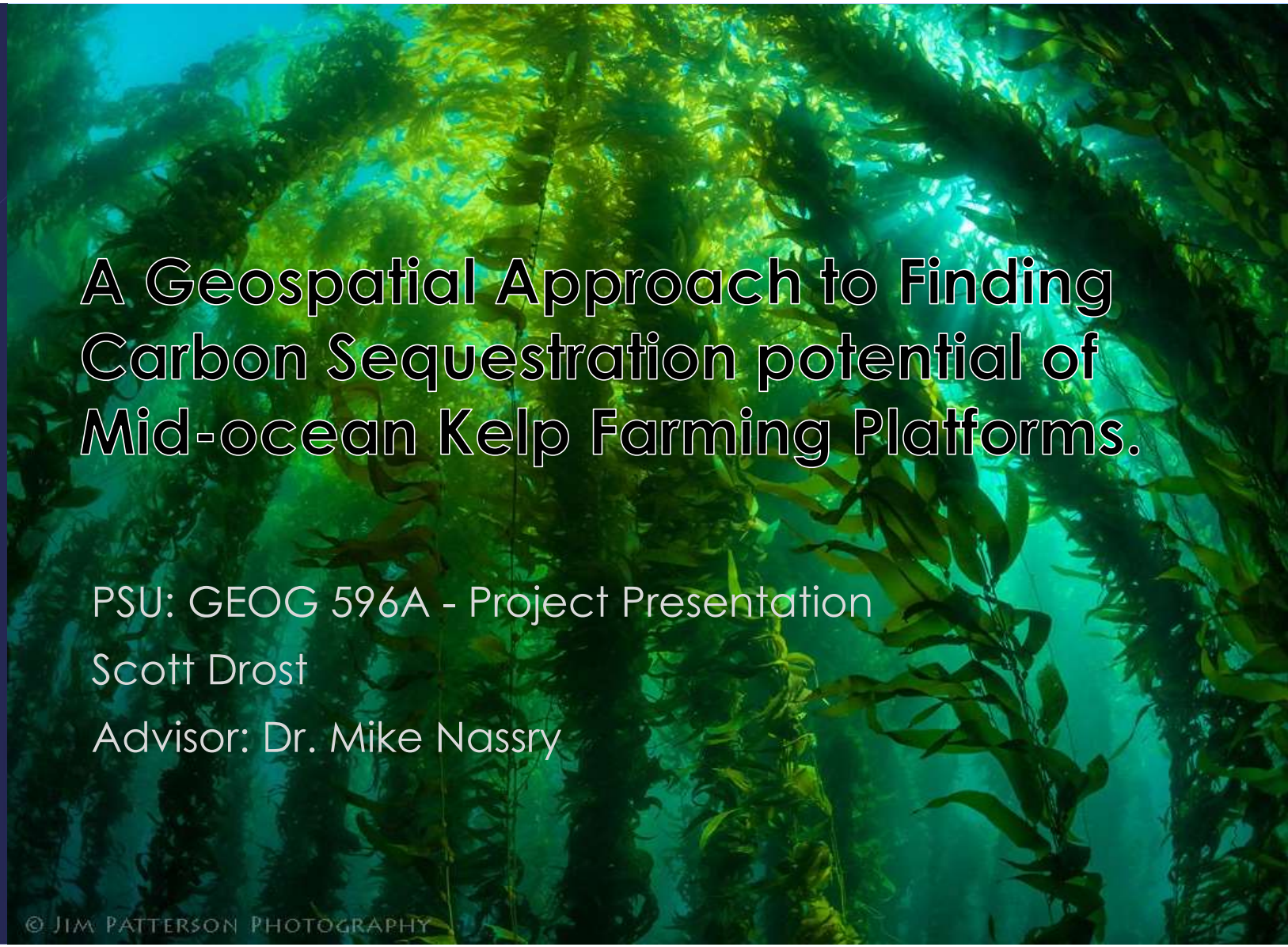


A Geospatial Approach to Finding Carbon Sequestration potential of Mid-ocean Kelp Farming Platforms.

PSU: GEOG 596A - Project Presentation

Scott Drost

Advisor: Dr. Mike Nassry

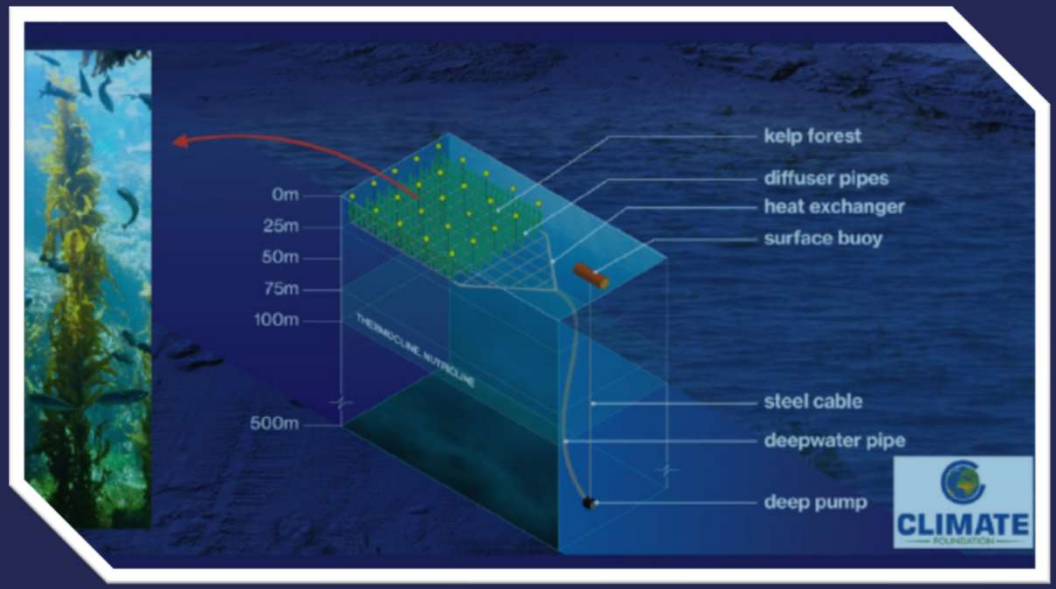
Presentation

- Objectives
- Literature Review
- Methodology

(Picture 1: Giant Kelp from Yale 360, https://e360.yale.edu/features/as-oceans-warm-the-worlds-giant-kelp-forests-begin-to-disappear#)

Objectives

- 1. To find optimal geospatial locations for vast arrays of floating kelp farming platforms considering:
  - Ecological niches
  - Ocean surface temperatures
  - Weather conditions
  - Ocean depths
  - Ocean currents
- 2. Derive the carbon capture potential of all these platform systems.
  - Comparing this value to the IPCC 2018 published CO^2 value.



(Figure 1: PMKF from The Climate Foundation, retrieved from http://www.climatefoundation.org/)

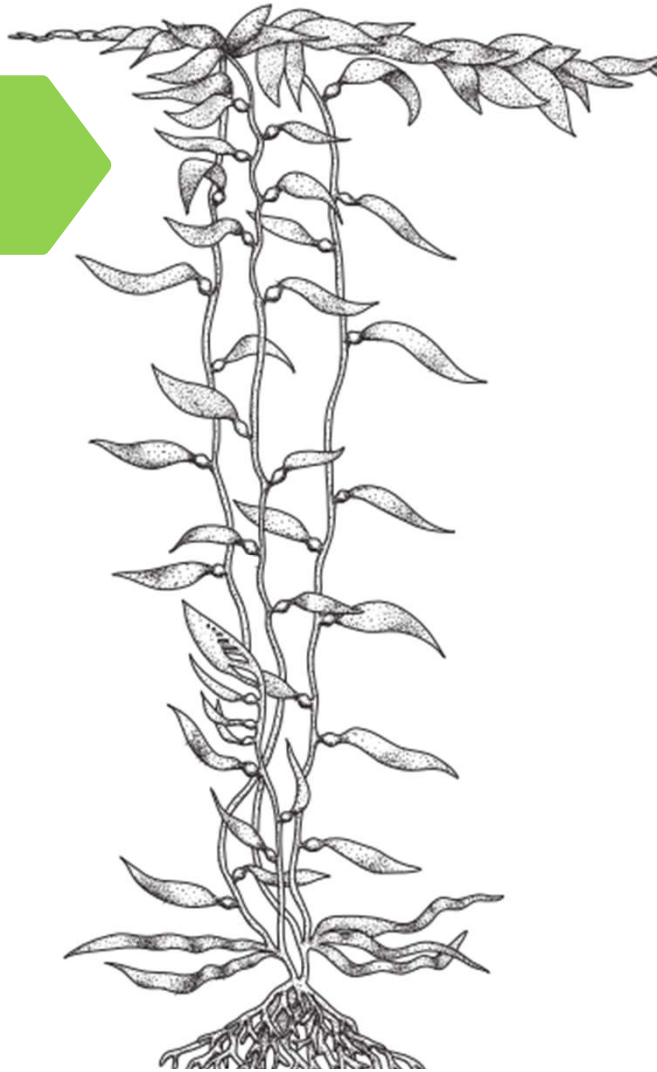
(Picture 2: Giant Kelp Leaves from Futurity, retrieved from https://www.futurity.org/wp/wp-content/uploads/2019/05/giant-kelp-leaves_1600.jpg)

