LANVIA

FLOATING COMMUNITY GARDEN

SDES 439 / 739 BIOMIMICRY METHODOLOGY
PROFESSOR SCOTT BOYLSTON
SPRING 2019

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DESIGN TEAM

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BIOLOGIST AT THE DESIGN TABLE

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Masters of Education, Science
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Founding Chair
Gray's Reef National Marine
Sanctuary

We were fortunate to have a highly experienced biologist at the design table, guiding our reconnection with nature, answering our many questions about functions, and providing valuable feedback on our designs. Cathy has worked for NOAA as a Scientific Diver, Aquanaut, and submersible pilot. She also was Education Coordinator for the organization she co-found: Gray's Reef National Marine Sanctuary. Today, she continues her ecological work the city to advocate for dune habitat restoration on Tybee Island among many other affiliations, including the Ocean Exchange, that she also co-founded.

Photo credits:: Lara Isaacson

METHODOLOGY

Photo credit: Government of Western Australia

METHODOLOGY

BIOLOGY TO DESIGN

Implementing Biomimicry 3.8's model of *Biology to Design*, we started with a reconnection to nature, discovering 'nature's genius' in the 3.8 billion year old resulting adaptations that create functions and strategies we see in organisms today. As opposed to the *Challenge to Biology model*, we did not start with a problem to solve, but rather inspiration from nature that led to a human context which nature could lend its expertise. Through multiple field studies in the Savannah, GA area led by our Biomimicry instructor: Professor Scott Boylston and our biologist at the design table: Cathy J. Sakas, we cleared our minds of preconceived notions about what we wanted to design and let ourselves be inspired. We looked at a number of others before settling on one to emulate. To see those organisms, see the appendix.

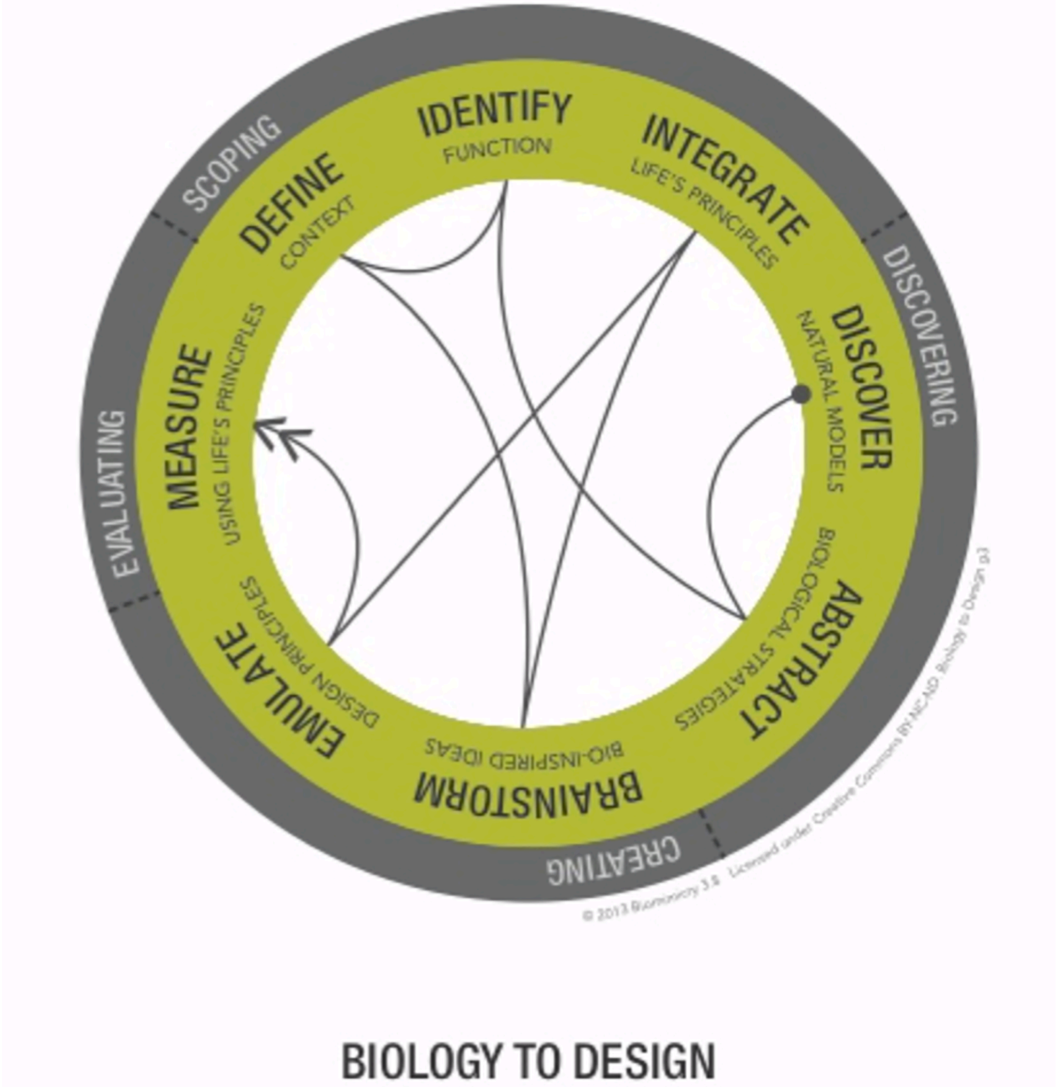


Photo credit: Biomimicry 3.8

FIELD STUDIES

WASSAW ISLAND

We took a trip with our instructor, Scott and our biologist at the design table, Cathy to Wassaw Island, a National Wildlife Refuge that is only accessible by boat. While there, we learning about how rising tides were causing the island to migrate. The migration revealed layer of muddy clay that used to be under the island on the shore. The salt water invasion also killed many trees, leaving them to bleach in the sun, like a ‘bone yard.’ While doing an iSite, we were fascinated by water marks left in the sand and the encroachment on the marshes. This field trip lead us to think about Sea Level Rise as a possible context for our project.

Photo credit:: Lara Isaacson

LAKE MAYER iSITE

Some group mates did an iSIte at Lake Mayer, a human-made lake in southern Savannah that hosts many birds who have been drawn the fresh water and numerous native and landscaped plants. While there, the group noticed a small creek running off the lake, on this river there was a floating plant, stretching out in to the water from the shore. The water was dark and slow moving and the plant bright green. After some digging, the plant was identified as Giant Salvinia which would become the model organism for the project. Later, another group mate found Salvinia at Savannah Wildlife Refuge, further inspiring us with its resiliency.

Photo credit:: Olivia Vargas

MODEL ORGANISM

Photo credit: invasive.org

GIANT SALVINIA

SALVINIA MOLESTA

A free-floating aquatic fern

Photo credit: Texas Monthly

GEOGRAPHIC REGION

Giant Salvinia is native to Southeast Brazil and Northern Argentina

Invasive across the Southern U.S.

Photo credit: Georgia Department of Natural Resources

Photo credit: Virginia Invasive Species

HABITAT

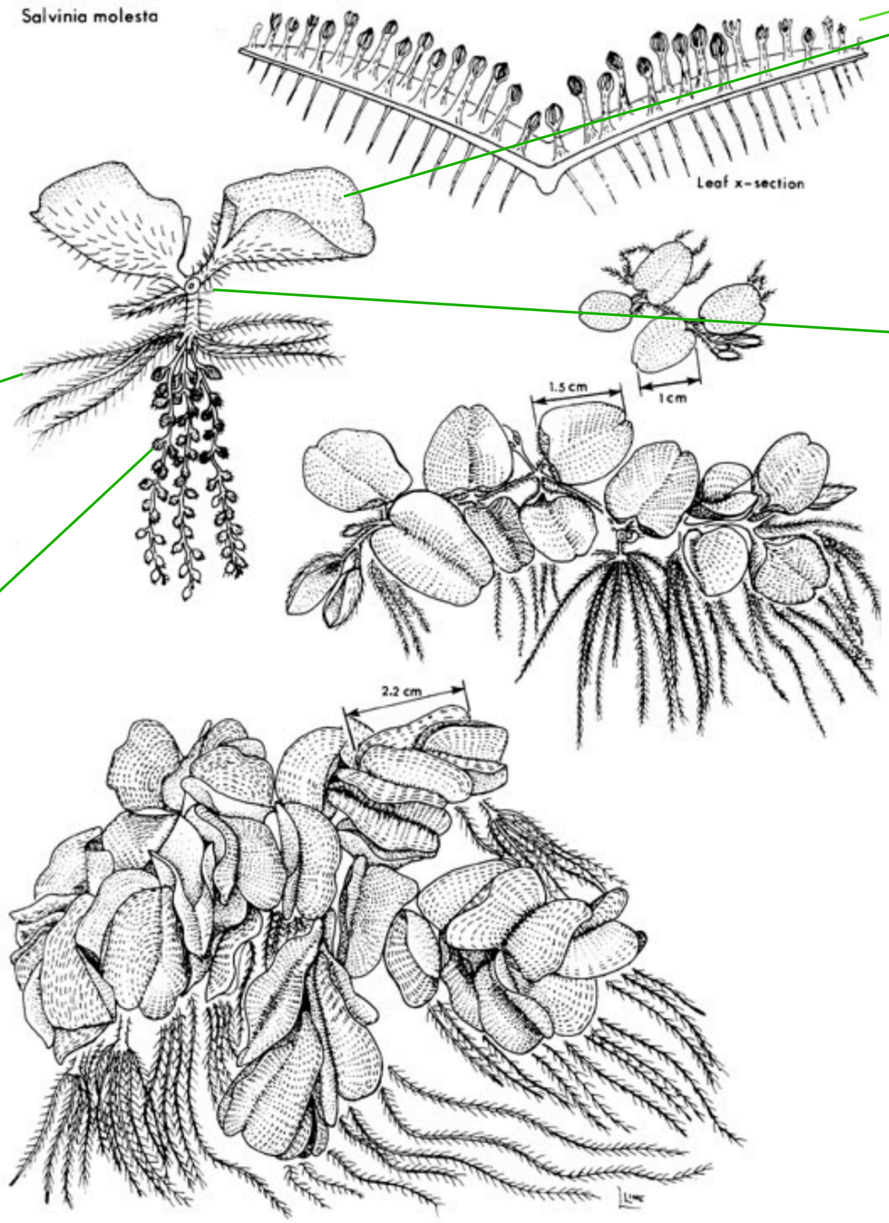
Still or slow moving fresh water

Dark (nutrient rich) waters

Warmer climate (no ice)

Photo credit: Mediad Public Broadcasting

PLANT PARTS



Leaf Hairs
(coated in hydrophobic wax except at tip)

Bud for Reproduction

Underwater Fronds
(leaves or Pseudo-roots)

Sporocarps
(typically sterile)

Photo credit: Texas A&M Aqualife Extension

MODEL ORGANISM

GIANT SALVINIA

As we began to abstract Salvina's functions, we looked to the Biomimicry Taxonomy for common functions and purposes found in Nature.

First, Salvinia is free floating (meaning it does not need to attach to soil or shore). This gave up the Group: move of stay put, Sub-Group: move, Function: on liquids. In other words, Salvinia floats to move on liquids.

Next Salvinia reproduces quickly an easily through asexual reproduction, leading us to the Group: make, Sub-Group: reproduce and Function: self-replicate. Salvinia Reproduces by self-replicating.

Salvinia's fast growth creates dense mats that suffocate plants below the surface, leading us to the Group: maintain community, Sub-Group: cooperate and compete, and Function: between different species. Salvinia's quick growth allows it to compete against other species.

Additionally, Salvinia has evolved cage-like leaf hairs that allow it to float even if submerged, leading us to the Group: modify, Sub-Group: adapt/optimize, and Function: buoyancy. Salvinia adapted to remain buoyant in changing conditions.

Salvinia also has pseudo roots for absorbing nutrients leading us to the Group: Get, Store, or Distribute Resources, Sub-Group: capture, absorb, or filter, and Function: chemical entities. In other words, Salvinia's pseudo-roots capture chemical entities.

After looking at all these functions separately, we started to see them are two main functions: invasive strategies for survival and free-floating or remaining location general for adaptability.

