Marine Zones for the Culture of Fish in Puerto Rico

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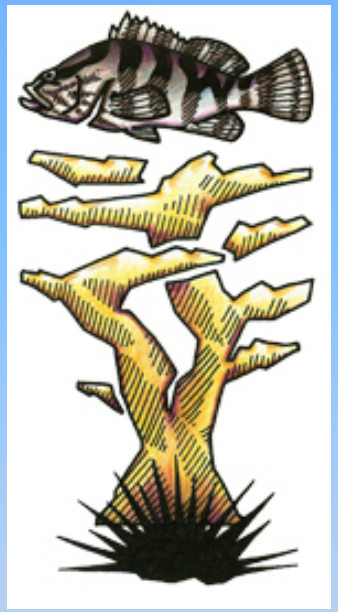
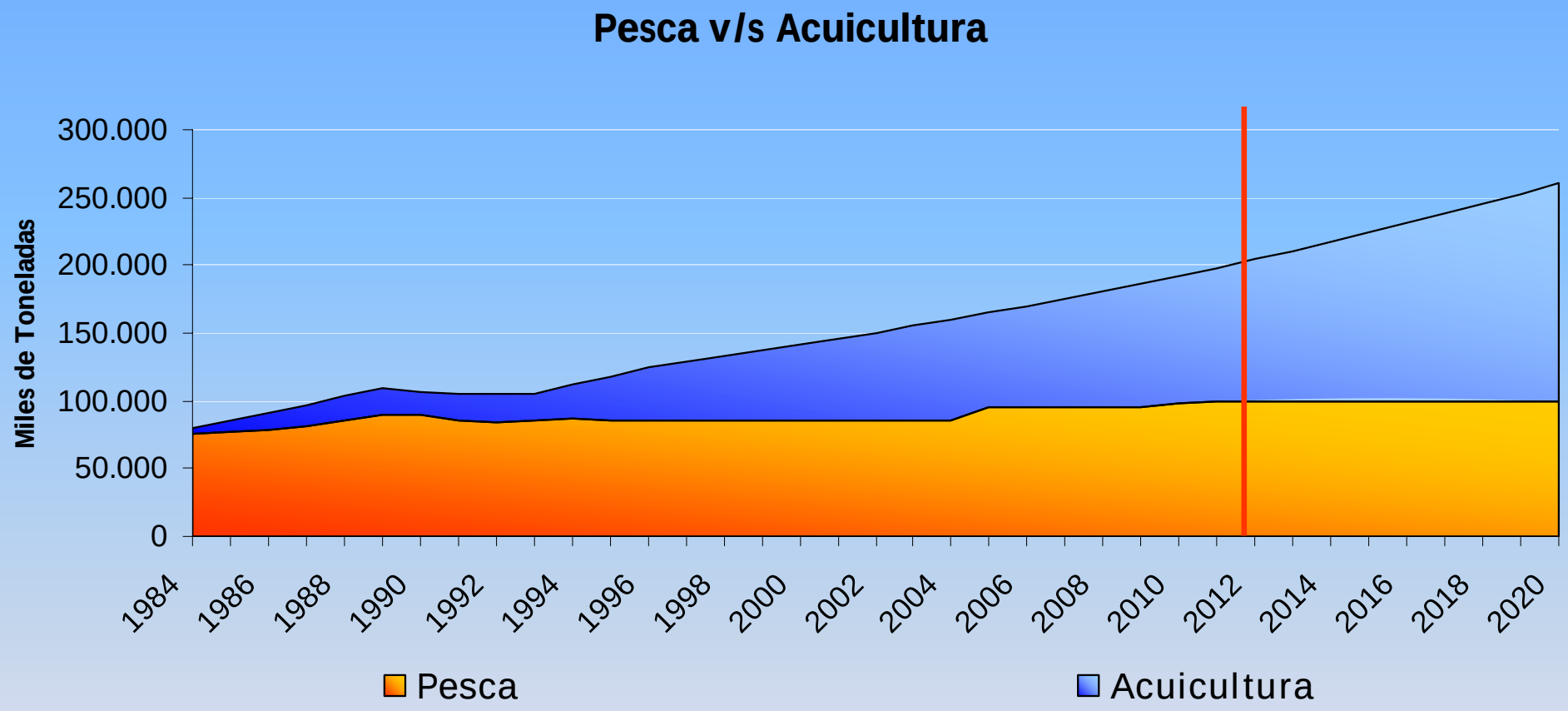
ACKNOWLEDGMENTS:

