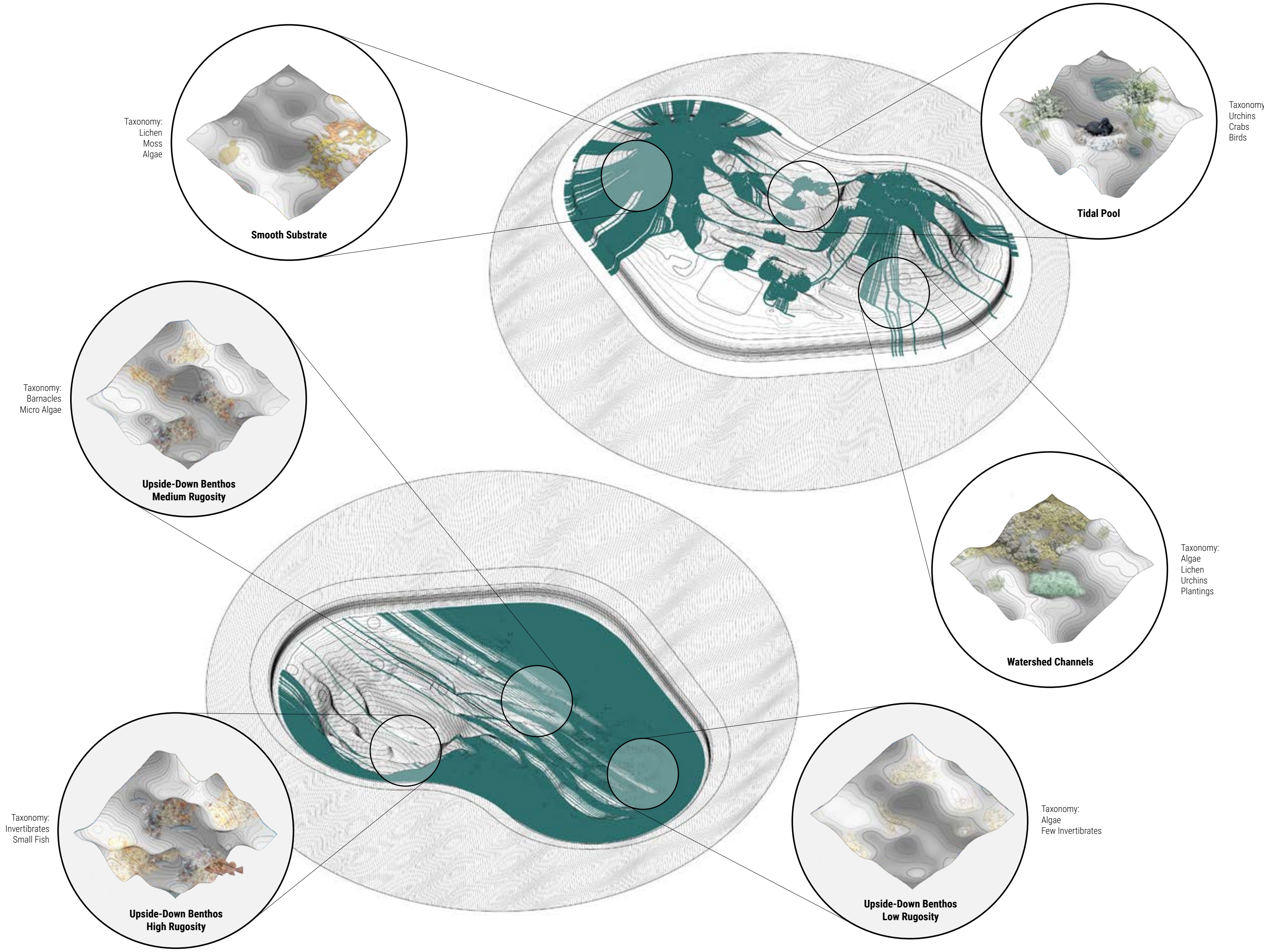
PROOF OF CONCEPT #1

Comparison of a flat control substrate (left) with one of the optimized substrate prototypes after installation underwater for 18 months (right) provides confirmation of a correlation between surface area and density of settlement patterns. The optimized substrate contains denser communities of invertebrates, which are arrayed in gradients according to the substrate's variable topography.



