GOLDEN JELLYFISH

AND ITS IMPACT ON TOURISM REVENUE IN PALAU

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EXECUTIVE SUMMARY

The purpose of this project is to create a dashboard that signals changes in a geographic region's biodiversity geared for use by scientists and the nation's leaders to provide a basis for new policy. We were tasked to focus on the Pacific Islands and the various ways in which climate change has impacted the numerous plants, animals, and humans who reside in this archipelago. Our dashboard addressed the most topical threats in the region for the internationally admired golden jellyfish, or Mastigias papua, with the goal of catalyzing legislative action.

PRELIMINARY RESEARCH

To begin our dashboard creation process, we looked into the numerous environmental problems faced by the Pacific Islands, an archipelago comprises of three ethno-geographic groupings—Melanesia, Micronesia, and Polynesia. Based on our findings, we compiled the following table of the most immediate and devastating issues.

SOURCE	ENVIRONMENTAL ISSUE	CAUSES	IMPACT
http://www.unesco.org/csi/smis/siv/inter-reg/climate.pdf	Hurricanes	• ENSO Warm Phase (The El Niño-Southern Oscillation a naturally occurring phenomenon that involves fluctuating ocean temperatures in the equatorial Pacific.)	• Death of hundreds of people • Infrastructure damage from high winds • Flooding • Sea surge • Longer drought periods • More marked rainy periods
https://www.ifad.org/documents/10180/9054c140-a03c-4c6e-ae9e-ab9d7972dd19	Agriculture Crisis	• Ocean warming • Frequent tropical cyclones • Flash floods • Droughts • Increased precipitation	• Local livelihood affected • Drop in competitiveness of cash crops • Longer drought periods • Loss of soil fertility • Soil degradation • In the absence of adaptation, a high island such as Fiji, could experience damage of USD 23 million to 52 million per year by 2050. • The overall change in agricultural welfare is expected of a range between -8 and +4 billion USD per year facing with 2-4 C° temperature increase.

https://www.ifad.org/documents/10180/9054c140-a03c-4c6e-ae9e-ab9d7972dd19	Salinization	• Rise in sea level • Sea flooding • Inundation	• Estimated impacts of sea-level rise on Pacific Islands' coastal communities are quantified in 77,018 km of shoreline affected with direct costs of 1,419 million of USD per year at sub-regional level associated to a 30-50 cm of sea-level rise.
http://researchonline.jcu.edu.au/8197/1/02whole.pdf	Decline in Coral Reef Cover	• Ocean warming • Exposure to bacterial pathogens at elevated temperatures • Acidity • Higher storm frequency • Growing anthropogenic stress on reefs • Aquatic diseases such as coral bleaching • Exposure to increased radiation	• Since the mid 1980's three major bleaching events have struck coral reefs in the Caribbean - Glynn 1984, Goreau and Hayes 1994. • Two mass bleaching events in 1998 and 2002 have caused devastation in the Great Barrier Reef and in the Indo-Pacific ocean.
http://www.cakex.org/sites/default/files/documents/NCA-PIRCA-FINAL-int-print-1.13-web.form_.pdf	Species Extinction	• Increased temperatures • Reduced rainfall	• Native Pacific Island plant and animal populations and species are put under stress, especially in high-elevation ecosystems, with increased exposure to non-native biological invasions and fire and with extinctions a likely result.

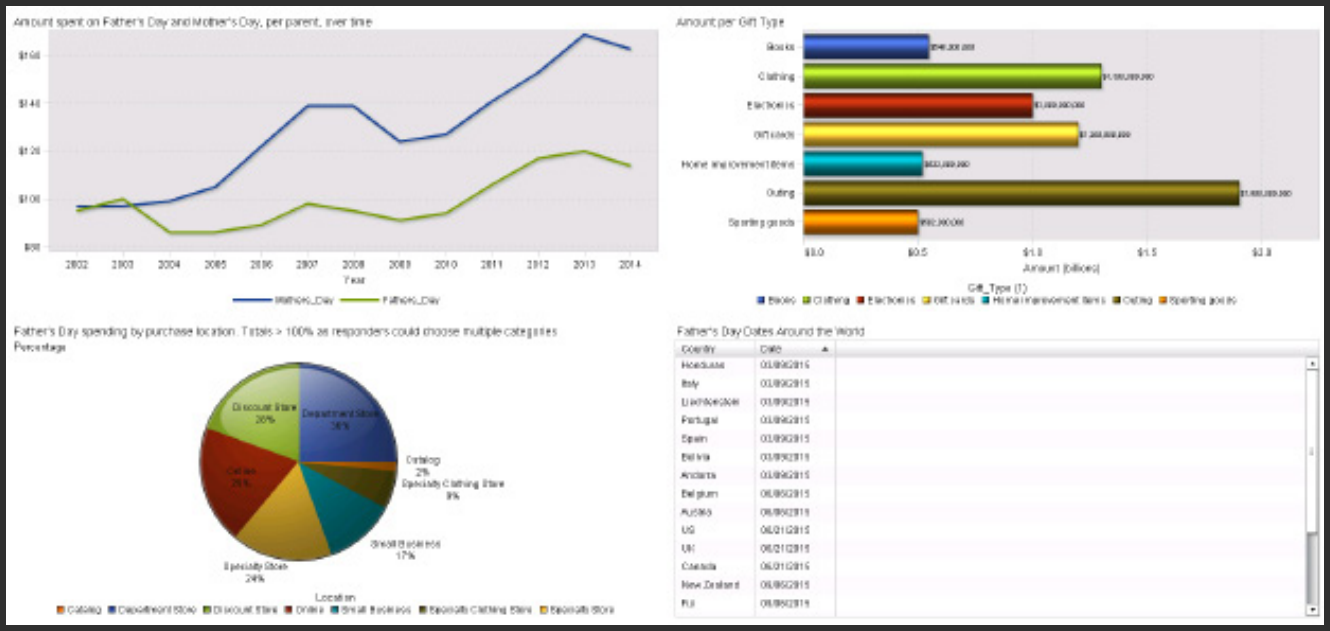
https://www.ifad.org/documents/10180/9054c140-a03c-4c6e-ae9e-ab9d7972dd19	Fresh Water Scarcity	• Infrastructure deterioration resulting in major leakages • Water pollution from soil erosion • Herbicide and pesticide runoff • Livestock waste • Liquid and solid waste disposal	• Climate models show that a 10% reduction in average rainfall by 2050 is likely to correspond to a 20% reduction in the size of freshwater lens on Tarawa Atoll, Kiribati.
https://www.ifad.org/documents/10180/9054c140-a03c-4c6e-ae9e-ab9d7972d	Decline in the size of the islands	• Land loss accompanying seal-level rise	• This is expected to reduce the depth of the freshwater lens on atolls by as much as 29% • For Majuro atoll in the Marshall Islands and Kiribati, it is estimated that for a 1m rise in sea level, as much as 80% and 12.5%, respectively, of total land would be vulnerable.
https://www.gdrc.org/oceans/sin-problems.html	Deforestation	• Removal of forestry for agriculture or use	• Loss of habitat for animal species • Soil erosion • Water shortage

DASHBOARD EXAMPLES

In addition to conducting preliminary research, we were also asked to bring in photo examples of a dashboard that is visually appealing but difficult to understand and one that is visually unappealing but easy to comprehend.

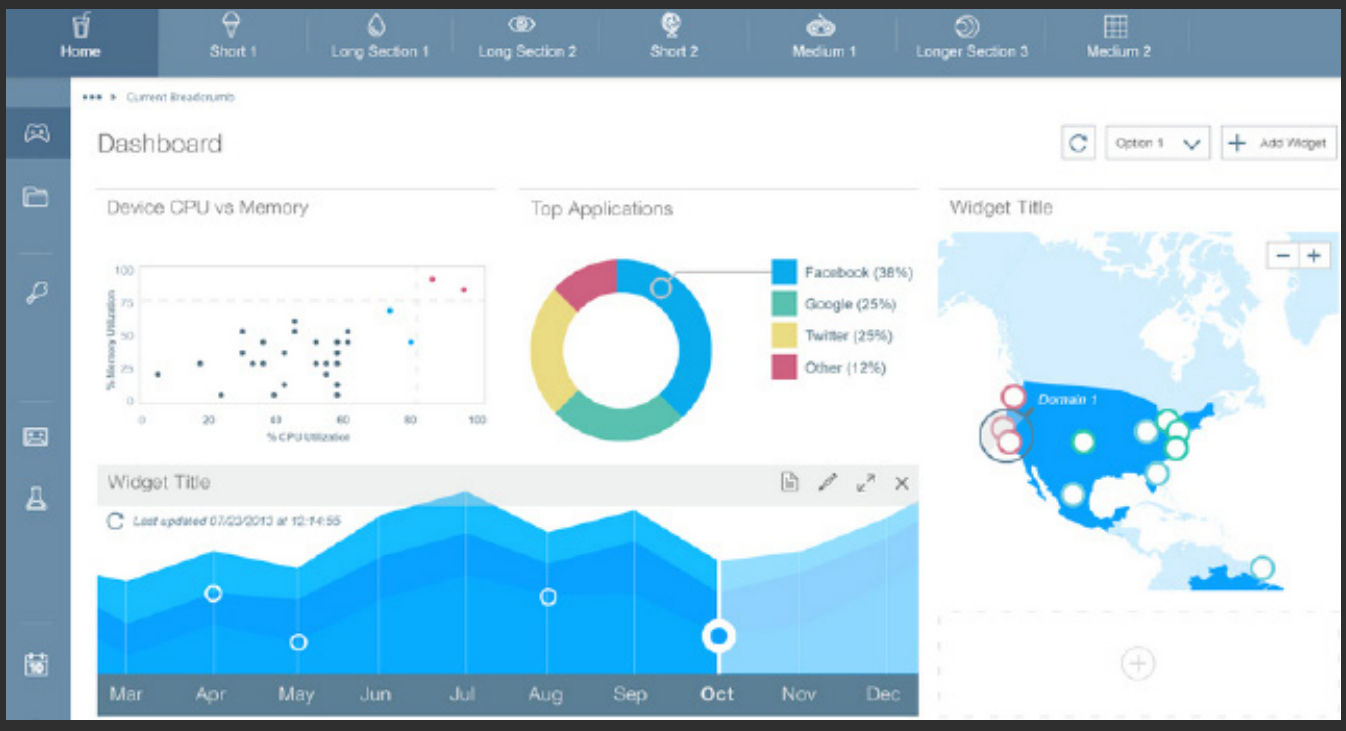
VISUALLY UNAPPEALING, EASY TO UNDERSTAND

We chose this example because, although the colors are awful, it's very easy to understand the information presented in each graph. The layout is not confusing and the dashboard clearly conveys the messages to the reader. From both the visually appealing and visually unappealing examples, we were able to gather ideas for what our dashboard could potentially look like and what elements we could use.



VISUALLY APPEALING, NOT EASY TO COMPREHEND

We chose this example because the dashboard at first glance looks simple and clean, yet it's unclear what the information is referring to, especially the map of North America displayed at the right. It's unknown what the green and red circles refer to, and there is no legend to understand it.