Literature Review Topics

- Algae Species
- Blue Carbon Sequestration
  - Deep Sea Carbon Sequestration
- Photo-Voltaic powered mid-ocean kelp farming (PMKF) platforms
- Primary and Secondary locations

Macrocystis pyrifera (Giant Kelp)

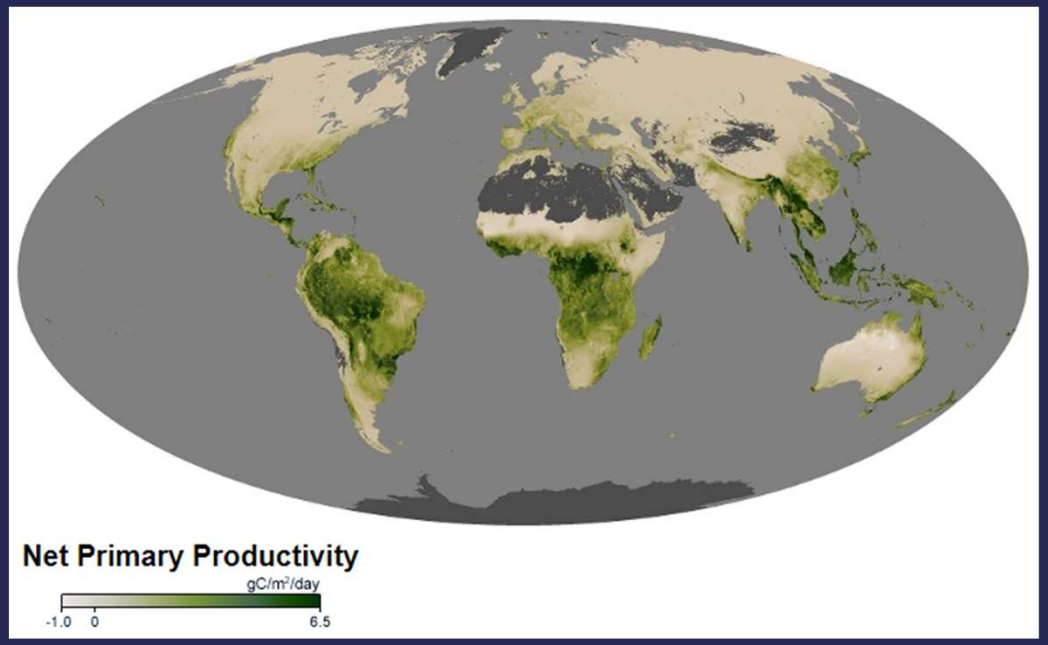
- Fastest Growing Autotroph
  - Typically Exceed Lengths of 25m
  - Growth of 0.5m a day
  - Known to reach 60-150m
    - @500 feet (1.66 football fields)



(Picture 3: Macrocystis pyrifera from The biology and ecology of giant kelp forests)

Net Primary Productivity (NPP) potential

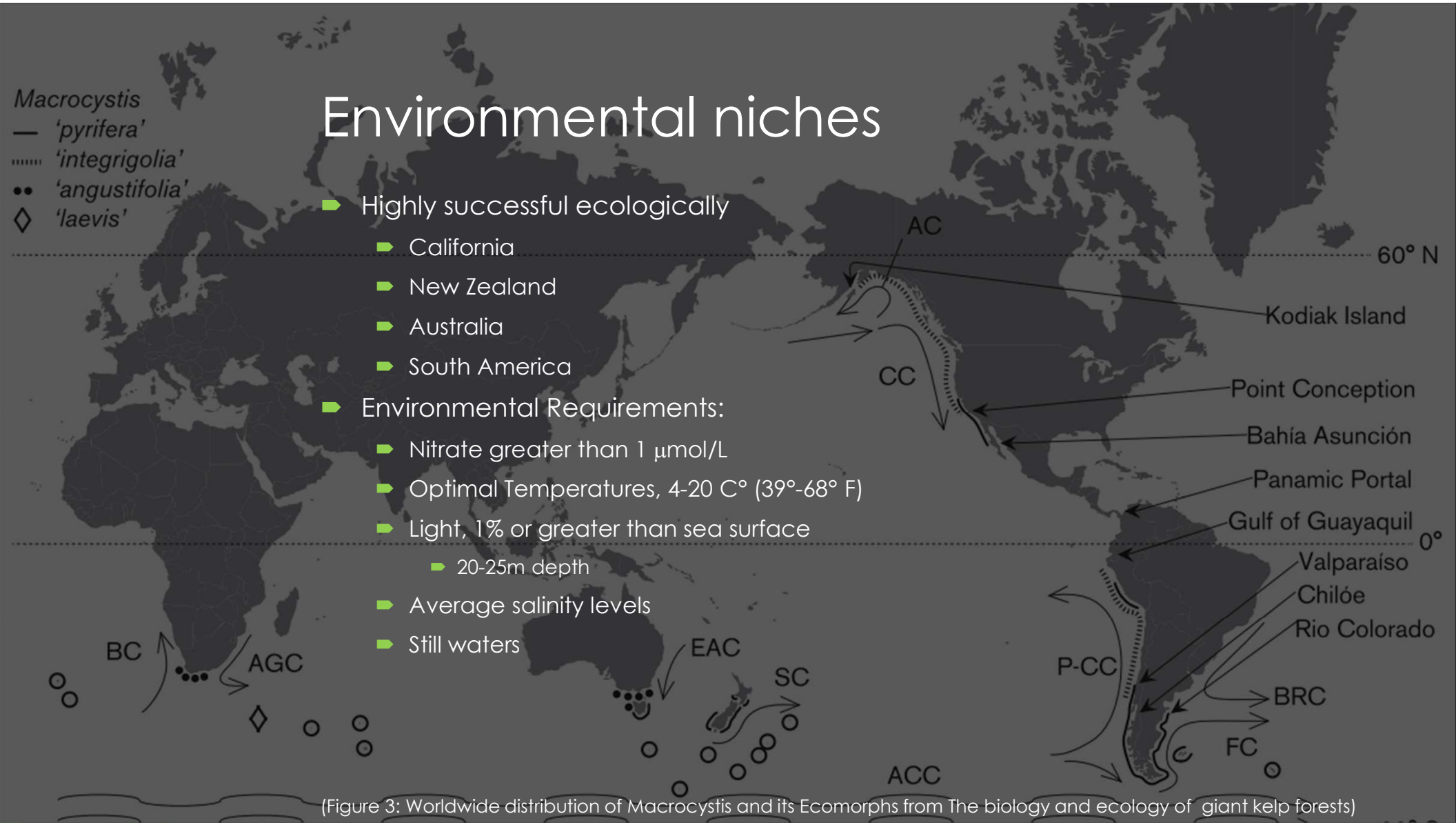
- Defined:
  - Rate of Photosynthesis, minus respiration by the photosynthesizers.
- Macrocytosis pyrifera (Southern California)
  - 5.2 kg dry mass m^2 per year
  - 20-40% of NPP is Carbon
- Moderate Resolution Imaging Spectroradiometer (MODIS)
  - 0.65 g C per day
  - **2.37 kg** of C per year



(Figure 2: NPP (MODIS) from Earth Observatory, retrieved from https://earthobservatory.nasa.gov/global-maps/MOD17A2_M_PSN)

Environmental niches

- Highly successful ecologically
  - California
  - New Zealand
  - Australia
  - South America
- Environmental Requirements:
  - Nitrate greater than 1 μmol/L
  - Optimal Temperatures, 4-20 C° (39°-68° F)
  - Light, 1% or greater than sea surface
    - 20-25m depth
  - Average salinity levels
  - Still waters



(Figure 3: Worldwide distribution of Macrocystis and its Ecomorphs from The biology and ecology of giant kelp forests)