PROOF OF CONCEPT #2

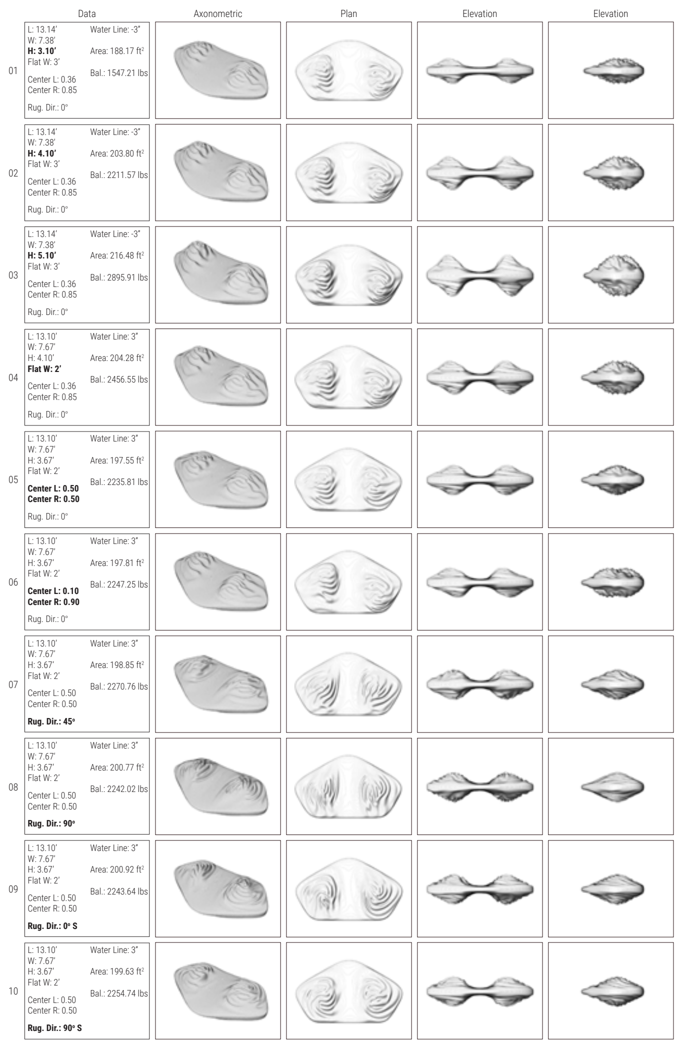
Comparison of ecological substrate prototype before underwater installation (left) with the same prototype after 12 weeks installed underwater in Monterey Bay (right) reveals that variable topographies can yield variable settlement patterns of marine invertebrates.



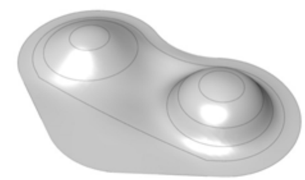
SCALING UP: ECOLOGICAL PERFORMANCE, ABOVE AND BELOW

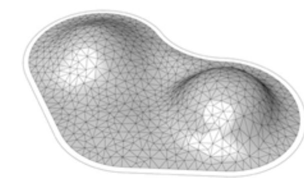
Building upon the successes of the initial prototypes, the Float Lab scales up the research and incorporates the ecological substrate with variable topographies that perform both above and below the water. Underwater, the hull geometry varies to provide a range of scales of habitat and test the optimization logics across a larger surface. On the top, the topography is engineered to channel rainwater and produce watershed pools for intertidal or terrestrial habitats.