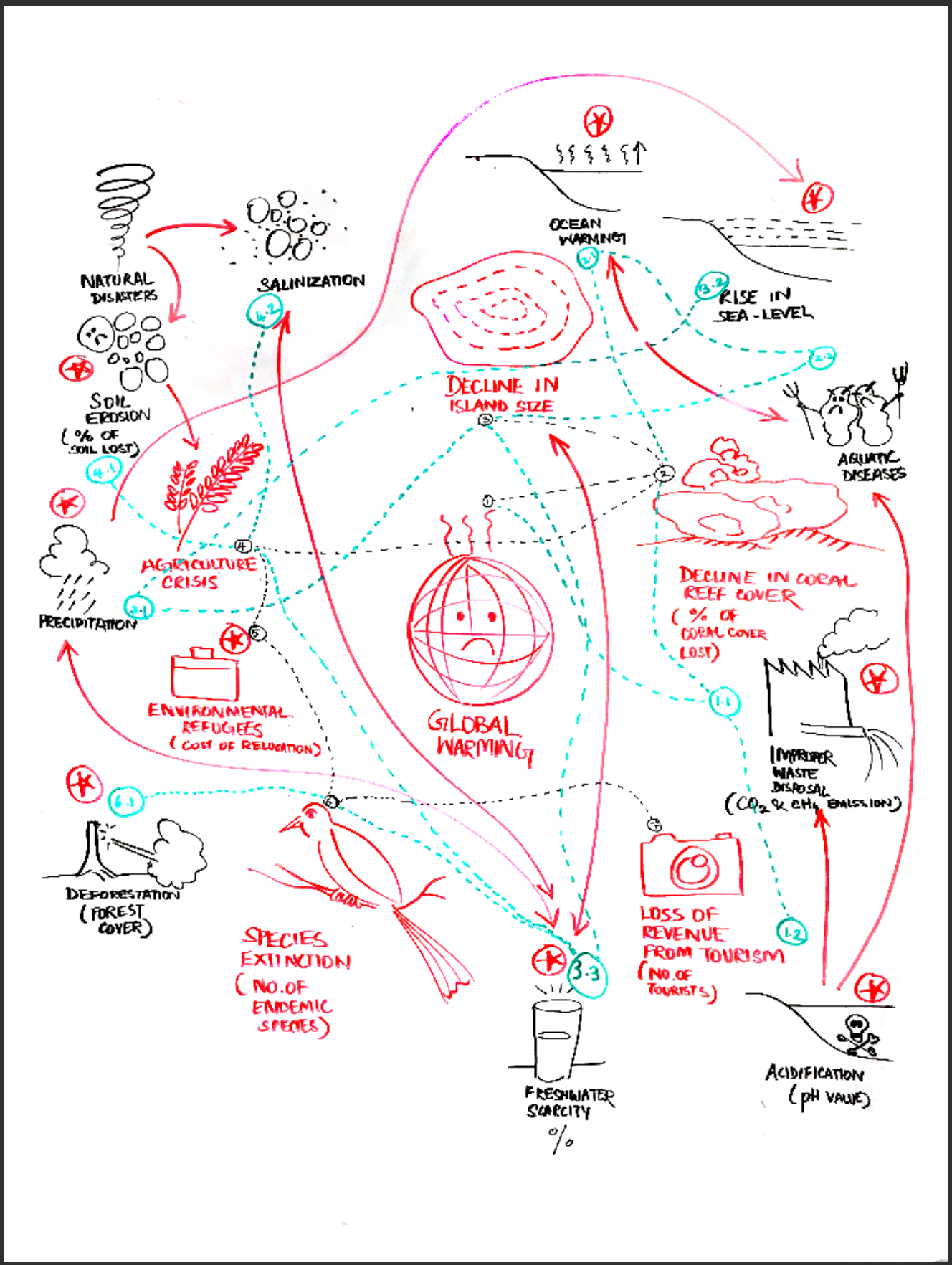
KEY THREATS AND INDICATORS

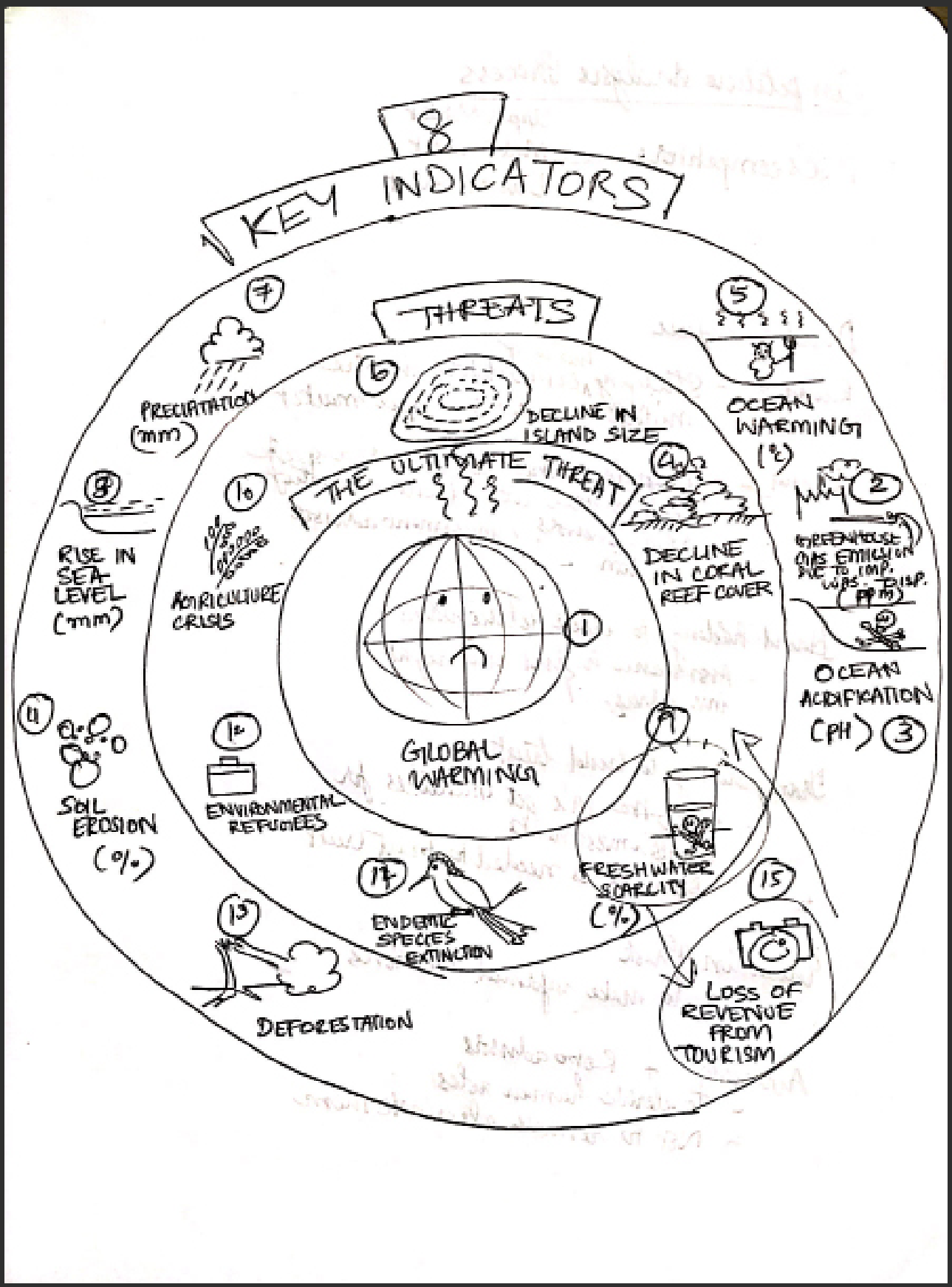
From the initial findings of our research, we narrowed down to a few key threats that we felt were most pressing to the Pacific Islands :

- Agricultural decline
- Decrease in island size
- Economy from fisheries and tourism
- Species extinction and threats to the ecosystem
- Depletion of water resources
- Pollution from sewage systems and greenhouse gases

We also chose indicators that would be used to measure these threats:

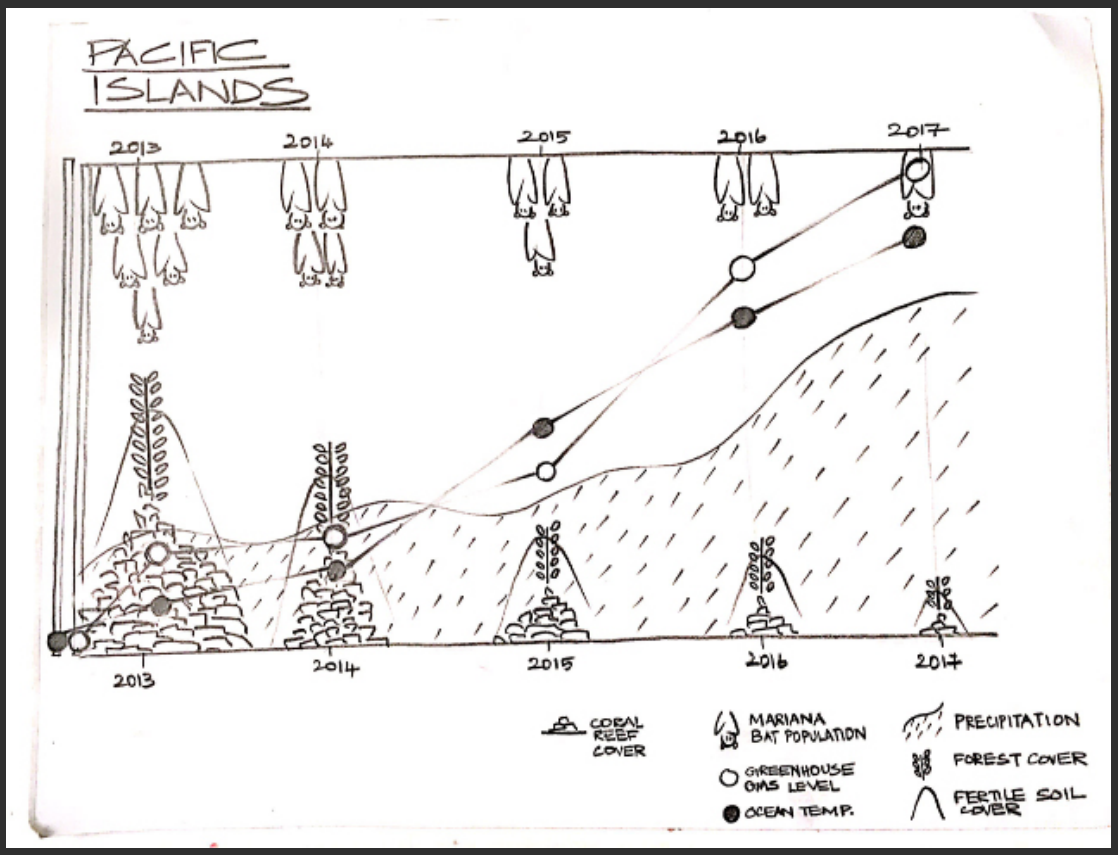
- Sea level
- Soil erosion
- GDP
- Natural disasters
- Loss of land
- List of endangered and extinct species
- Cost of relocation for environmental refugees
- Greenhouse gas emissions/carbon footprint

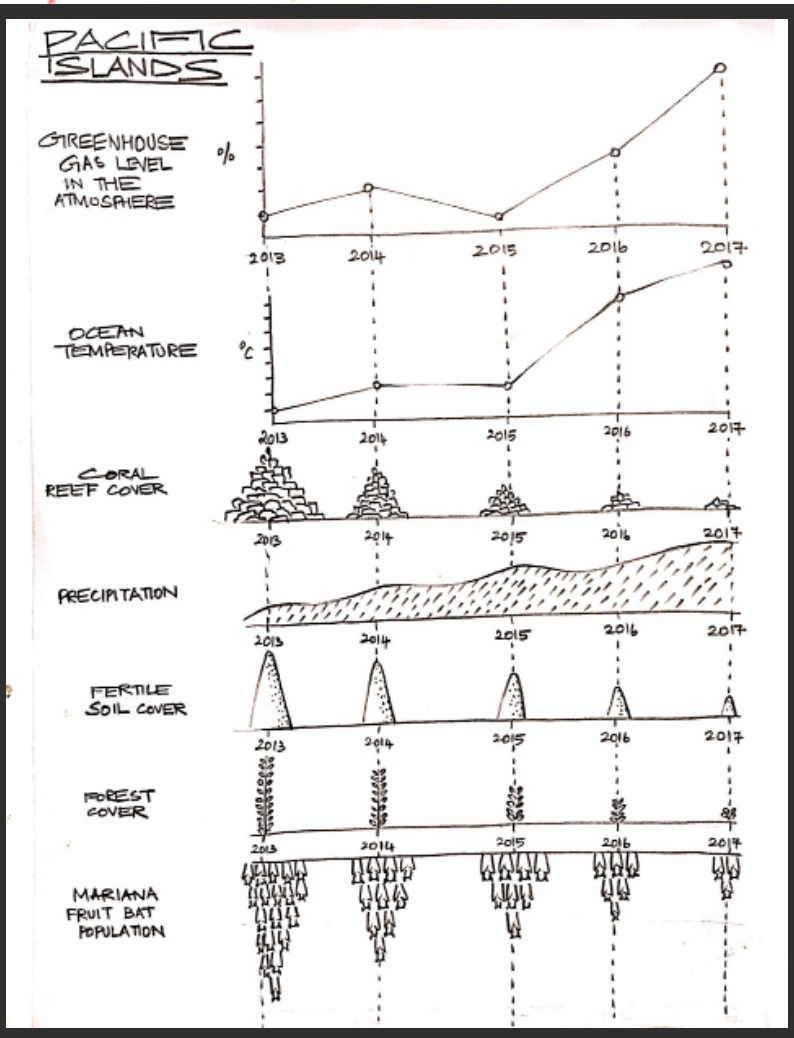

NATURAL DISASTERS
SALINIZATION
SOIL EROSION (% OF SOIL LOST)
OCEAN WARMING
RISE IN SEA-LEVEL
DECLINE IN ISLAND SIZE
AQUATIC DISEASES
AGRICULTURE CRISIS
PRECIPITATION
DECLINE IN CORAL REEF COVER (% OF CORAL COVER LOST)
ENVIRONMENTAL REFUGEES (COST OF RELOCATION)
GLOBAL WARMING
IMPROPER WASTE DISPOSAL (CO_2 & CH_4 EMISSION)
DEFORESTATION (FOREST COVER)
SPECIES EXTINCTION (NO. OF ENDEMIC SPECIES)
LOSS OF REVENUE FROM TOURISM (NO. OF TOURISTS)
FRESHWATER SCARCITY %
ACIDIFICATION (pH VALUE)

