A LOW COST REGIONAL SCALE SITE SUITABILITY FRAMEWORK FOR AQUACULTURE IN OFFSHORE ZONES; A CASE STUDY FOR OʻAHU HAWAIʻI
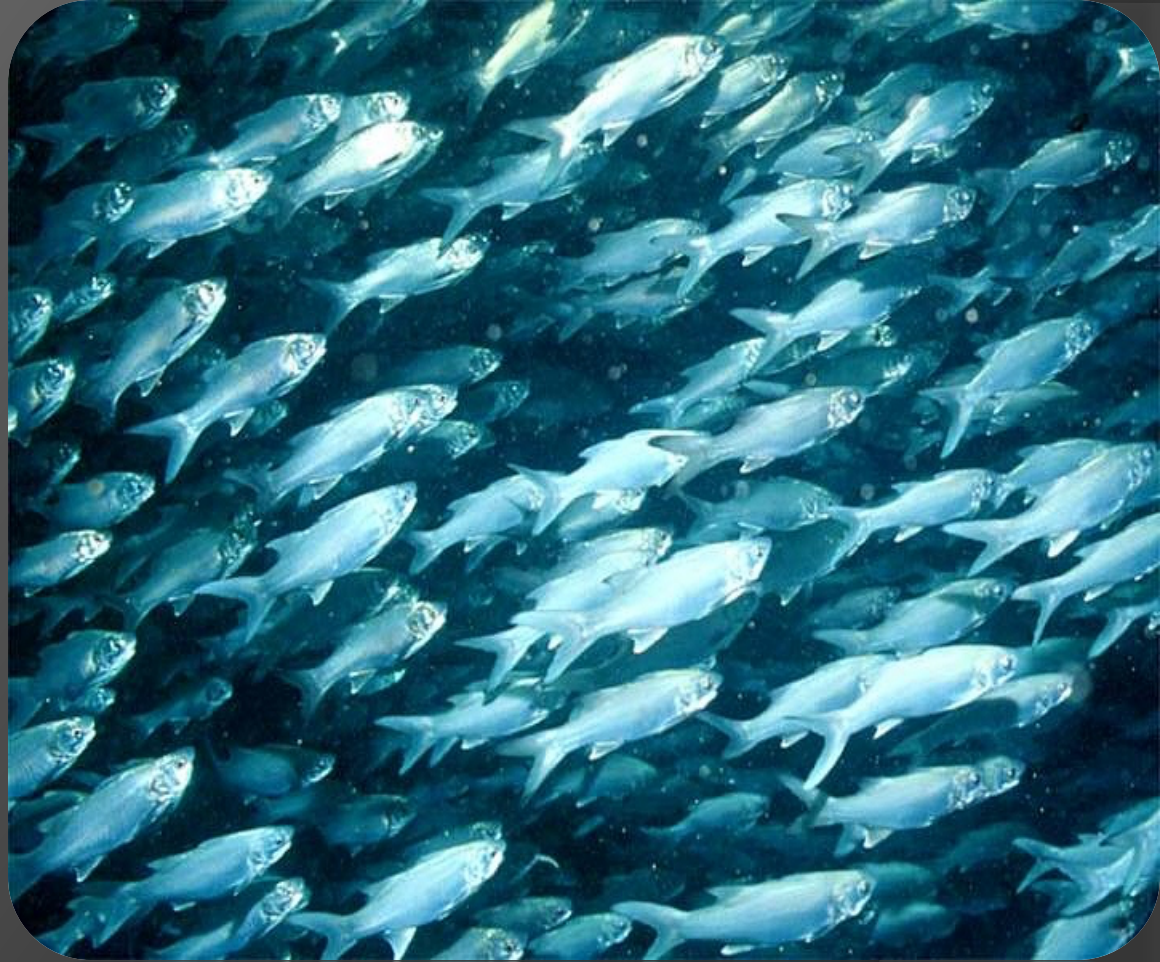
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Topics

- Introduction
  - Problem
  - *History*
  - Offshore
  - Selection v Suitability
  - Objective
- Models
  - Basic
  - Environmental
  - Economic
 - Social
  - Combined
- Conclusions
- Questions?

Introduction

Statement of Problem

- Siting issues worldwide & Hawai'i
  - Environmental, cultural issues, economics

- Goal:
  - Bridge environmental, social, and economic
  - Increase aquaculture production
    - Lessen demand on wild stocks

- How?
  - Simple Multi-Criteria Decision Making Model

Problems

Environmental Risks of Marine Aquaculture
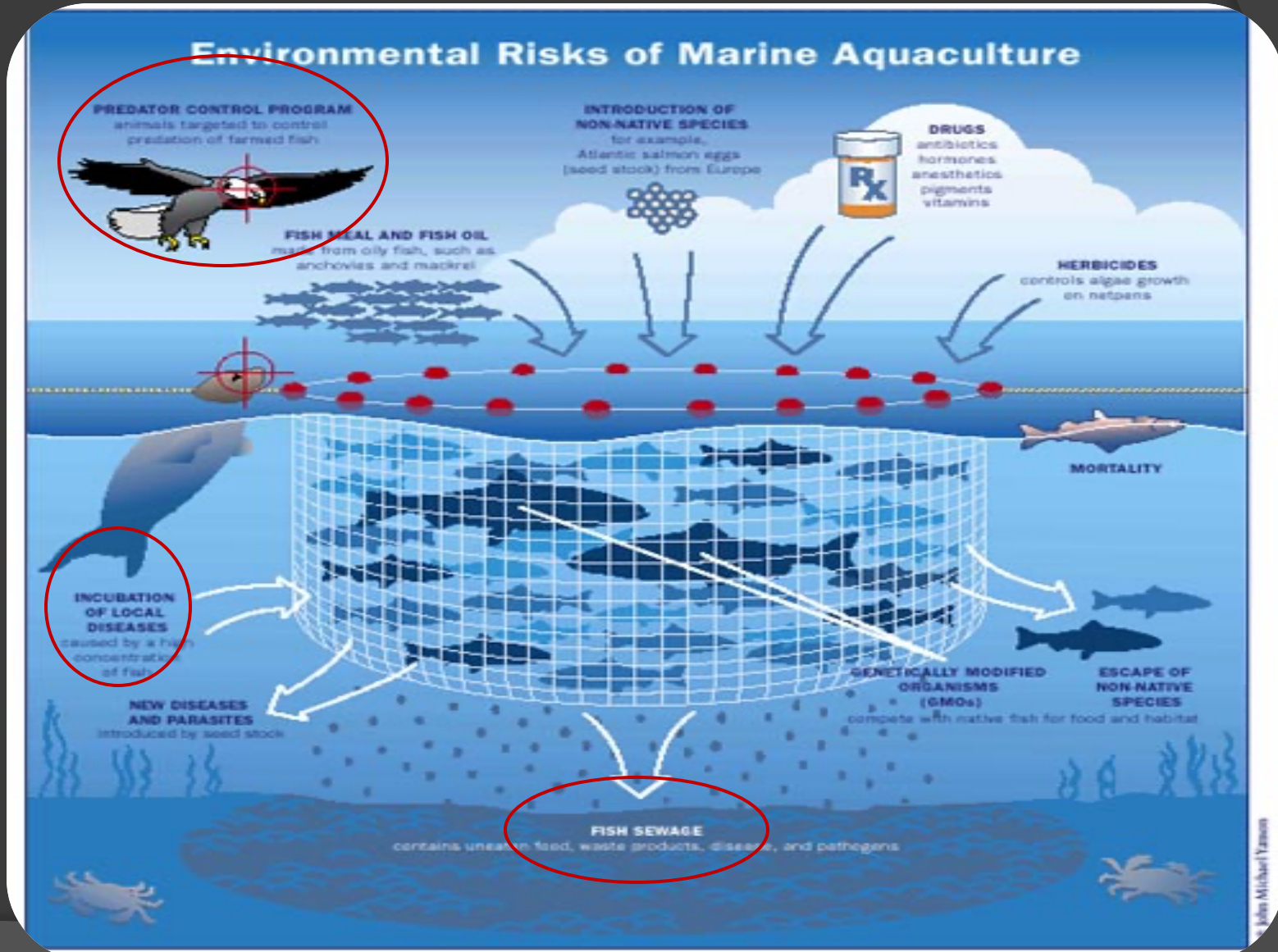
A Bit
of
History

Hawaiian Aquaculture

- Practiced extensive & semi-intensive aquaculture
- 488 total ponds ID on 6 main Hawaiian Islands
  - Oʻahu and Hawaiʻi had most (178 and 138 ponds)
- Historical estimates in 1800
  - 350 ponds operating
    - >1.5 millions #s