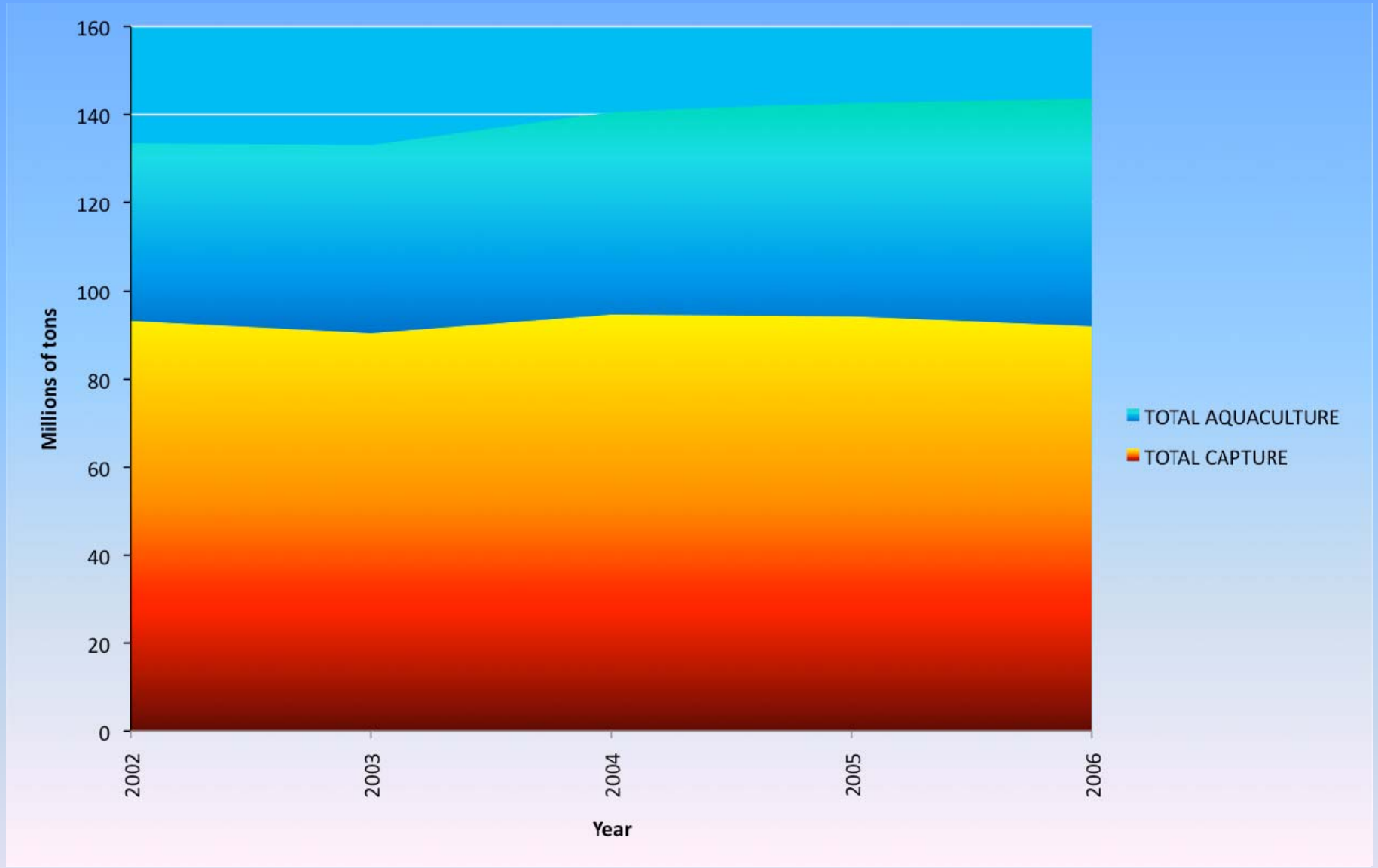


University of Puerto Rico at Mayagüez
Caribbean Coral Reef Institute

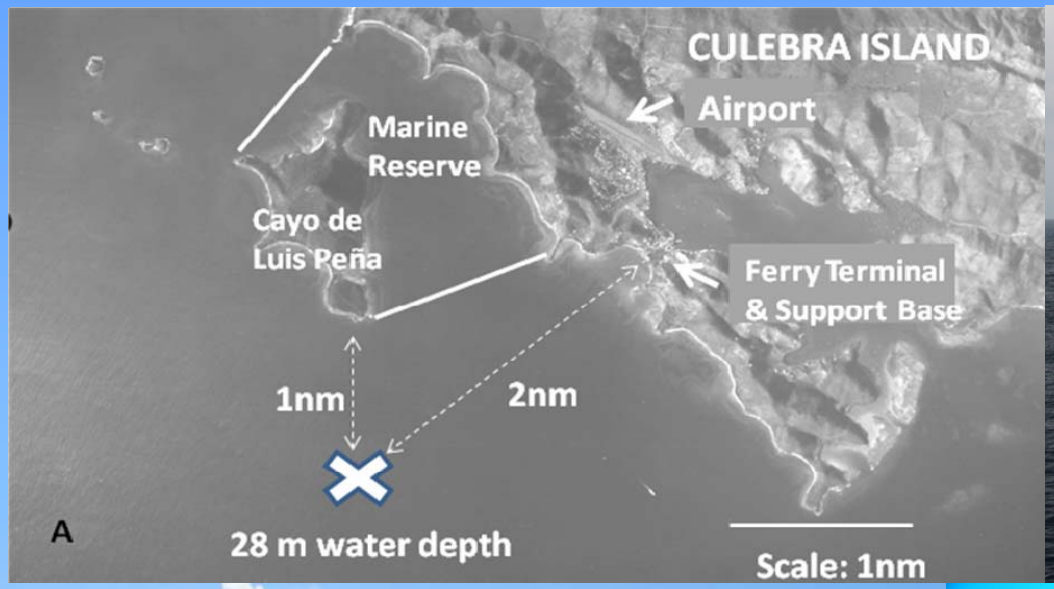
Acuicultura



Courtesy of Cristian Swett, OCEA, Chile