A note on Giant Kelp Morphology

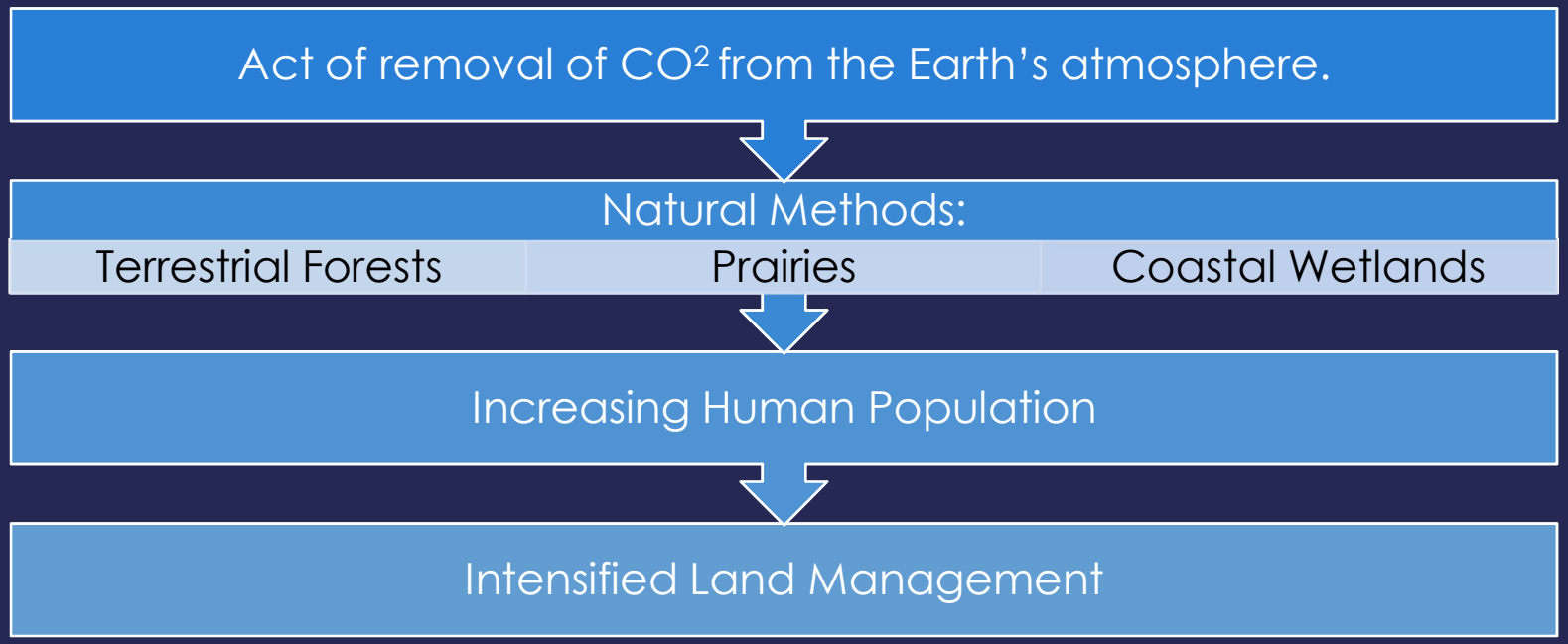
Southern California (5.2 kg NPP):

"Because our data represent intensive sampling at three sites from a 20 km stretch of coast, attempts to extrapolate beyond this geography must be done with caution and consideration of the wide variation in this species."

~Dr. Andrew Rassweiler

Other Morphologies from different regions need further study for regional deployment

Carbon Sequestration



Blue Carbon Sequestration

Carbon, sequestered into the Ocean's ecosystem	• Coastal Areas • Prone to natural disturbance and human activity
International Waters	• No ownership • No conflict

An Ultimate Question

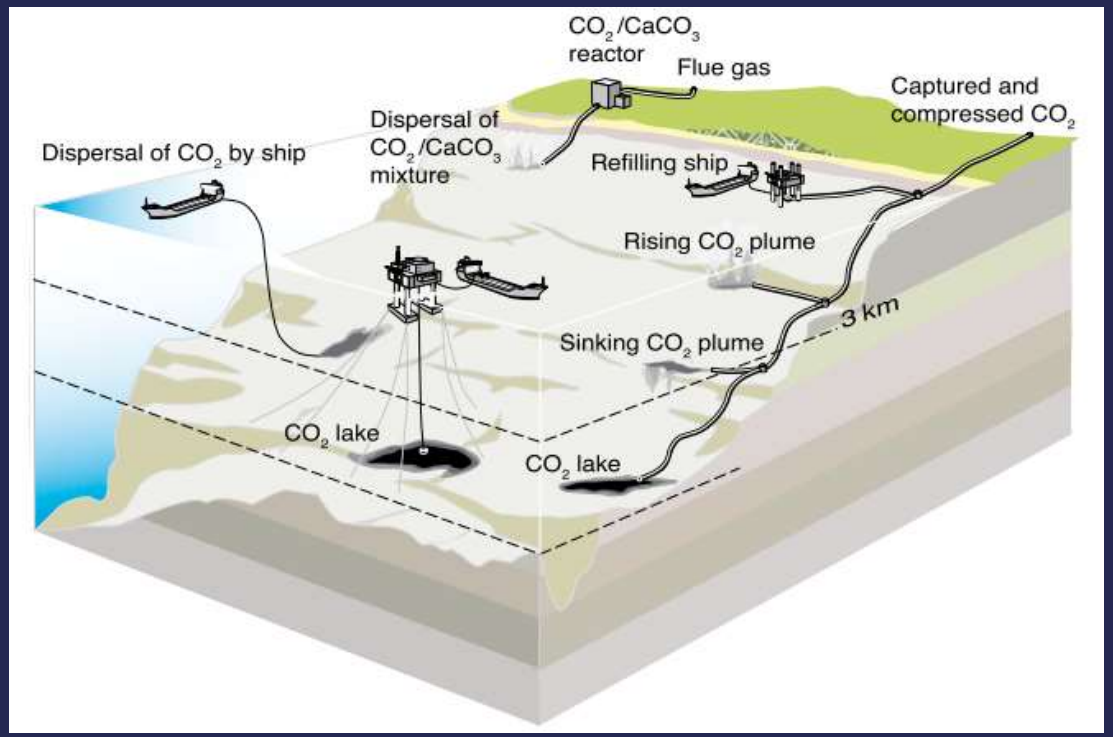
- What if humanity could guide blue carbon sequestration by proliferating Giant Kelp on massive floating structural arrays so that the carbon captured could be locked within the floors of deep oceans by the simple act of clipping and shredding the Kelp at the ocean's surface?

Deep Ocean Carbon Storage

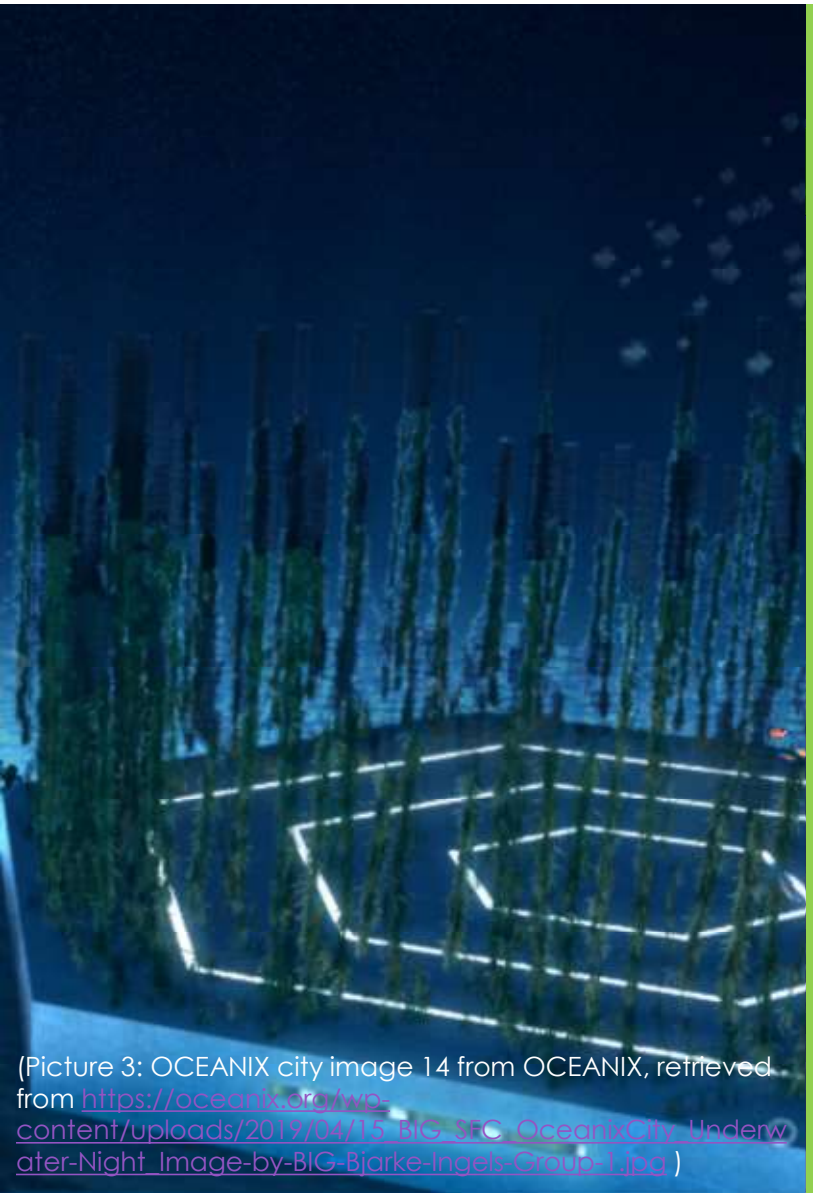
- Intergovernmental Panel on Climate Change (IPCC)
  - IPCC Special Report on Carbon dioxide Capture and Storage
    - Chapter 6 – Ocean Storage
- Ocean surface holds most of the CO^2
  - Decrease in PH of 0.1
  - Massive die offs of many species predicted

Chapter 6 – Ocean Storage

- Isolate CO^2 for centuries
- States of CO^2:
  - 0-500m: GAS
  - 500-3000m: LIQUID
  - >3000m: CRYSTALLINE
- CO^2 Lakes will form.