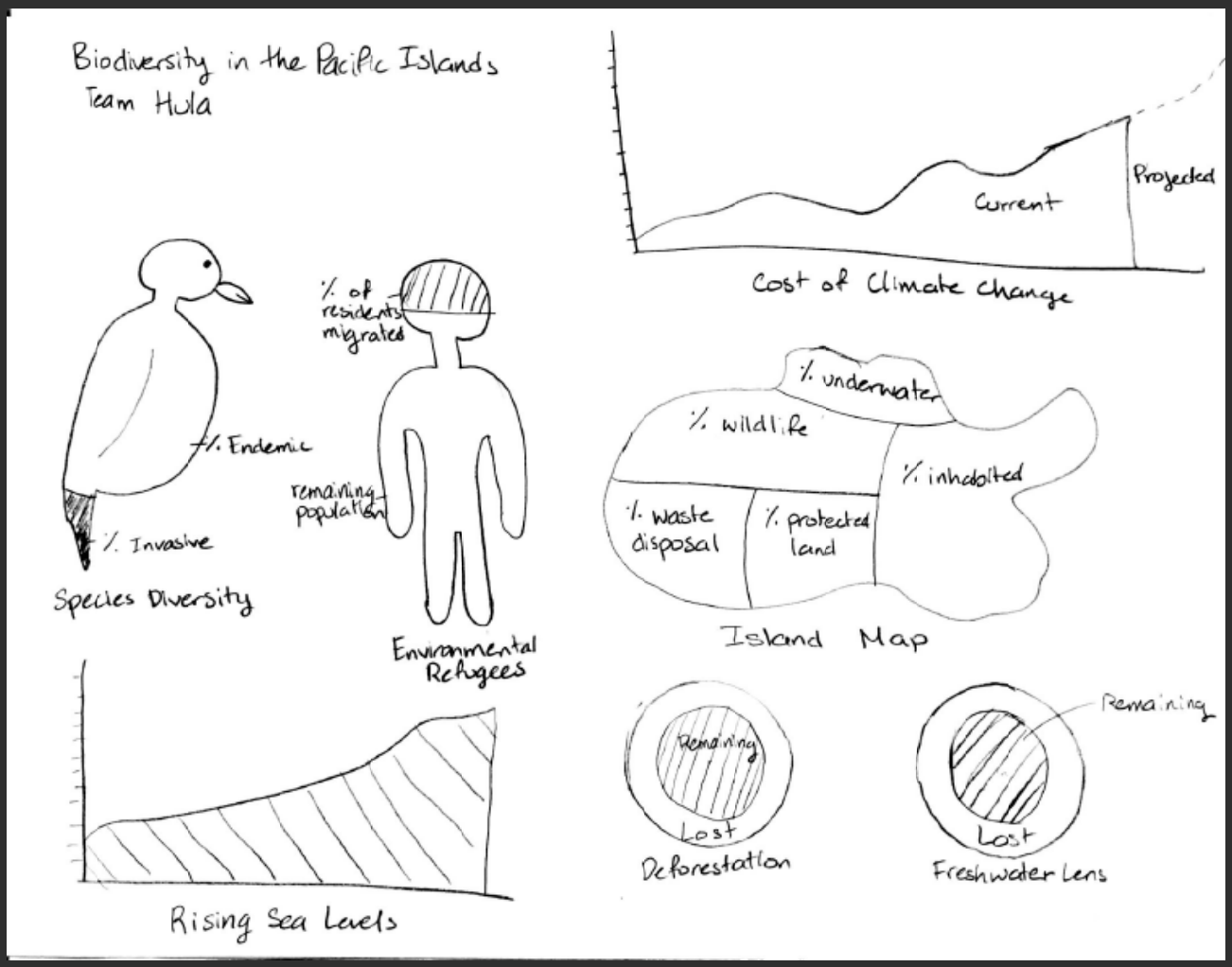

8
KEY INDICATORS
THREATS
THE ULTIMATE THREAT
GLOBAL WARMING
1
PRECIPITATION (mm)
7
OCEAN WARMING (°C)
5
DECLINE IN ISLAND SIZE
6
DECLINE IN CORAL REEF COVER
4
GREENHOUSE GAS EMISSION DUE TO IMP. FUELS (PPM)
2
OCEAN ACIDIFICATION (PH)
3
FRESH WATER SCARCITY (%)
9
LOSS OF REVENUE FROM TOURISM
15
ENDEMIC SPECIES EXTINCTION
14
DEFORESTATION
13
ENVIRONMENTAL REFUGEES
12
AGRICULTURE CRISIS
10
SOIL EROSION (%)
11
RISE IN SEA LEVEL (mm)
8

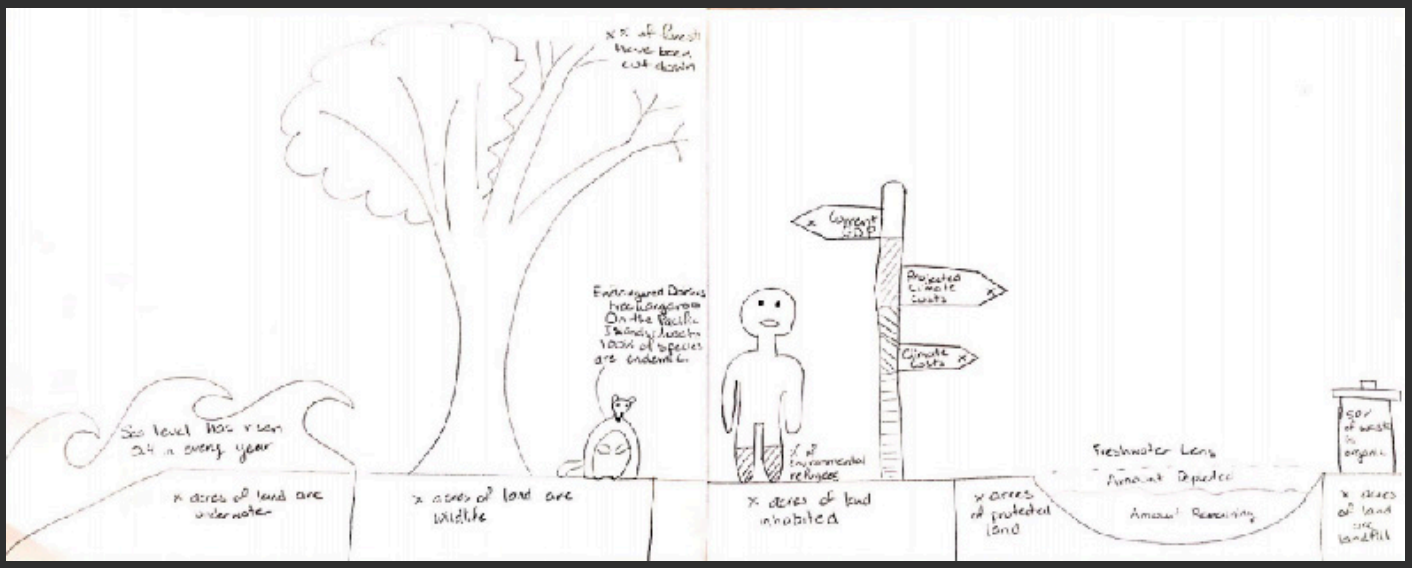
HAND-DRAWN SKETCHES: FIRST ITERATIONS

After our in-class presentation on our threats and indicators, we began exploring various data visualizations and dashboard designs and created a few hand-drawn sketches


PACIFIC ISLANDS
2013
2014
2015
2016
2017
CORAL REEF COVER
MARIANA BAT POPULATION
GREENHOUSE GAS LEVEL
OCEAN TEMP.
PRECIPITATION
FOREST COVER
FERTILE SOIL COVER

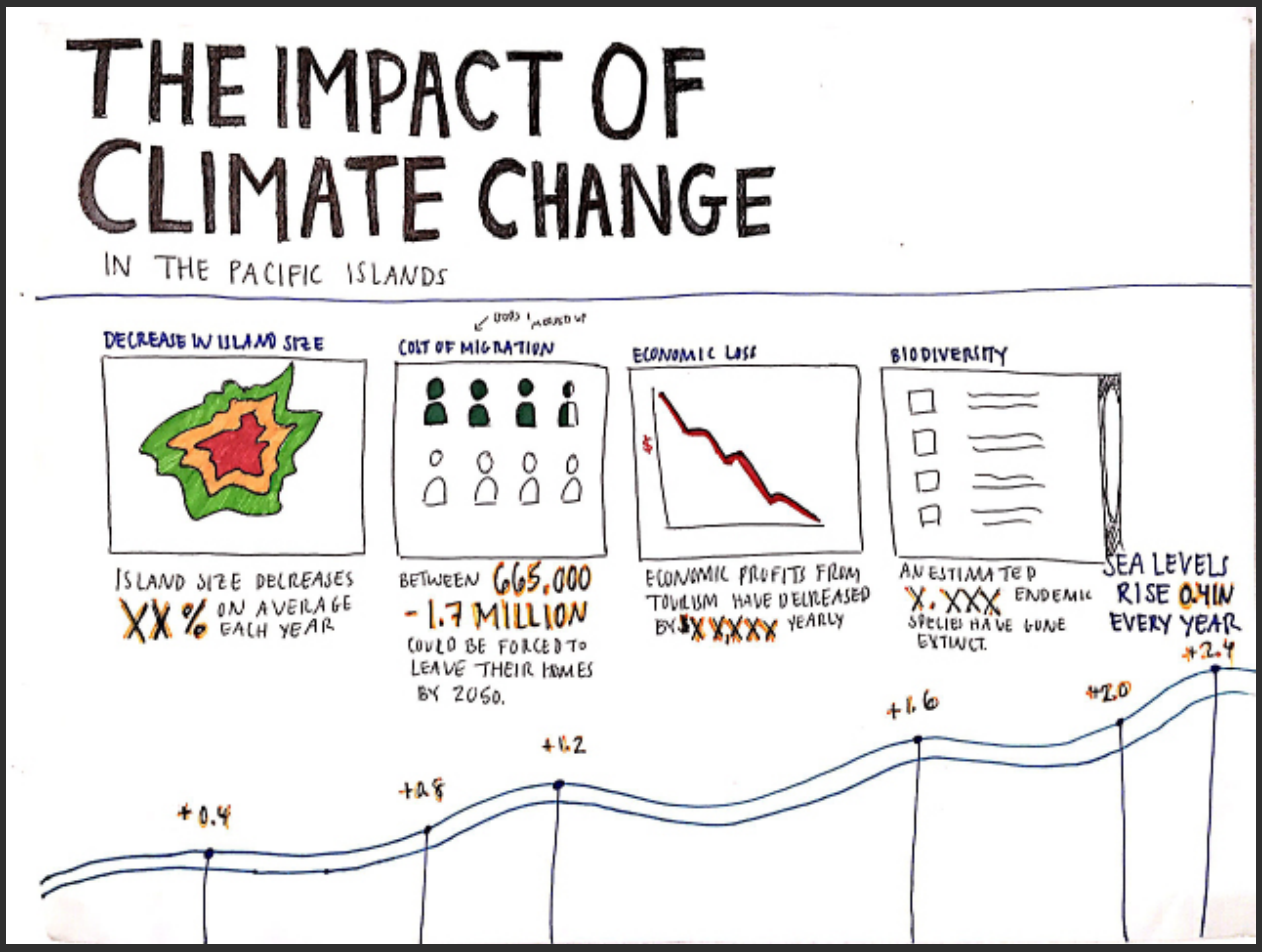

PACIFIC ISLANDS
GREENHOUSE GAS LEVEL IN THE ATMOSPHERE
%
OCEAN TEMPERATURE
°C
CORAL REEF COVER
PRECIPITATION
FERTILE SOIL COVER
FOREST COVER
MARIANA FRUIT BAT POPULATION
2013
2014
2015
2016
2017


Biodiversity in the Pacific Islands
Team Hula
Current
Projected
Cost of Climate Change
% of residents migrated
% Endemic
remaining population
% Invasive
Species Diversity
Environmental Refugees
% underwater
% wildlife
% inhabited
% waste disposal
% protected land
Island Map
Rising Sea Levels
Remaining
Lost
Deforestation
Remaining
Lost
Freshwater Lens


x% of Forest have been cut down
Endangered species throughout the Pacific Islands. Nearly 100% of species are endemic.
Sea level has risen 24 in every year
x acres of land are underwater
x acres of land are wildlife
Current cost
Projected climate costs
Climate costs
% of environmental refugees
x acres of land inhabited
x acres of protected land
Freshwater Lens
Amount Depleted
Amount Remaining
x% of waste is organic
x acres of land are landfill

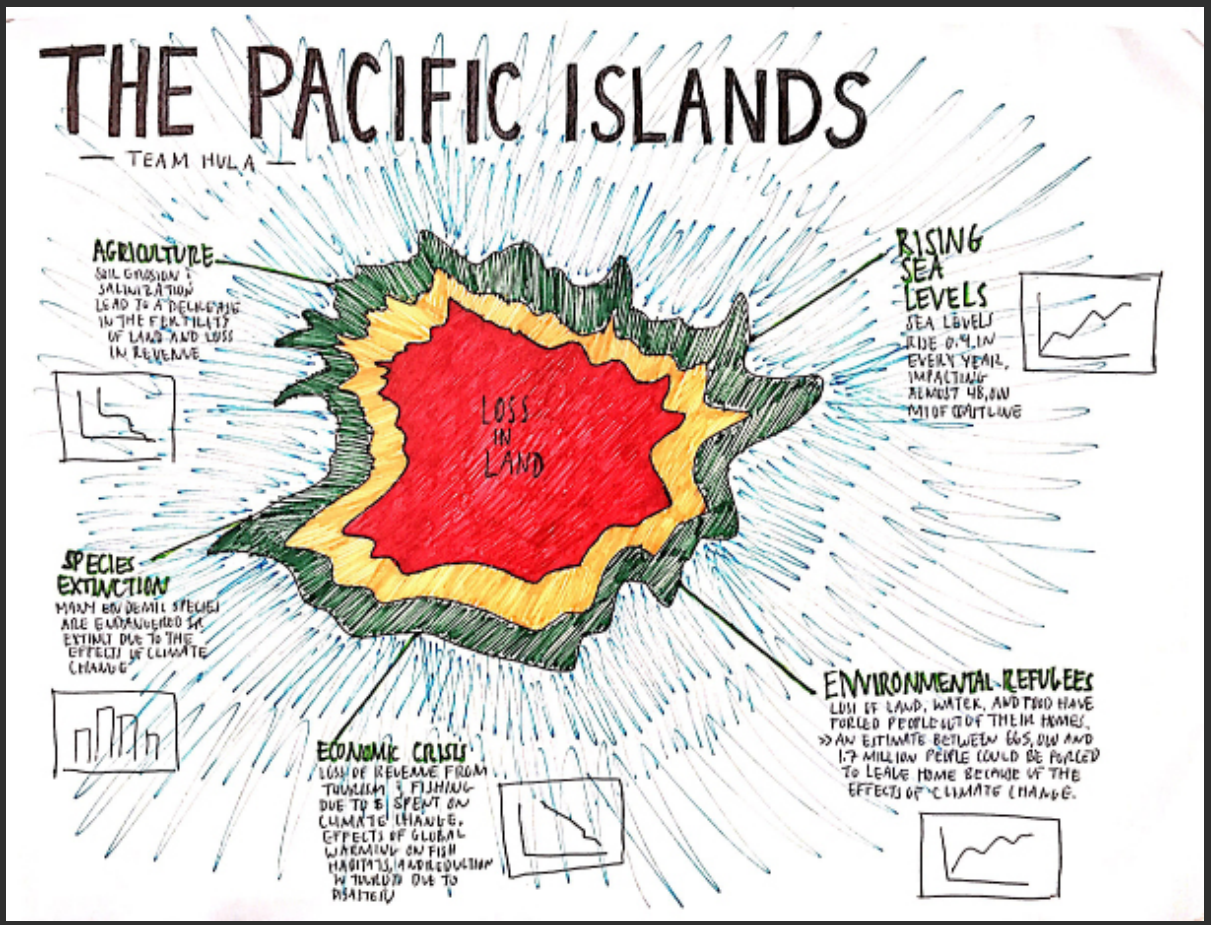
THE IMPACT OF CLIMATE CHANGE

IN THE PACIFIC ISLANDS



THE PACIFIC ISLANDS

— TEAM HULA —



- INFOGRAPHICS, DIA not really data
- are graphs changing or static
- think about color scheme (light/dark)
- multiple images on top of each other can be confusing → separate is better
- graph: some things can go under the x-axis (negative)
- more graph, less text
- how to better interconnect info to show relationships/effects

SUGGESTIONS

- circular arrangement w/ detailed stats around it
- get rid of outliers in the interconnections
- think more about what politicians care about and can affect
  - changing ocean temps → what policy?