Why Offshore?
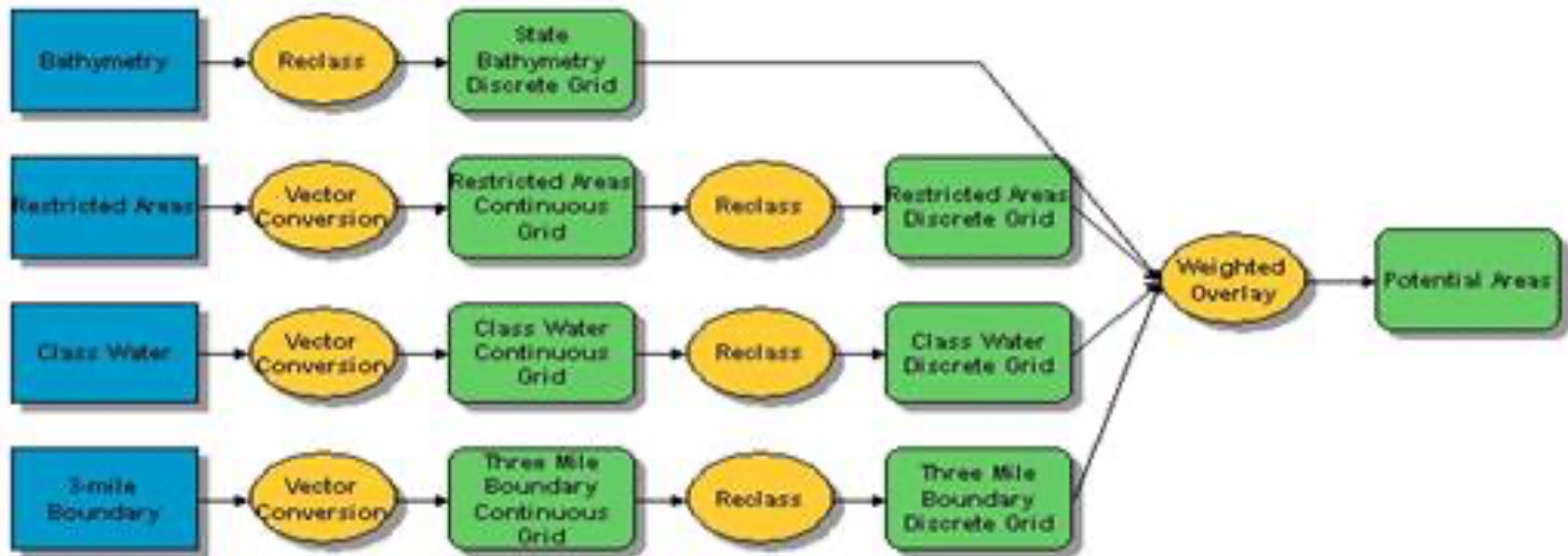
- 1990, 6 ponds: 31,639 pounds/year
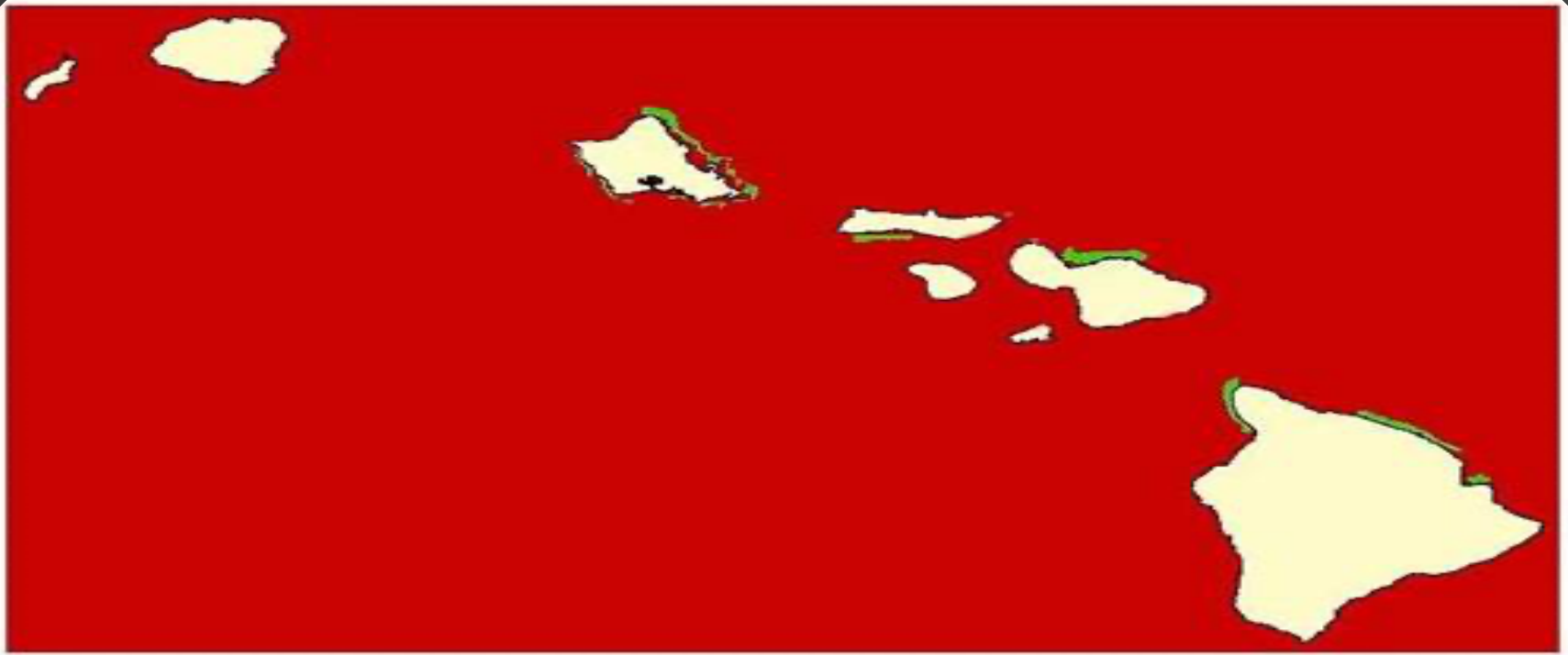

a. 1928   b. 1949   c. 1971

GIS in Aquaculture

GIS in Aquaculture

100   0   100   200 Miles

Potential Aquaculture Areas
- Restricted
- 1
- 2
- 3
- No Data

Selection VS Suitability

- Matter of scale
  - Selection:
    - ID specific spot where to place farm
    - Local
    - Well studied, data rich environments
  - Suitability
    - ID general areas that may be possible (planning, environmental management)
    - Regional
    - National level models (LENKA), rely on statutes and laws as well as science

Objectives

- Create a minimal data-set framework based on publically available data
  - Identify appropriate regions for further detailed research (adapted from FAO)
    - Most Suitable
    - Moderately Suitable
    - Least Suitable
- Transferable, with low overhead cost
  - Home computer with moderate specs and ArcGIS software
  - Free /low-cost information

The Model Components

Model Components

- Basic & Military Constraints:
  - Areas incompatible with offshore cages
- 3 broad criteria
  - ○ Environment
  - ○ Economics
  - ○ Social -scenarios
- WLC
  - Environment + Economic

Basic Map Contents

- Anything that can conflict (the kitchen sink approach)
  - If point data, created buffer
  - Buffers based on published data (some layers no buffer)
    - Wrecks assumed average was 30m
- Has to be detailed as possible
  - Offshore farms have exclusive use zones

Basic Layers

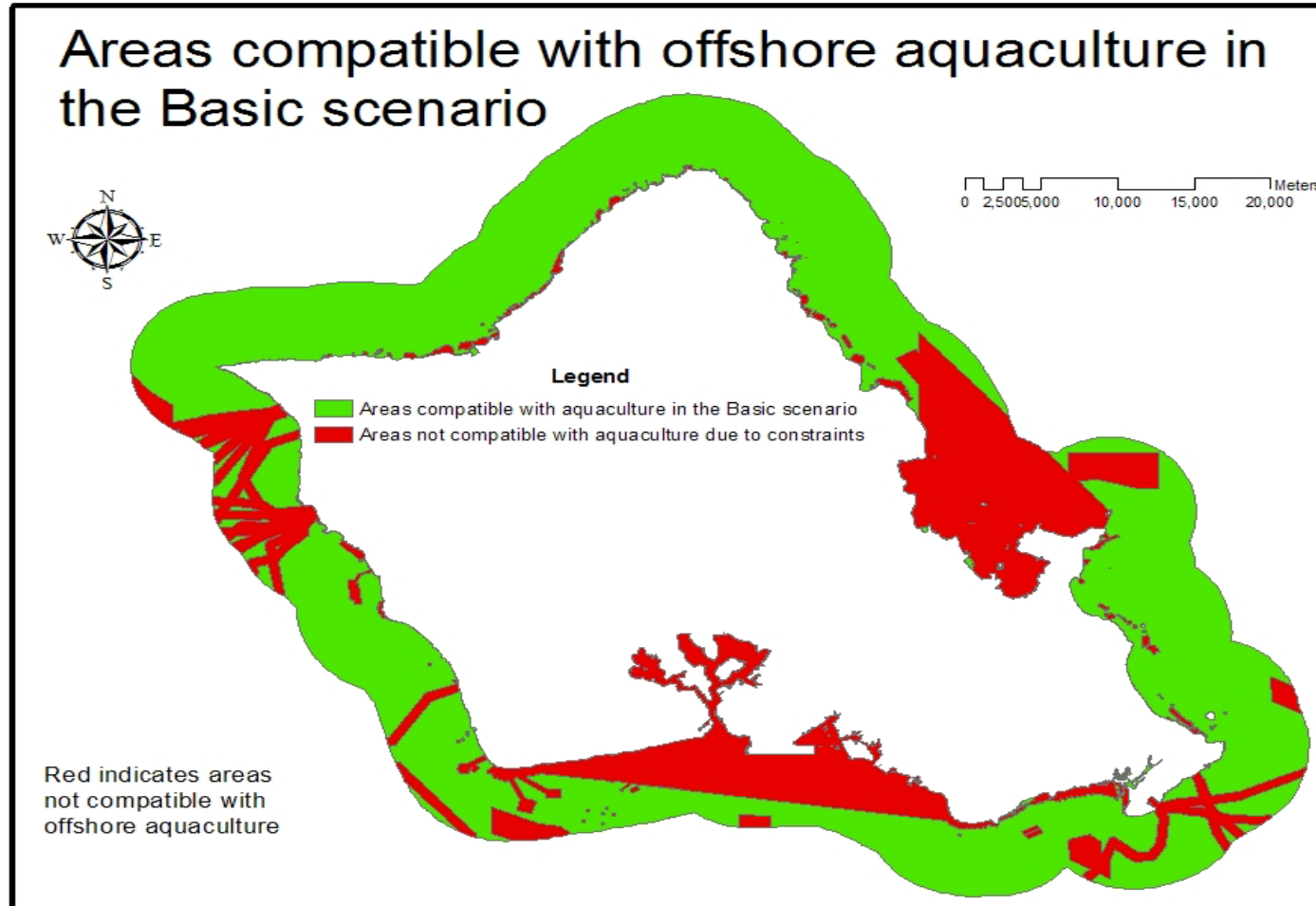| Layer	Buffer (m)	Notation on Buffer
Anchor	100	Assuming various vessel sizes and drift
Cables	350	Based on repair ship limitations
Coral (NOAA Navigation Charts)	30	From Cates EIS, 30m is distance from cage where bacterial levels reach ambient concentrations
Dumping	None	Buffer assumed during designation
Explosive Dumping	None	No areas within 3mile limit of O'ahu, added for completeness
Fish Aggregating Device	100	Analogous to buoys, State statutes prevent encroachment on Buoys
Fish Haven	None	Buffer assumed during designation