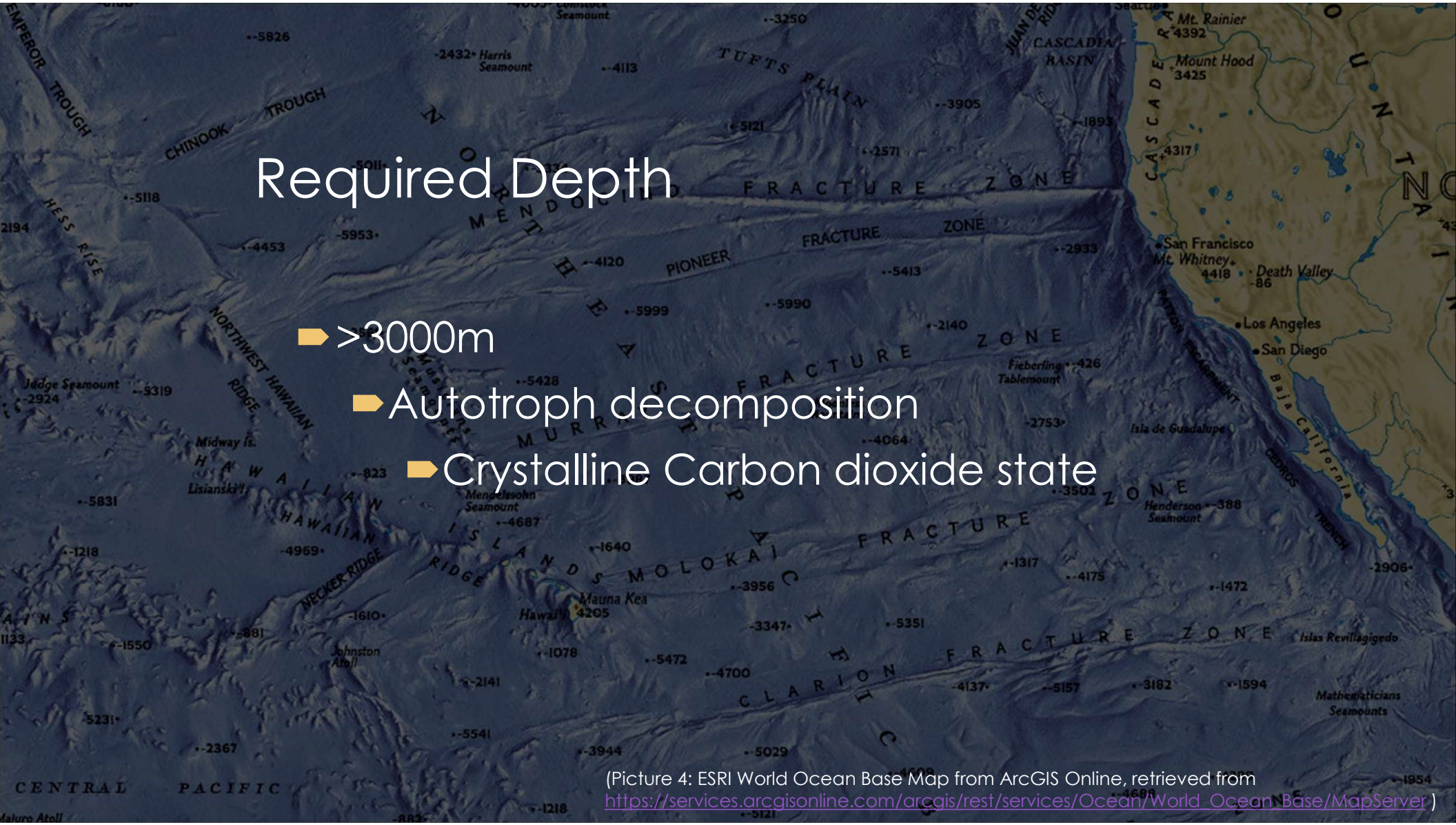
(Figure 4: Illustration of some of the ocean storage strategies from IPCC Special Report on Carbon dioxide Capture and Storage, Chapter 6 – Ocean Storage)



(Picture 3: OCEANIX city image 14 from OCEANIX, retrieved from https://oceanix.org/wp-content/uploads/2019/04/15_BIG_SEC_OceanixCity_Underwater-Night_Image-by-BIG-Bjarke-Ingels-Group-1.jpg)

GIANT KELP vs. CO^2 Injection

- Carbon within Giant Kelp
- Vehicle to Ocean Depths
- Cutting / Shredding Device
  - Solar panel powered



(Picture 4: ESRI World Ocean Base Map from ArcGIS Online, retrieved from https://services.arcgisonline.com/arcgis/rest/services/Ocean/World_Ocean_Base/MapServer)

Photo-Voltaic powered mid-ocean kelp farming (PMKF) platforms

Howard Wilcox (Physicist)

- President Johnson Admin
  - November 22, 1963 – January 20, 1969
- Biofuel Production Usage

Technological Advances

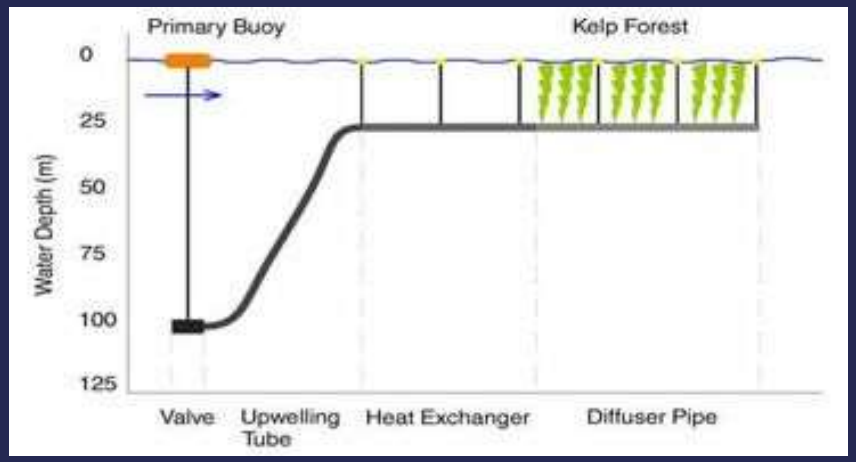
- Carbon Polymer
- Solar Power
- Computers
- Weather Science
- GPS Technology

Mid-Ocean farming

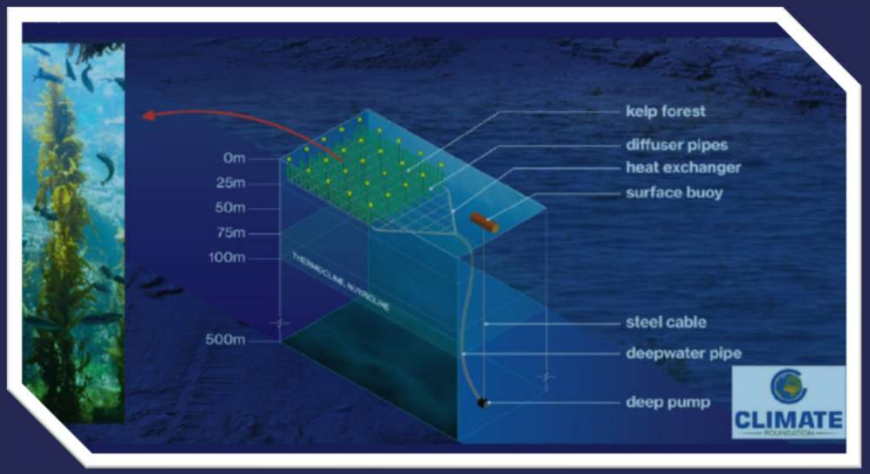
- Isolate growth from Human interference
- Coastal weather
- Fresh water rivers

Photo-Voltaic powered mid-ocean kelp farming platform(PMKF)

- Climate Foundation: Dr. Brian Vonn Hertzen
  - "Floating, open ocean kelp ecosystems."
    - Sequester atmospheric carbon
    - Proliferate fish populations
- Platform Components:
  - Wave Powered Pump
    - Pulls nutrients from deeper water
  - Heat Exchanger
  - Diffuser Pipe
  - Voltaic Solar Array
    - GPS
    - Mobility (Satellite)
      - Vertical
      - Horizontal



(Figure 5: PMKF platform from the Climate Foundation, retrieved from http://www.climatefoundation.org/what-is-marine-permaculture.html)



(Figure 1: PMKF from The Climate Foundation, retrieved from http://www.climatefoundation.org/)

(Picture 5: Honeycomb from Britanica, retrieved from https://www.britannica.com/science/honeycomb-biology)

Hexagonal Array

- Bee Hives
- Hexagons Advantages:
  - Less Materials
    - Less Construction Cost
    - Hexagon Perimeter < Square Perimeter for same area within.