FOCUS ON THE FANIHI

From the feedback received in class, it was apparent that we needed our dashboard to look less like a infographic, think about how to better connect the data we choose to show, and consider what elements policymakers will care the most about. We decided that it was best to choose an animal mascot that would serve as a central point to connect all of our data together.

We identified the Mariana Fruit Bat, also known as Fanihi, as a key species in terms of its cultural significance as well as its significance in the ecosystem. An important pollinator, the fanihi is also an endemic species, meaning that it specifically resides in the Pacific Islands and cannot be found elsewhere. We felt that these factors would make the fanihi a compelling mascot for a policymaker to make changes to the Pacific Islands. To begin our secondary research phase, we researched environmental factors that are directly contributing to the dwindling numbers of the fanihi.

THE FANIHI STORY

In addition to simply researching information that we feel is important or compelling, we also felt that it was important to create a story to tell through our dashboard. Writing out the story of the fanihi helped us more consciously become mindful of how to tie together the various elements of our dashboard.

The Pacific Islands suffers from the impending loss of several of its endemic species, one of the most endangered being the Mariana fruit bat, commonly referred to as 'Fanihi.'

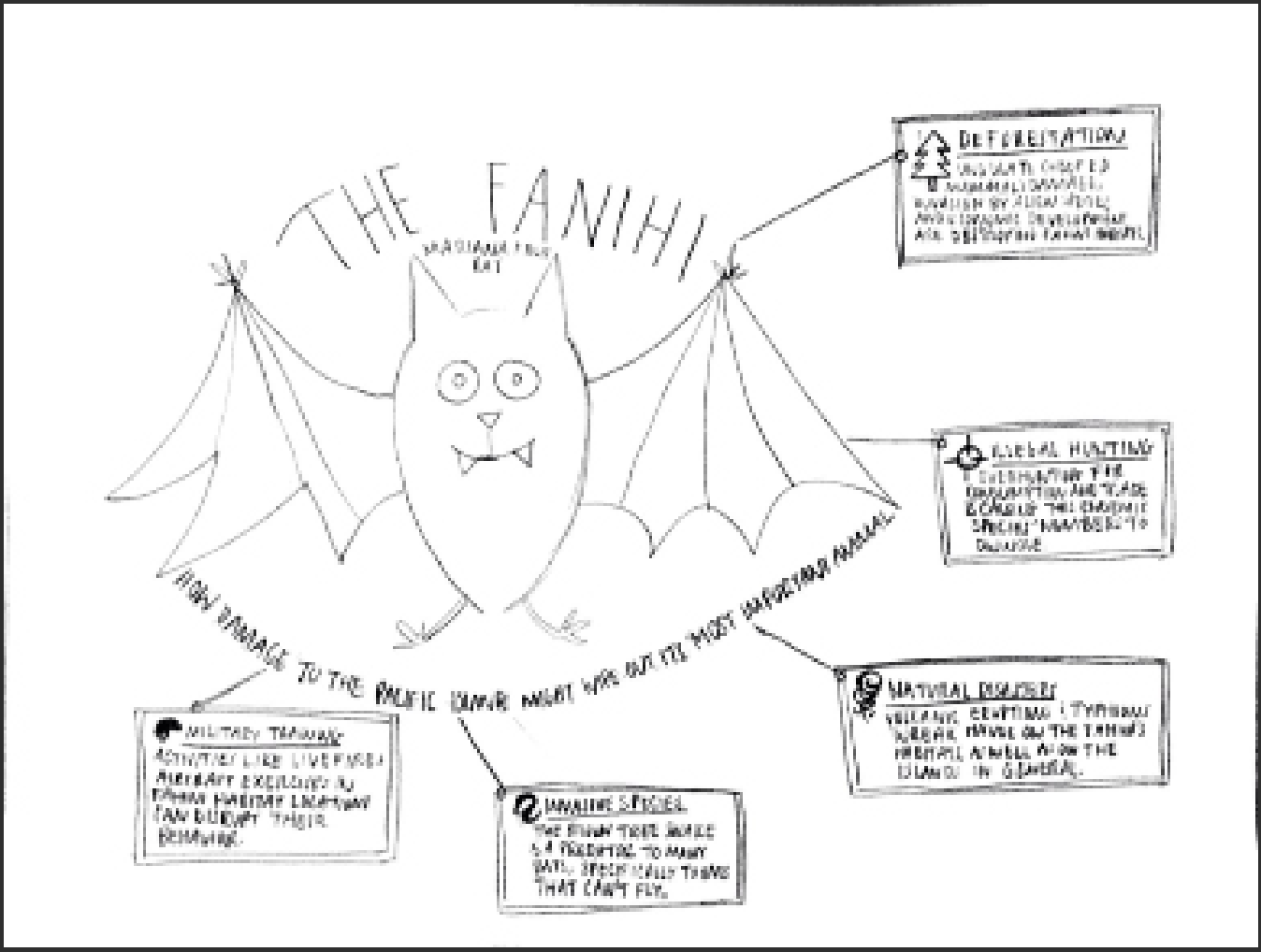
The fanihi population is dwindling due to the following factors:

- Degradation and loss of forest habitat due to
- Ungulate (hoofed mammal) damage
- Invasion by alien plant species
- Economic development
- Consumption as food by humans as part of a significant cultural tradition.
- Overhunting for commercial trade.
- Illegal hunting for local consumption.
- Preying on non-volant (lacking the ability to fly) young bats by the Brown Tree snake (Boiga irregularis) which prevents their population from growing.
- Typhoons (see Wiles and Brooke in press for a discussion of density-dependent typhoon effects).
- Volcanic eruptions.
- Military training activities in areas used by fanihi
- Limited enforcement of hunting ban and lack of investigations or convictions

The governmental measures taken so far to protect the Fanihi:

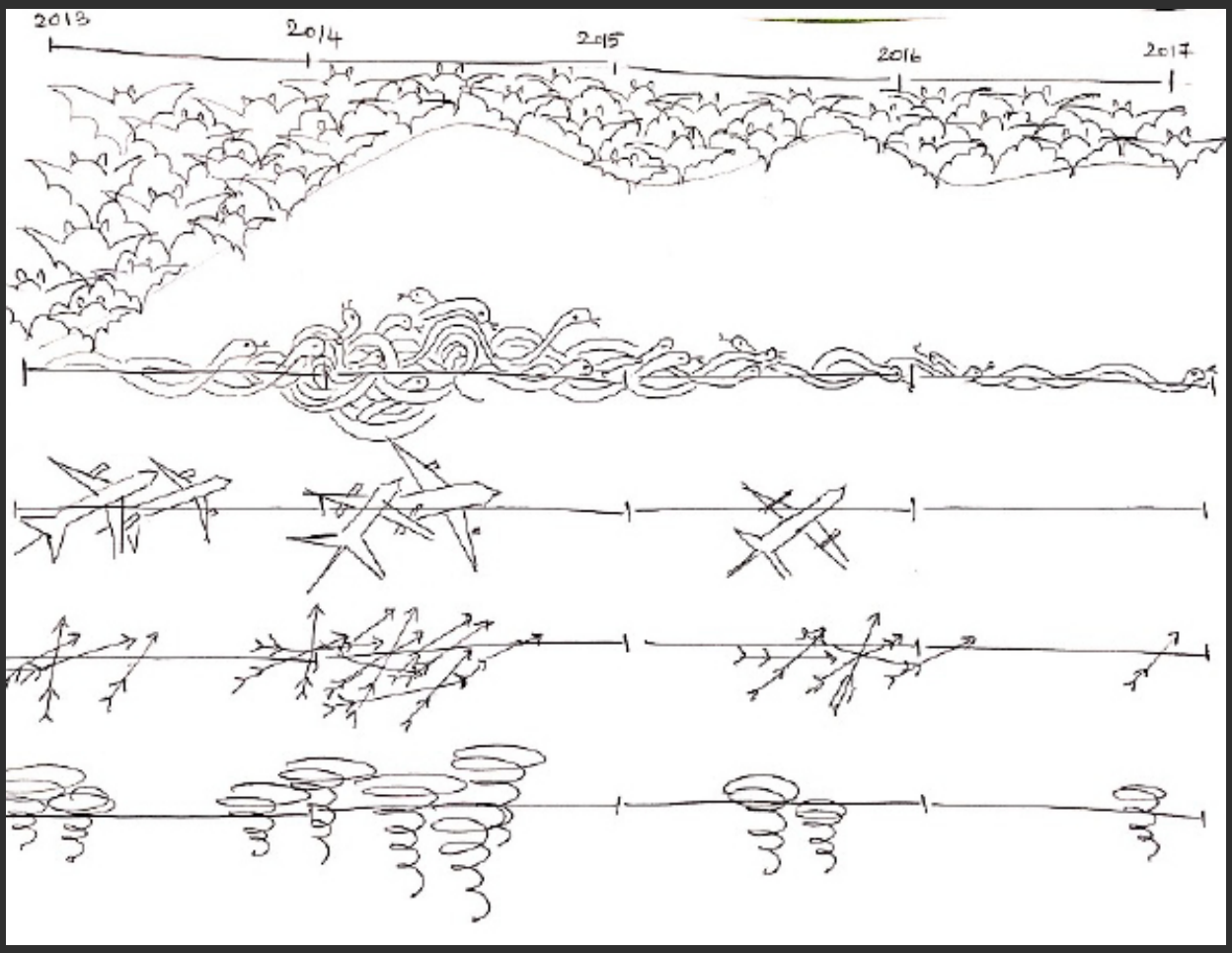
- Hunting regulations prohibiting the hunting, killing, or possessing of fanihi.
- Human-initiated population redistribution among the Pacific islands and post distribution monitoring.
- Protection of the best existing habitat and enhancement of additional suitable habitat.
- Effective control and interdiction of the brown tree snake.
- Impacts of urban development and military training on the fanihi are being avoided, minimized, or mitigated so that they do not endanger the survival of the fanihi.

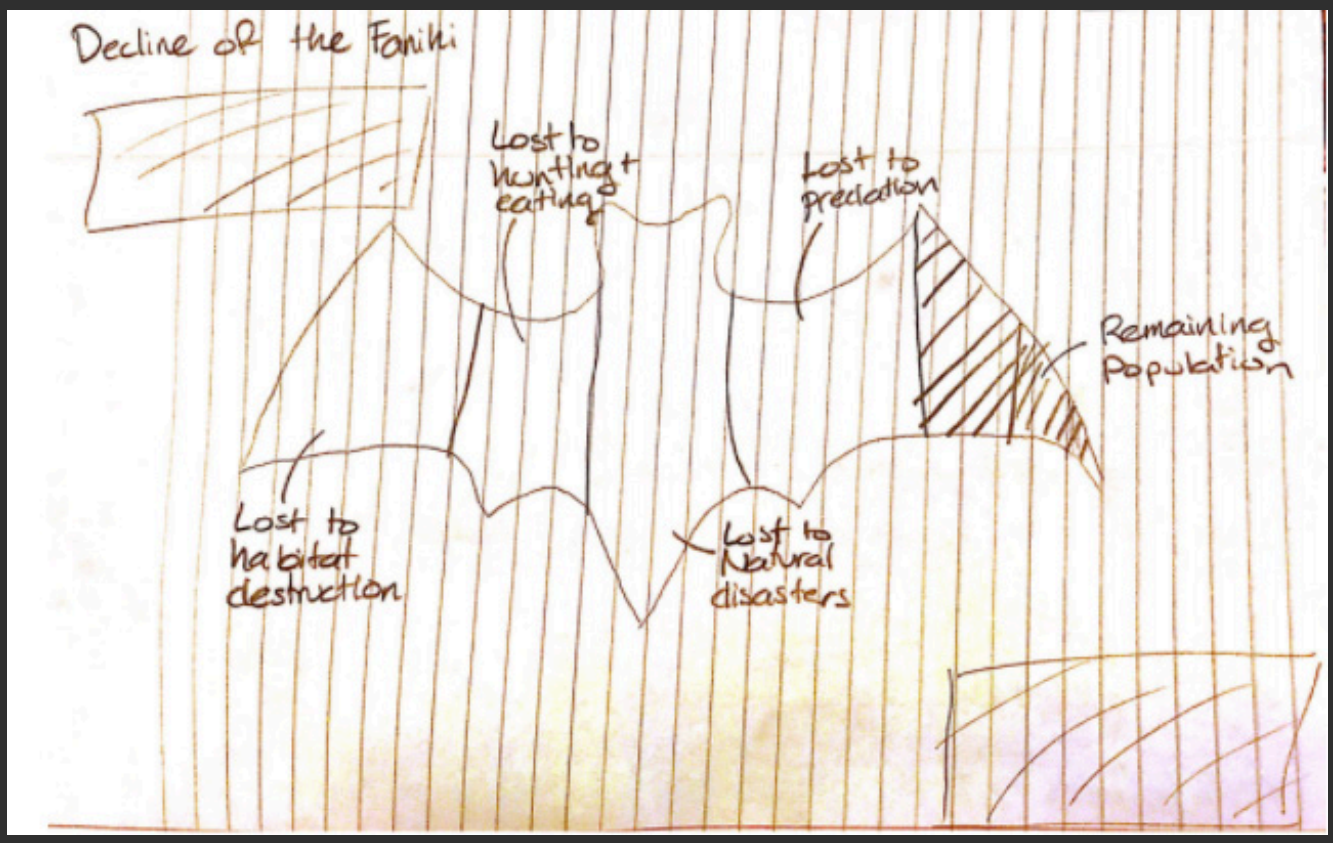
The fanihi population is clearly too precarious at present to support a hunting season, which is the greatest threat towards its survival. However, if illegal hunting and other threats are reduced, the species' status can improve substantially. There is a need to use the knowledge of population dynamics and threats to identify a limited, sustainable hunting regime consistent with recovery of the species.