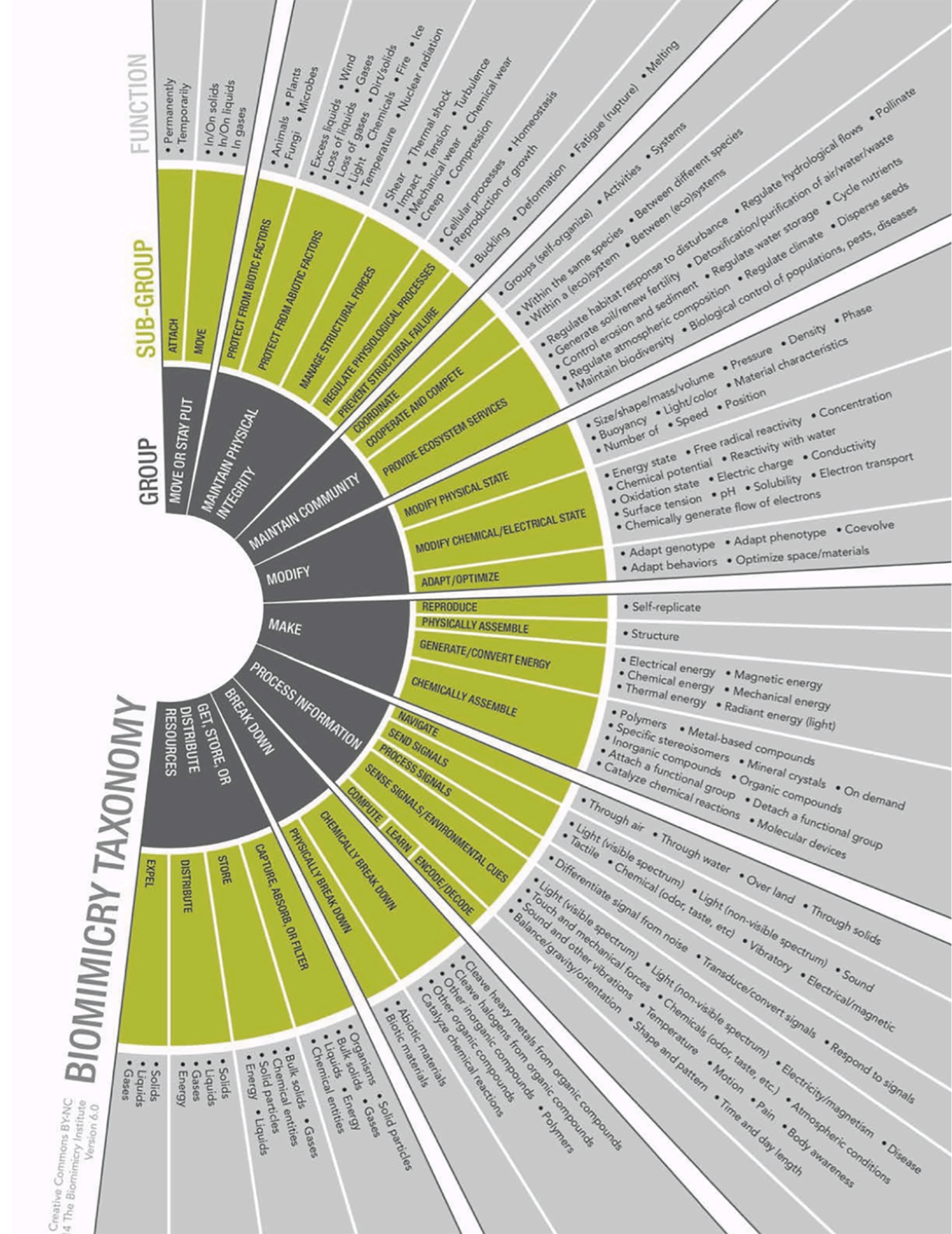


Photo credit: Biomimicry 3.8

Photo credit: Plant Sam

STRATEGY 1: RAPIDLY REGENERATING

(Asexuality, Mats, & Pseudo-roots)

MECHANISM

Salvinia is invasive all across the Southern US. How does it do so well? Over time, Salvinia adapted to reproduce asexually and without need for true roots. The plant can then float throughout bodies of water to find new food sources. The plant can grow quickly to create dense mats that out-complete organisms below the surface.

STRATEGY

Floating and reproducing quickly without partners in order to disperse and collect food easily

DESIGN PRINCIPLE

Fitting into various locations and being easy to assemble to allow for moving where resources are available

FUNCTION

Living partially submerged in a fluid to allow for easy relocation and nutrient collection and self-replication for resilience

ABSTRACTION

With our project we will be mimicking Giant Salvinia's process of fitting into various locations, collecting nutrients from water with native floating plants, and reproducing quickly with a simple, easily replicable design.

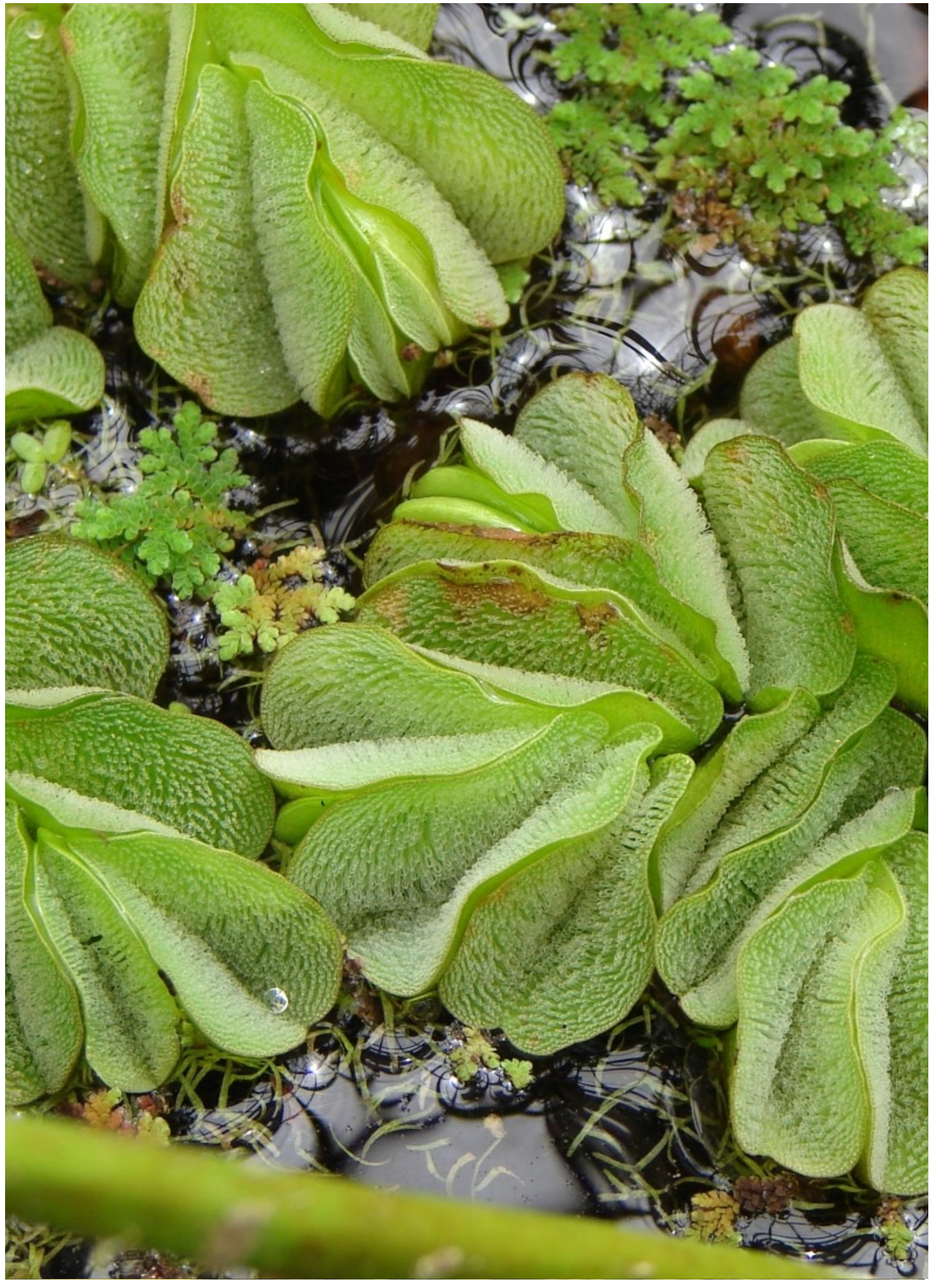


Photo credit: Invasive.org

STRATEGY 2: FLOTATION

(Leaf Hairs & Pseudo-roots)

MECHANISM

Salvinia relies on the water it lives in for nutrients, and so it floats (untethered by proper roots to find those nutrients in dark waters. Salvinia has also evolved egg-beater shaped hairs on its leaves to trap air bubbles should the leaf get submerged, allowing the plants to remain buoyant. The hairs are covered in a hydrophobic wax everywhere except the tip (which is hydrophilic) to 'pin' the water above but not on the leaf surface (trapping air).

STRATEGY

Holding air bubbles while underwater and floating freely

DESIGN PRINCIPLE

Structuring and coating to create bubbles of gas in fluid and remaining location general

FUNCTION

Tiny cage shaped, moisture wicking structures trap gases to maintain flotation in fluid and collecting nutrients from fluid not soil

ABSTRACTION

With our project we will be mimicking Giant Salvinia’s form that traps air to stay afloat and stationing the project on water.

SIMILAR FUNCTIONS

In an attempt to find from deep principles, further inspiration, and understand Salvinia's function better, we looked at other organisms that shared similar functions: we looked at other plants that are invasive in the US and other organisms that float.

ADDITIONAL FUNCTION CARDS: RAPID REGENERATION

HAIRY CRAB GRASS

Digitaria sanguinalis

Photo credit: Katy Chayka

Photo credit: SmartPicvids on YouTube

MECHANISM

Hairy Crab Grass forms dense mats with runners in many directions. It can re-root from portions of lower stems, making it difficult to remove. It can also reproduce from seed and sprouts quickly.

REGION

Invasive across the U.S.

STRATEGIES

Reproducing quickly through seeds and regrowing from stem parts.

DESIGN PRINCIPLES

Reproduce work quickly and remain location flexible.

FUNCTIONS

Multiplying quickly to control an area

ADDITIONAL FUNCTION CARDS: RAPID REGENERATION

BLUE GUM EUCALYPTUS TREE

Eucalyptus globulus

Photo credit: Gardens Online

Photo credit: CalPoly

MECHANISM

The Blue Gum Eucalyptus Tree was originally brought in to make rot-resistant railroad ties and furniture. Adjacent California native species have difficulty competing with the Blue Gum 25 ft per season growth when it is young. There is also a chemical in their leaves that prevents species from growing underneath it.

REGION

Native to Tasmania
Invasive in California

STRATEGIES

Handicap competing plants with leaf toxins and grow quickly to shade out competition

DESIGN PRINCIPLES

Getting there first is a big advantage to setting up shop

FUNCTIONS

Quickly lengthening allows for more access to light and giving off toxic substances to ward away competition

ADDITIONAL FUNCTION CARDS: FLOTATION

MOSQUITO

There are hundreds of species

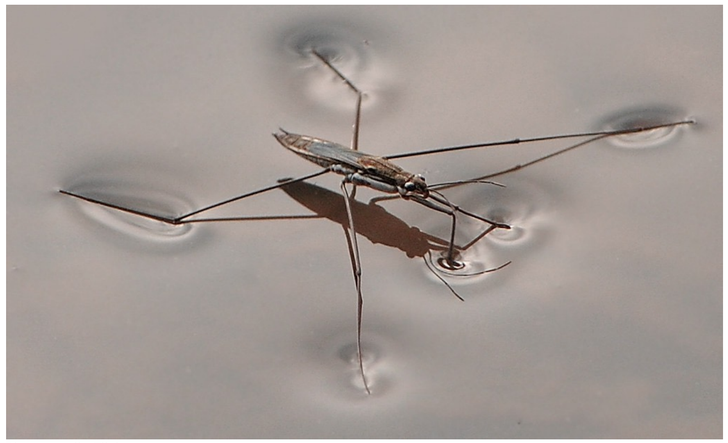


Photo credit: Flickr

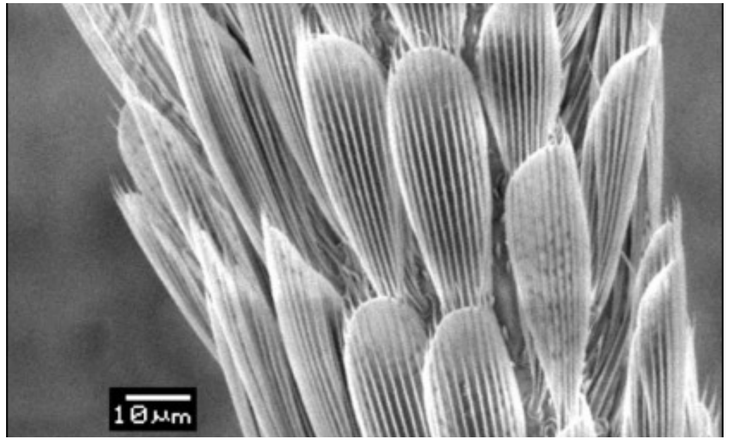


Photo credit: Ask Nature

MECHANISM

Mosquitos have microscopic scales on their legs. They are hairy which help then walk on land and walls, but on water the scales trap tiny pockets of air that allow the mosquito to float on water.

REGION

All over the world

STRATEGIES

Using air pockets to float/walk on water

DESIGN PRINCIPLES

Small air pockets assist in flotation when over a large surface area

FUNCTIONS

Small conjoined and consecutive plates trap gas between a fluid surface and the plates allowing for buoyancy

ADDITIONAL FUNCTION CARDS: FLOATATION

BEAKED SEDGE

Carex rostrata

Photo credit: FreeNatureImages.eu

Photo credit: Ask Nature

MECHANISM

Beaked Sedge can grow out of dense mats of rhizomes, allowing it to float even in times of flood and reroot elsewhere.

REGION

Northern North America (U.S. and Canada)

STRATEGIES

Forming root-like mats to use as a raft

DESIGN PRINCIPLES

Tightly woven strings sit on water to create buoyancy

FUNCTIONS

Entangled stringy appendages create more surface area on fluid to stay afloat

LESSONS FROM SIMILAR FUNCTIONING ORGANISMS

Photo credit: CalPoly

Invasive plants usually have little or no natural predators (and they stamp out competition), but they also usually reproduce quickly and grow quickly. There is resilience in numbers.