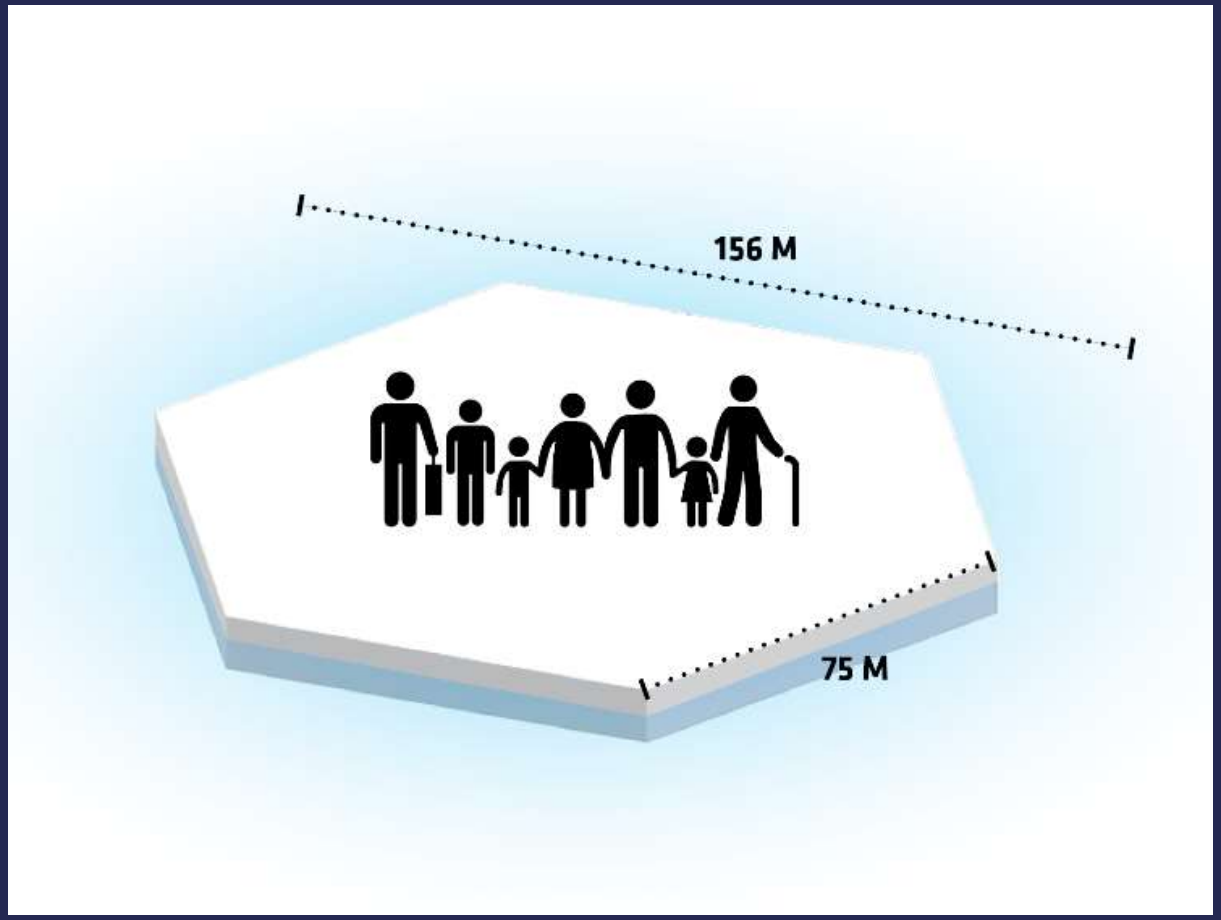
OCEANIX

- Hexagonal Floating Platforms
- United Nations Effort
  - Ocean Bound Floating Cities
    - Self Sustainable - Aquaculture

(Picture 6: OCEANIX City Image 1 from OCEANIX, retrieved from https://oceanix.org/wp-content/uploads/2019/04/01_BIG_SFC_OceanixCity_Aerial_Image-by-BIG-Bjarke-Ingels-Group-1.jpg)

OCEANIX (Neighborhood)

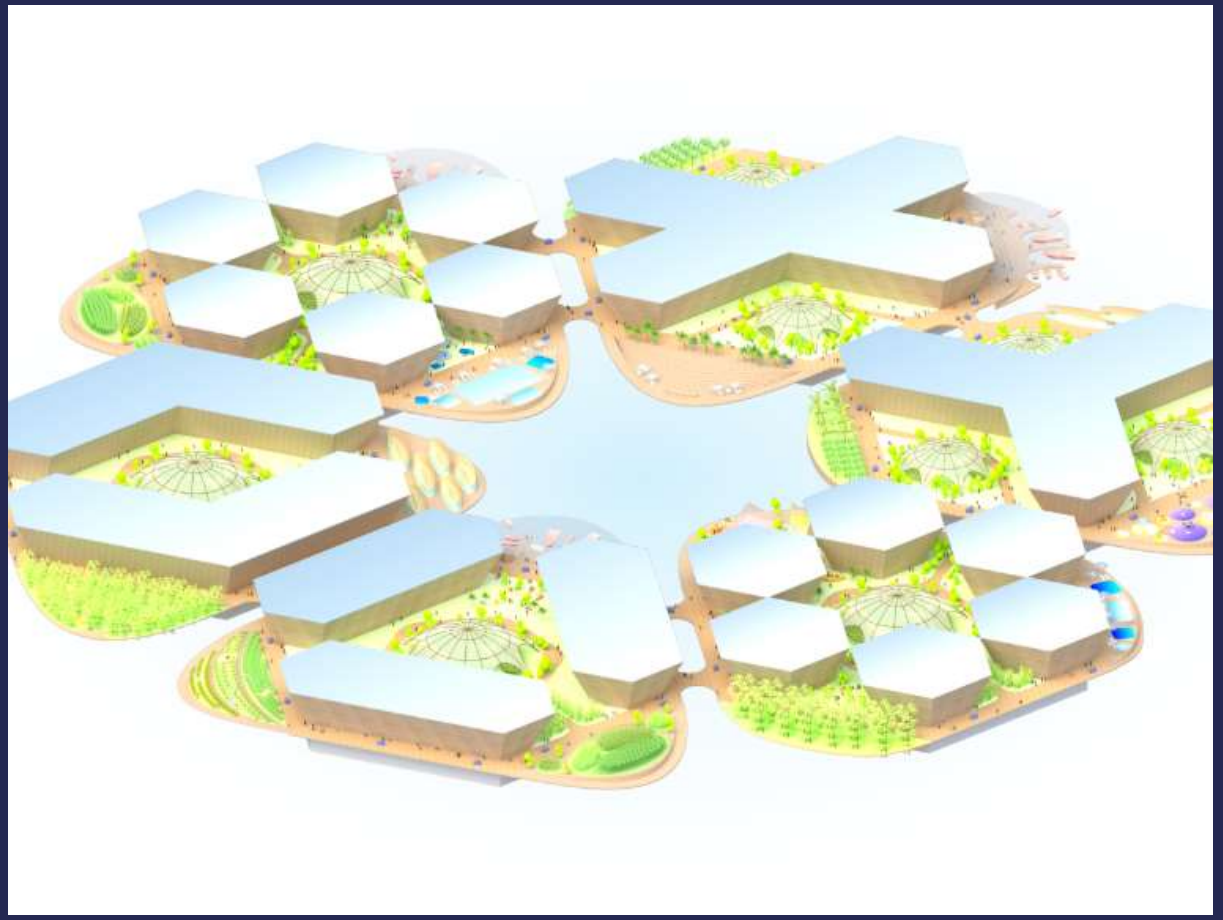
- Dimensions:
  - Face – 75m
  - Vertex to Vertex – 156m
- 300 Residents



(Figure 6: OCEANIX city image 28 from OCEANIX, retrieved from https://oceanix.org/wp-content/uploads/2019/04/BIG_SFC_Oceanix-City_Image-by-BIG-Bjarke-Ingels-Group_13.jpg)

OCEANIX (Village)

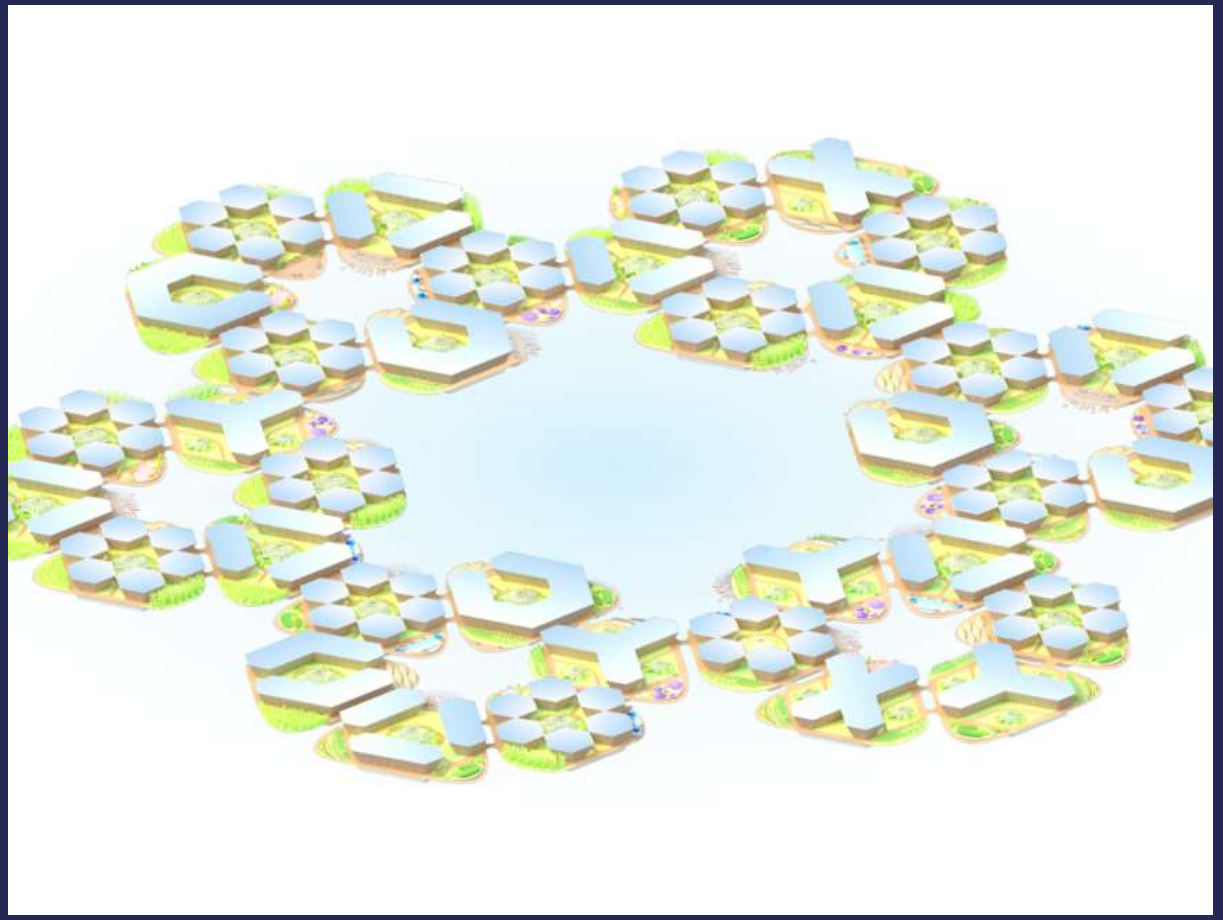
- Cluster of 6 Neighborhoods
- 1,800 Residents