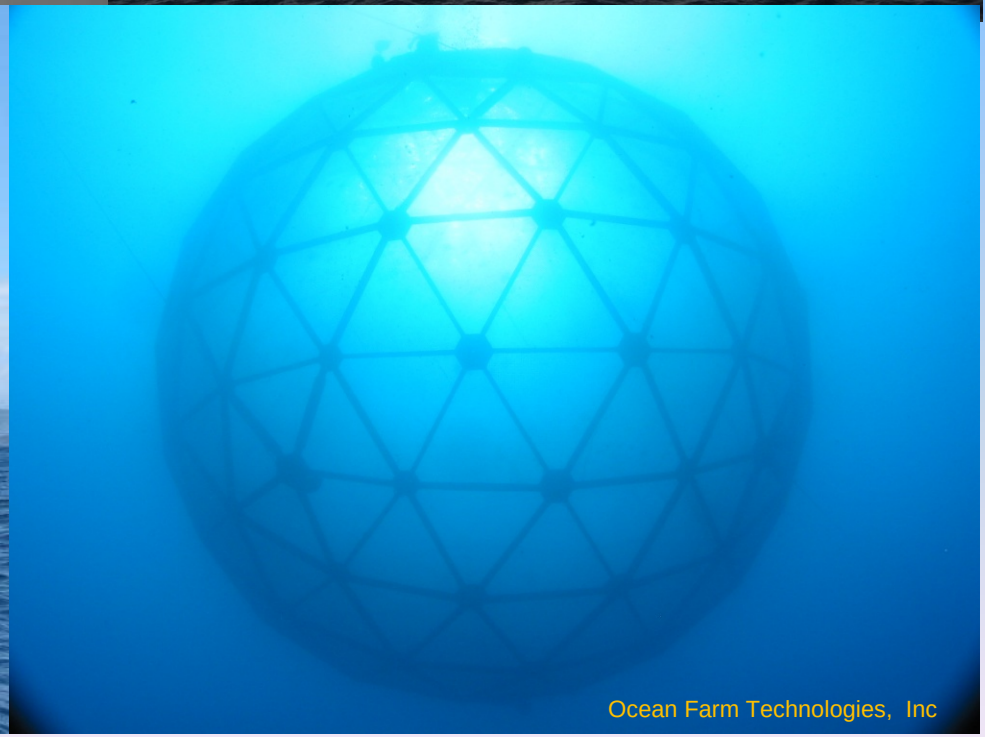


Data from FAO, SOFIA, 2006


CULEBRA ISLAND
Airport
Marine
Reserve
Cayo de
Luis Peña
Ferry Terminal
& Support Base
1nm
2nm
A
28 m water depth
Scale: 1nm