Basic Layers

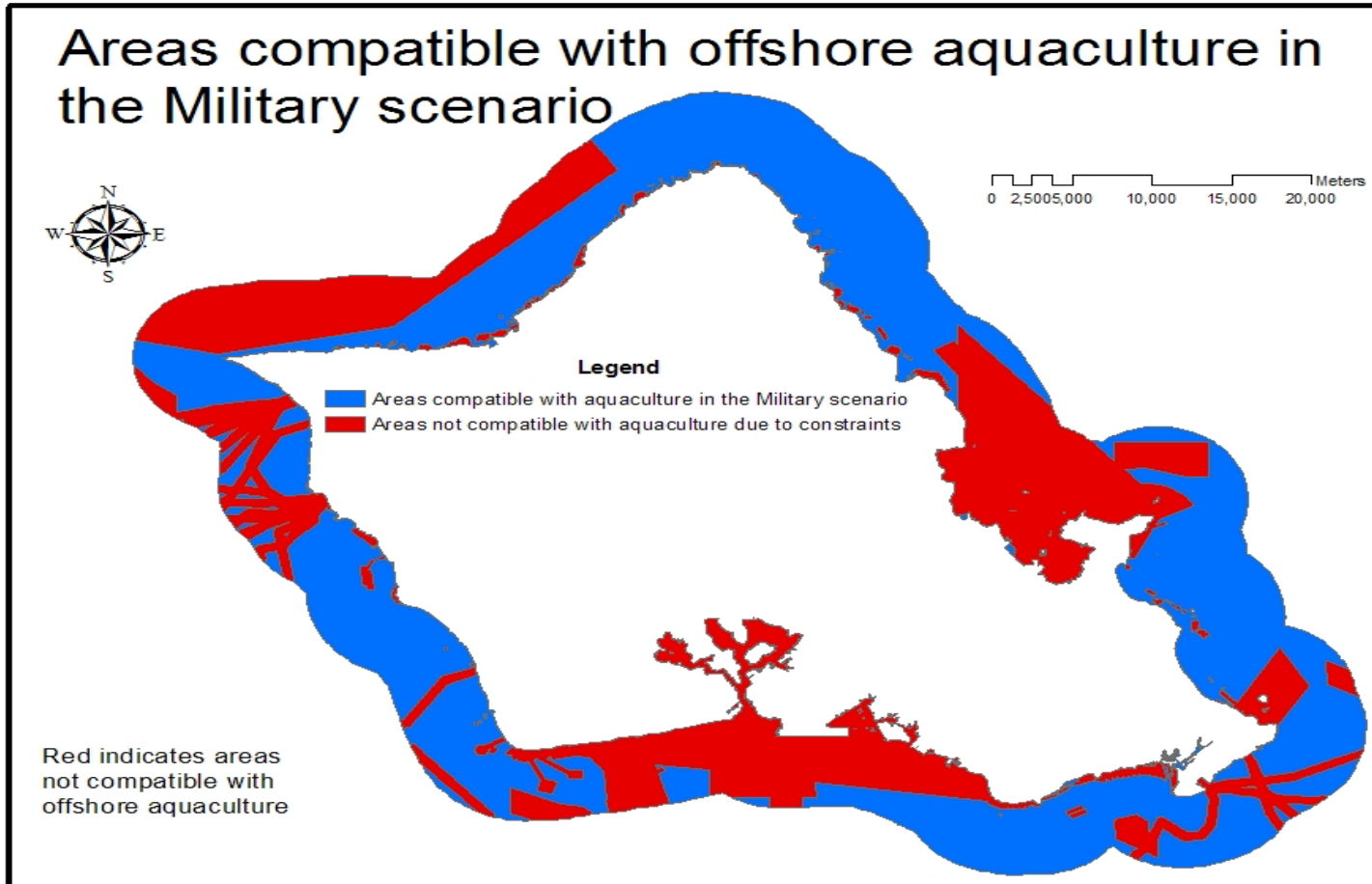| Layer	Buffer (m)	Notation on Buffer
Natural Area Reserve	None	Only on Maui, added for completeness
Fish Management Area	None	Buffer assumed during designation
Marine Life Conservation District	30	From Cates EIS, 30m is distance from cage where bacterial levels reach ambient concentrations
Marine Managed Area	None	Buffer assumed during designation
Navigational Aide	100	Analogous to buoys, State statutes prevent encroachment on Buoys
Obstruction	30	Point file, buffer added for safety of

Basic Layers

Layer	Buffer (m)	Notation on Buffer
Offshore Installation	100	Based on point data, prevent overlap of exclusive use zones
Sub-surface Buoys	100	Analogous to buoys, State statutes prevent encroachment on Buoys
Sewer lines	100	Additional safety margin to prevent contamination during a sewage spill
Unexploded Ordinance	100	Point File and none within O'ahu 3 mile area
Wrecks	100	Averaged size of various wrecks (planes and ships)
Military	None	*Contains Multiple layers which author does not have permission to disclose

Basic

Areas compatible with offshore aquaculture in the Basic scenario

Legend
- Areas compatible with aquaculture in the Basic scenario
- Areas not compatible with aquaculture due to constraints

Red indicates areas not compatible with offshore aquaculture

Military

Areas compatible with offshore aquaculture in the Military scenario

Legend
- Areas compatible with aquaculture in the Military scenario
- Areas not compatible with aquaculture due to constraints

Red indicates areas not compatible with offshore aquaculture

Area

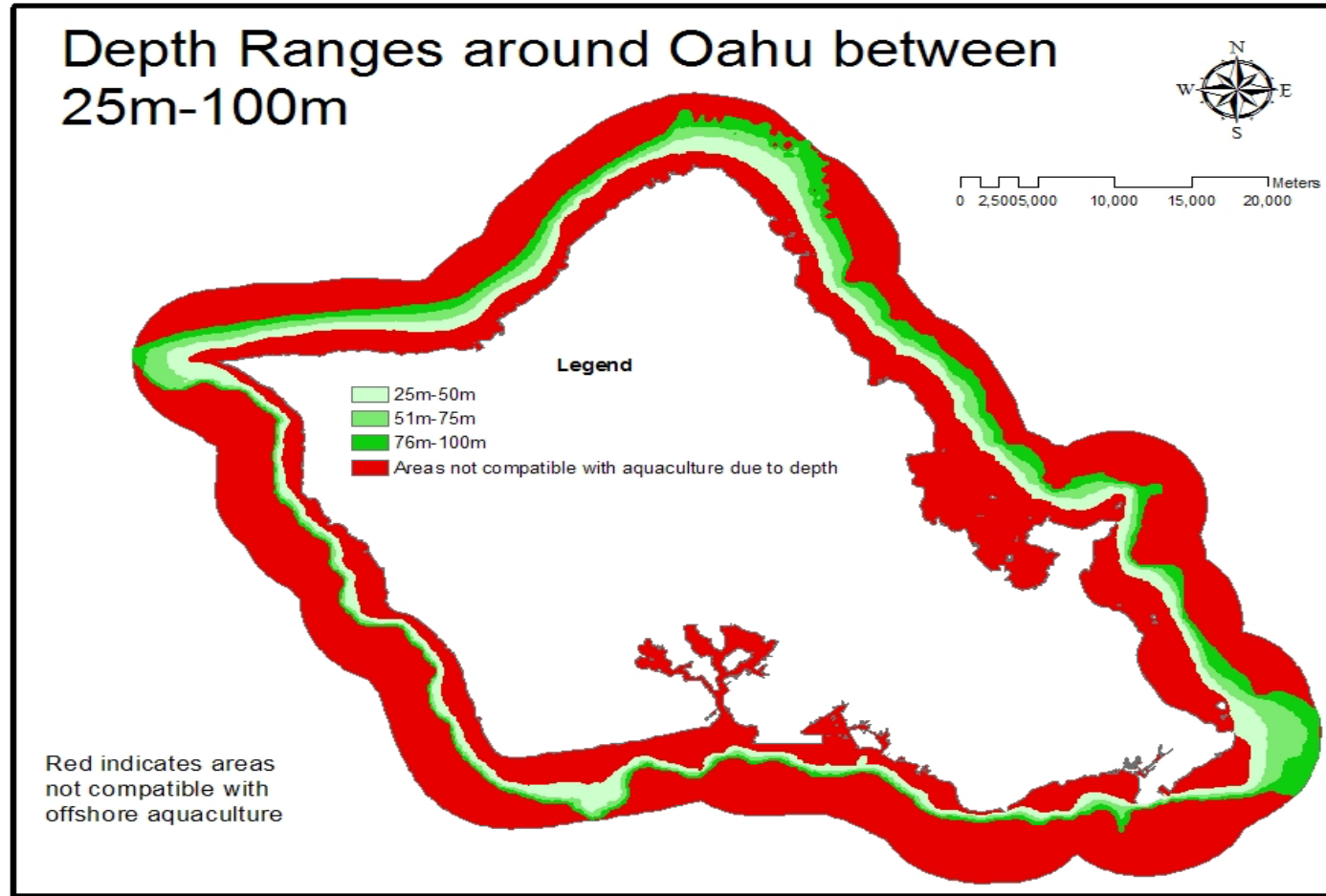| Layer	Size (m^2)	%
Oʻahu Full Extent	1,310,550,784	100
Basic	924,000,191	70.5
Military	769,486,606	58.7