Our project will:

Have easy to build and repair design

Have multiple units and many types of plants to increase resiliency

Emulate process

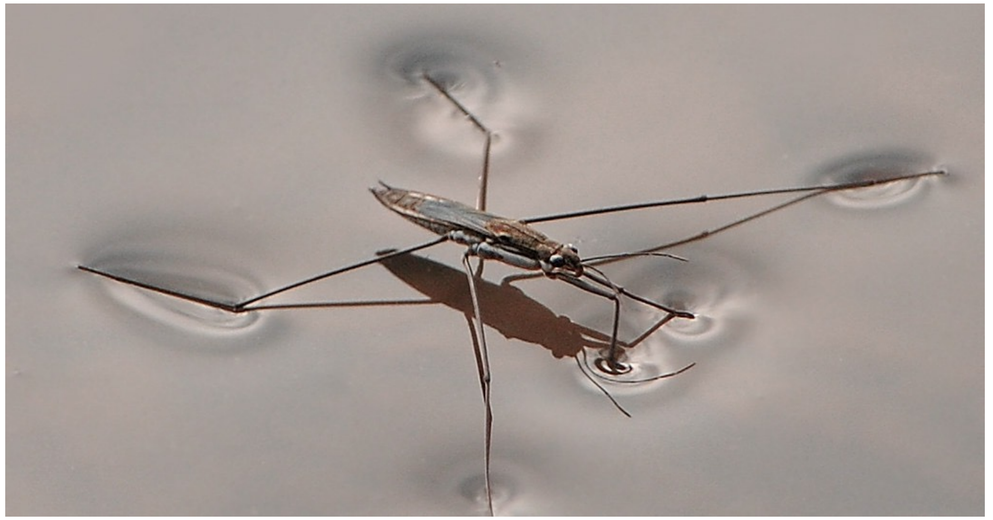


Photo credit: Flickr

Flotation is not about size, but buoyancy strategy: shape and resistance to water through coatings

Our Project will:

Float using a rounded shape on top and hydrophobic surfaces to keep water off plants even in storms

Emulate form & function

CONTEXT

Photo credit: KOMU

PROBLEM STATEMENT

CONTEXT: SAVANNAH, GA in 2075

Sea levels are predicted to rise between 0.5 to 1.5 meters by 2100. 145 million people live within 1m of sea levels world wide. Globally, more people live in urban areas than in rural areas, with 55% of the world's population residing in urban areas in 2018. In 1950, 30% of the world's population was urban, and by 2050, 68% of the world's population is projected to be urban.

Since 1950, the sea level in Georgia has risen to 11 inches. There are 100 miles of coastline and 14 boundary islands on Georgia's coast in danger from sea level rise. In Georgia this rise could cause the loss of imperative wetlands. and more than 13,000 properties are at risk from regular tidal flooding in Georgia. The state is arranging over $1 billion in sea level rise mitigation, which incorporate digging ventures, building seawalls, and seepage upgrades. Savannah, GA Is both urban and coastal. 21% of the county is in a 100-year floodplain already.

Because we were inspired by the vibrant nature of the Georgia riparian areas and coast, and given Savannah's vulnerability as the climate changes, we decided to give our community this project. With many cities, homes, and infrastructure already at risk, there are 3 options: Retreat, Build & Protect, Float & Accommodate. For this project, we are taking Salvinia's lead and will be floating some of that critical infrastructure. We have decided also to look forward to the year 2075 for implementation, giving a buffer of 25 years before the full 3 feet of sea level rise is realized.

The particularly vulnerable in the Savannah community are lower income residents who struggle with food security. Especially in times of disaster, such as hurricane, these people may not have the means to evacuate in land. Grocery stores will be closed and a stock of extra food at home may already be limited. These Savannah residence and all residents need better preparation for disasters, food access, and social resilience. Therefore, our project focuses on an inclusive social infrastructure piece that addresses resiliency, food shortages, and community building.

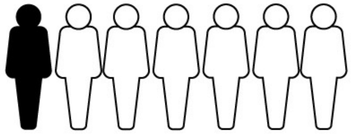
Photo credit: philly.com

SAVANNAH STATISTICS

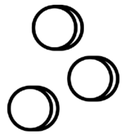
POPULATION

145,094

0.261% Growth



1 in 7 PEOPLE
STRUGGLE WITH HUNGER



POVERTY

26%

SEA LEVEL RISE

11 inches since 1950

6 more inches by 2030

Icon credit: Noun Project

SAVANNAH WITH 3’ SEA LEVEL RISE

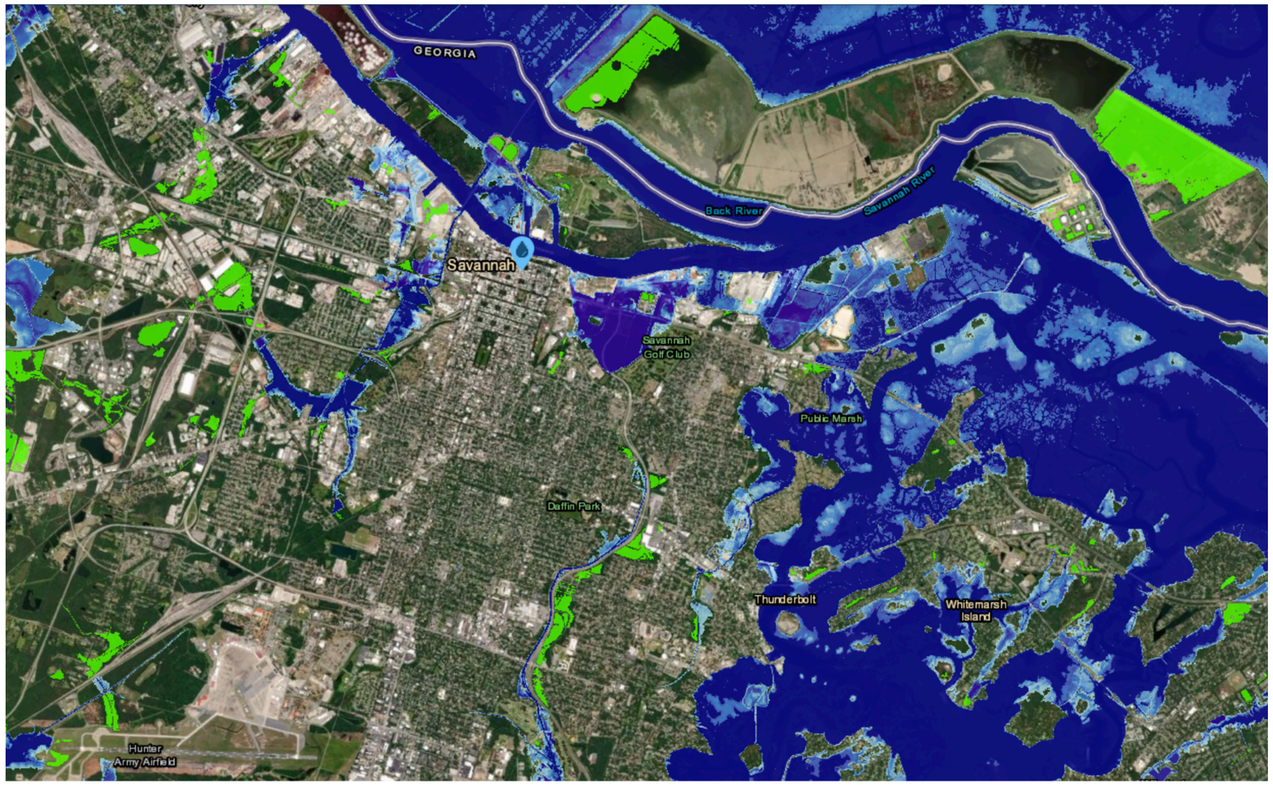


Photo credit: NOAA

AGRICULTURAL & HUMAN IMPACT

As sea levels rise, we not only lose homes, we lose community spaces and agricultural lands. Social infrastructure (such as parks and libraries) have become undervalued and are not often the focus of preservation. However, they provide space for building social resiliency in collaboration and interaction, promote equality through access to education and health resources, and build the physical assets of the community. With our project we will be contributing to Savannah's social infrastructure while addressing food access.

"Our community centers, parks and other public spaces are more than the sum of their parts -- they are critical social infrastructure that provides the fabric for a city's health and wellbeing." - Dan Horrigan, Mayor of Akron, Ohio

Photo credit: ???

FOOD PRODUCTION

Decentralized from urban spaces
With sea rising, there is less local land to farm or garden
Loss of farmland can lead to economic hardship and food shortages
Food shortages promote inequality as food prices rise

Photo credit: Farm the World

COMMUNITY GARDENS

Enable socialization and create a safe, green space
Promote an earth to table connection to raise health awareness
Reduce neighborhood waste through compost
Provide a non-monetized food source
Promote active work and recreation

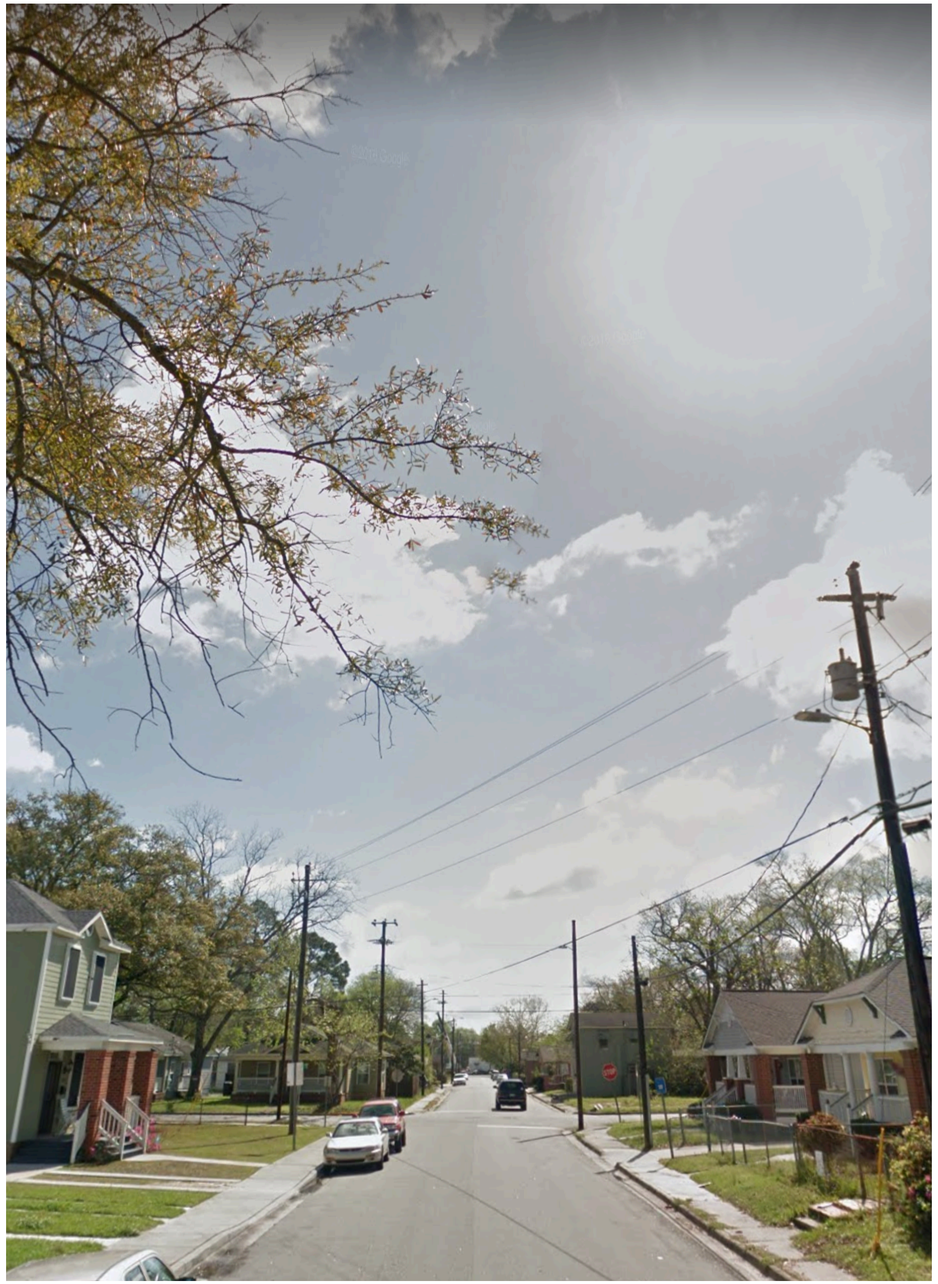


Photo credit: Google Earth

ARCHETYPES

CONTEXT: SAVANNAH, GA in 2075

Given our context of Savannah, GA, we have identified two types of people (or archetypes) that would benefit from solutions to these issues.

Community Members in Need

BIOGRAPHY

Much of Savannah is situated in a food desert - areas that have limited access to affordable and high quality food. Members of the community that aren't able to get to a grocery store would otherwise turn to unhealthy food options. They value their families and their homes.

APPRECIATES

Providing the best for their family

REJECTS

Investing in projects without tangible results

MOTIVATORS

Saving money

Disaster Victims

BIOGRAPHY

Within the next decade, much of the southeast will experience intense flooding from rising sea levels. As a result, food shortages will be severe, and victims of the situation will be especially vulnerable. Particularly, there are many low-income savannah residents that cannot evacuate when hurricanes come, leaving them without infrastructure in disasters, including access to food.