Open Blue Sea Farms, LLC


SnapperFarms, Inc


Ocean Farm Technologies, Inc

Snapperfarms, Inc

Snapperfarms, Inc

Brian O´Hanlon & Pesquera Delly, Guaymas, Mexico

PAPER

Site Selection Criteria for Open Ocean Aquaculture

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ABSTRACT

With aquaculture steadily expanding, the need for suitable space has been followed by the development of more efficient, cost-effective, and environmentally sustainable methodologies. Avoiding possible conflicts between the development of commercial aquaculture operations and the environmental impact in coastal areas, utilizing the offshore environment offers the greatest potential for expansion of the industry in most regions throughout the world. Although currents and greater depths generally increase the assimilation capacity and energy of the offshore environment and offer many advantages for aquaculture, a number of challenges associated with developing any activity in the open ocean environment must be taken into consideration. This article summarizes these advantages and challenges, focusing on the first and most crucial step for project development: site selection criteria for open ocean aquaculture. Although most of the concepts and criteria are common to other marine net pen aquaculture operations, we review and present those conditions that are inherent to the open ocean environment and must be considered before developing any offshore aquaculture activity. These encompass basic premises; assumptions; logistics; infrastructure; availability of manpower, services, and materials; legal framework; socioeconomic and political issues; and oceanographic, biological, environmental, and technological criteria. There are no defined set of criteria, as most are interacting and not fixed but interdependent (e.g., depth vs. current velocity). However, suitable sites must meet basic crucial standards summarized here.

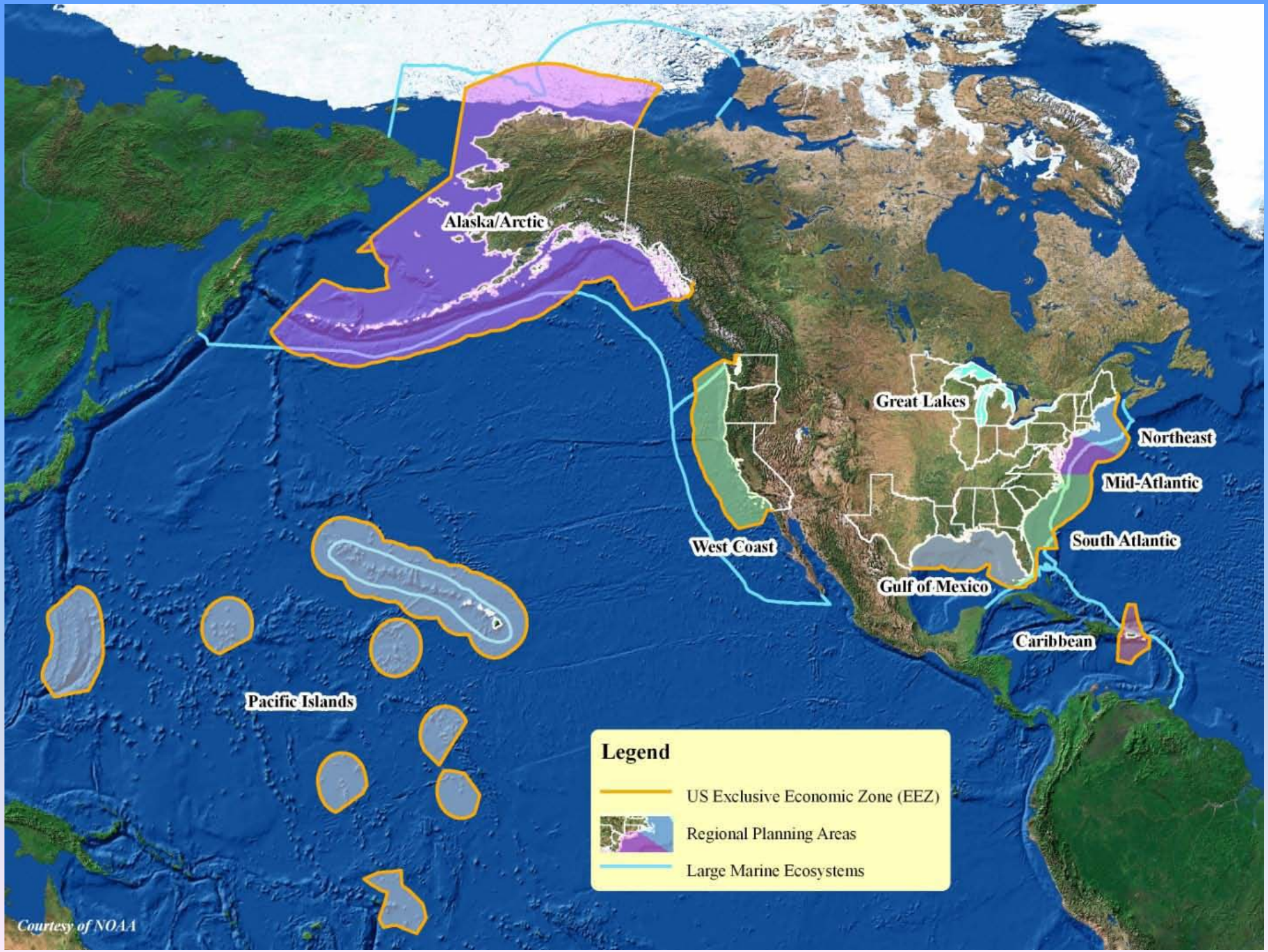
Site selection is one of the most important decisions for the establishment of a fish farm operation. Satellite images, hydrographic charts, maps, Google Earth, and Geographic Information Systems can all provide important information for preliminary work on site assessment; however, a very careful *in situ* survey is mandatory to evaluate the suitability of the area.