Environmental

Environmental

- Based on publications and existing site suitability models
  - Basic and near-ubiquitous trait: Bathymetry
    - Missing data interpolate using Natural Neighbor
- 3 classifications
  - 25m-50m
  - 51m-75m
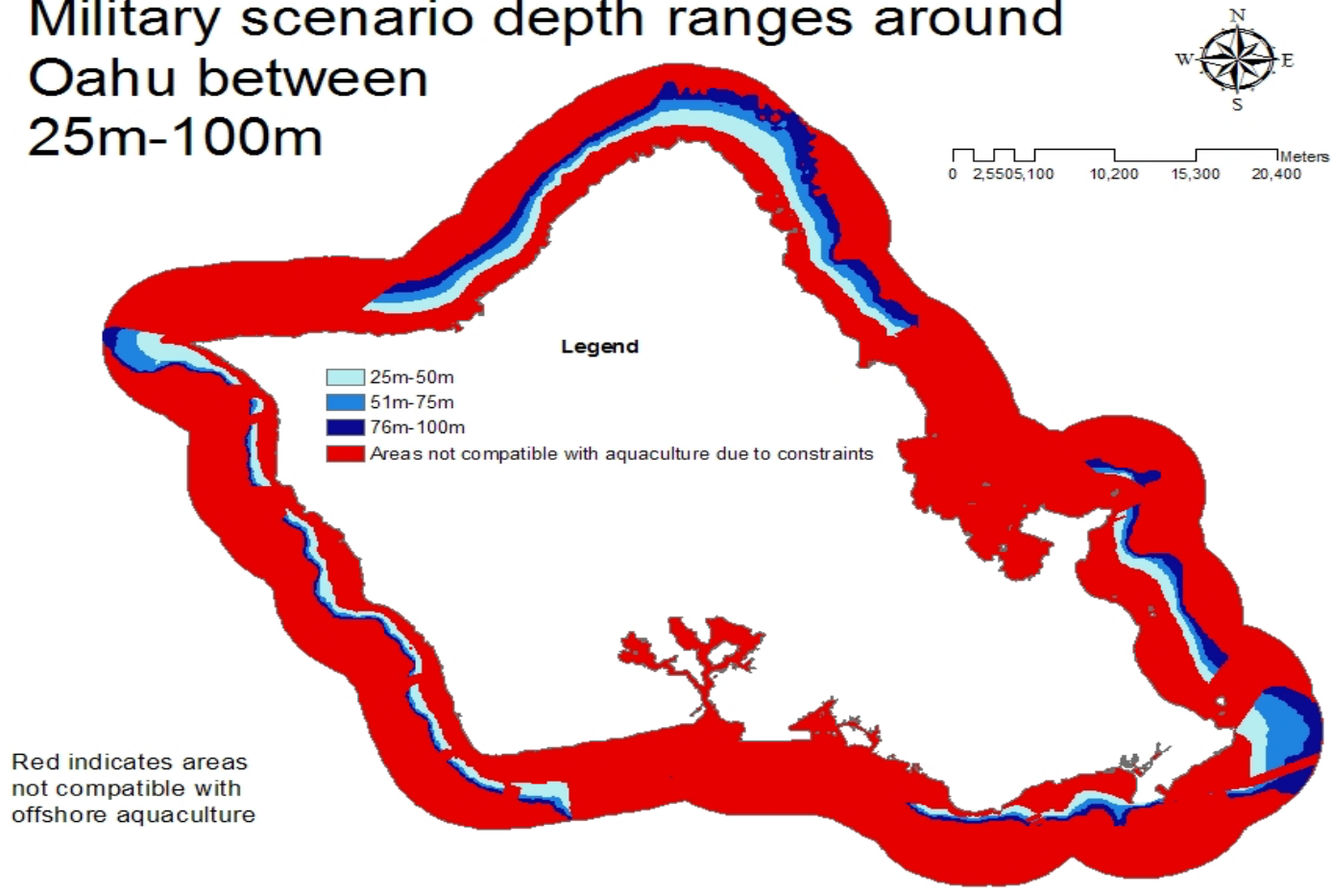 - 76m-100m

Bathymetry

Depth Ranges around Oahu between 25m-100m

Legend
- 25m-50m
- 51m-75m
- 76m-100m
- Areas not compatible with aquaculture due to depth

Red indicates areas not compatible with offshore aquaculture

Bathymetry Military

Military scenario depth ranges around Oahu between 25m-100m

Legend
- 25m-50m
- 51m-75m
- 76m-100m
- Areas not compatible with aquaculture due to constraints