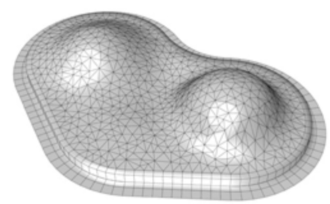
Float Lab Massing Iterations

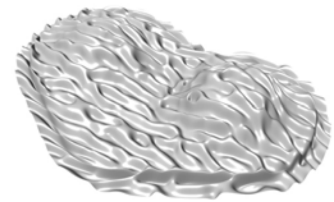


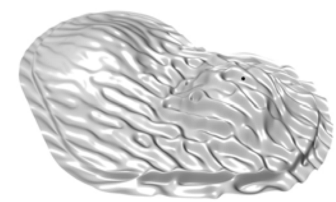

Primary control curves

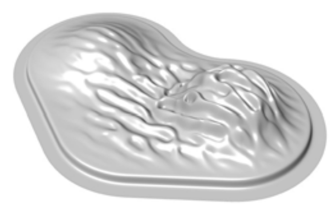

Initial surface


Enhanced resolution


Perimeter flange extension


Mapping of ecological habitat geometry


Global gradient across length

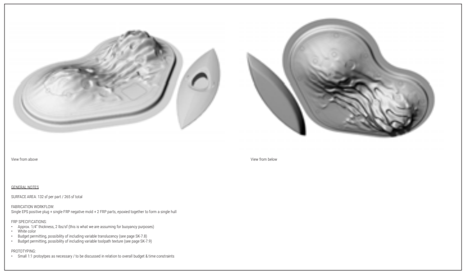
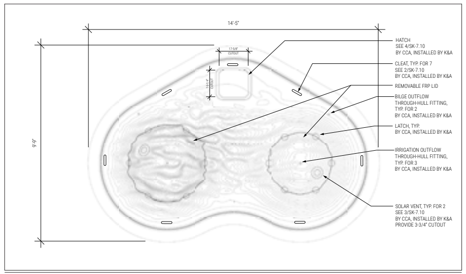
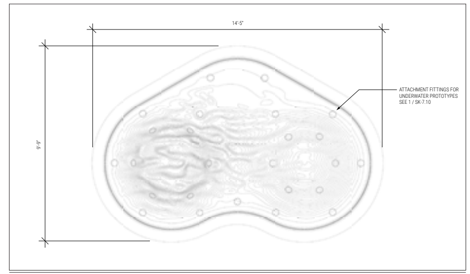
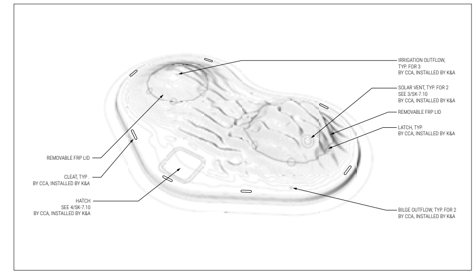
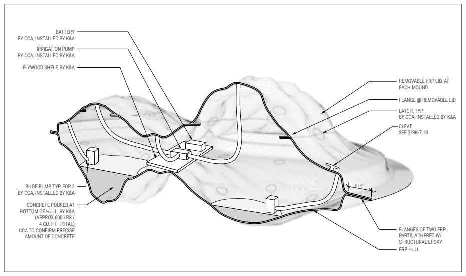
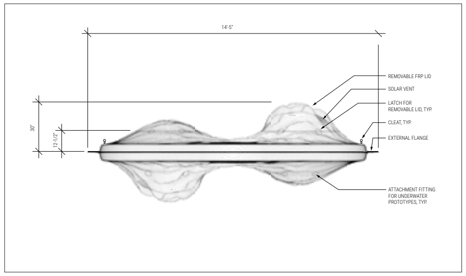
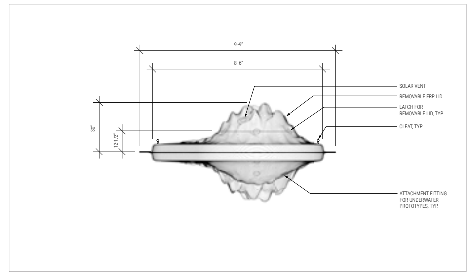
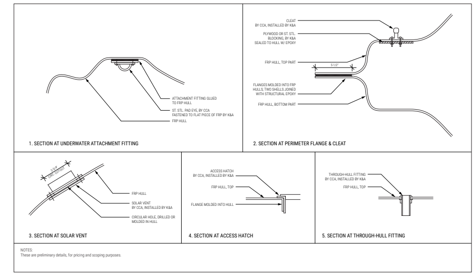
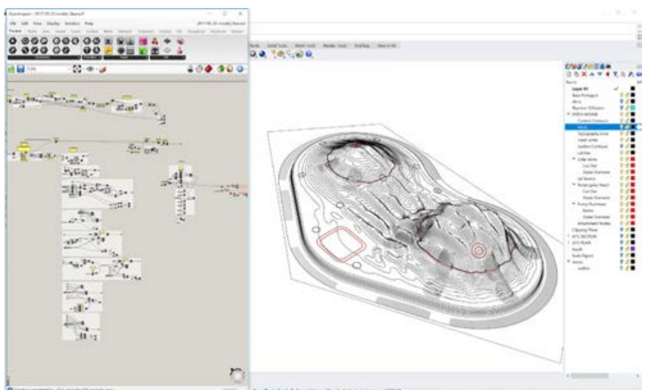
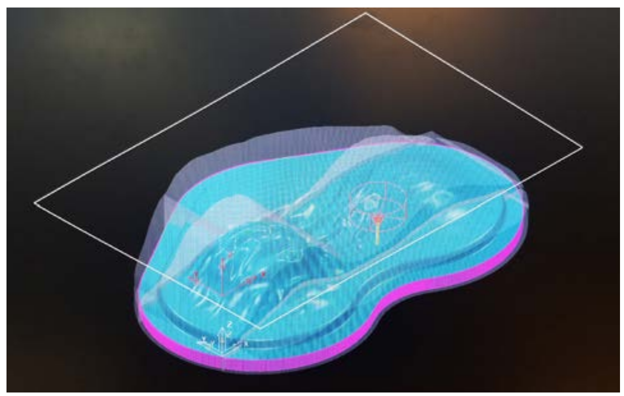