(Picture 7: OCEANIX City Image 45 from OCEANIX, retrieved from https://oceanix.org/wp-content/uploads/2019/04/BIG_SFC_Oceanix-City_Image-by-BIG-Bjarke-Ingels-Group_13.jpg)

OCEANIX (City)

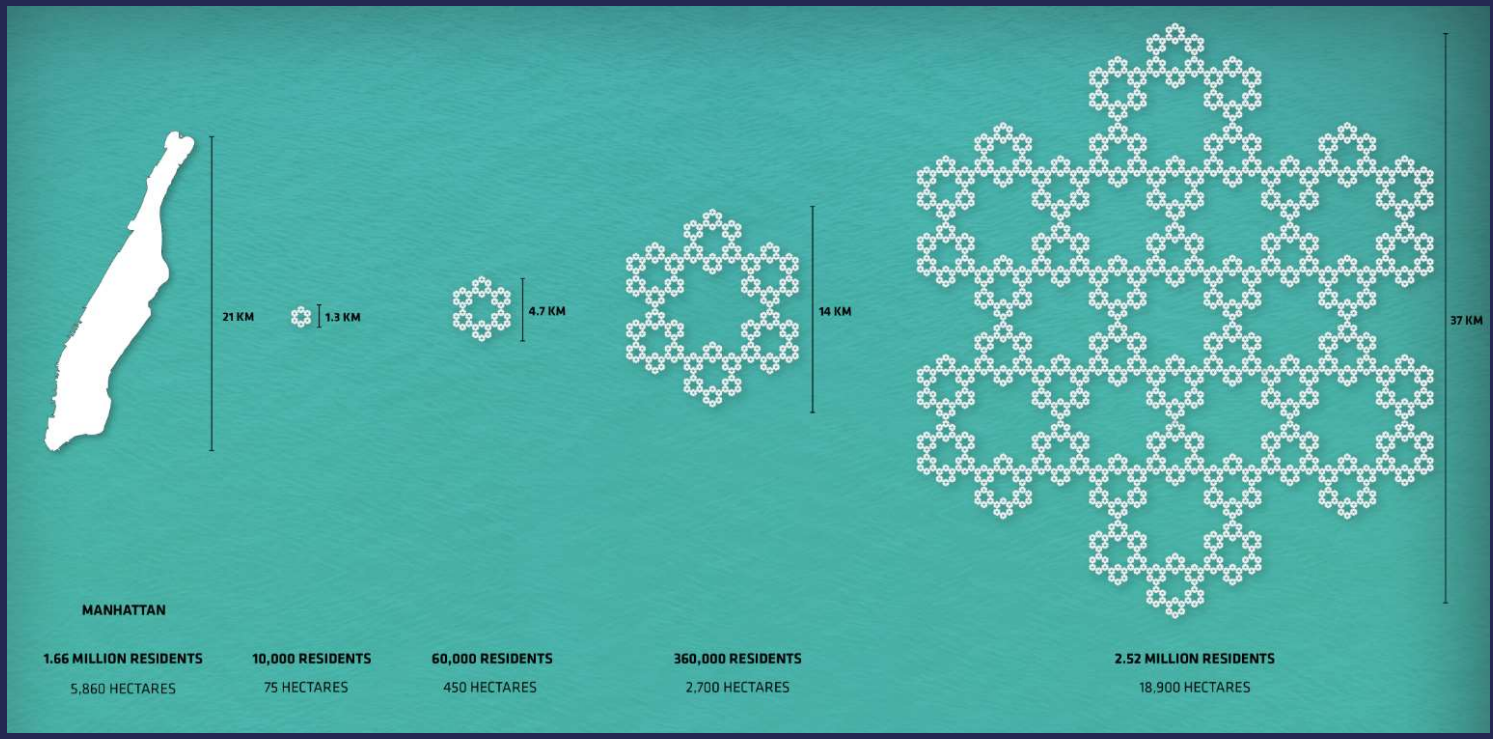
- Cluster of 6 Villages
- 10,000 Residents



(Picture 8: OCEANIX City Image 46 from OCEANIX, retrieved from https://oceanix.org/wp-content/uploads/2019/04/BIG_SFC_Oceanix-City_Image-by-BIG-Bjarke-Ingels-Group_31.jpg)

OCEANIX (Metropolises)

- Largest array consists of 1,296 neighborhoods.
- 21.5 million residents
- Largest array
  - Prime candidate for this study's PMKF.



(Picture 9: OCEANIX City Image 17 from OCEANIX, retrieved from https://oceanix.org/wp-content/uploads/2019/04/BIG_SFC_Oceanix-City_Image-by-BIG-Bjarke-Ingels-Group_38.jpg)

3 Major Considerations:

- Extreme Weather
- Ocean Currents
- Depth (>3000m)

2 Minor Considerations:

- Ecological Niche
- Ocean Surface Temperature

Primary Site Locations (PMKF)