Red indicates areas not compatible with offshore aquaculture

Environmental

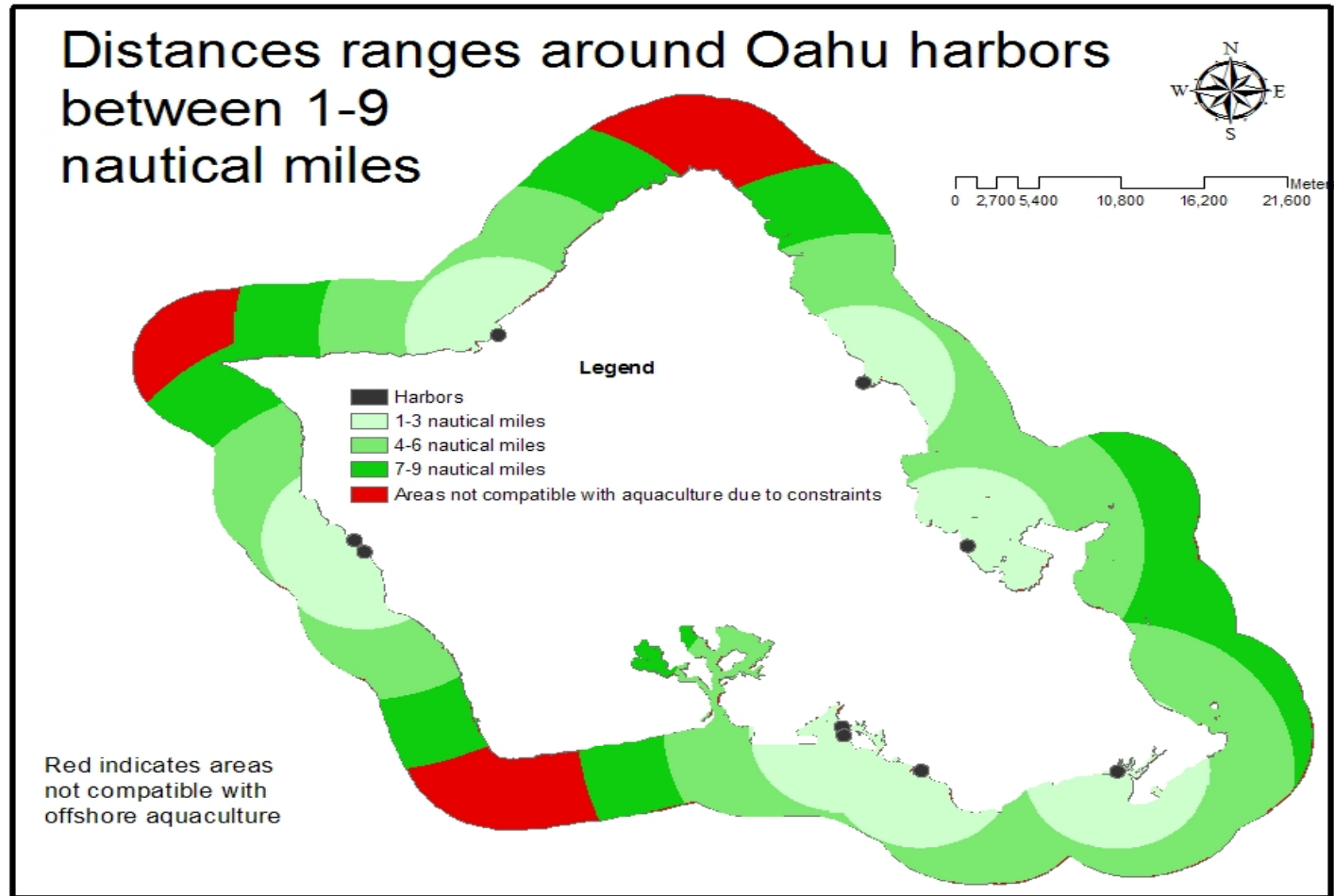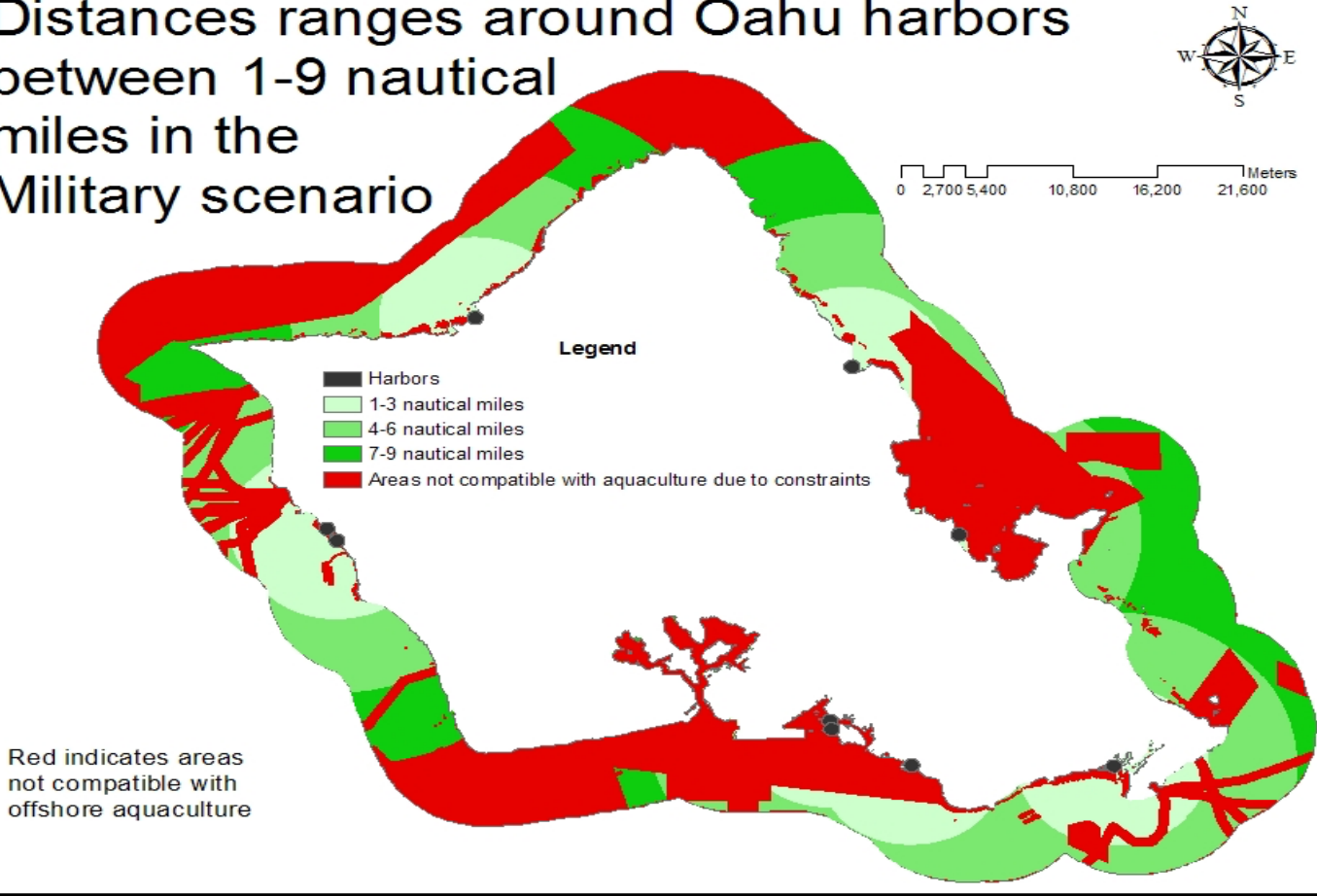| Depth	Full Extent Size (ha)	Base Size (ha)	Military Size (ha)
25m-50m	1,196,870	9,895	8,151
51m-75m	950,858	7,692	6,431
76m-100m	925,996	8,253	6,900
Total	3,073,724	25,840	21,482

Economics

Economics

- Any harbor with reasonable area around it can be used
  - Storage space for feed maintenance equipment
- Why only distance from harbor?
- 3 classifications
  - 9 knots typical ship
  - 1-3 nautical miles
  - 4-6 nautical miles
  - 7-9 nautical miles

Economics

Distances ranges around Oahu harbors between 1-9 nautical miles

Legend
- Harbors
- 1-3 nautical miles
- 4-6 nautical miles
- 7-9 nautical miles
- Areas not compatible with aquaculture due to constraints

Red indicates areas not compatible with offshore aquaculture

Economics Military

Distances ranges around Oahu harbors between 1-9 nautical miles in the Military scenario

Legend
- Harbors
- 1-3 nautical miles
- 4-6 nautical miles
- 7-9 nautical miles
- Areas not compatible with aquaculture due to constraints

Red indicates areas not compatible with offshore aquaculture

Economic

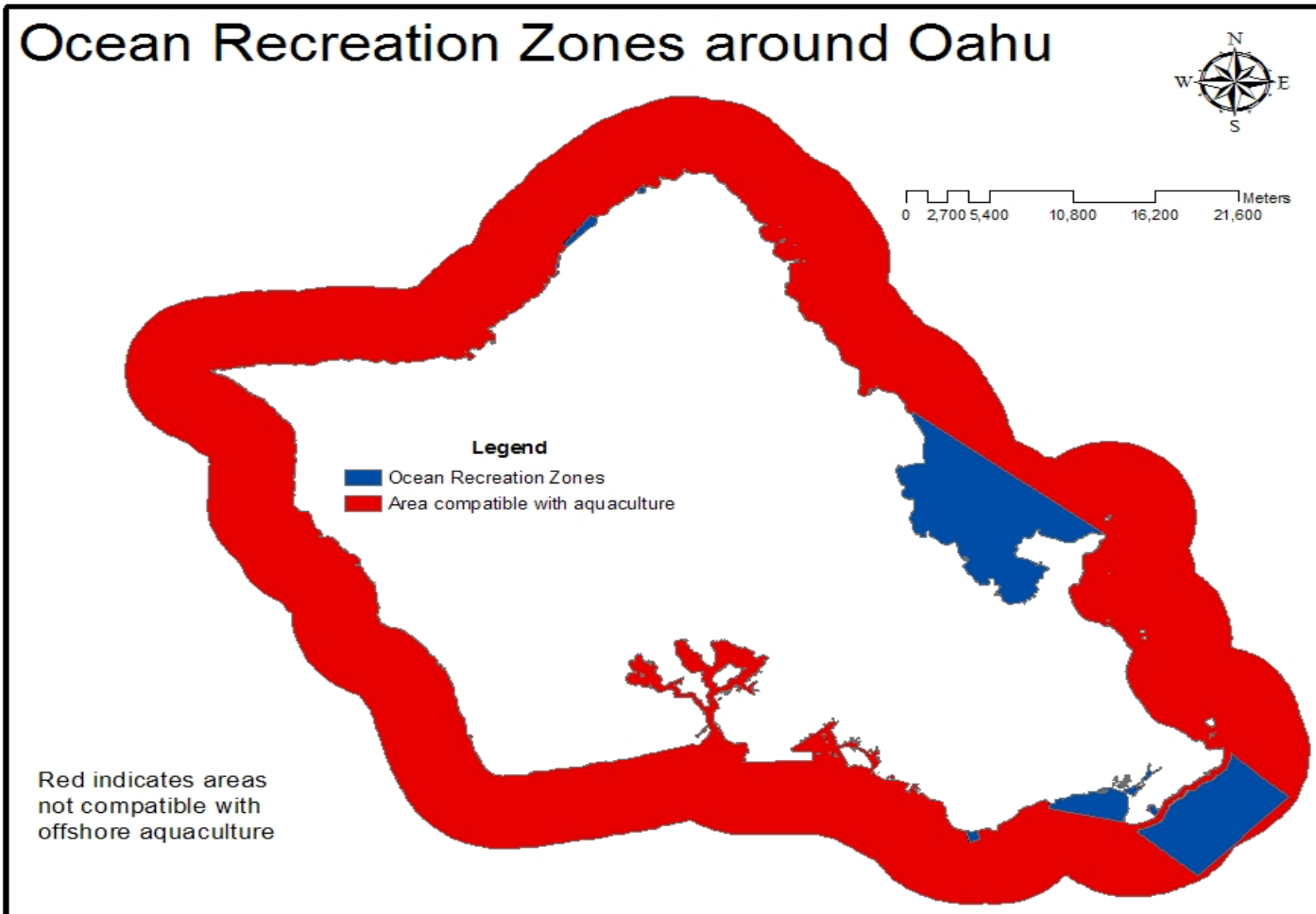| Distance (nautical miles)	Full Extent Size (ha)	Basic Size (ha)	Military Size (ha)
1-3	33,008	17,361	16,995
4-6	51,878	36,186	29,078
7-9	30,441	25,490	20,284
Total	115,327	79,037	66,357