Gradient at perimeter


Pattern adjustment to infrastructure


Float Lab

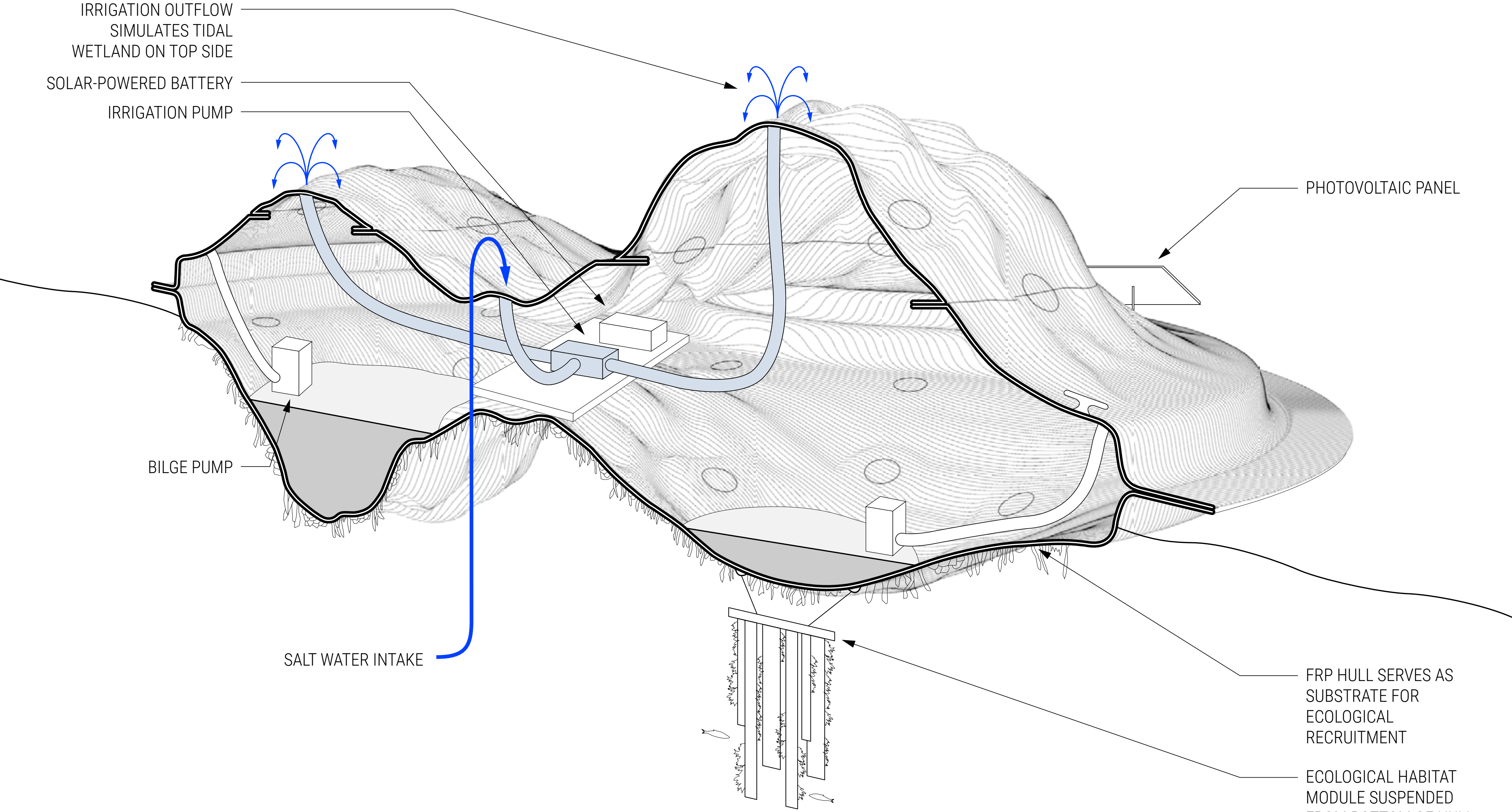
INTEGRATED PARAMETRIC MODEL

The project was designed entirely within a parametric framework, which allowed for the precise calibration of form and geometry to both the localized *rugosity*, or surface variation, and quantitative metrics like displacement volume and weight, which are crucial for calculating buoyancy and determining the amount of required ballast. This approach enabled iterative workflows, allowing the team to quickly test and evaluate design options. The sequence of diagrams at right explain the evolutionary process from initial control curves to final prototype form.