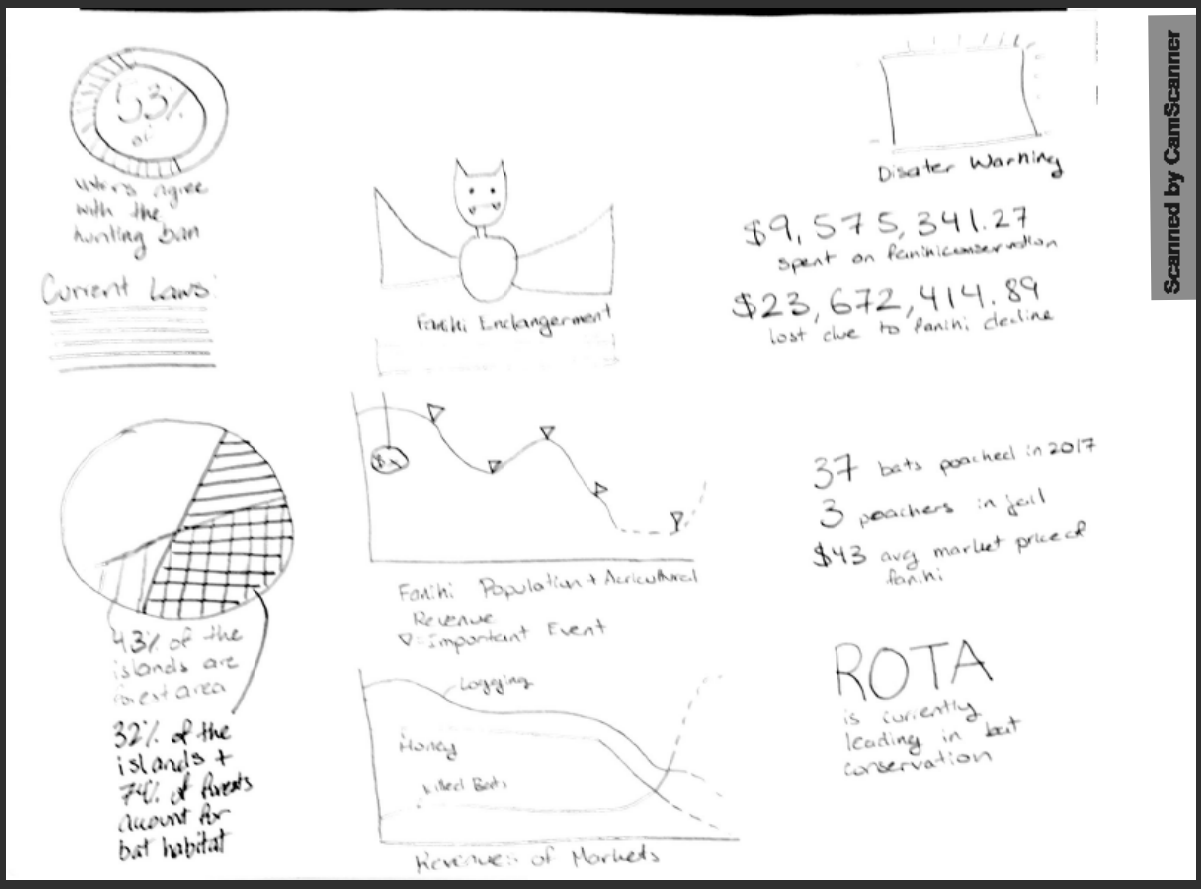


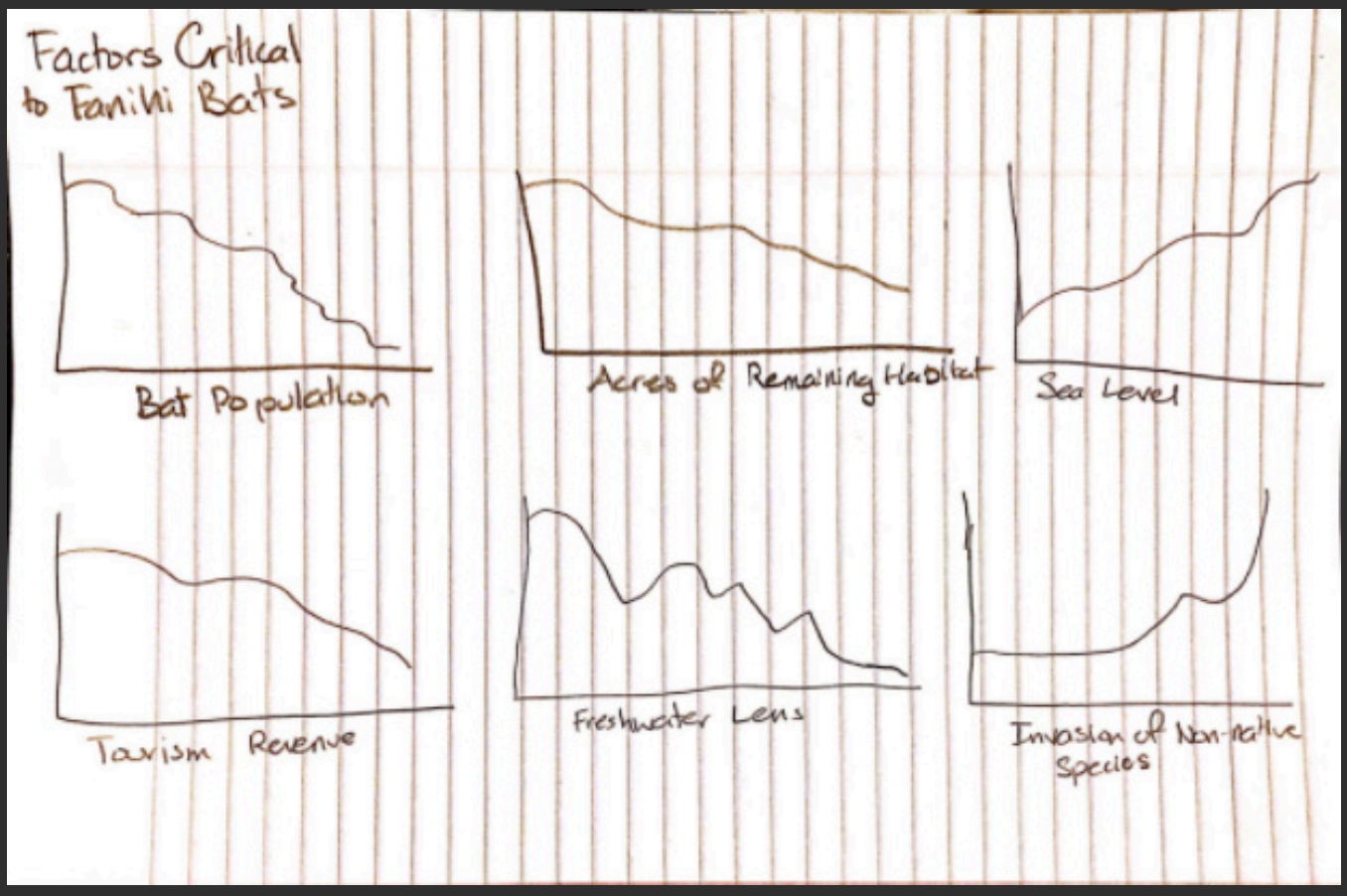
FANIHI HAND-DRAWN SKETCHES

After compiling a list of the five most important threats to the fanihi, we created the following dashboards before beginning our digital sketches. The process of doing this allowed us be on the same page about what elements are to include in the dashboard and discuss the strongest dashboard elements.


2013
2014
2015
2016
2017


Decline of the Fanihi
Lost to hunting + eating
Lost to predation
Remaining population
Lost to habitat destruction
Lost to Natural disasters


53%
of voters agree with the hunting ban
Current Laws
Fanihi Endangerment
Disaster Warning
$9,575,341.27
spent on Fanihi conservation
$23,672,414.89
lost due to Fanihi decline
43% of the islands are forest area
32% of the islands + 74% of forests account for bat habitat
Fanihi Population + Agricultural Revenue
▽= Important Event
37 bats poached in 2017
3 poachers in jail
$43 avg market price of fanihi
ROTA
is currently leading in bat conservation
Logging
Honey
Revenues of Markets

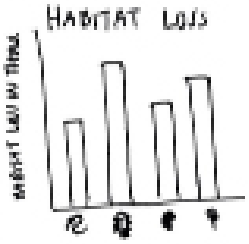

Factors Critical to Fanihi Bats
Bat Population
Acres of Remaining Habitat
Sea Level
Tourism Revenue
Freshwater Lens
Invasion of Non-native Species

FAHINI [THE MARIANA FRUIT BAT]

THE FAHINI IS AN ENDEMIC SPECIES NATIVE TO GUAM. THEIR EXISTENCE IS BEING THREATENED BY ISSUES THAT COULD BE PREVENTABLE THROUGH GOVERNMENT ACTION. AS AN IMPORTANT CULTURAL SYMBOL, THERE SHOULD BE MORE DONE TO PROTECT THEM, SINCE THEIR WELL-BEING IS A REFLECTION OF THE ENVIRONMENTAL STATE OF THE PACIFIC ISLANDS.

FAHINI DECLINE OVER TIME

HABITAT LOSS



KEY
- DEFORESTATION
- NATURAL DISASTERS
- INVASIVE TREE SPECIES
- MILITARY TRAINING

HUNTING

XX% OF FAHINI DECLINE HAS BEEN ATTRIBUTED TO OVERHUNTING/ILLEGAL HUNTING.

TRADE

XX% OF FAHINI DECLINE HAS BEEN ATTRIBUTED TO COMMERCIAL TRADE & CONSUMPTION.

IF THIS CONTINUES...

XX% OF FAHINI SPECIES AS A WHOLE WILL BE LOST BY THE YEAR XXXX.

KEY STATS

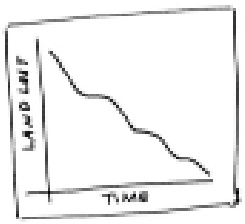
$$ GOVERNMENT MONEY LOST AS A RESULT OF...

FAHINI

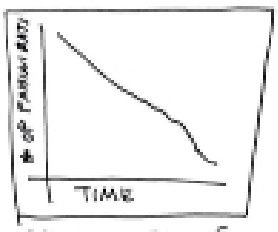
- DEFORESTATION
- HUNTING
- NATURAL DISASTERS
- INVASIVE SPECIES
- MILITARY TRAINING

DEFORESTATION

HOW IS IT THREATENING THE FAHINI & THE PACIFIC ISLANDS?

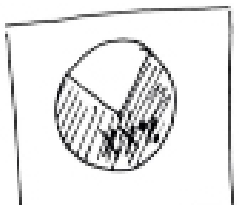


LOSS OF HABITAT — KEY STAT

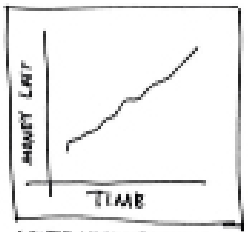


SPECIES DECLINE — AS A RESULT OF HABITAT LOSS...

WHAT CAN BE DONE?



PERCENT EXPECTED TO DECLINE BY XXXX IF THIS CONTINUES



GOVERNMENT MONEY LOST DUE TO DEFORESTATION

FANIHI DIGITAL SKETCHES

Our next step was to improve on the ideas explored in our hand-drawn sketches and turn them into digital ones. We tried to incorporate elements that we felt most strongly conveyed the information we wanted to focus on, including:

- Image of focus species at center
- Donuts that show progress
- Critical points and levels (ex: point after which species will die out).