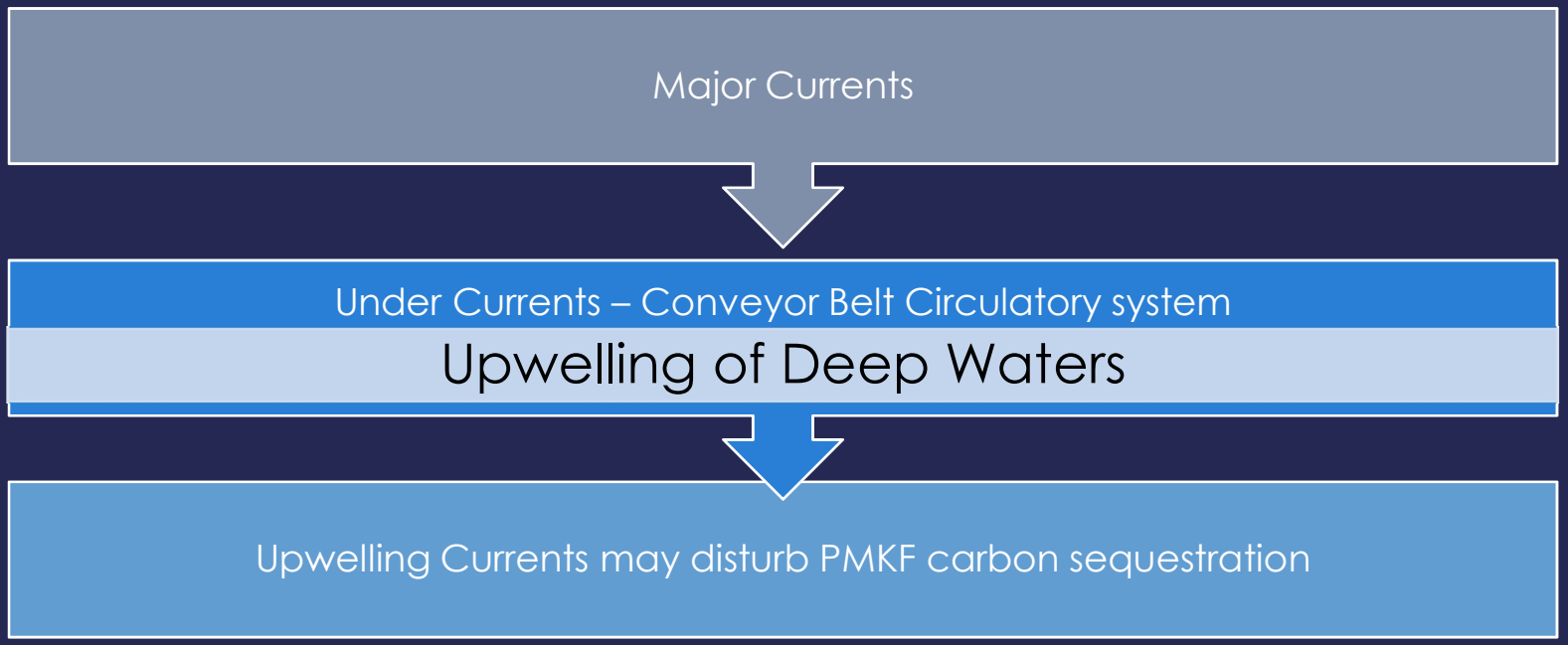
1. Extreme Weather

Wave damage to PMKF platforms

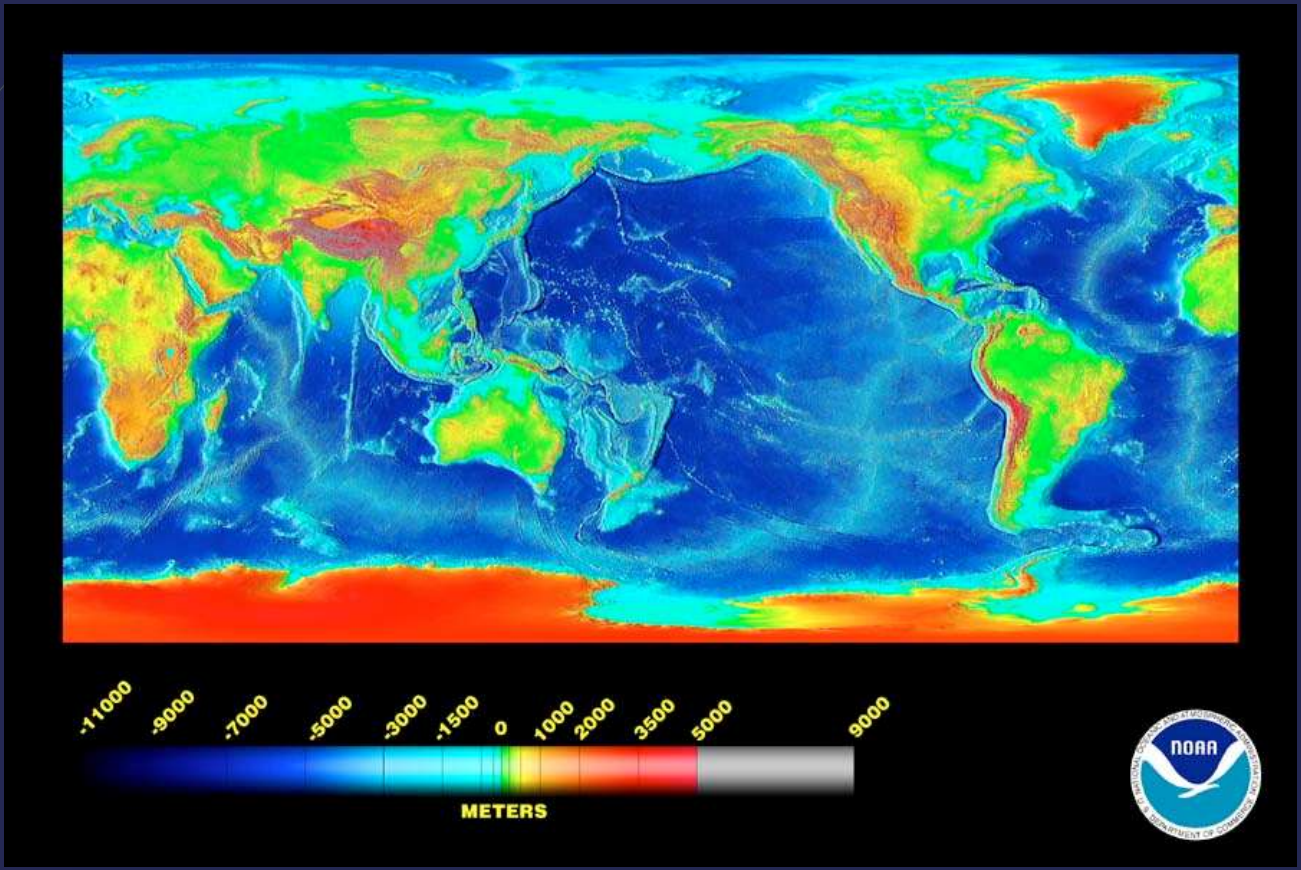
Kelp ripped from rocky holdfast

Rafts or Paddies

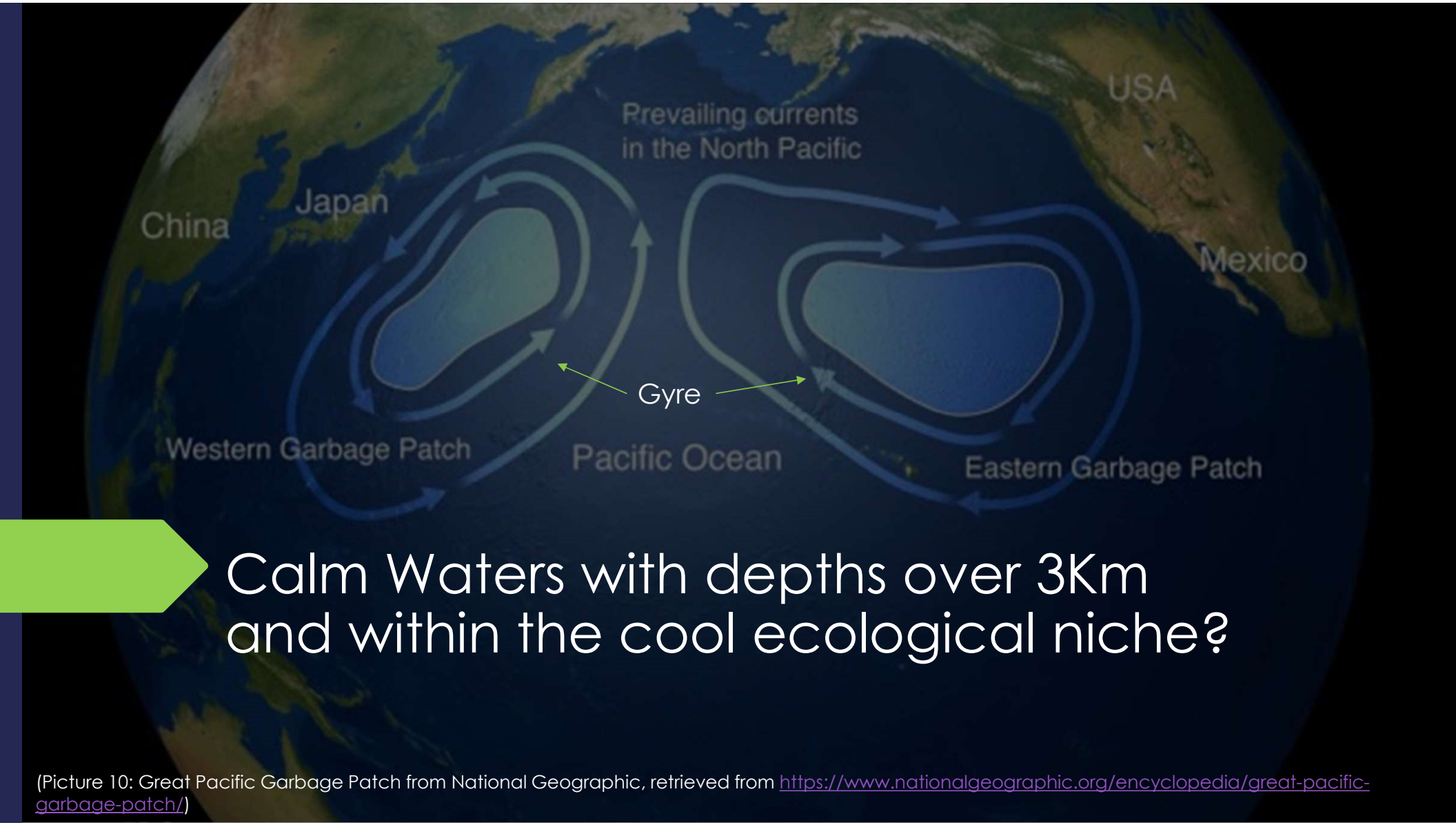
2. Threatening Currents



3. Depth of 3000m



(Figure 7: World View Mercator Projection from NOAA, marine Geology and GeoPhysics , retrieved from https://www.ngdc.noaa.gov/mgg/image/relief_slides2.html)