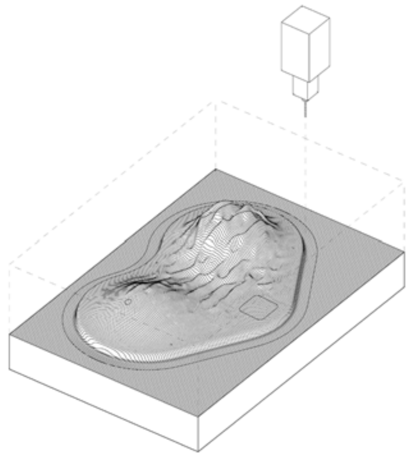

CONSTRUCTION DRAWINGS & DIGITAL TRANSLATION OF DATA

A condensed set of construction drawings was produced primarily for reference purposes, as all fabrication and assembly information was translated via digital model. The seamless translation from Rhino/Grasshopper to PowerMill toolpathing software eliminated the shop drawing process altogether, dramatically streamlining the transition from design to production.

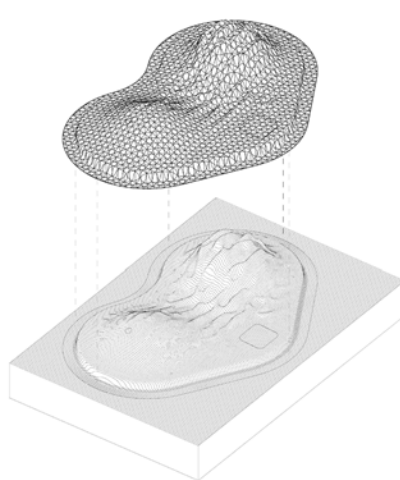


LONGITUDINAL SECTION

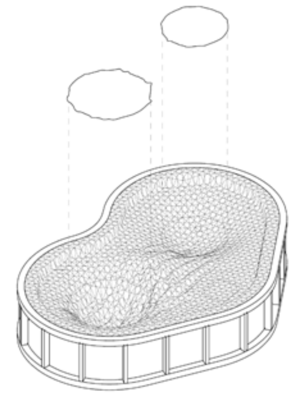
The section through the Float Lab shows its basic structural logic and integration of systems. The vessel's interior includes ballast, solar powered low-voltage electrical system, bilge pumps, and a small irrigation system to circulate salt water to create tidal pools on the top side. On the underside, attachment fittings allow for the suspension of ecological substrate modules to recruit additional marine organisms and provide wave attenuation capacity. Although the interior of this prototype is not designed to be occupiable by people, the form and structural logics are scalable and begin to suggest what an ecologically productive floating architecture could look like.



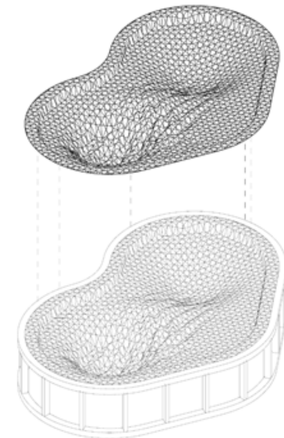
1. POSITIVE FORM
A robotically controlled router carves the positive form of the Float Lab hull from a block of EPS foam. Integrated file-to-factory workflows ensure precise translation of optimized geometry.



2. FABRICATE REUSABLE MOLD
Fiber-reinforced polymer (FRP) is applied over the positive to create a negative, reusable fiberglass mold to be used for fabrication of the hull.



3. NEGATIVE MOLD
The FRP negative is mounted to a support frame. Foam knockouts are added as needed for hull penetrations, such as the hatch and solar vent.



4. FABRICATE FLOAT LAB HULL
FRP is applied in the negative mold to produce the hull's two identical parts, which are then adhered together with resin. This process can be repeated to produced additional Float Lab modules.

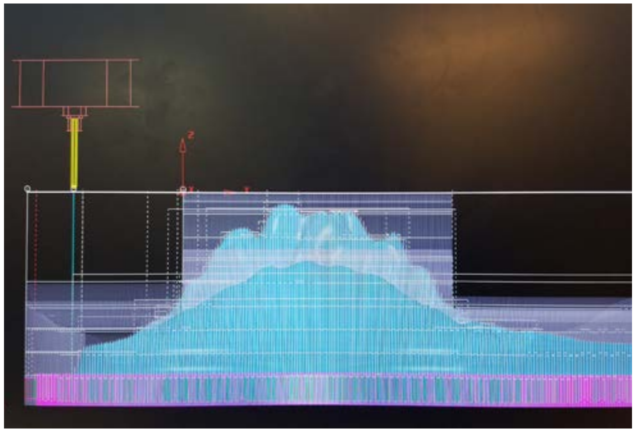
Clustered Aggregation

Hexagonal Aggregation I

Hexagonal Aggregation II

FABRICATION STRATEGY & MODULAR LOGIC

Embedded within the Float Lab's design and fabrication process is a modular logic that anticipates future deployment at a greater scale. The pentagonal plan geometry allows for a variety of configurations that can accommodate networked archipelagos of wave-attenuating floating breakwaters that help limit coastal erosion. When scaled up, the aggregations also allow for a buoyant urbanism of floating communal habitats. The reliance on reusable molds to mass-produce the FRP composite components provides an economy of scale and material.