APPRECIATES

Providing the best for their family

REJECTS

Being left behind

MOTIVATORS

Preparing for oncoming flooding and disasters

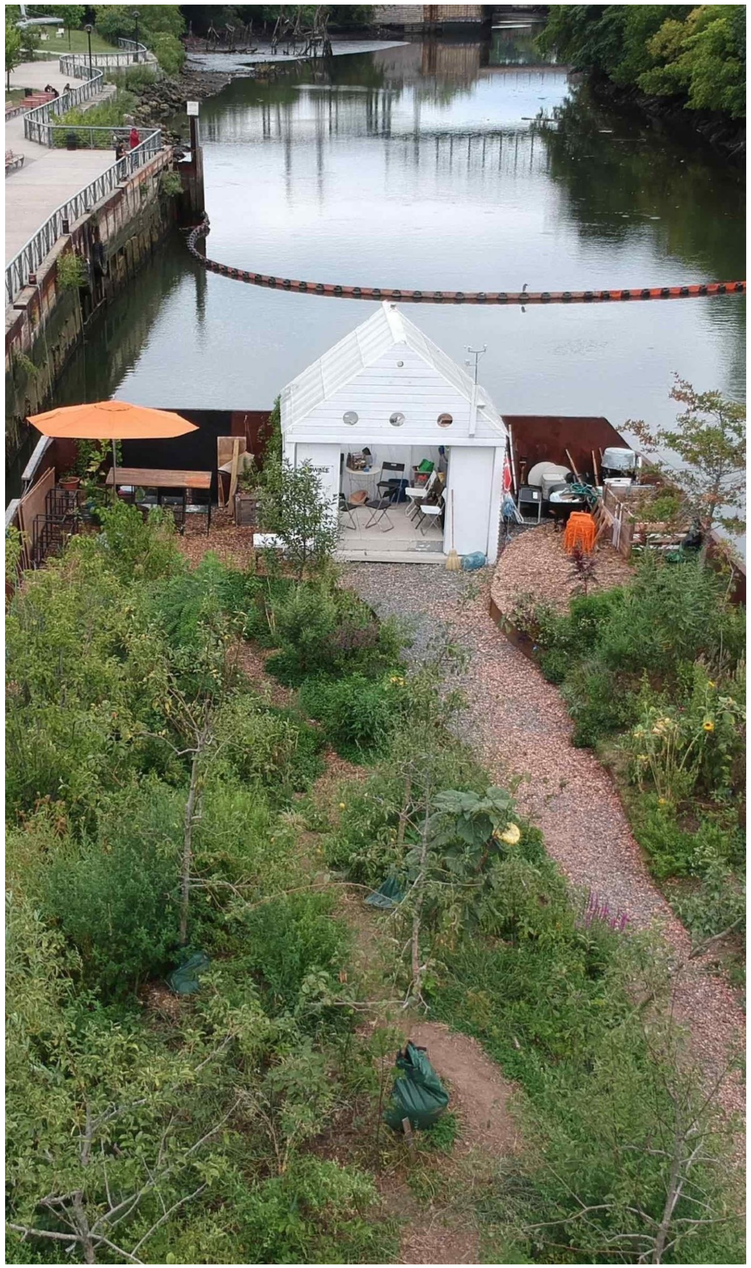
RESEARCH

Photo credit: SWALE

CASE STUDIES

With our target audience and context in mind, we began to brainstorm possible opportunities for addressing food needs in an urban space that is going to be heavily affected by sea level rise and increased storms from Climate Change. We explored the case studies of floating gardens and homes that remind us of our plant: Giant Salvinia, freely floating and gathering nutrients form the water. Some case studies of floating homes and personal gardens were also evaluated; however, our passion is for building community and protecting all members, not just a few individuals. Additionally, the project could be scaled down to fit individual needs in another project, so there was no need to think small at the start.

Photo credit: Wikimedia



SWALE

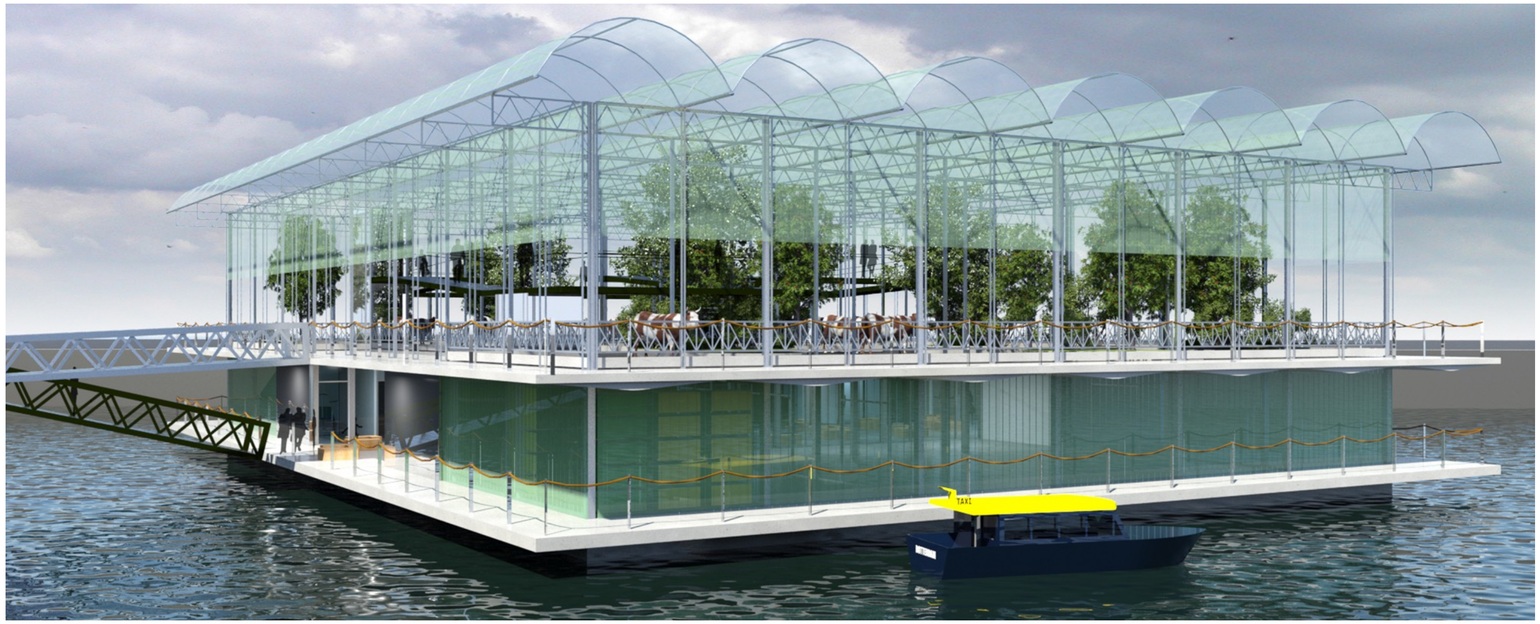
Brooklyn, New York - 2017

Response to NYC's lack of connection to fresh food

Built on old barge because public foraging is illegal in NYC

Encourages environmental awareness

Mobile education



DAIRY FARM

Rotterdam, Netherlands - 2018

Dairy cow farm

Takes advantage of unused space

Reduces expense and pollution linked to transportation

Closed loop system:

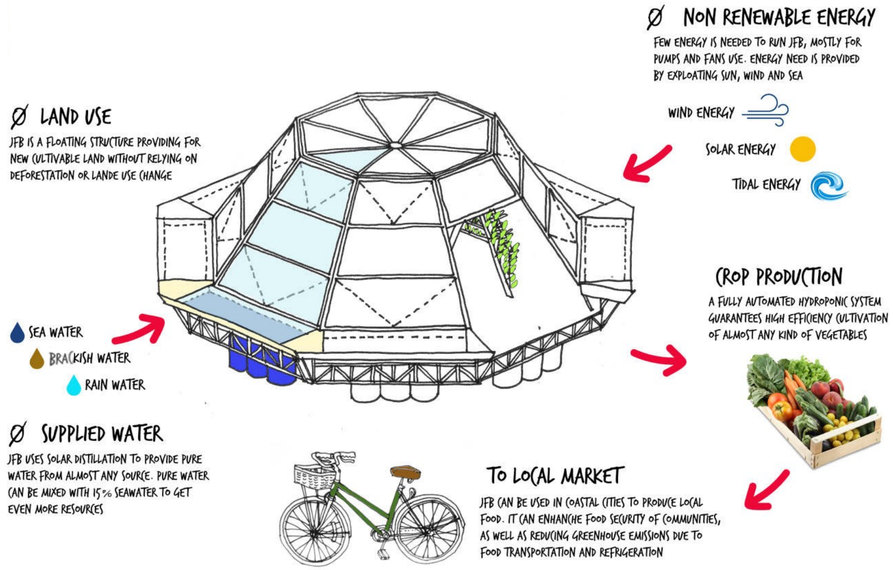
- Solar panels, water filtration
- Cow manure used as fertilizer for vegetation

JELLYFISH BARGE

Florence, Italy - 2014

Collects rainwater for watering plants

Plants vertically to increase growing area



BIOHAVEN

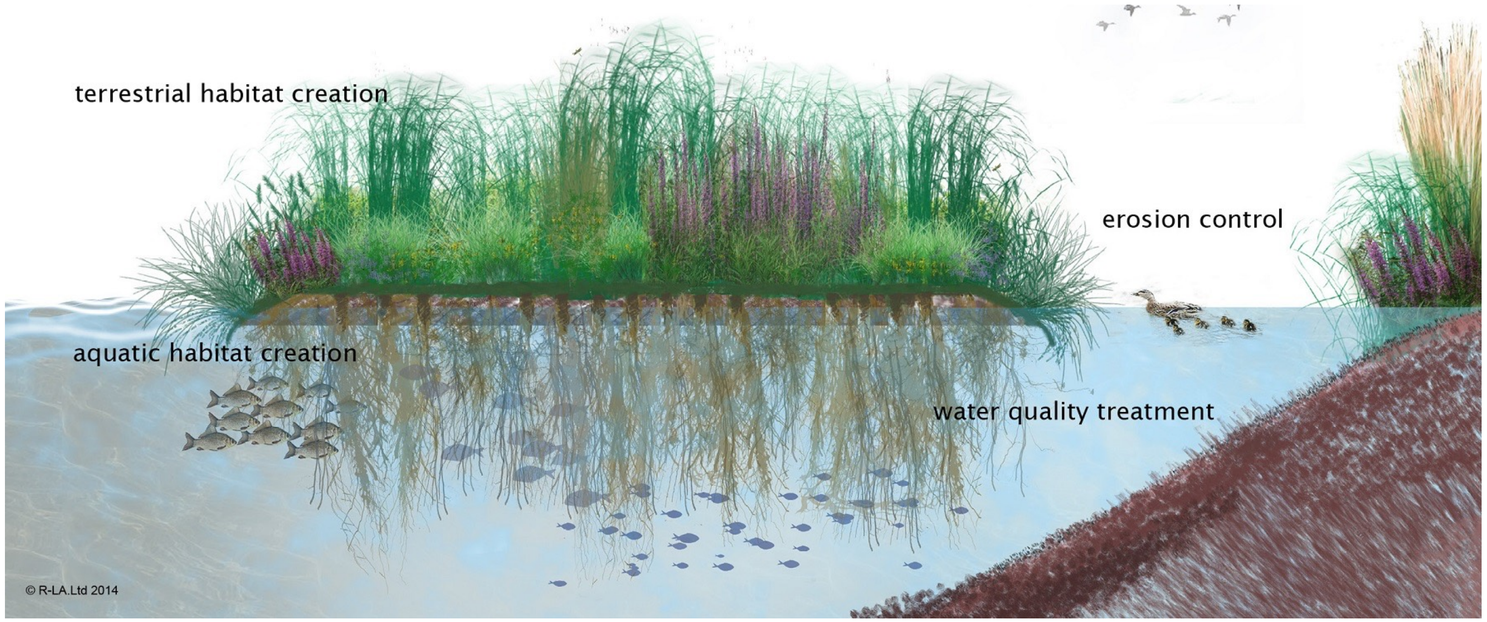
Floating Wetlands - 2015

Began from study on removing heavy metals from stormwater

Feeds multiple habitats/ecosystems

Biofilm develops on roots which creates a natural water filtration system

Filtration creates less algae, allowing for stable fish populations



RECYCLED PARK

Rotterdam, Netherlands - 2016

Litter traps collect floating plastic

Litter is converted to molded plastic garden beds

Prevents plastic from reaching the ocean

Creates community and garden space

Creates micro habitat for flora and fauna

CASE STUDY ANALYSIS

Two aspects we focused on in the analysis of our case studies were: scale and social impact. We wanted to see how the physical size related to the human impact the project could have and where we could find new opportunity to provide services the others did not already provide.

We discovered that since the main focus of the Jellyfish, the Dairy Farm, and Biohaven was on plants and farming, that their social impact was lower despite their scale. Additionally, though SWALE and the Recycled Park provided community space, their impacts seem limited in to this.

Therefore, we opted to design a multifunctional community space (providing food year-round and in disasters) all while being modular and scalable.