FAHINI: THE MARIANA FRUIT BAT

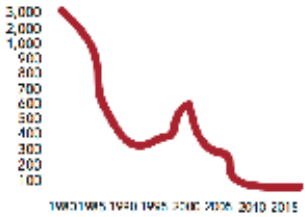
HOW ENVIRONMENTAL DAMAGE COULD WIPE OUT THE PACIFIC ISLAND'S MOST BELOVED SPECIES

HUNTING

50% of the loss in total fahini population were due to illegal hunting practices

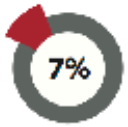
If something isn't done about illegal hunting, 90% of the total fahini population will be gone by 2080

FAHINI POPULATION

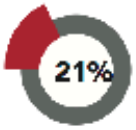


NATURAL DISASTERS

Percents Attributed to Habitat Loss

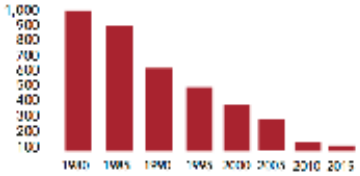


VOLCANOES

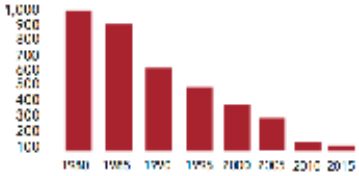


TYPHOONS

INVASIVE SPECIES: PREDATION BY THE BROWN TREE SNAKE

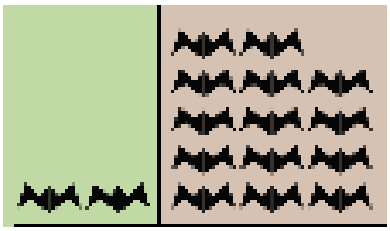


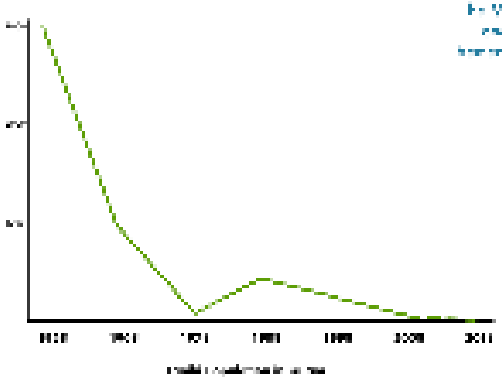
DEFORESTATION'S EFFECT ON HABITAT LOSS

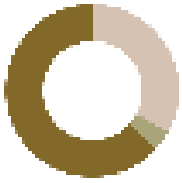


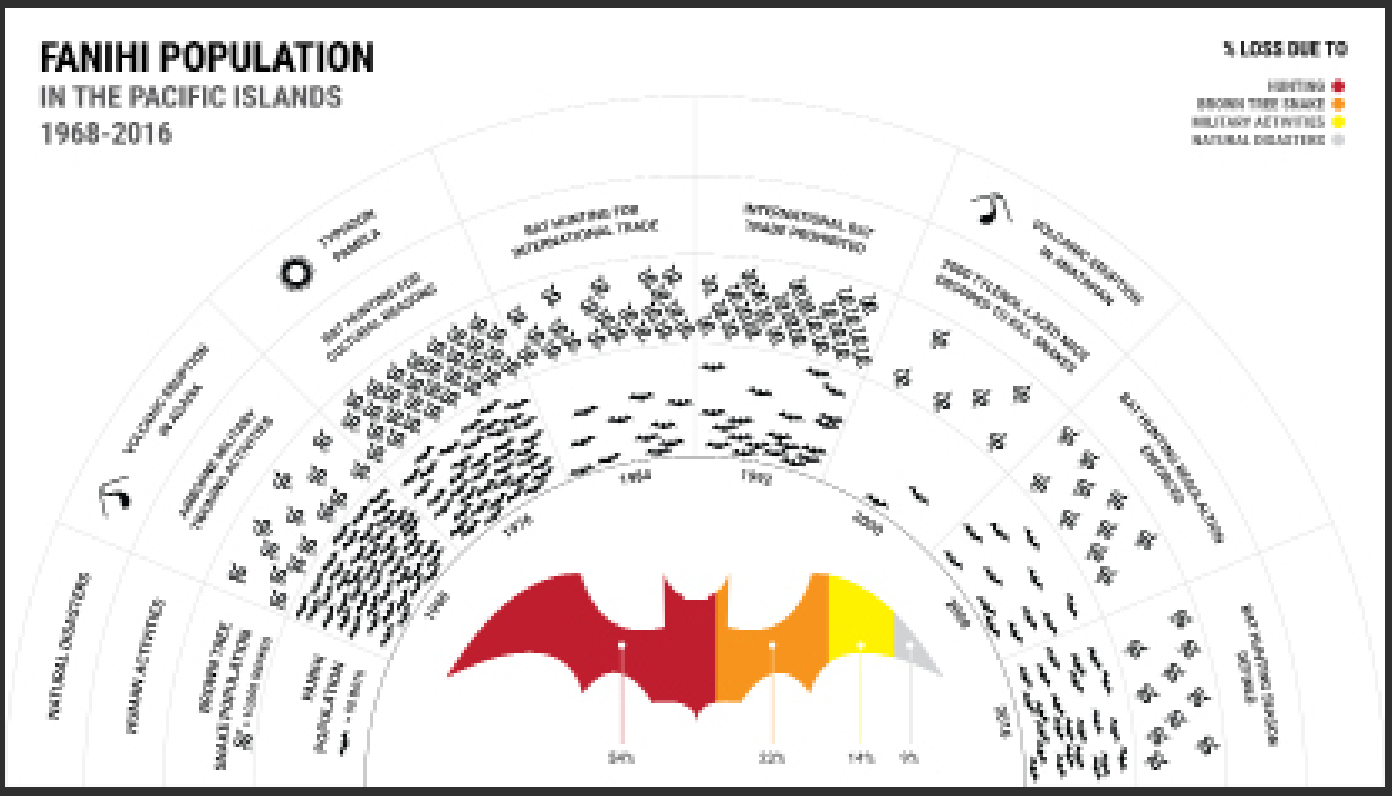
Fanihi Endangerment in the Pacific Islands

$8,329,443








FANIHI POPULATION
IN THE PACIFIC ISLANDS
1968-2016
% LOSS DUE TO
HUNTING
BROWN TREE SNAKE
MILITARY ACTIVITIES
NATURAL DISASTERS
1968
1974
1980
1986
1992
1998
2004
2010
2016
94%
32%
14%
9%

FEEDBACK ON DIGITAL SKETCHES

We presented our sketches in class and received the following feedback from our peers:

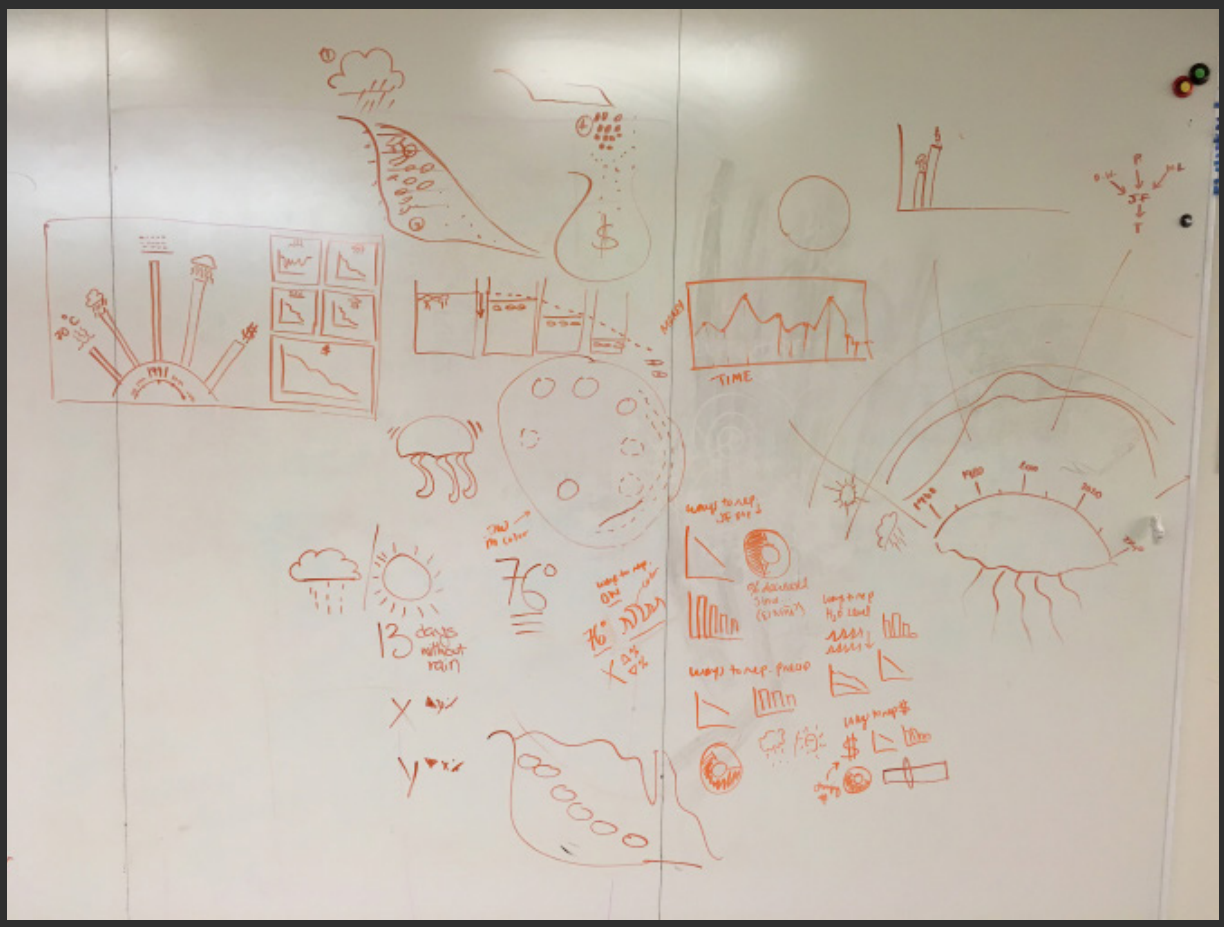
- Arc has a lot of small details, may be off-putting
- Red is overwhelming
- Bat is good, but other elements need to match in fidelity
- Looks too much like an infographic, reduce text, focus on data
- Show changes in real time
- Show projected data and compare with real-time data
- Standardize format
- Signal events that cause significant changes
- Focus on what the policy maker should understand
- Focus on what value the bats have to the islands/the ecosystem
- Highlight differences between what governments of different islands are doing
- Add a geographical component
- Find trade-offs between bats and other things
- How does decline in bat population affect the environment or the economy?
- Use qualitative data to tell a story supported by quantitative data

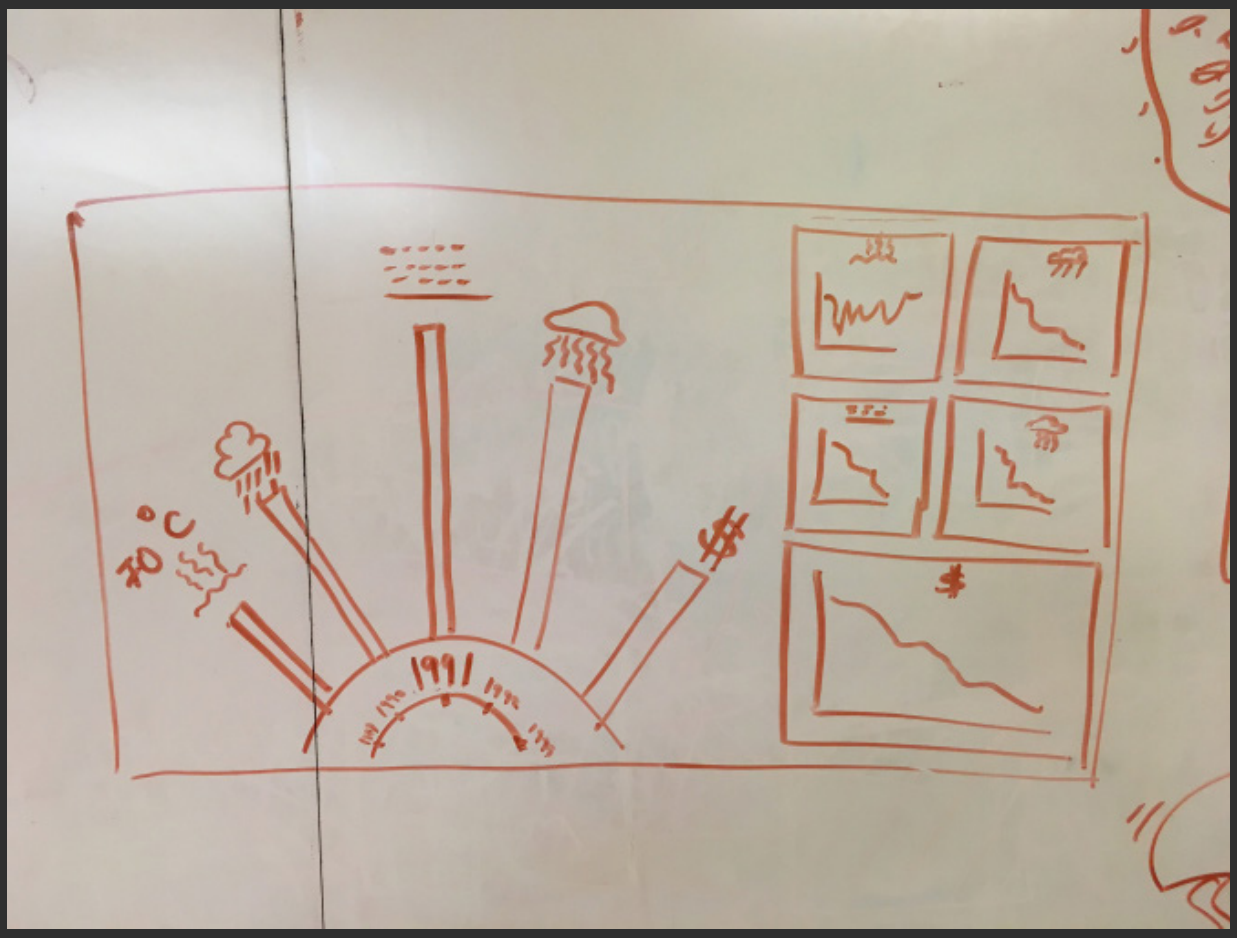
PIVOT

However, after reviewing this feedback, we decided it was best to pivot and focus our dashboard on the Golden Jellyfish, a Palau native. While the fanihi is a valuable member of several ecosystems, we could not find data to sufficiently connect the bat's extinction to any economic impact. Therefore, we felt that the jellyfish, which contributes to significant tourism revenue and is in danger of extinction, was a better representative for biodiversity crisis in the Pacific Islands as well as a problem space that could better motivate policymakers to take action.