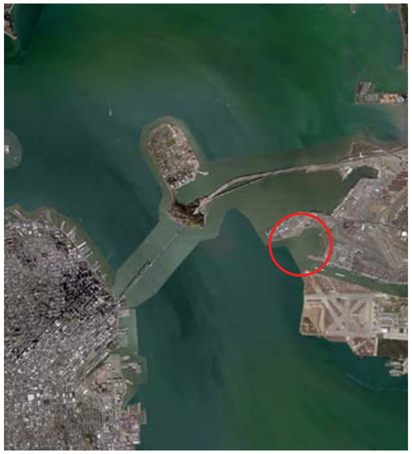


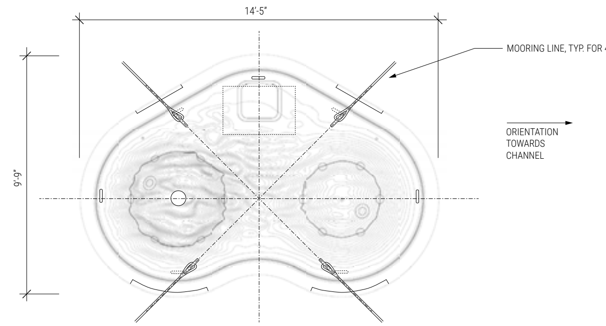
FABRICATION PROCESS

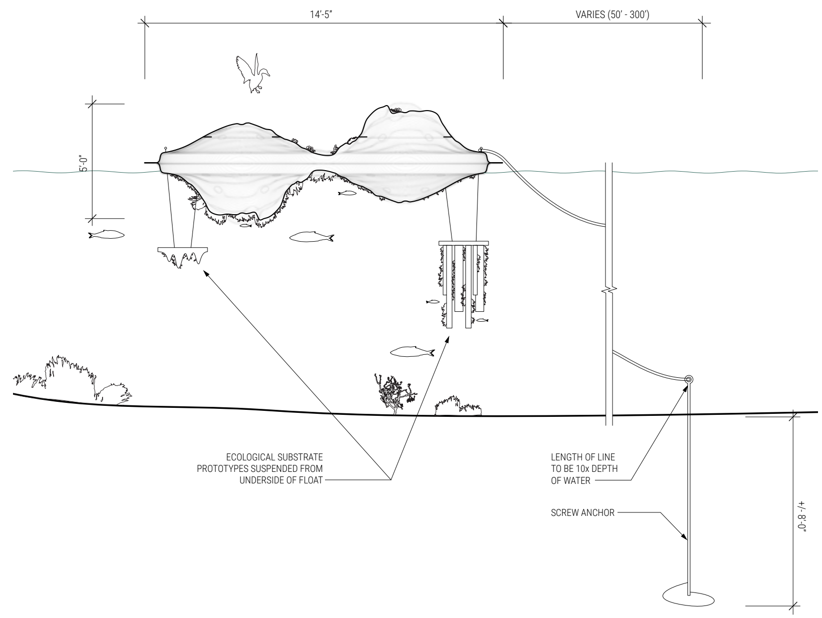
Much of FRP manufacturing relies on single-use, one-off EPS molds, resulting in a significant amount of material waste. With economies of scale and material in mind, the Float Lab was designed to be symmetrical about its horizontal axis such that it could be fabricated from two identical parts using a single, reusable mold. To make this mold, a single expanded polystyrene (EPS) foam positive was milled with a robotic router. This positive plug was used to produce a single FRP negative mold, which was then used to fabricate the two parts that constitute the Float Lab. The negative mold can be reused in the future to create additional floating breakwater modules.

DEPLOYABLE PROTOTYPE

The Float Lab is bean-shaped in plan, roughly the size of a small automobile, which allows it to be transported and deployed with relative ease. The vessel consists of two identical parts that form the top and bottom, like a clamshell. The geometry incorporates surface variation at two different scales. First, two larger “mountains” create a valley in the center of the structure, and second, the finer grain of surface rugosity is distributed across hull.