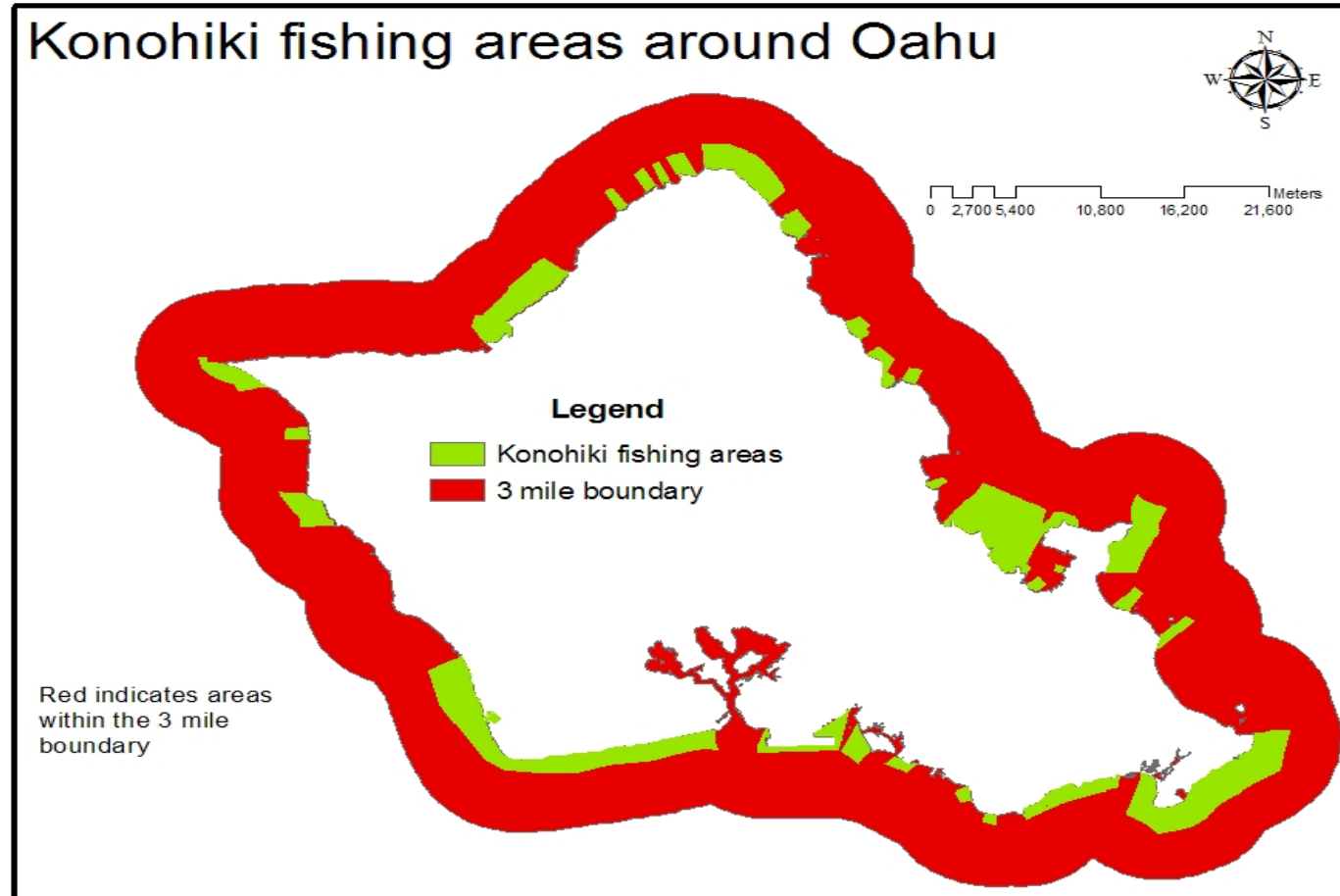# Social

Ocean Recreation

&

 Konohiki

Social

- Modern use
  - Ocean Recreation Zone
    - Based on DLNR regulations
- Traditional use
  - Konohiki fishing area associated with Ahupua'a
    - Historically important
    - Proxy for cultural uses

Ocean Recreation

Ocean Recreation Zones around Oahu

Legend
- Ocean Recreation Zones
- Area compatible with aquaculture

Red indicates areas not compatible with offshore aquaculture

Konohiki

Konohiki fishing areas around Oahu

Legend
- Konohiki fishing areas
- 3 mile boundary

Red indicates areas within the 3 mile boundary

COMBINED

Combined

- Run WLC of Environment & Economics, equal weight, within the Social dataset
- Combination of Ocean Recreation and Konohiki Fishing areas:
  - All Ocean recreation and k*onohiki* Fishing areas are available
  - No Ocean Recreation or k*onohiki* fishing areas are available for exclusive lease,
  - Only Ocean recreation zones but no k*onohiki* fishing areas are available for exclusive use
  - Only k*onohiki* fishing areas but no Ocean Recreation Zones
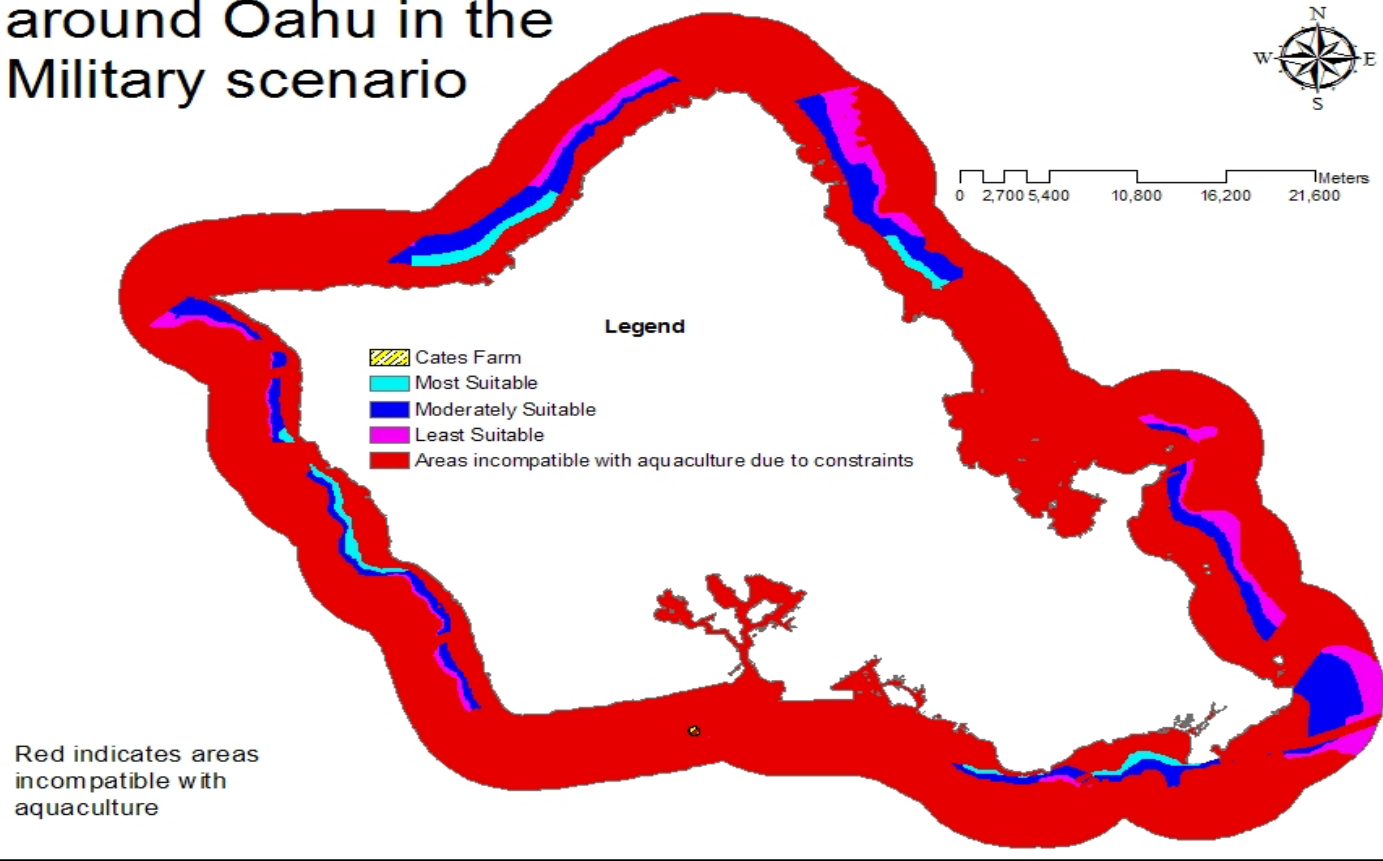
WLC