The Golden Jellyfish Lake in Palau is a major tourist attraction where snorkelers can swim with harmless jellyfish, and the only place in the world where this happens. Described as a breathtaking encounter, tourists travel from all over the world to experience the jellyfish. Unfortunately, due to climate change-related factors, the jellyfish population has been declining rapidly and is now nearing extinction. Faced with mounting lake salinity and temperatures, as well as a lack of precipitation, which introduces beneficial nutrients from runoff, jellyfish have been dying earlier in their life cycle, leading to a decline in the number of offspring. As a result, tours to Jellyfish Lake have been cancelled and Palau's tourism revenue has decreased dramatically.

We used this information to map out several data visualization ideas. Building off of our other ideas, we settled on creating a dashboard that would show current data in detail, coupled with historic and projected trends.


TIME
76°
13 days without rain


70 °C
1991

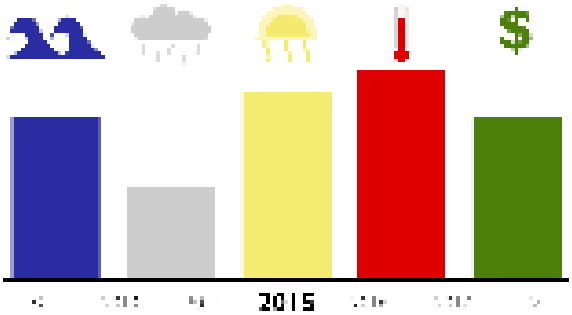

EXIT

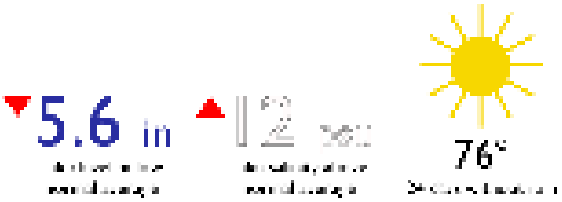
KEY THREATS AND INDICATORS

Based on this general idea, we created three digital dashboards to imagine different ways we could visualize the data. For the sake of the project and due to the unavailability of the desired statistics, the data we used was based on the information we found and does not reflect actual values. However, we strived to reflect the overall trends to the best of our ability.

During the in-class critique, we received feedback that it was difficult to tell that the dashboard was focused on the jellyfish population. Returning to the (digital) drawing board, we sought to incorporate the jellyfish as the centerpiece of our dashboard, an element that we had liked in our earlier dashboard renditions of the fahini. In order to make our design more cohesive, we decided to choose one digital sketch of the three that we felt was the strongest to continue exploring.

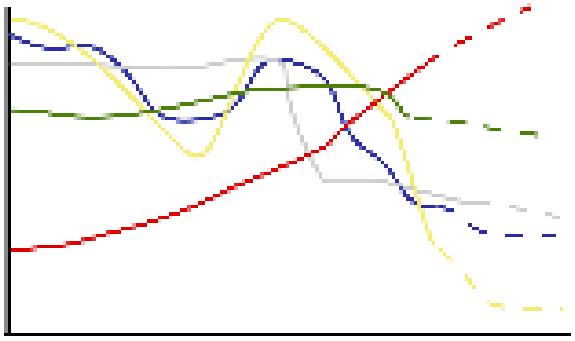
Golden Jellyfish in the Pacific Islands



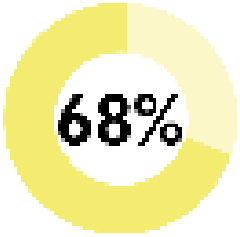


$265,988
on Recovery

$3,247,900
in Tourism

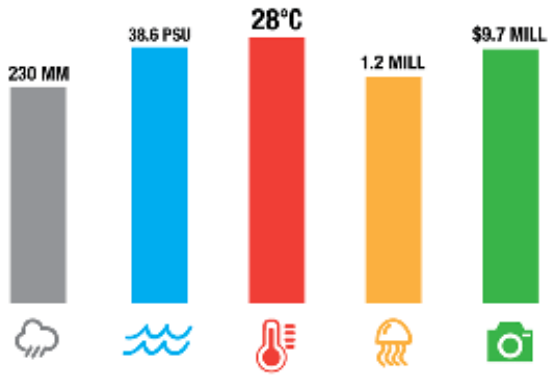


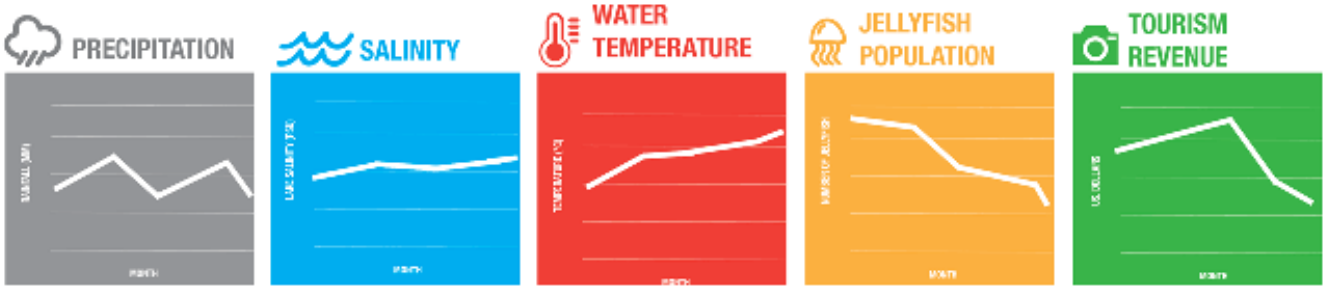
Trends over Time

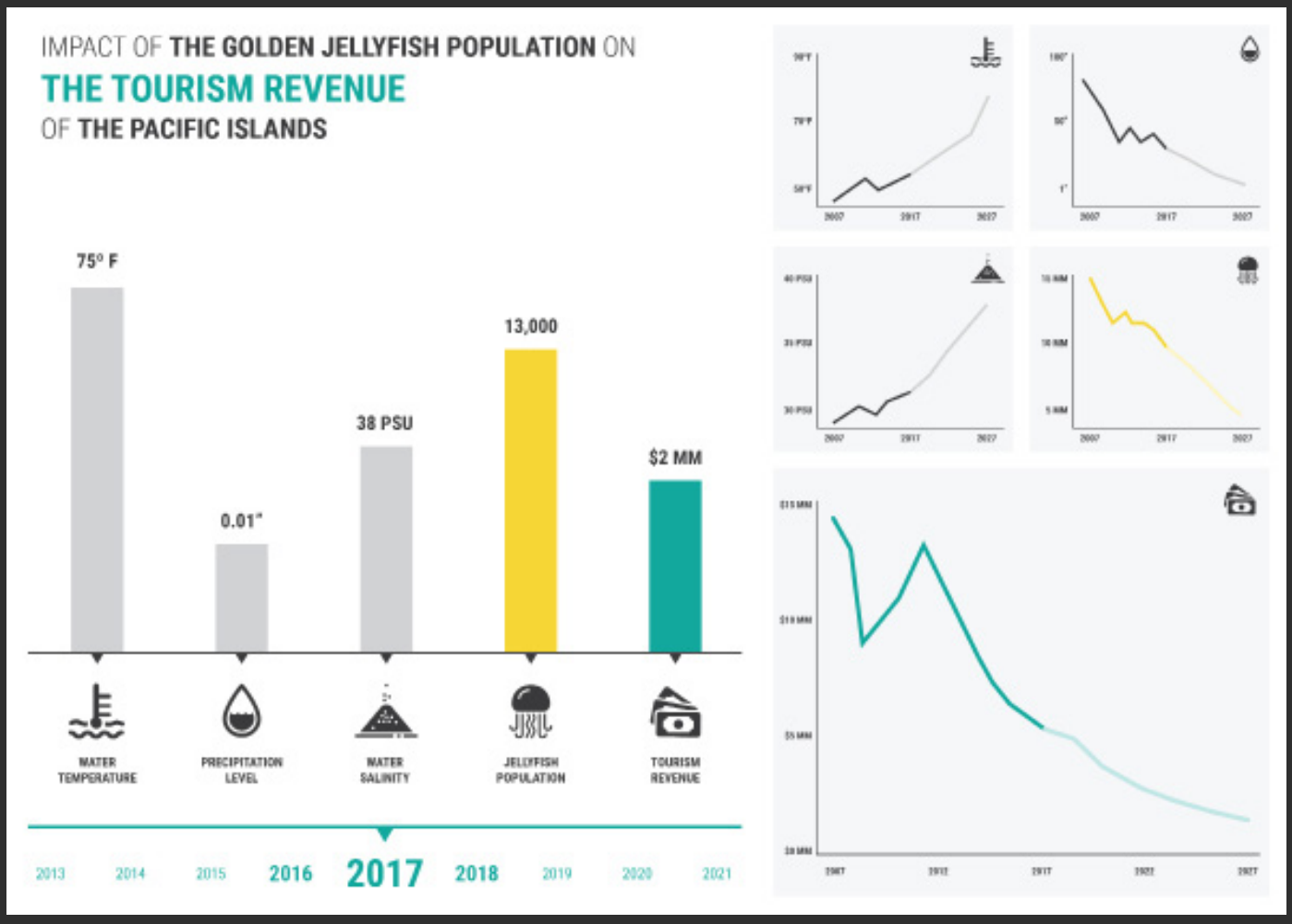


HOW DECLINE OF THE GOLDEN JELLYFISH REFLECTS DAMAGE TO THE PACIFIC ISLANDS

2015
AVERAGE MEASURES

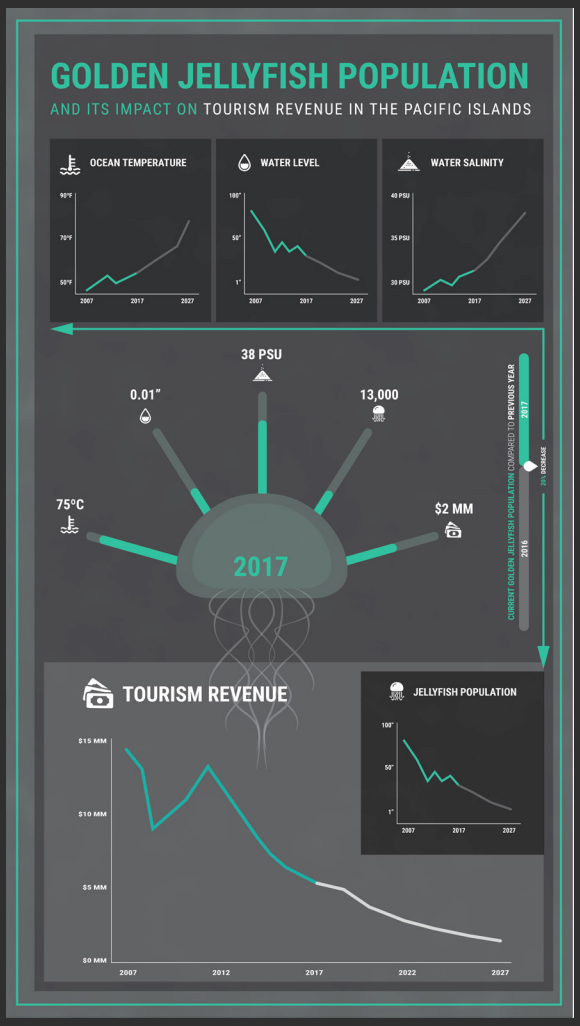


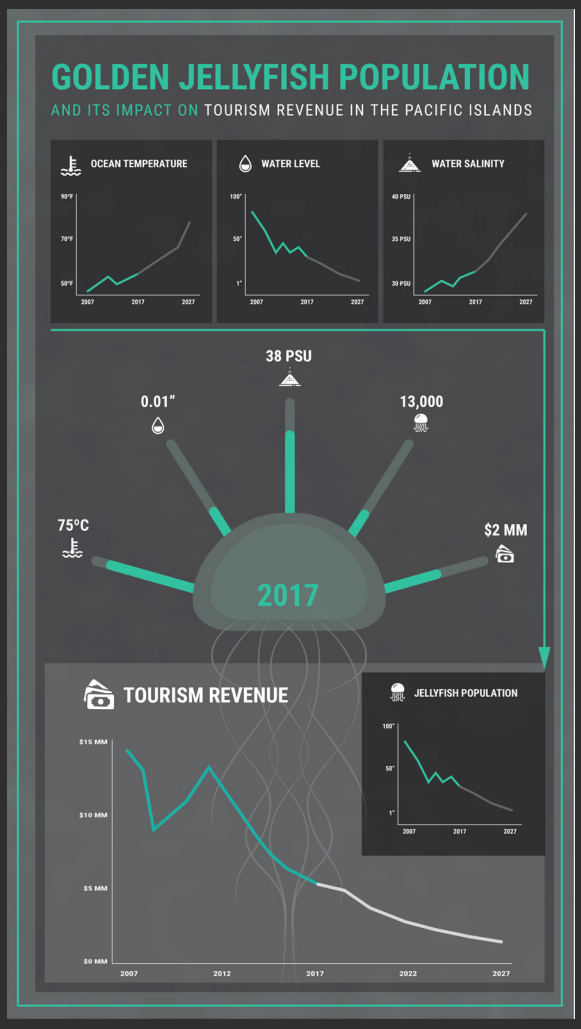



IMPACT OF THE GOLDEN JELLYFISH POPULATION ON
THE TOURISM REVENUE
OF THE PACIFIC ISLANDS
75° F
0.01"
38 PSU
13,000
$2 MM
WATER TEMPERATURE
PRECIPITATION LEVEL
WATER SALINITY
JELLYFISH POPULATION
TOURISM REVENUE
2013
2014
2015
2016
2017
2018
2019
2020
2021

DASHBOARD ITERATIONS

Compiling the best ideas from our previous dashboards, we settled on a final overall design and then made several iterations, varying the elements and their presentation. Once we settled on a design, we had to focus on making the dashboard equally informative and visually appealing, while conveying important details with salient cues.