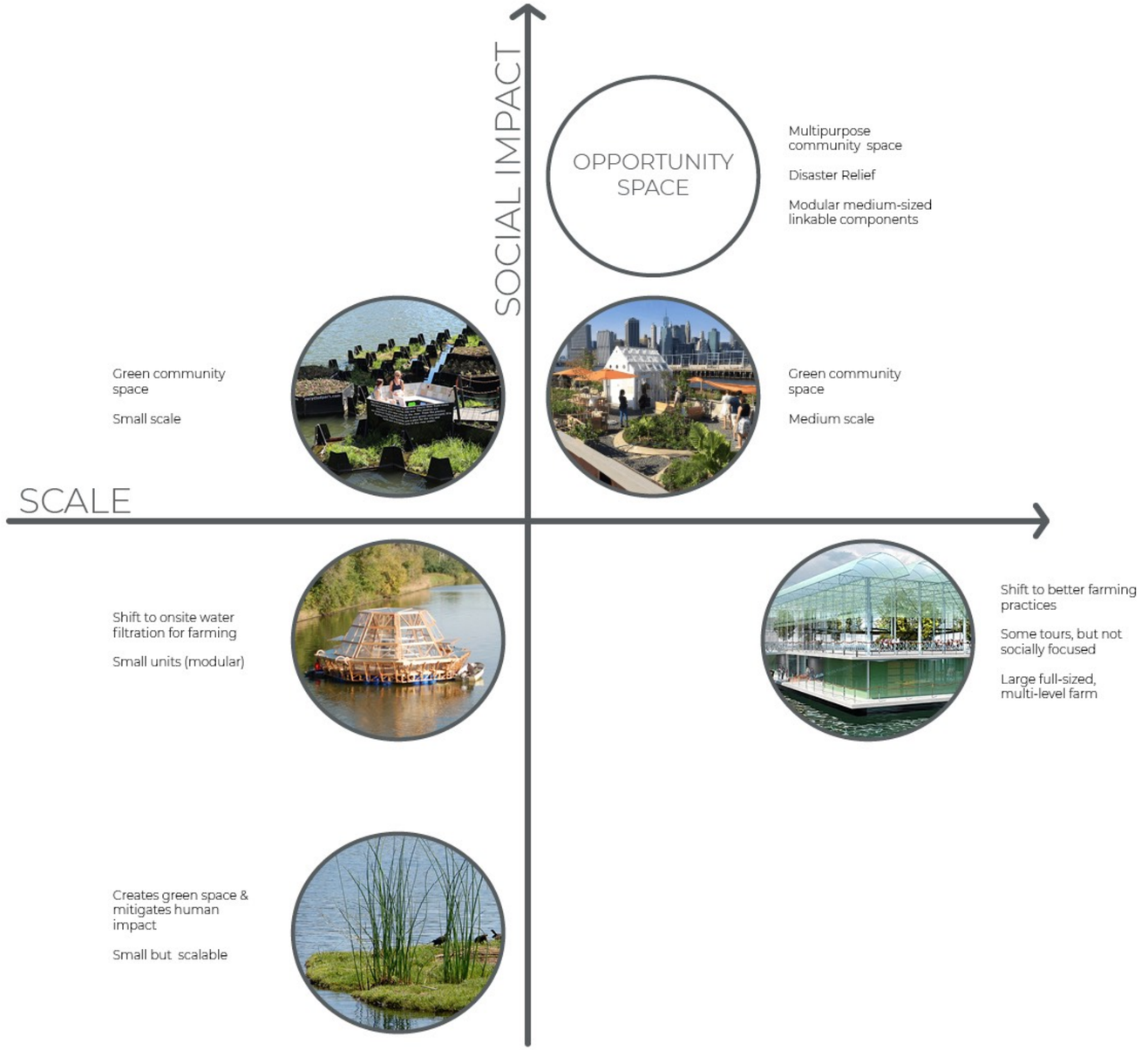


Photo credit: Jellyfish Barge-LINV , Swale-6SQFT, Dairy Farm-Global Construction Review, Floating Marsh-Midwest Floating Island, Recycled Park-Recycled Island Foundation

CASE STUDY ANALYSIS

Two other aspects we focused on in the analysis of our case studies were: resource efficiency and resiliency. We wanted to see how if the more resilient structures were also resource efficient.

We noticed that SWALE, the Jellyfish, and Biohaven were a bit too exposed and delicate to be storm resilient while the Farm and the Recycled Park had respectively scale or adaptability to increase resilience. There were aspects of almost all the case studies that made them more resource efficient, such as the Jellyfish collecting rainwater for the plants, the Farm making compost from manure, and the Recycled Park being made of recycled litter. However, there was room for improvement.

Therefore, we opted to design a garden that is both storm resilient and uses resources wisely (combining, composting, with rainwater capture, and using recycled litter plastics).

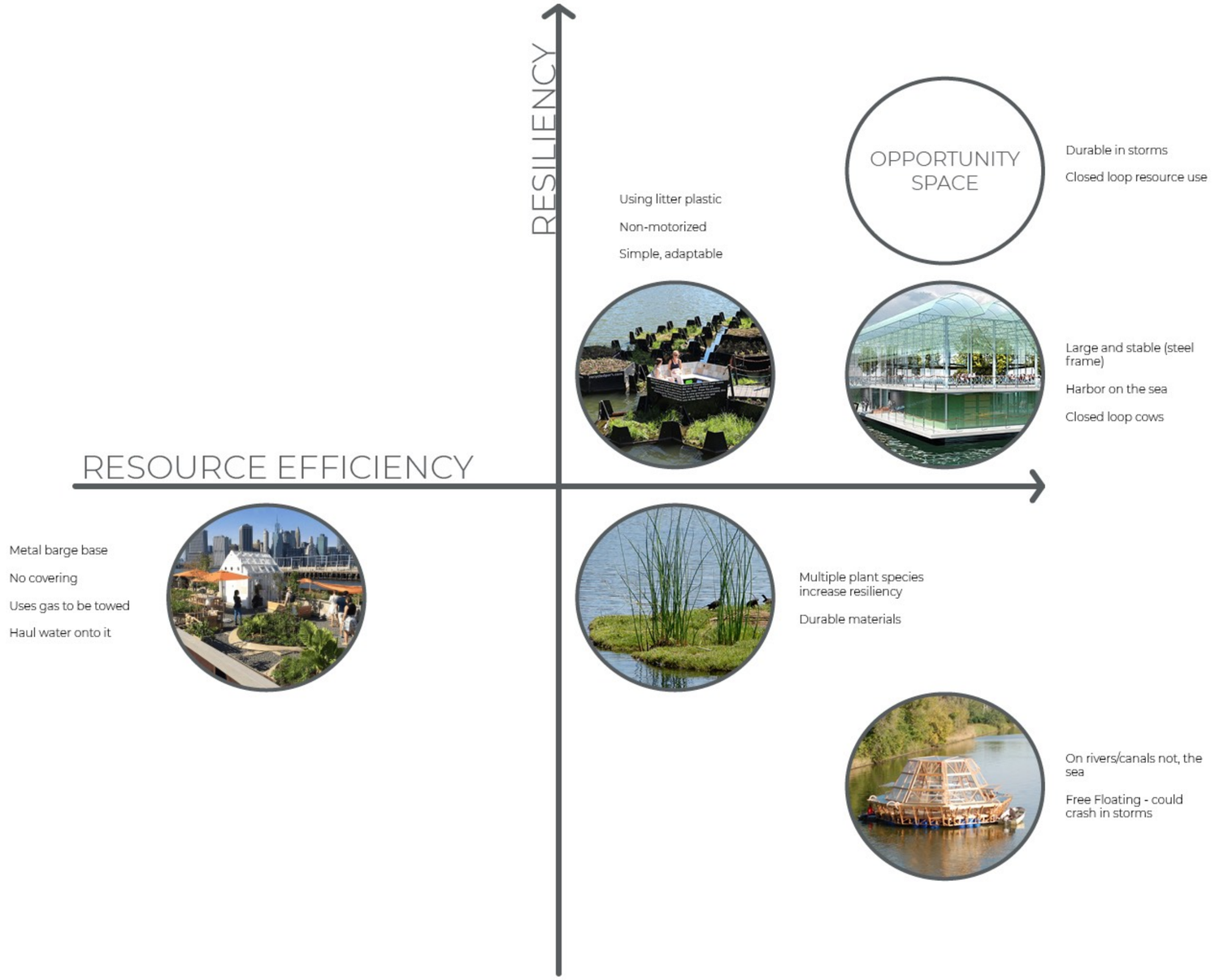


Photo credit: Jellyfish Barge-LINV , Swale-6SQFT, Dairy Farm-Global Construction Review, Floating Marsh-Midwest Floating Island, Recycled Park-Recycled Island Foundation

FOCUSED RESEARCH

After analyzing our case studies, we saw the opportunity to build a medium scale, modular, and multipurpose community space that would provide food year-round and be resilient in disasters (such as hurricanes that frequent savannah. However, we now had built up some assumptions and realized some knowledge gaps, so we set out to do some primary and more secondary research.

Photo credit: savannah.com

Photo credit: timeout.com

ASSUMPTIONS

Low income residents and residents in food deserts in Savannah will want access to more green spaces and free, fresh produce.

The river and marshes of Savannah are too polluted and too salty to use the water for growing food.

There are places where these structures can be moored and regularly accessed.

KNOWLEDGE GAPS

What system for growing food plants on brackish water is best, given that we want a closed loop system?

Hydroponics: Does it work outdoors, in salty air specially?

How much do we need to filter the water to use it for plants? (Desalination)

What are the best crops to grow?

Aquaponics: Can it work with open sea salty water, how much filtration to get rid of pollution?

Are there places where this can be moored currently?

PRIMARY SOURCES

GOVERNMENT ASSISTANCE

We went straight to the source of the most accurate sea level rise disaster plan information: local government. Overall, we discovered a great need for more planning and infrastructure. Our community garden project is equipped to help. A few main points informed us and gave us more confidence in the necessity of our project:

21% of Chatham is in a 100 year floodplain (CEMA).
Since 1948, over 1400 homes have flooded (CEMA).
Tybee Island has the only Sea Level Rise Plan (NOAA).
Savannah's city sustainability mentions sea level rise once (SavannahGA.gov).
Part of the disaster food plan is to coordinate with non-city organizations (CEMA).
Georgia allows rainwater harvesting (GA State)

DISASTER PHASES:

Governments and disaster relief agencies often use phases to organize and simplify the various stages and types of disaster preparedness. The graphic shows how the phases are cyclical, always needing improvement and adaptation as disasters come and go, just as nature adapts over time to storms and shifts in climate. Although arguably, our solution for Savannah can fit in all four phases, since it will be an ongoing fixture of the community, we are focusing on two phases: Mitigation and Response. We are addressing the phase of mitigation by assessing community needs, providing infrastructure for the community before disaster hits, and providing a space for community education and cooperation. Then, once a disaster occurs, our solution will be providing care in the form of fresh produce to residents affected by the disaster. Our solution helps build resilience into disaster planning.

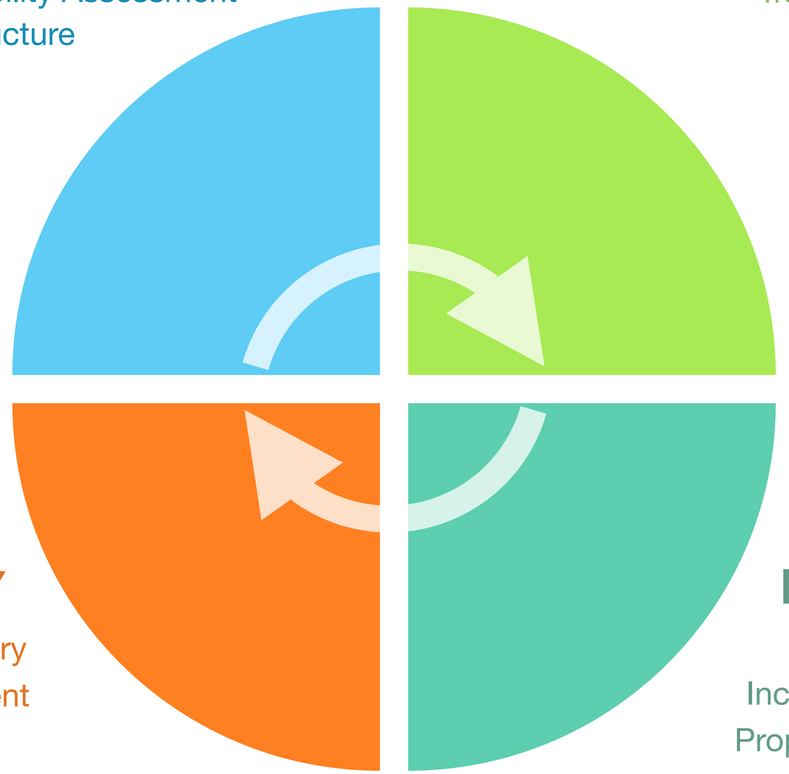


Photo credit: Ottawa County, Michigan

PRIMARY RESEARCH INTERVIEWS

In order to discover if our assumptions are correct and fill in the gaps that secondary research could not answer, we conducted interviews with local community organizers, farmers, and those who use innovative food growing techniques. Here are some key take aways from these interviews.

PAULA KREISSLER

Director of Healthy Savannah

Meeting Place: Foxy Loxy Cafe

Type: In-person

“Savannah wants community gardens. They want it...the city has a community garden policy [where] they allow people to **build on FEMA lots.**”

Emphasized the importance of **faith-based organization** within Savannah.

“Technology helps to move things in directions - the prediction is always a challenge... Technology tends to **disrupt our thinking**, but it can be in a good way.”

Photo credit: planning.org

ANGIE MEE

Owner of Ebenezer Greens

Meeting Place: Forsyth Park Farmer's Market

Type: In-person

What method of growing do you use?

> "We grow in our home microgreens, which are young vegetable greens that grow in small periods of time. We use **LED lights and soil.**”

What kind of produce do you grow and how long does it take to harvest?

> “We grow **broccoli, cabbage, Wasabi mustard, arugula, beet, chervil, kale,** among others. For example, we harvest microgreen kale in 14 days."

Photo Credit: Ebenezer Greens Facebook

WILLIAM DUDLEY DUGGER III

Owner of Billy's Botanicals

Meeting Place: Forsyth Park Farmer's Market

Type: In-person

Do you think is wise to use Savannah's river water or nearby rivers for an Aquaponic System?

> “Definitely, no. The water from the river is far **too contaminated** and contains metals and toxins you wouldn't want the fish to swim in. I would only recommend to use drinkable water. **Filtering the river water would not be economical** and still wouldn't get clean enough for the fish to thrive.”

What crops and fish work best with this kind of system?

> "The best crops would be mint, bok choy, chives, celery, watercress, kale, rosemary, and more. Fish is tricky, I don't sell the fish I use in the system because they are the heart of the system itself. The more time they are in there **the better for the bacteria for the plants**."