WLC Military
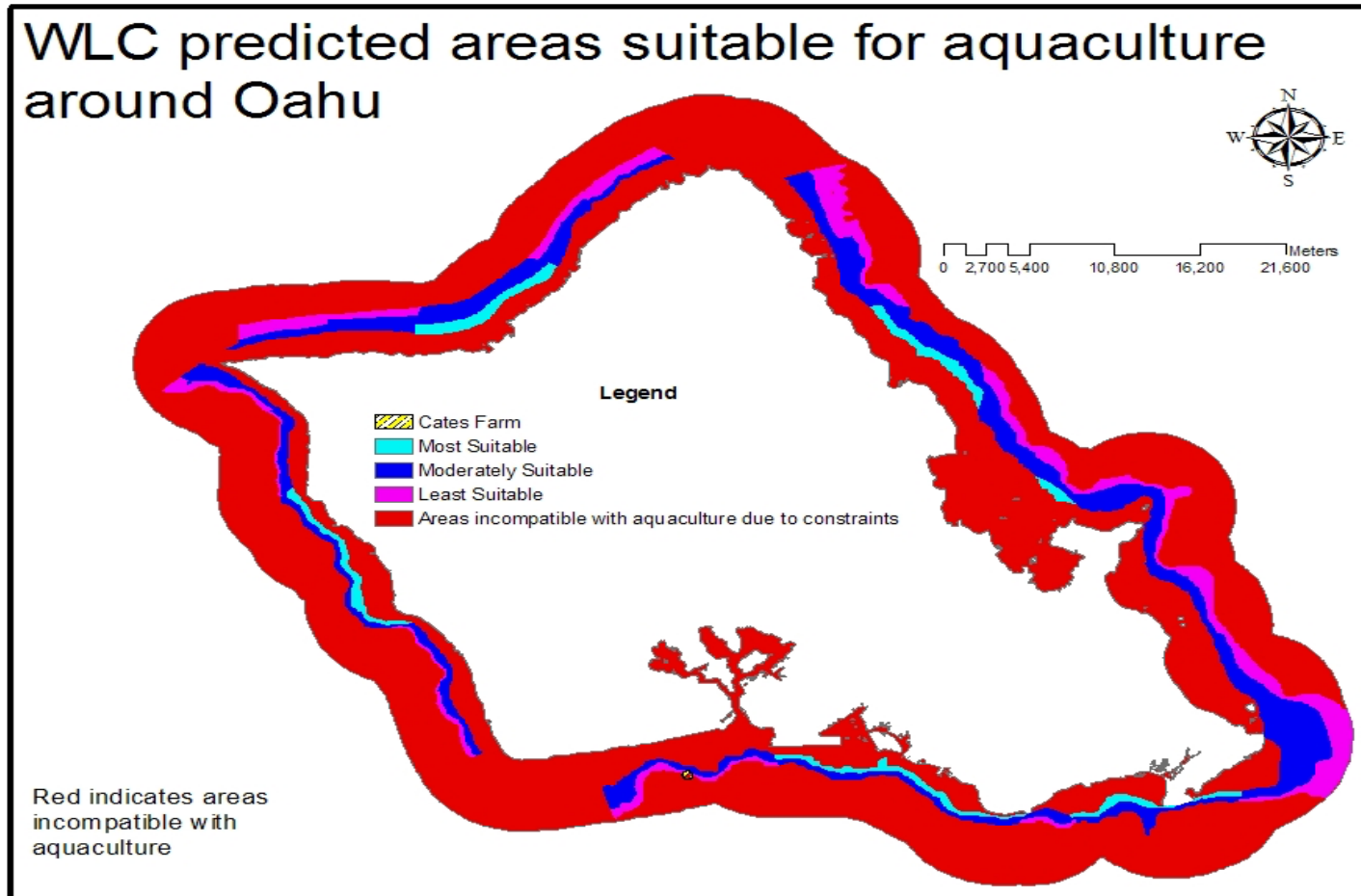
WLC predicted areas suitable for aquaculture around Oahu in the Military scenario

Legend
- Cates Farm
- Most Suitable
- Moderately Suitable
- Least Suitable
- Areas incompatible with aquaculture due to constraints

Red indicates areas incompatible with aquaculture

WLC Sizes

WLC Prediction	Full Extent Size (ha)	Basic Size (ha)	Military Size (ha)
Most Suitable	3,304	2,020	2,020
Moderately Suitable	15,430	11,547	9,532
Least Suitable	8,159	6,643	5,231
Total	26,893	20,210	16,783

Total Area
WLC in Social Scenarios

WLC Prediction	Basic(ha)	Military(ha)
Full	20,210	16,783
No Konohiki	17,779	14,549
No Orec/Konohiki	17,195	13,965

Discussions & Conclusions

Validation

Model validation via overlap of Cates far with benthic layer and distance from harbor in the Military scenario

Legend
- Cates Farm
- 25m-50m
- 51m-75m
- 76m-100m
- Harbors
- 1-3 nautical miles
- 4-6 nautical miles
- 7-9 nautical miles
- Areas incompatible with aquaculture due to constraints

Red indicates areas incompatible with aquaculture
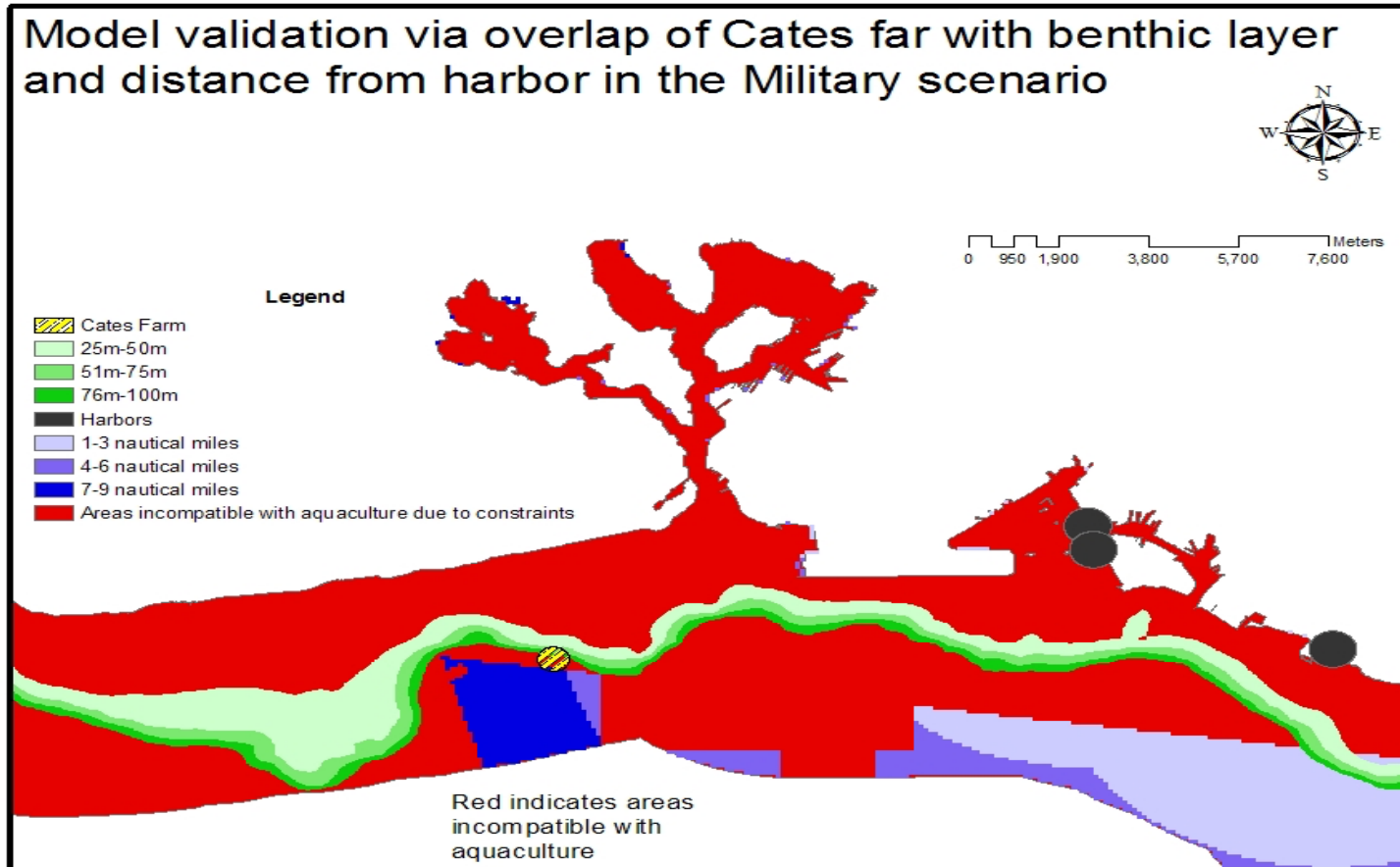
Discussion