GOLDEN JELLYFISH POPULATION
AND ITS IMPACT ON TOURISM REVENUE IN THE PACIFIC ISLANDS
OCEAN TEMPERATURE
WATER LEVEL
WATER SALINITY
38 PSU
0.01"
13,000
75°C
$2 MM
2017
CURRENT GOLDEN JELLYFISH POPULATION COMPARED TO PREVIOUS YEAR
2017
2016
3X INCREASE
TOURISM REVENUE
JELLYFISH POPULATION
$15 MM
$10 MM
$5 MM
$0 MM
2007
2012
2017
2022
2027


GOLDEN JELLYFISH POPULATION
AND ITS IMPACT ON TOURISM REVENUE IN THE PACIFIC ISLANDS
OCEAN TEMPERATURE
WATER LEVEL
WATER SALINITY
38 PSU
0.01"
13,000
75°C
$2 MM
2017
TOURISM REVENUE
JELLYFISH POPULATION
$15 MM
$10 MM
$5 MM
$0 MM
2007
2012
2017
2022
2027

ANIMATION

Since one of the requirements of this assignment is to have information that updates in real-time, the next step of the process was to begin thinking about the role of animation in our dashboard. The dashboard on the following page is our first attempt at animation.

The jellyfish in the center presents data from the last five years and projected data from the next five years, while the corresponding graphs above animate with it. The jellyfish then returns to the current year and progress bars demonstrating daily tourism revenue and jellyfish population appear.

Our dashboard contains multiple elements, which may be overwhelming to a first-time user. Initially, we had our line graphs draw themselves as the data by year changed, but we received feedback that this was too confusing to watch. Therefore, in our final design, we opted to have a circle that moves along the lines instead. We also had the jellyfish progress bar compare populations from today and yesterday; however, this presented a problem as the population could increase or decrease. In our final dashboard, we compare today's jellyfish population and national revenue with both the daily historic highs, giving viewers an understanding of how far removed we are from the desired outcome.

PALAU'S GOLDEN JELLYFISH LAKE

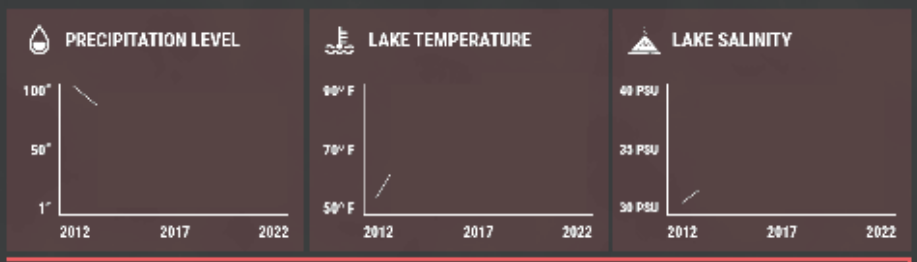
AND ITS IMPACT ON **TOURISM REVENUE** IN PALAU, A PACIFIC ISLAND COUNTRY

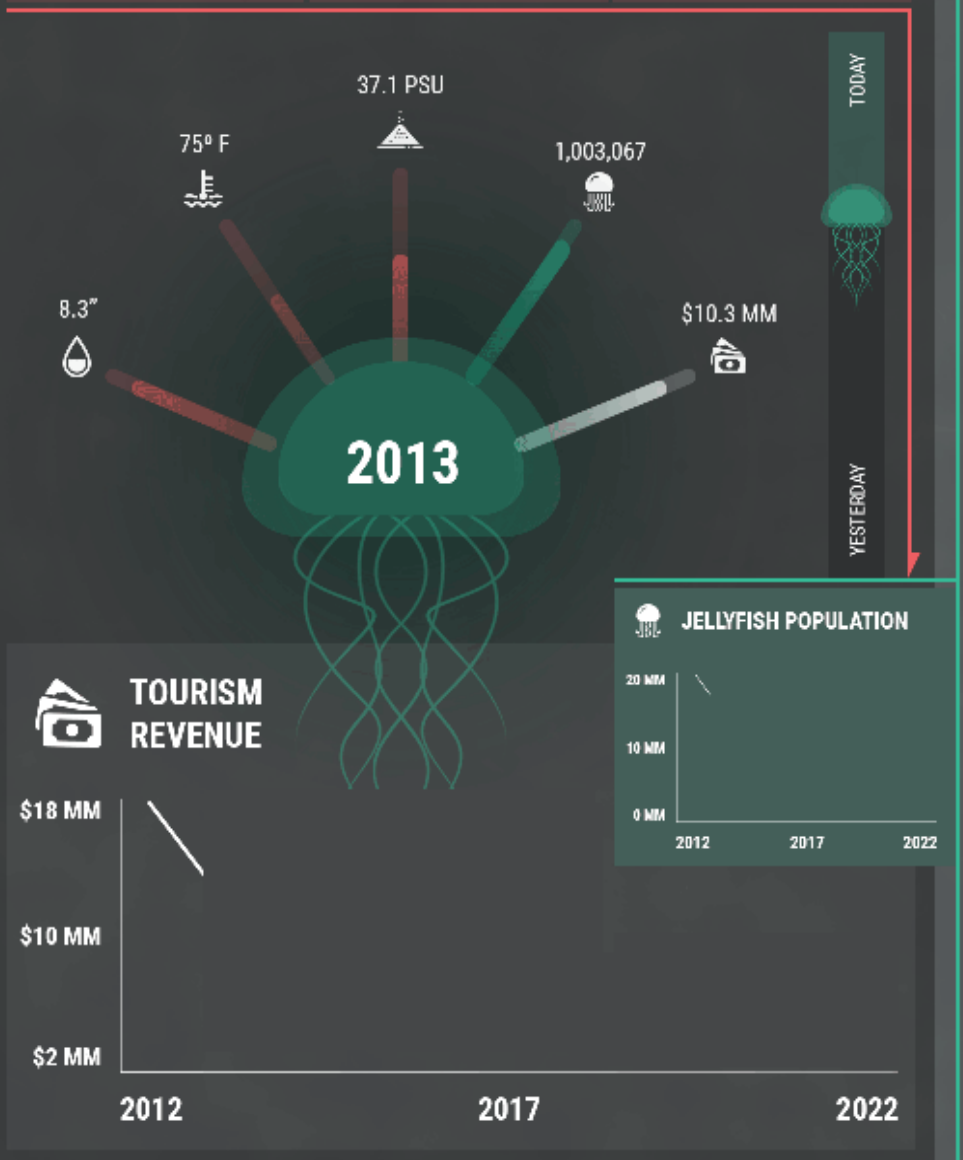
PALAU'S JELLYFISH LAKE IS A UNESCO WORLD HERITAGE CENTER

THE MILLIONS OF JELLYFISH ATTRACT TOURIST SNORKELERS

TOURISM REVENUE CONTRIBUTION TO PALAU'S GDP IS 60%

GLOBAL WARMING EFFECTS IMPACTING JELLYFISH POPULATION





FINAL DESIGN

Our final dashboard demonstrates the current state of affairs, as well as historic and projected trends. The jellyfish in the center indicates the current values of five key indicators, while progress bars on the two sides display the tourism revenue and jellyfish population relative to historical daily highs. The three graphs above the jellyfish are the direct causes for the trends in the bottom graph, elucidating an important relationship between the changing environment, animal survival, and economic impact.

Furthermore, the threshold lines on the graphs represent the critical values that, if crossed, require immediate action and signal a likely extinction of the jellyfish. These, coupled with trends over time, allow the viewer to understand how close we are to a critical loss of biodiversity. Overall, we anticipate that this dashboard prompts users to critically examine the harsh impacts of climate change with the case of Palau's golden jellyfish in detail, and that it serves as a catalyst for innovation in recovering and promoting biodiversity.

PALAU'S GOLDEN JELLYFISH LAKE

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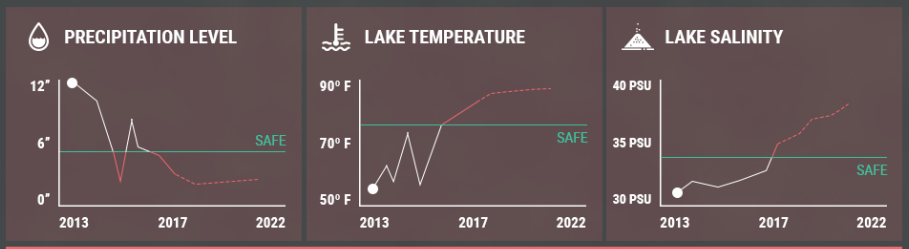

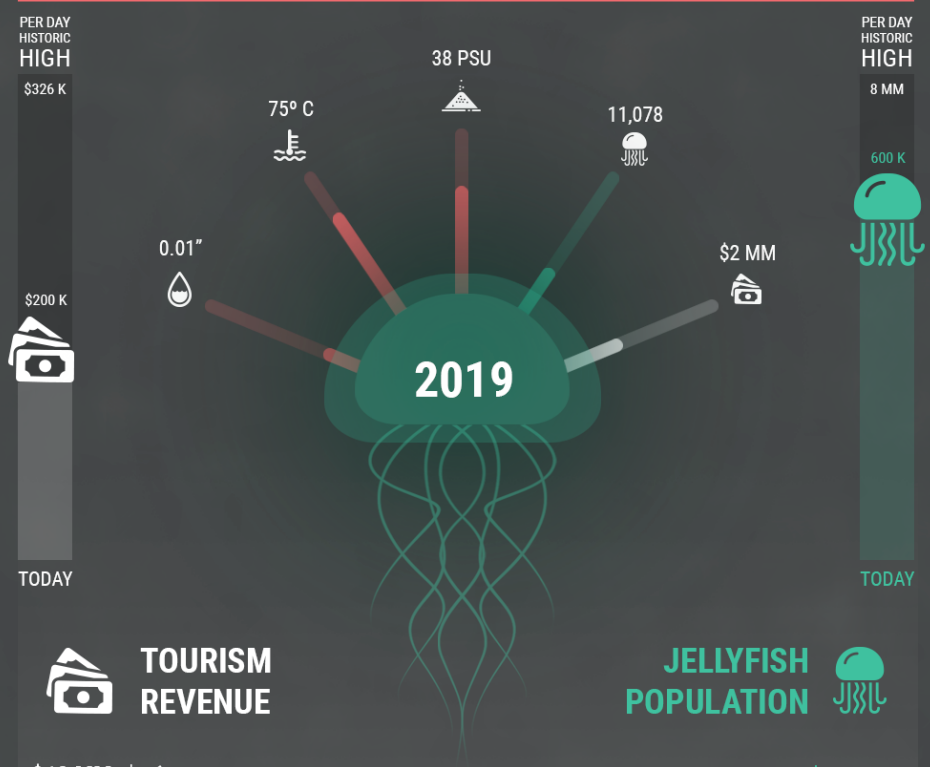

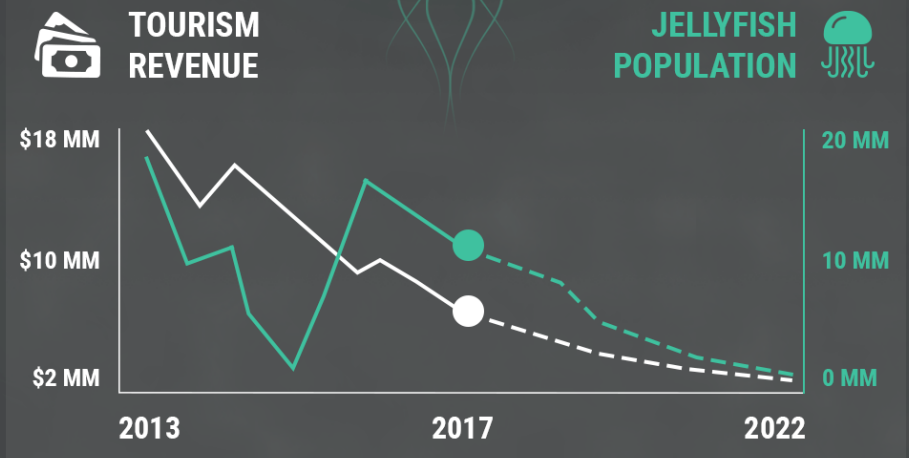

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