Photo credit for Dugger’s aquaponics system: Billy’s Botanicals

GRANT ANDERSON

Owner of Better Fresh Farms

Type: Phone Interview

“Part of the plan is **education of the consumer**...There’s also [is] a great deal of misinformation [about what can be grown] and what little bit people know about hydroponics or indoor farming systems.”

“We still see some of those **same labor challenges as traditional agriculture,** so we don't really have the ability to expand. We see better success for livestock locally, but produce seems to be a lot of **smaller scale operations** for the local market.”

“You want to be in a position where you know every time you get those plants there get that **ideal range of nutrient balance** and using a water source that will fluctuate so much like that river will inevitably have some impact on your plant cycles each week.”

Photo Credit for Anderson’s hydroponic boxes: Better Fresh Farms

RESEARCH INSIGHTS

After all our research, we narrowed our findings down to a few key insights that overall confirmed our assumptions, filled in our knowledge gaps, and informed our design. Our biggest relief was knowing that savannah residents do desire access to green space and community gardens. We also had multiple people confirm that if we are going to be growing plants, we should not be using Savannah river water to using energy to desalinate brackish water. Therefore, we brainstormed a new closed-loop water source option: rainwater.

Low income residents and residents in food deserts in Savannah **do want** access to more green spaces and free, fresh produce.

Many edible plants, including: Chives, Celery, Watercress, Kale, Rosemary, arugula, and cucumber **can grow well in Savannah**.

The river **is too polluted** (even though the salt water sinks below the fresh) to use the water for growing food, but we can **capture rainwater**.

A traditional **raised-planter soil-based system** is ideal for our floating application.

There **are** places where these structures can be **moored** and regularly accessed when sea level rise in 2075..

Faith-based organizations are the way to get local residents involved.

Icon credits: Noun Project

PROJECT SCOPE

Photo credit:Indagare

Photo credit: SWALE

LANVIA GARDENS

PROJECT SCOPE

Given the opportunity to build a resilient food source for Savannah residence as the sea levels rise, the team decided to design Lanvia Gardens. Lanvia Gardens emulate the Giant Salvinia to create a productive modular floating garden that will provide food for Savannah neighborhoods. Lanvia Gardens are physically resilient and promote community interaction that builds social resilience.

FLOATING

COMMUNITY

FOOD SOURCE

GARDEN

VALUE PROPOSITION

We are often told to prepare for the first 72 hours post-disaster as we wait for help to arrive. We have estimated the amount of food needed to supply product to a Savannah suburban neighborhood in that 72 hour period and designed Lanvia Gardens to fill that need.

Additionally, Lanvia Gargens will provide year-round green community space and healthy produce, bringing people together around slow food and fostering social networks for resilience.

With sea levels rising, Lanvia will promote health and wellbeing for Savannah residents even when storms hit.

PERFORMANCE CHARACTERISTICS

Lanvia Gardens are:

Scaleable with population size

Modular for flexibility

Resilient in storms

Resource efficient in water, energy, and materials

Community building in cooperation

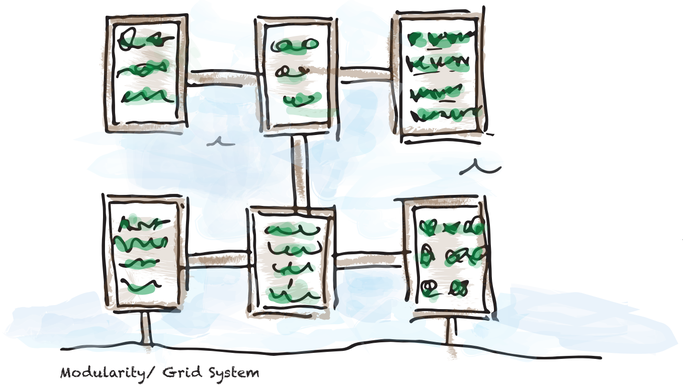
Adaptable to food and community space needs

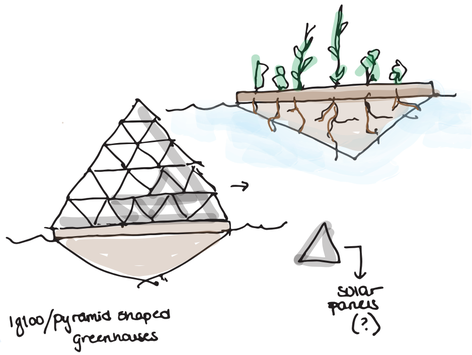
IDEATION

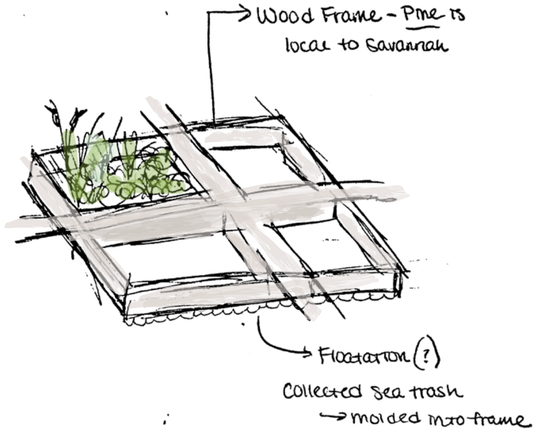
Photo credit: Andrew Esiebo on YouTube

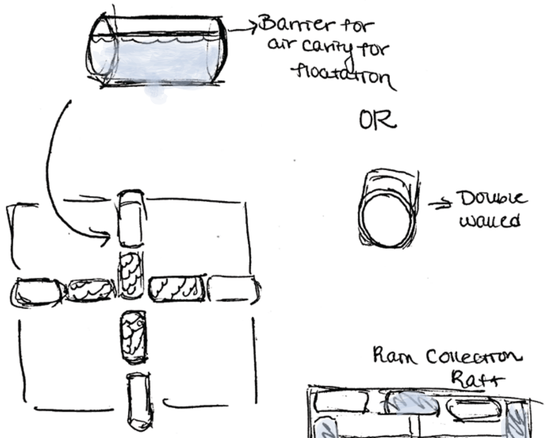
SKETCHES

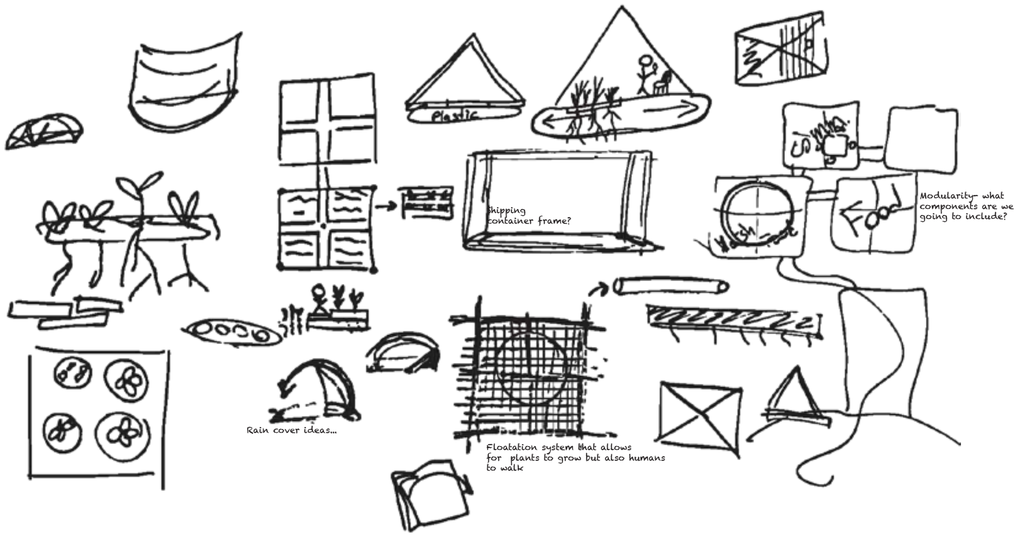
In our initial ideation sketches, we were entranced by the strong triangular shapes we saw in some case studies such as the Jellyfish Barge. We also initially wanted to design low-tech so as to give the community the ability to build the structures quickly and by themselves. Although these are valid directions, for this project we decided that modeling after farm and garden hoop houses would increase food production (to reliably help people in a disaster) and that we needed more resilient technology than low-fidelity materials and assembly could offer. However, our ideation confirmed our commitment to a community garden, rather than individual home model. Additionally we maintained the idea of emulating Salvinia's flotation by trading air in many pockets.

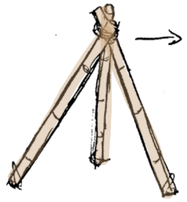


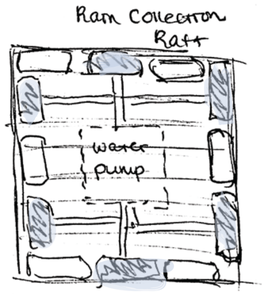


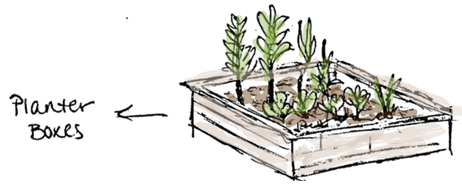












FINAL DESIGN

Photo credit: A Little Adrift

LANVIA

FLOATING COMMUNITY GARDEN

COMMUNITY SPACE

INTERIOR OF HOOP HOUSE

HOOP HOUSE SECTION

SCALABILITY

AERIAL VIEWS

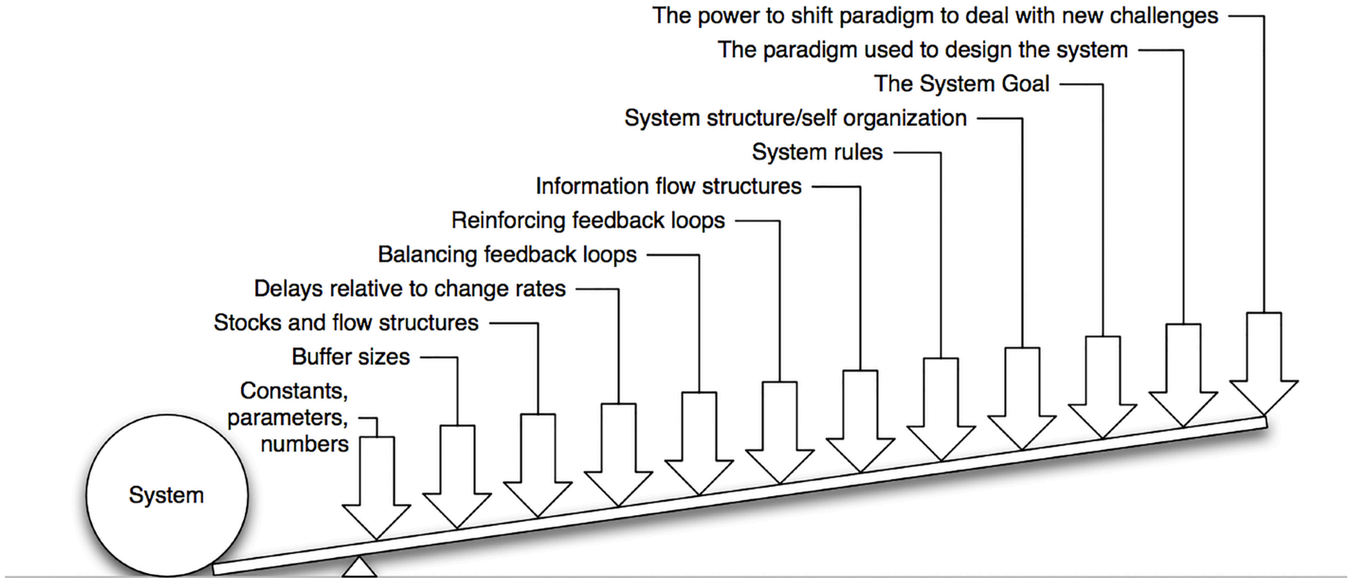
Diagram credit: Jewish Educational Alliance

COMMUNITY GARDEN MODEL

Lanvia Gardens are designed to support a free-access community garden where the public is welcome to use the space and visit, similar to a library. Yet, there'll be sponsors for each of the plots or hoop houses by various local community groups, religious organizations, and families. There would be a paid city educator and facilitator to maintain each Lanvia Garden. This way, the community is knowledgable and invested in the project while not putting a large burden on city staff.

Lanvia Gardens would be operated using regenerative design principles of co-evolving with nature. Through rainwater collection, creating marsh plant habitat, removing litter from Savannah rivers, and growing healthy food to reducing inequality in diets due to income disparity. Lanvia gardens will restore some pieces of the broken pieces of local systems while leaving room for adapting with nature over time. Community activities and use of the community space can change over time just as the plants can change with the weather and tastes of the community. Permaculture and sustainable agriculture practices such as companion planting, soil restoration through crop rotation, and planting diverse plant varieties for resilience are core to the Lanvia model.

Diagram credit: Composite Creative



LEVERAGE POINTS

In Donella Meadow's Book Thinking in Systems and also in the Biomimicry resource Handbook, she outlines 'leverage points' for intervening in a troubled system. Some leverage points are more or less effective as illustrated here. Self-Organization is a fairly high leverage point and also one of the Life's Principles. Lanvia Gardens are designed to be self-organizing. Meadows describes self-organization as "the power to add, change, or evolve the system structure." Lanvia Gardens are decentralizing and diversifying the food system, allowing for community innovation, and starting a process of environmental restoration.

POSSIBLE PARTNERSHIPS

Given that Lanvia Gardens are social infrastructure, similar to a library, the city will naturally be involved in the project. The city can partner with existing community garden and health oriented non-profits to ensure community participation and adoption as well as to help with garden maintenance. Additionally, as we learned in our interviews, faith-based organizations can be great partners in Savannah for reaching a large number of residents.