- Results comparison to ADP Phase 1
  - Problematic at best
  - Low resolution state-wide map, no details or quantifiable numbers (Phase 2 never completed)
- Results comparison to other regional scaled models
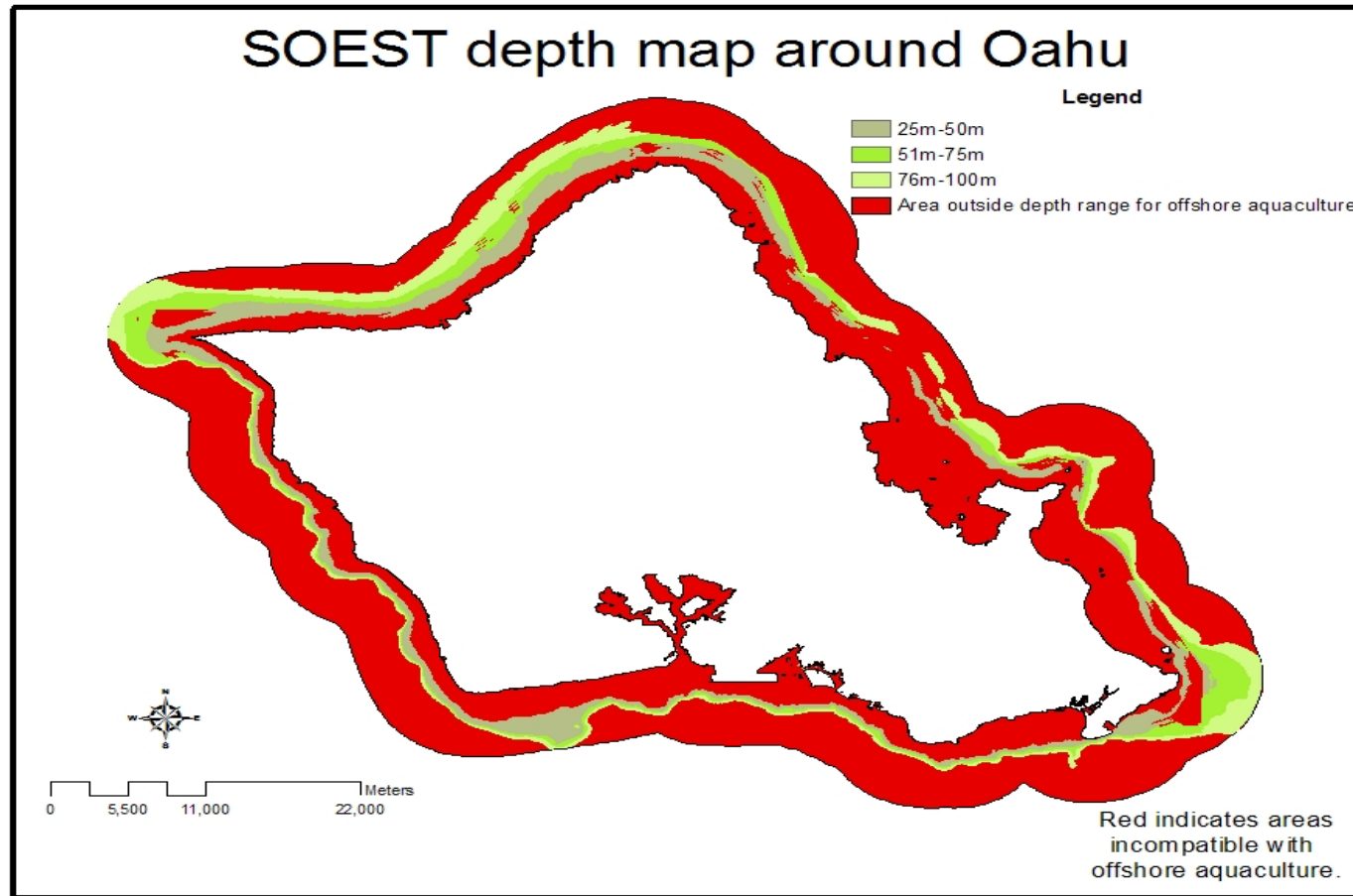 - Incorporates similar information
    - New to the Pacific Islands

Discussion

- Errors
  - Rasterization
  - Public data
    - Poor metadata
    - Improper digitization
    - Interpolation
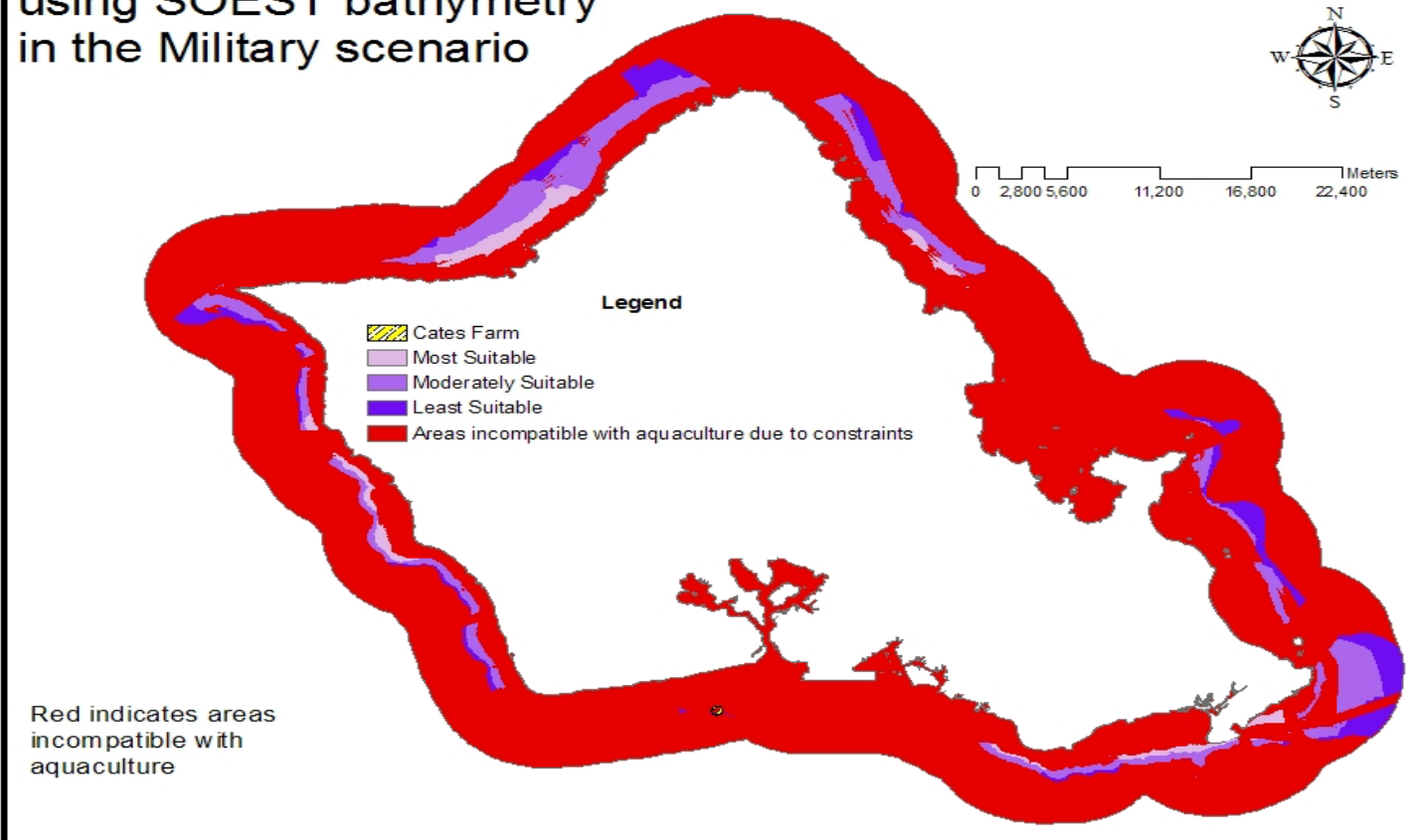 - 10%-25% error not uncommon in GIS analysis
- Different data =?= different results

SOEST Bathymetry

SOEST WLC Military

WLC predicted areas suitable for aquaculture around Oahu using SOEST bathymetry in the Military scenario

Legend
- Cates Farm
- Most Suitable
- Moderately Suitable
- Least Suitable
- Areas incompatible with aquaculture due to constraints

Red indicates areas incompatible with aquaculture

Discussion

- ## Radiarta et al (2009)
  - Information about the relative importance of the criteria is required.
- ### Bio-physical
  - Sea temperature, food availability (measured as chlorophyll-a), suspended Sediment and bathymetry
- ### Social– infrastructural
  - Distance to town ; Distance to piers ; Distance to land-based facilities
- ### Constraint
  - Harbor (inside and entrance) ; Town/industrial ; River mouth
- ## Why mine is different?

Discussion

- Data Availability
  - Previous studies mostly in Data Rich areas
  - Allows for highly detailed outputs
- Regional vs. Local scale
  - Step process
  - Regional first-
    - eliminates areas
    - Allows concentration of limited resources in appropriate local areas

Conclusions

- Importance of suitability
- Proper siting
  - Saves:
    - Time
    - $ (governments, and businesses)
  - Eases growing pains in new markets
    - Local community support
- Few places around Oʻahu possible for expansion
  - State focus on Maui which is equally problematic
- Structure of model functions:
  - Cates operation within acceptable area

Conclusions

- Needed for next phase (Site Selection)
  - AHP based WLC with more detailed information
    - Information allows for alteration of weights
  - More accurate bathymetry
  - Currents
  - Waves
  - Temperature
  - Turbidity
  - Tides
  - More detailed infrastructure

Conclusions

- Transferability
  - Framework applicable for majority of Pacific Islands / Tropical Coastal regions
    - Open source data (nautical charts)
      - Minimal financial commitment
    - Can be adapted to most coastal regions by expanding limitations in Basic layer
  - Identifies suitable areas for further in-depth research to determine specific sites

Mahalo nui

- Committee
  - Drs Evensen, Leung, Robotham, Szuster, Tamaru
- HI ADP
  - Dr Young
- DURP
  - Dr Minerbi
- Kona Blue
  - Neil Sims
- UH Hilo
  - Drs Haws, Gibson, Potemra
  - Noe, Lisa

Questions?