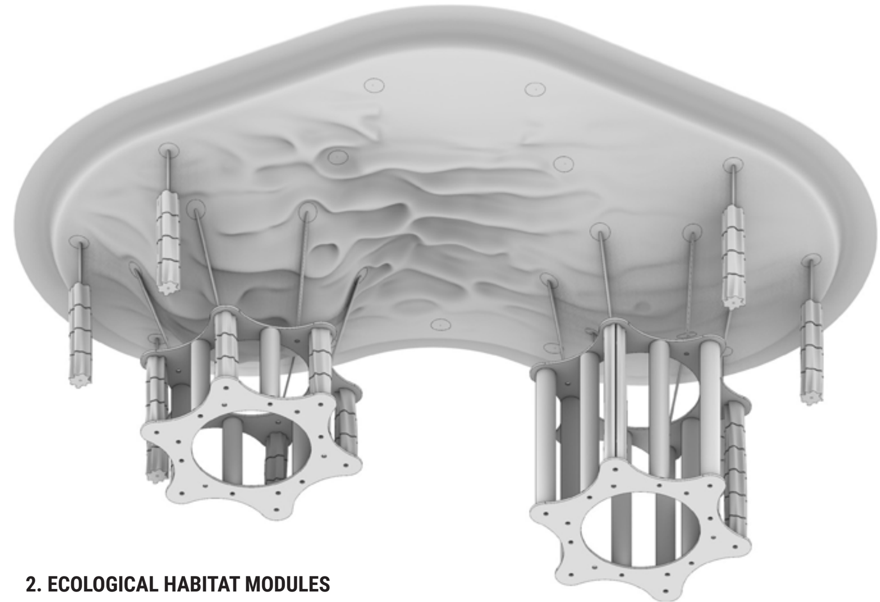
PERMITTING AND DEPLOYMENT, AUGUST 2019

The Float Lab received permits from both the state San Francisco Bay Conservation and Development Commission and the federal U.S. Army Corps of Engineers for deployment in the harbor of Oakland, California in August, 2019. The site is Middle Harbor Shoreline Park, a public recreational area developed by the Port of Oakland as an ecological education resource for the adjacent neighborhood of West Oakland. The deployed Float Lab supports ecological habitat modules to continue the development of the wave-attenuation substrates, and it will also serve as a public demonstration project for the park, where it will interface with public education and outreach efforts with schoolchildren from Oakland Unified School District. **This is the first project of its kind to permitted by both state and federal authorities for deployment in San Francisco Bay.**