SAVANNAH
savannahga.gov

Healthy Savannah
Connect • Inspire • Grow

SAVANNAH URBAN
GARDEN ALLIANCE
A COMMUNITY GARDEN NETWORK

Savannah
community gardens

SUSTAINABLE DEVELOPMENT GOALS

The United Nations created a set of 17 goals and target for humans to achieve globally in order to achieve a sustainable future for all. Many organizations and projects around the world are inspired by and sharing their commitments to theses goals. We see Lanvia Gardens as primarily addressing 4 of the goals below, helping create urban resiliency for food and well-being in the face of Climate Change.

Providing food year round to those in need and in disaster scenarios

Create green space and multipurpose education space for local residents

Situated in urban Savannah to increase wellbeing and resiliency in the city

Responding to Climate Change caused sea level rise & bringing resilience

Photo credit: United Nations

LIFE'S PRINCIPLES EVALUATION

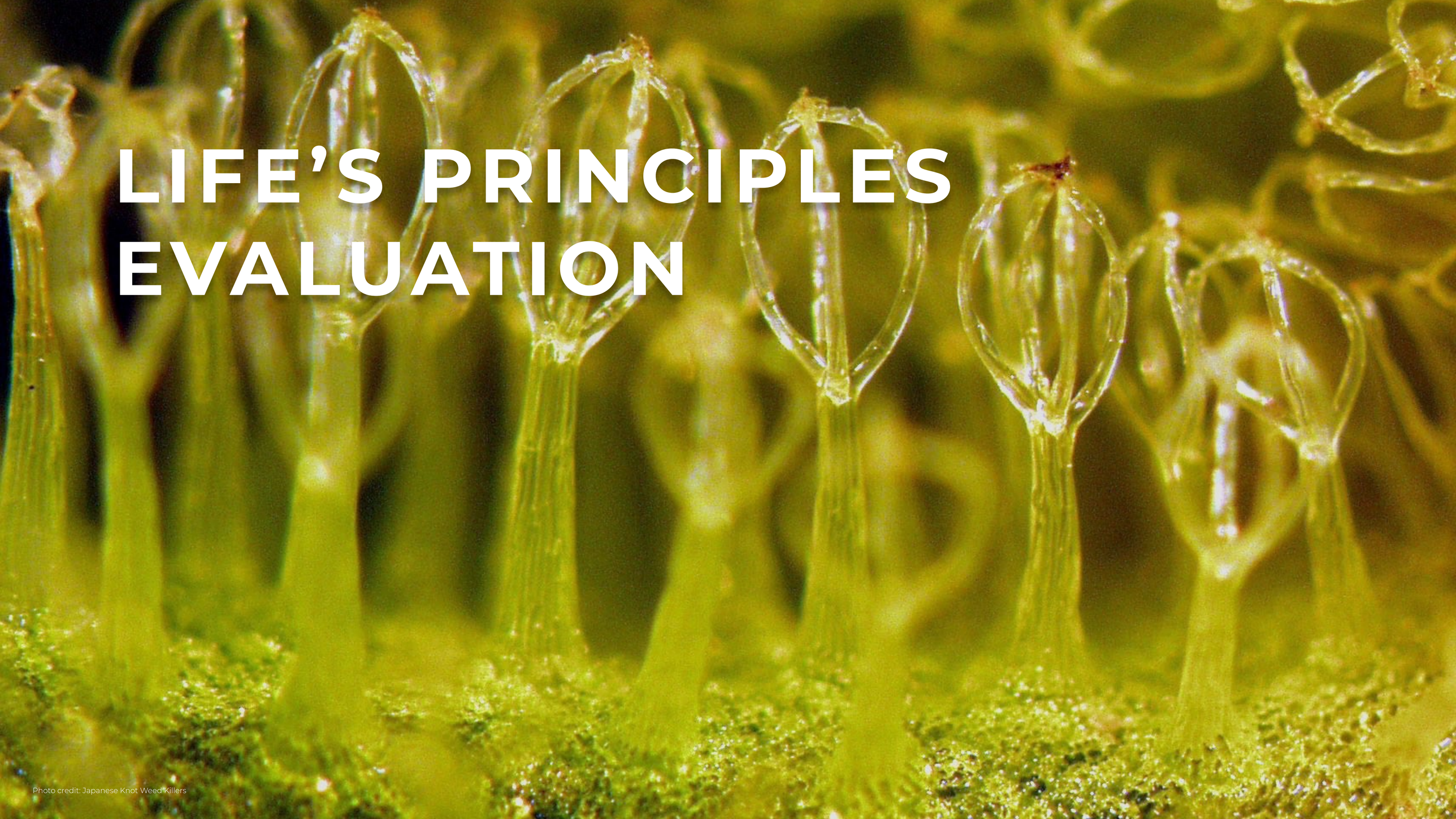


Photo credit: Japanese Knot Weed Killers

LIFE'S PRINCIPLES EVALUATION

Throughout the project we have returned to Life's Principles to ensure we are designing for co-evolution with nature. With the design complete, we again return to Life's Principles for an evaluation of our work, using nature as a model and measure. Lanvia Gardens incorporate aspects of each of the main Principles.

Lanvia Gardens are a big step to co-evolving with nature and integrating humans back into eco systems. Through tuning into Life's Principles holistically, new infrastructure can emulate nature's intelligence, and provide for the future.

Photo credit: Biomimicry 3.8

EVOLVE TO SURVIVE

REPLICATE STRATEGIES THAT WORK

- Lanvia is primarily modeled after the free-floating aquatic fern: Giant Salvinia. Salvinia reproduces asexually, by growing new buds that break off at the base of the plant. The plant also does not have true roots (only pseudo-roots) that collect nutrients from water without being tied to soil. Additionally, the leaf hairs of Salvinia have a cage-like structure that trap air and keep the plant afloat if it becomes submerged in water. Similarly, Lanvia gardens are designed to float with the currents, trap air in barrels to stay a float, and be easy to replicate. Thus, Lanvia is following the strategies that work from Giant Salvinia.
- Giant Salvinia is an invasive plant to the South US, as is Blue Gum Eucalyptus in CA, and Crab Grass throughout the US. Invasive plants of course out compete their neighbors, but they also grow and reproduce quickly. They adapt easily to new environments. Taking these lessons of success and giving them positive impact, Lanvia gardens are meant to have simple design that is easily replicated and built. Lanvia is also able to adapt to changing climate and is location flexible. However, the design leaves plenty of sun for the plants beneath the water unlike Salvinia. Lanvia fosters cooperative relationships, rather than competition.
- Lanvia Gardens are made up of modular units that can be modified and/or replicated and well as configured in many shapes. If the garden is successful and needs more planter beds, more rain collection, more community space, or more marsh habitat, Lanvia can replicate what works.

INTEGRATE THE UNEXPECTED

- Because Lanvia can trap air inside as waves wash over it, the garden is resilient in changing weather. The sturdy structure made of recycled plastic, metal pipe, and thick bioplastic sheeting is also meant to withstand the increase in frequency and intensity of storms that is associated with hurricanes. Inside the ‘hoop houses’ that contain the farms, there are extra braces to help the structure stand up to strong winds. Since Lanvia floats, the storm energy can also push the structure around while the plants stay anchored and protected.

Photo credits:: Olivia Vargas

ADAPT TO CHANGING CONDITIONS

MAINTAIN INTEGRITY THROUGH SELF-RENEWAL

- The edible plants and marsh plants of Lanvia Gardens, will reproduce and regrow with careful attention to choosing plants that grow well together and replenish, not deplete, the soil. Additionally, the food scraps and any trimmings can be collected to make compost that will further help soil health and keep organic waste out of landfills.
- Some plants can be left to ‘go to seed.’ Seeds can be collected from plants to be planted again, creating a nearly close-looped garden system.

EMBODY RESILIENCE THROUGH VARIATION, REDUNDANCY AND DECENTRALIZATION

- There are multiple units with many different species of edible and marsh plants in the Lanvia Garden design, allowing for redundancy and variation that increase resilience.
- Additionally, one of the functions of Lanvia garden is to add another healthy food source and community space to increase food and community systems resiliency in light of sea level rise and increased storms from climate change. The Gardens are designed to provide produce to an entire neighborhood in the first three days after a natural disaster (e.g. hurricane) while help is coming. This primarily will assist those unable to evacuate, but also people as they return.
- The barge itself also contains barrels, some with chambers to hold air to maintain buoyancy and some to hold captured rainwater. The multiple barrels and chambers in the barrels allow for damage to part of the structure without the entire structure sinking. Just as with the leaf hairs on the Giant Salvinia, redundant structures create resilience.

Photo credit:Thyme to Garden Now

BE LOCALLY ATTUNED AND RESPONSIVE

LEVERAGE CYCLICAL PROCESSES

- Lanvia Gardens are designed to be planted with the seasonally and site appropriate plants in order to use less time and energy to grow food and to ensure produce is available year-round.

USE READILY AVAILABLE MATERIALS AND ENERGY

- Lanvia Gardens capture and filter rainwater—which is available year-round in Savannah—in barrels under each of the ‘hoop houses’ in order to reduce dependence on the Floridian Aquifer and the Savannah River for fresh water.
- Lanvia Gardens’ barges are built with recycled plastic from litter collected in the rivers and around the city. Thus, Lanvia uses a readily available material resource that was polluting the environment to promote life through providing space for food growth and community space.
- The metal pipes used to hold up the ‘hoop houses’ are recycled steel, and the Pine timber for the planter boxes is locally sourced.
- Lanvia Gardens also make use of natural sunlight to grow food in the ‘hoop houses’ and solar photovoltaics to run water filters and pumps.

Photo credit: Save Our Water

BE LOCALLY ATTUNED AND RESPONSIVE

USE FEEDBACK LOOPS

- The cyclical information flows we have identified include: sea levels rise, changing community needs, and climate changes. As flooding and tides change from sea level rise, Lanvia is poised to be implemented in newly waterlogged areas. The more water covered Savannah, the more space Lanvia has to help the communities effected. Similarly as communities grow and shrink in various areas, Lanvia can grow or contract to the needs with modular units and flexible space on the floating barges. Finally, as the climate changes, and storms are more intense and frequent, Lanvia is built strong to withstand the weather and provide for people affected by it.

CULTIVATE COOPERATIVE RELATIONSHIPS

- Lanvia Gardens are community gardens that promote cooperative relationships amongst neighbors and community organizations. The Gardens are designed to engage families/ households and local organizations (including religious organizations) in order to attract people, give them space to interact, and connect around a basic human need and pleasure: food. Generosity and shared experience in time or relative prosperity will set precedence for cooperation in times of hardship.
- Lanvia Gardens also feature floating wetlands of marsh plants in the community space that cultivate a more symbiotic relationship between people and their environments, by providing habitats for local flora and fauna while using natural processes to clean the water.

Photo credit: IA-Capital

USE LIFE-FRIENDLY CHEMISTRY

BREAK DOWN PRODUCTS INTO BENIGN CONSTITUENTS

- We will be coating the recycled plastic with a coating that is safe for potable water to prevent photodegrading under the sun, preventing the plastic from again becoming litter.
- The marsh plants in Lanvia Gardens help filter the water that has been polluted by humans and natural waste, using native plants adapted to take nutrients from water, similar to Giant Salvinia (without the invasiveness).

BUILD SELECTIVELY, WITH A SMALL SUBSET OF ELEMENTS

- The Lanvia Gardens recycled plastic barges are coated with a seal to prevent photodegrading and re-polluting the waters with plastic.
- The Gardens are also made with few materials (primarily: recycled plastic, recycled steel, bioplastic sheeting, soil, plants) for easier repair and expansion. These elements are also either inert or break down into benign constituents in the natural environment.

Photo credit: Recycled Park

BE RESOURCE EFFICIENT

USE LOW ENERGY PROCESSES

- Lanvia Gardens float with waves and do no require motorized mobility. They are anchored in place to be easily accessible by a bridge to land that raises and lowers with water levels.
- Lanvia Gardens are also watered with captured rainwater, eliminating the need for water transportation, therefore, using less energy than other gardens would.
- Lanvia's only consistent energy needs are for water filters and pumps that are powered by photovoltaics. Drip irrigation applies the water to prevent water loss from evaporation.

USE MULTI-FUNCTIONAL DESIGN

- Lanvia gardens are not only a space to grow food, but a space for communities to connect, building social and physical resilience. Given that Lanvia is a piece of social infrastructure (similar to a library), the functions of Lanvia can be multiplied and changed as often as needed and designed. Especially the center platform can be used as a classroom one minute, a harvest sorting station the next, and then a space for a community meal after. The possibilities are as diverse as the communities served.
- Additionally, the gardens capture and filter water while added more space for Marsh habitat which is important as sea level rise pushes this habitat inland (often into developments where it cannot adapt to survive).

Photo credit: NOVUS

BE RESOURCE EFFICIENT

RECYCLE ALL MATERIALS

- Lanvia Gardens are made of recycled litter plastic.
- The metal pipes used to hold up the ‘hoop houses’ are recycled steel, and the Pine timber for he planter boxes is locally sourced. All of the basic components have potential for easy repair, easy disassembly, and easy reuse or recycling. Unlike materials are not fused with glues or made into composite materials that would make them difficult to recycle or reuse.
- Lanvia Gardens compost on site, filter water on site, and produce food where people can gather. Nothing is wasted.

FIT FORM TO FUNCTION

- Inspired by the multitude of leaf hairs on the Giant Salvinia that trap air to keep the plant afloat if it becomes submerged, Lanvia Gardens have ‘hoop houses’ on top of each barge to trap air prevent sinking in the times of large storms. The barge itself also contains barrels, some with chambers to hold air to maintain buoyancy and some to hold rainwater. The chambers allow for damage to part of the structure without the entire structure sinking. The rainwater capture allows for benefit from the storms. Similarly the extra supports inside the hoop houses, allow for damage to part of the structure that can be repaired without destroying the whole.