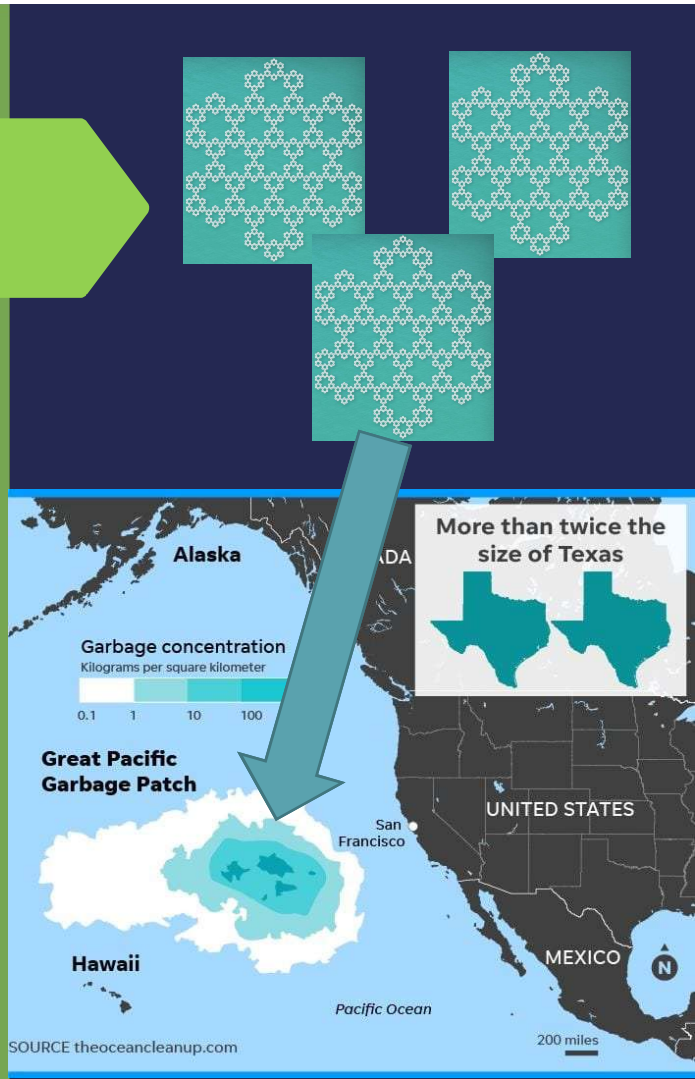


Calm Waters with depths over 3Km and within the cool ecological niche?

(Picture 10: Great Pacific Garbage Patch from National Geographic, retrieved from https://www.nationalgeographic.org/encyclopedia/great-pacific-garbage-patch/)

Methodology – Part 1

- ESRI FGDB creation.
  - OCEANIX array, Initial Manual Construction
    - ArcPy Module Script (Automation)
      - Writing Geometries and Attributes (Editor Class)
        - Insert Cursors (Geometries)
        - Update Cursors (Geometries and Attributes)
      - Tessellation of OCEANIX Array
        - Inside SITE Polygons
  - SITE Polygons
    - NOAA local and REST service data
    - Spatial Analysis
      - Surface Temperature
      - Depths
      - Weather
      - Currents

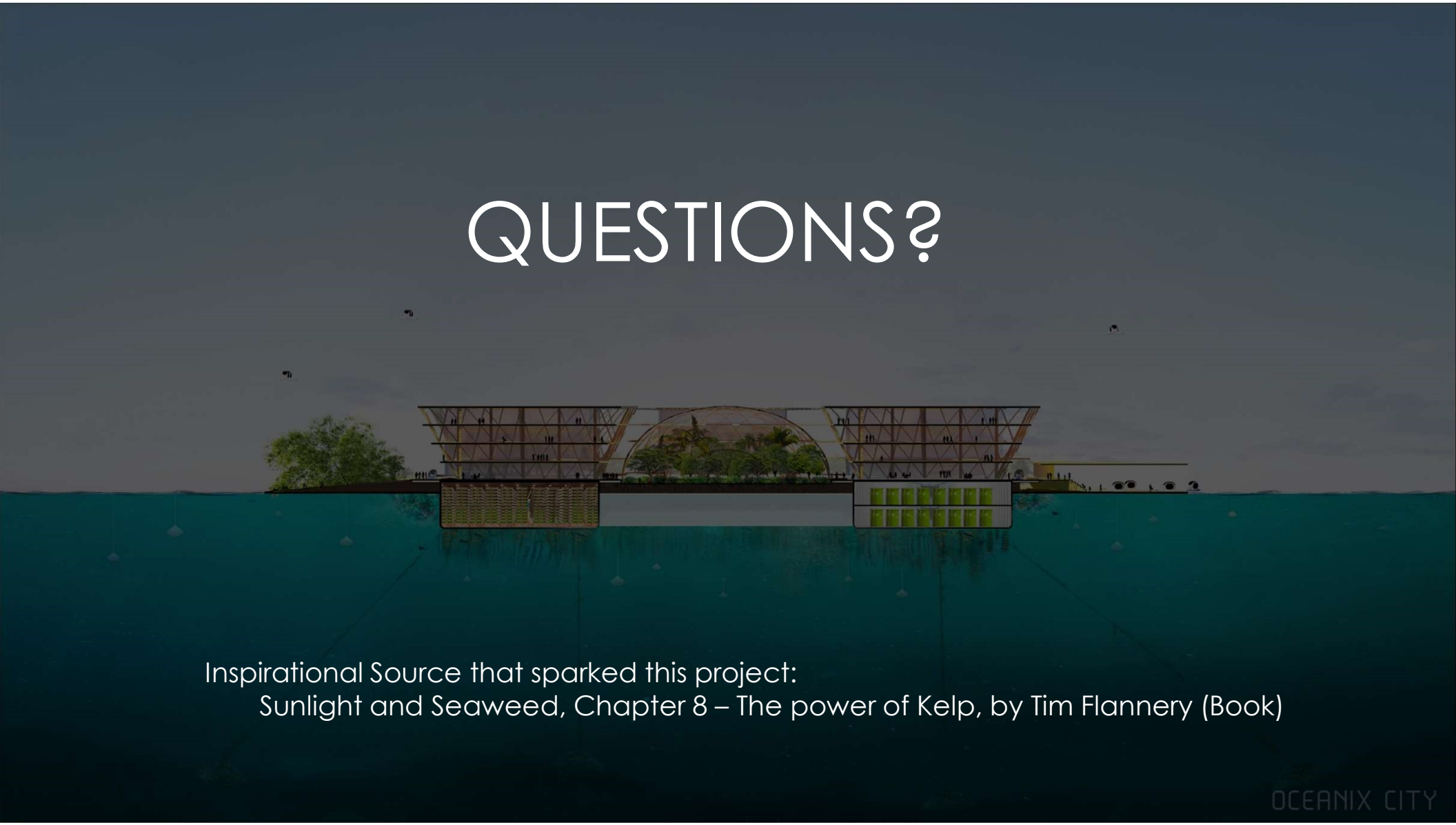


(Figure 8: Great Pacific Garbage Patch from The Ocean Cleanup, retrieved from https://sites.psu.edu/kaylatrancivicissue/2019/03/20/plastic-island/

Methodology – Part 2

- FGDB Uploaded to PSU's Portal for ArcGIS
  - Hosted Feature Service
    - Web Map
      - Operations DASHBOARD
- ESRI Operations Dashboard
  - Compare the 5.2kg m^2 per year (20-40% Carbon) vs. IPCC (2018)
    - How much does Giant Kelp grown on the platforms lower the carbon in the atmosphere?
      - 20% Selector (Conservative)
      - 30% Selector (Median)
      - 40% Selector (Aggressive)

QUESTIONS?



Inspirational Source that sparked this project:

Sunlight and Seaweed, Chapter 8 – The power of Kelp, by Tim Flannery (Book)

References:

Bendix, A. (2019, April 3). *Business Insider*. Retrieved from The UN is supporting a design for a new floating city that can withstand Category 5 hurricanes: https://www.businessinsider.com/un-floating-city-housing-hurricanes-2019-4

Clendenning, K. A. (1971). The biology of giant kelp beds (Macrocystis) in California. In K. A. Clendenning, *Photosynthesis and general development* (pp. 169-190).

Flannery, T. (2017). *Sunlight and Seaweed*. Text Publishing.

Hauer, F. R., & Lamberti, G. A. (2006). Primary Productivity and Community Respiration, Chapter 28. In F. R. Hauer, & G. A. Lamberti, *Methods in Stream Ecology* (p. 663). Elsevier Inc.

Hertzen, D. B. (2019). *Climate Foundation*. Retrieved from What is Marine Permaculture?: http://www.climatefoundation.org/marine-permaculture.html

Joseph, A. (2014). Oceanic Currents and Their Implications. In *Measuring Ocean Currents* (pp. 1-49).

Ken Caldeira, M. A. (2018). Chapter 6, Ocean Storage. In *IPCC Special Report on Carbon Dioxide Capture and Storage* (pp. 278-318).

Mernit, J. L. (2018, July 2). *YaleEnvironment360*. Retrieved from How Eating Seaweed Can Help Cows to Belch Less Methane: https://e360.yale.edu/features/how-eating-seaweed-can-help-cows-to-belch-less-methane

Mohammed, A. (2019, April 3). *United Nations*. Retrieved from Meetings Coverages and Press Releases: https://www.un.org/press/en/2019/dsgsm1269.doc.htm

N'Yeurt, A. d. (2012). Negative carbon via Ocean Afforestation. *Process Safety and Environmental Protection*, 467-474.

OCEANIX. (2018). *OCEANIX Humanity's Next Frontier*. Retrieved from Media: https://oceanix.org/media/

Rassweiler, A. (2018). IMPROVED ESTIMATES OF NET PRIMARY PRODUCTION, GROWTH AND STANDING CROP OF MACROSYSTIS PRYIFERA IN SOUTHERN CALIFORNIA. *ECOLOGY*, 1-42.

Schiel, D. R., & Foster, M. S. (2015). *The biology and ecology of giant kelp forests*.

Ward, K., & Carlowicz, M. (2019). *Earth Observatory (NASA)*. Retrieved from Net Primary Productivity: https://earthobservatory.nasa.gov/global-maps/MOD17A2_M_PSN