CCA ARCHITECTURE / ARCHITECTURAL ECOLOGIES LAB

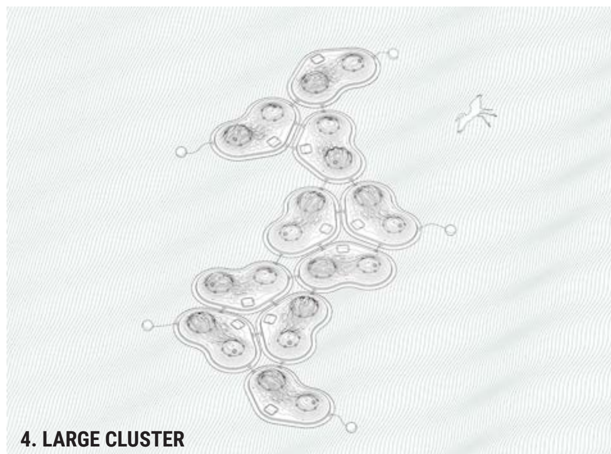

CCA ARCHITECTURE / ARCHITECTURAL ECOLOGIES LAB

1. ECOLOGICAL SUBSTRATE

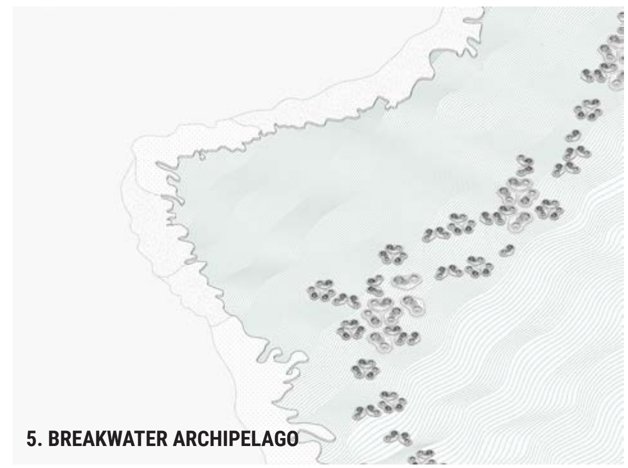


2. ECOLOGICAL HABITAT MODULES

3. SMALL CLUSTER



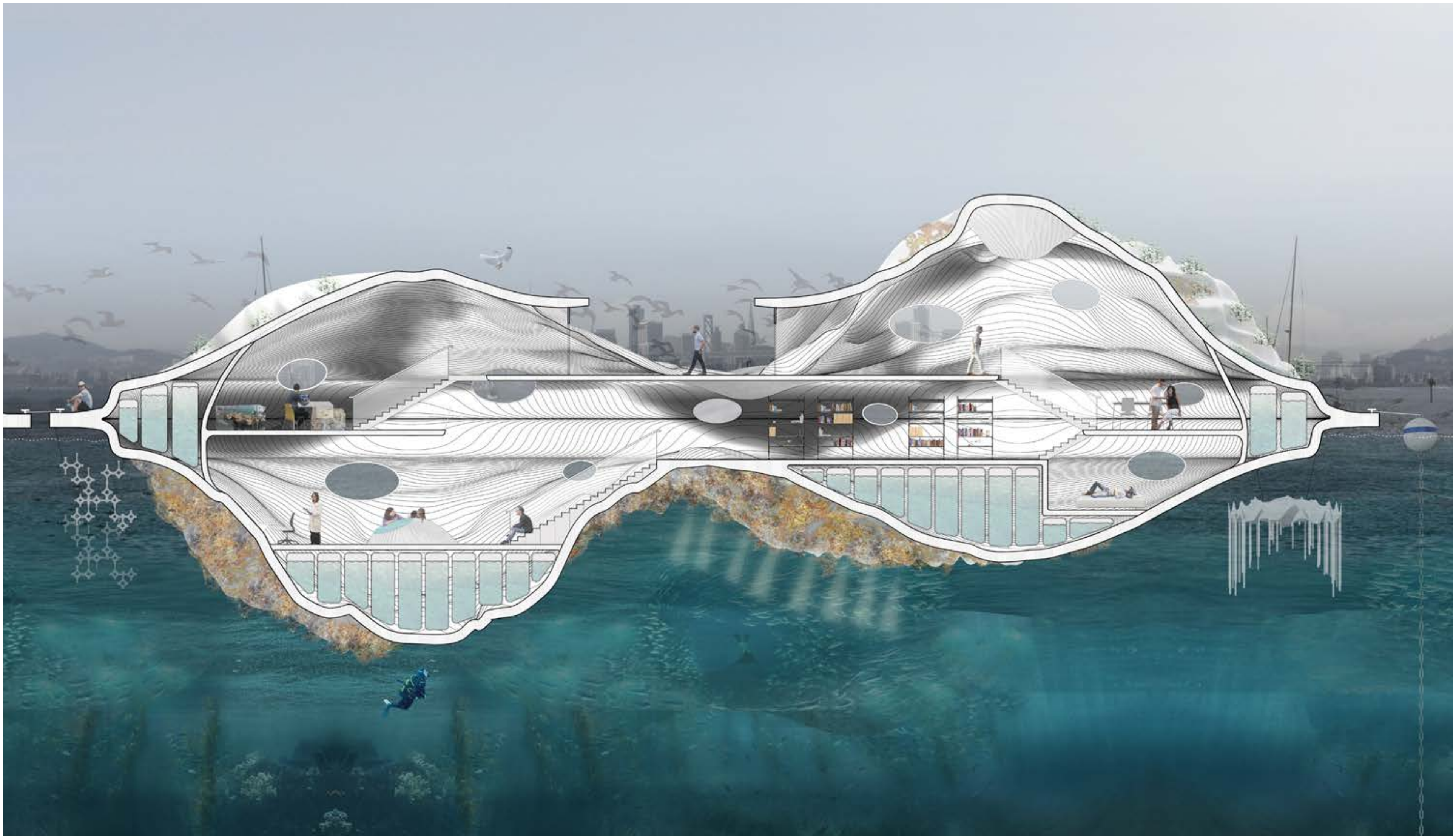
4. LARGE CLUSTER



5. BREAKWATER ARCHIPELAGO

SPECULATIVE FUTURES: FLOATING BREAKWATERS

These drawings project forward into the future and imagine a larger-scale deployment of floating breakwaters as a means to reduce coastal erosion and the impacts of sea level rise on shorelines. The necklace of buoyant wave-attenuating structures offers an adaptable and reconfigurable alternative to the more conventional fixed and permanent typologies of seawalls and barriers that many cities currently look to as models for coastal resilience.



SPECULATIVE FUTURES: FLOATING ARCHITECTURE

Although grounded in empirical, scientific research, the project also embraces more visionary aspirations for a floating architecture of the future predicated on mutually beneficial coexistence between humans and nonhumans. This speculative section begins to imagine how the Float Lab can scale up to inhabitable, multifunctional, self-sufficient floating structures that provide habitats for humans and animals. The ambition is to instigate new models for a whole-system concept of human habitation, nonhuman habitation, as well as ecological resilience in anticipation of the impacts of climate change and sea-level rise.