Photo credit: Emergent Structures

INTEGRATE DEVELOPMENT WITH GROWTH

SELF-ORGANIZATION

- Socially, gardens & community space empower community to care for themselves. They provide a physical space for facilitating relationships that serve the community in times of crisis and thriving. As flows and systems change, Lanvia fosters a self healing and adapting community.

COMBINE MODULAR AND NESTED COMPONENTS

- The Lanvia Gardens are made up of multiple connected units, creating resiliency in redundancy. Additionally Lanvia structurally is adaptable with its flexible walkways, and ability to move in currents while remaining anchored.
- Lanvia also has planter beds that are nested inside the recycled litter plastic barge that protects the wood and plants from rot as water washes across the sides of the barges.

Overall, we are incurably grateful for this opportunity to learn biomimicry methodology and design a meaningful and practical future social infrastructure for the Savannah Community that we currently call home. We found great value in using the Life's Principles holistically, and will be incorporating the ethos of designing for co-evolution with nature into our future work.

Photo credit: Gator Dock

APPENDIX

Photo credit: Plant San

DISCOVERY: ORIGINAL ORGANISM INSPIRATION

Before choosing Giant Salvinia as our primary organism to emulate, we collected a four other organisms and functions to inspire our project. After a bit of ideating human contexts for these functions, we saw the most potential in the Giant Salvinia. We have included them here to further explain our Biology to Design Process and to inspire other biomimicry efforts.

FOGSTAND BEETLE

Stenocara Gracilipes

Photo credit: Ask Nature

Photo credit: Ask Nature

MECHANISM

In the slaty light of one such foggy dawn, a long-legged Namib beetle stands on a small ridge of sand. Its head faces upwind, and its stiff, bumpy outer wings are spread against the damp breeze. Minute water droplets from the fog gather on its wings; there the droplets coalesce, until they finally grow big enough to release their electrostatic grip on the wing surfaces and roll down to the beetle's mouth parts, giving the animal an early morning drink.

REGION

Namib Desert, Southern Africa

STRATEGIES

Collects water on its back in bumps from morning dew and fog. The droplets stick to hydrophilic (water-loving) bumps, which are surrounded by waxy, hydrophobic troughs

DESIGN PRINCIPLES

Resource efficiency - minimizes energy use Adaptation to changing conditions

FUNCTIONS

Water conservancy

Passively cool body

HAIRY FROG “THE HORROR FROG”

Trichobatrachus robustus

Photo credit: Nerdist

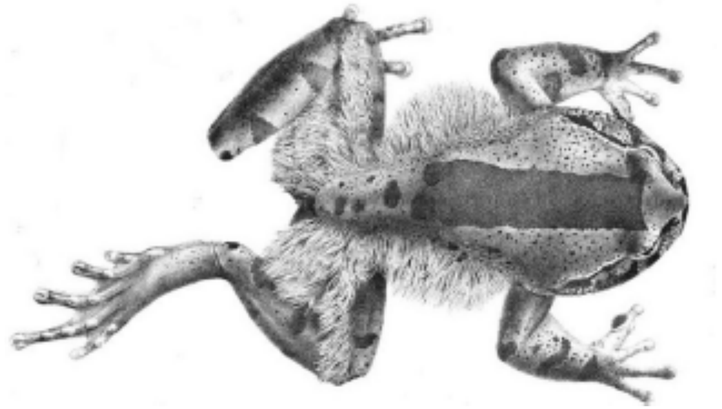


Photo credit: Gizmodo

MECHANISM

The Hairy Frog is able to break its own bones in its toes to produce cat-like claws when it is threatened. This occurs only in the hind feet, and when at rest, the bones are surrounded by a mass of connective tissue. Collagen connects the sharp piece to the tip of the toe bone, and the other end is connected to a muscle which contracts when the frog is threatened to pull the claw down through the skin. Unlike claws however, the hairy frog doesn't have a protective coating of keratin on the protrusions. It is unclear whether the frog is able to retract the claws after defense, as there doesn't seem to be another muscle to pull it back in. It is speculated that the bone naturally slides back in after the muscle relaxes.

REGION

Central Africa

STRATEGIES

Breaks own toes and shoves broken shards through skin as a weapon

Passive Process

Skin regenerates after retraction

DESIGN PRINCIPLES

Evolve to Survive

Adapt to changing conditions

FUNCTIONS

Defense

Grip / Survival Tool

HONEY BADGER

Mellivora capensis

Photo credit: Mental Floss

Photo credit: Shutter Stock

MECHANISM

Honey badgers are fearless animals that will defend themselves against larger carnivores (e.g., lions), but are also known to take on particularly dangerous prey such as venomous snakes. Honey badgers have been known to defecate in holes and mark with their urine or anal scent glands to indicate to other animals that their burrow is nearby.

REGION

Africa, Southwest Asia, and Indian subcontinent

STRATEGIES

Incredibly loose, thick skin to help in mobility & protection

Omnivorous

Developed venom-resistant properties

DESIGN PRINCIPLES

Evolve to get the most out of their environment

Only as strong as what you can resist

FUNCTIONS

Defense

CARIBBEAN HERMIT CRAB

Coenobita ciypeatus

Photo credit: Ask Nature

Photo credit: KK News

MECHANISM

Adults burrow and hide under the roots of large trees, and can be found a considerable distance inland. As with other terrestrial crabs, they utilize modified gills to breathe air. Their shell helps maintain the humidity necessary for gas exchange to function.

REGION

West Atlantic

STRATEGIES

Synchronous vacancy chains (lining up for new shells; signaling where the big shell is)

DESIGN PRINCIPLES

Be Resource Efficient - use little energy

Be Locally Responsive - cooperation

FUNCTIONS

Finding new homes as they grow

Species survival

SOURCES

SEA LEVEL RISE
http://maps.risingsea.net/Georgia.html
https://sealevelrise.org/states/georgia/
http://content.time.com/time/photogallery/0,29307,1925475_1953986,00.html
http://archive.boston.com/bigpicture/2009/09/flooding_in_the_southeast.html

URBANIZATION
https://www.un.org/en/development/desa/population/theme/urbanization/index.asp
https://population.un.org/wup/Publications/Files/WUP2018-Methodology.pdf
https://populationeducation.org/how-does-population-growth-impact-rapid-urbanization/
https://georgiastrait.org/issues/urbanization/
https://morphocode.com/global-trends-urbanisation/
http://www.floatingislandinternational.com/technology/

INTERVIEWEES
Paula Kriessler, Healthy Savannah
Angie Mee. Ebenezer Greens
https://www.facebook.com/EbenezerGreens/
William Dudley Dugger III, Billy's Botanicals
https://www.billysbotanicals.com/
Grant Anderson, Better Fresh Farms

PRIMARY SOURCES & OTHER RESEARCH
https://www.chathamemergency.org/hazard-mitigation-plan.php
https://www.chathamemergency.org/preparedness/flooding.php
https://stepupsavannah.org/works/
https://www.miottawa.org/Sheriff/emergency_management.htm
https://www.researchgate.net/publication/289999590_Tybee_Island_Sea-Level_Rise_Adaptation_Plan
https://seagrant.noaa.gov/News/Article/ArtMID/1660/ArticleID/555/Community-Resilience-Tybee-Island-creates-Georgia's-first-sea-level-rise-plan
http://www.savannahga.gov/DocumentCenter/View/10192/SUSTAINABLE-SAVANNAH-MATERIALS-C?bidId=
https://www.primalsurvivor.net/rainwater-collection-illegal/
https://www.dca.ga.gov/node/3643
https://coast.noaa.gov/slr/
https://drive.google.com/file/d/0B_f2XEFqZp8tXzV0VnE1OWNYNW8/view
https://www.researchgate.net/publication/289999590_Tybee_Island_Sea-Level_Rise_Adaptation_Plan
http://smartcities.ipat.gatech.edu/sites/default/files/Chatham-Co__Smart-Sea-Level-Tools-for-Emergency-Planning-and-Response__Release.pdf
https://www.savannahnow.com/news/2017-04-22/sea-level-rise-evident-chatham-county-if-you-know-where-look
http://www.savannahga.gov/DocumentCenter/View/10192/SUSTAINABLE-SAVANNAH-MATERIALS-C?bidId=
http://www.savannahga.gov/DocumentCenter/View/4686/Savannah-GA-Risk-Assessment-Presentation-11-12-14?bidId=
https://www.chathamemergency.org/hazard-mitigation-plan.php
https://www.chathamemergency.org/2013EMDocs/APP%2011-2%20FOOD%20AND%20WATER%20COORD.pdf

Fern: http://www.iucngisd.org/gisd/species.php?sc=569, https://plants.ifas.ufl.edu/plant-directory/salvinia-molesta/, https://asknature.org/strategy/leaf-structure-retains-air-layer-underwater/#.XK9jVy2ZPs0, https://aquaplant.tamu.edu/plant-identification/alphabetical-index/giant-salvinia/, https://www.environment.gov.au/biodiversity/invasive/weeds/publications/guidelines/wons/pubs/s-molesta.pdf, https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=298

Problem Statement: https://www.skepticalscience.com/sea-level-rise-predictions.htm, https://www.greenbuildermedia.com/resilient-housing/housing-solutions-to-rising-sea-levels, http://www.beachapedia.org/Sea_Level_Rise, https://www.sciencedirect.com/topics/earth-and-planetary-sciences/sea-level-rise, https://www.governing.com/gov-institute/voices/col-parks-community-centers-public-spaces-critical-social-infrastructure.html?fbclid=IwAR1pCxHyYtAhz1VZ8mxWlXER6Nw2Rbag9YMEBWehZQzSh0Ogofyd5AGwvqs, https://datausa.io/profile/geo/savannah-ga/#economy, https://coast.noaa.gov/slr/#/layer/slr/3/-9025623.984460225/3771855.5176553978/13/satellite/none/0.8/2050/interHigh/midAccretion, https://attra.ncat.org/attra-pub-summaries/?pub=351, http://alivebynature.com/pub/UAHealthArticle.pdf, https://www.sciencedaily.com/releases/2017/01/170118082423.htm, https://ocean.si.edu/through-time/ancient-seas/sea-level-rise, https://www.ciwf.org.uk/factory-farming/people-and-poverty/

Case Studies: https://www.kickstarter.com/projects/694835844/pool-a-floating-pool-in-the-river-for-everyone, http://studiomobile.org/Jellyfish-Barge, https://floatingfarm.nl/?lang=en, https://www.kickstarter.com/projects/1152620801/swale/posts/1637583, https://www.6sqft.com/swale-floating-park-returns-this-spring-with-a-new-look/ http://recycledisland.com http://www.floatingislandinternational.com/wp-content/uploads/2018/08/BioHavens®-and-Plastics.pdf

New Function Cards: https://www.wildflower.org/plants/result.php?id_plant=CARO6,https://asknature.org/strategy/floating-mats-adjust-to-water-levels/, https://asknature.org/strategy/scales-allow-floating/, https://www.livescience.com/1707-mosquitoes-walk-water-walls.html, https://forestinvasives.ca/Intro-to-Invasives/What-Makes-a-Species-Invasive, http://www.mosquitoreviews.com/mosquito-genus-species.html, http://ipm.ucanr.edu/PMG/WEEDS/large_crabgrass.html, https://ugaurbanag.com/crabgrass/, https://www.kcet.org/redefine/invasive-species-week-the-blue-gum-eucalyptus

Permaculture: https://asknature.org/idea/the-land-institute-permaculture/

Boat floating: https://science.howstuffworks.com/science-vs-myth/everyday-myths/question254.htm

SDGs: https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Partners: http://www.savannahga.gov/1209/Community-Gardens, http://healthysavannah.org/east-savannah-community-transformation-plan/, http://sugacentral.org

SOURCES

FOOD SOURCE SCALE CALCULATIONS
https://www.thespruce.com/how-many-vegetables-per-person-in-garden-1403355

LEARNING ABOUT BIOMIMICRY
Baumeister, D., Tocke, R., Dwyer, J., RItter, S., & Benyus, J. (2014). *Biomimicry Resource handbook: A seed Bank of Best Practices.* Missoula, Montana: First Public Printing.

LEVERAGE POINTS
Meadows, D. H. (2009). *Thinking in Systems: A Primer*. Earthscan.

OTHER SOURCES:
https://stepupsavannah.org/works/
https://pin.it/sx6exwat6v6tfn
https://materialdistrict.com/material/fantastic-bioplastic/
https://issuu.com/andreahaynes/docs/patri_booklet_issuu/20
https://www.hunker.com/13425614/what-wood-for-building-a-dock
https://www.academia.edu/5099048/THE_USE_OF_SALVINIA_MOLESTA_IN_BROILER_DIET_AND_ITS_EFFECT_ON_DIGESTIBILITY_PROTEIN_DEPOSITION_AND_CARCASS_COMPOSITION

Fogstand Beetle: https://asknature.org/strategy/water-vapor-harvesting/

Hairy Frog: https://www.newscientist.com/article/dn13991-horror-frog-breaks-own-bones-to-produce-claws/ , https://defensemechanisms.weebly.com/hairy-frog.html

Honey Badger: https://animaldiversity.org/accounts/Mellivora_capensis/

Hermit crab: https://www.wikiwand.com/en/Caribbean_hermit_crab, https://asknature.org/strategy/social-networking-aids-housing-search/#.XKpsIi2ZNQI , https://sta.uwi.edu/fst/lifesciences/sites/default/files/lifesciences/documents/ogatt/Coenobita_clypeatus%20-%20Caribbean%20Hermit%20Crab.pdf