Keywords: Open ocean aquaculture, Offshore fish farming, Selection criteria for ocean fish farming

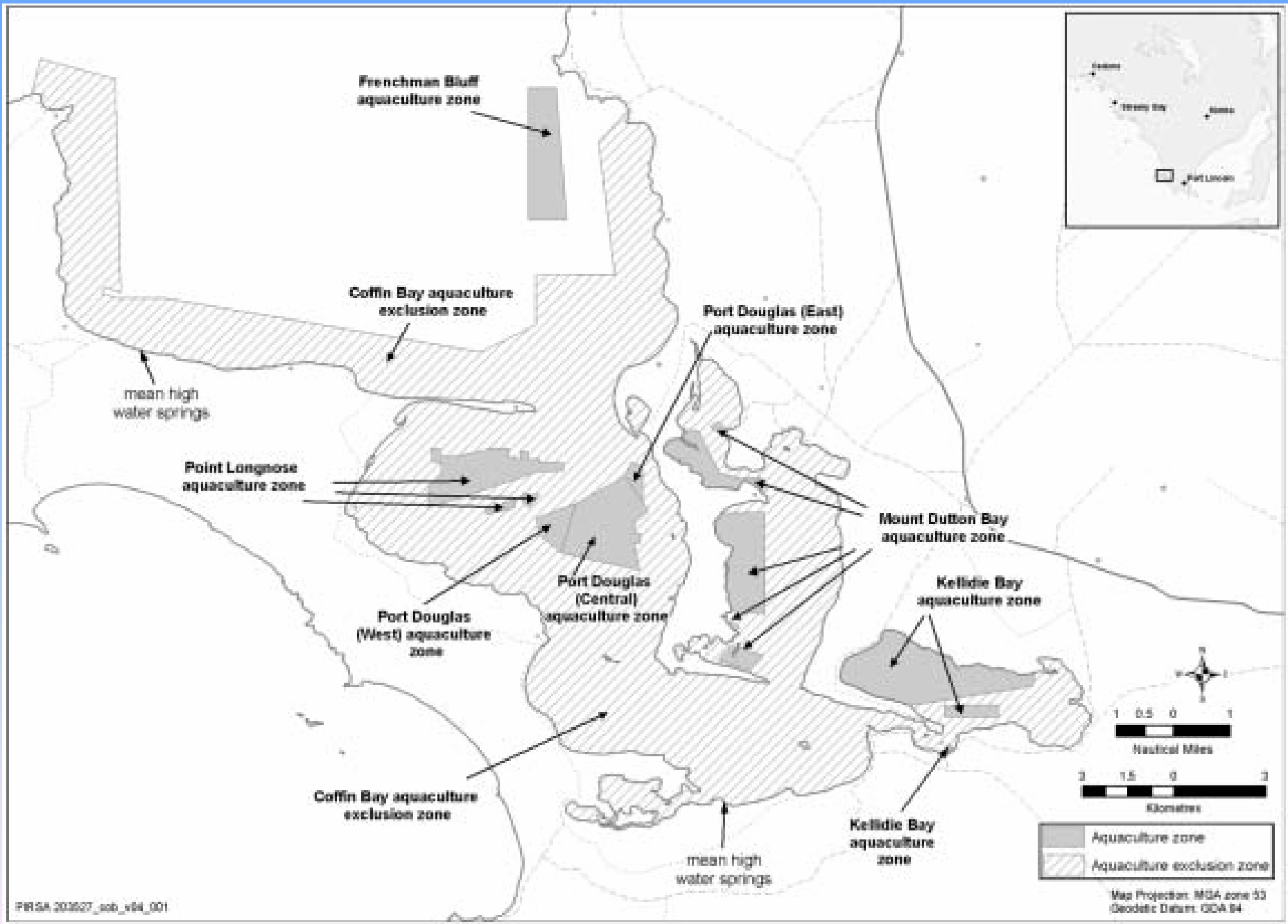
Introduction

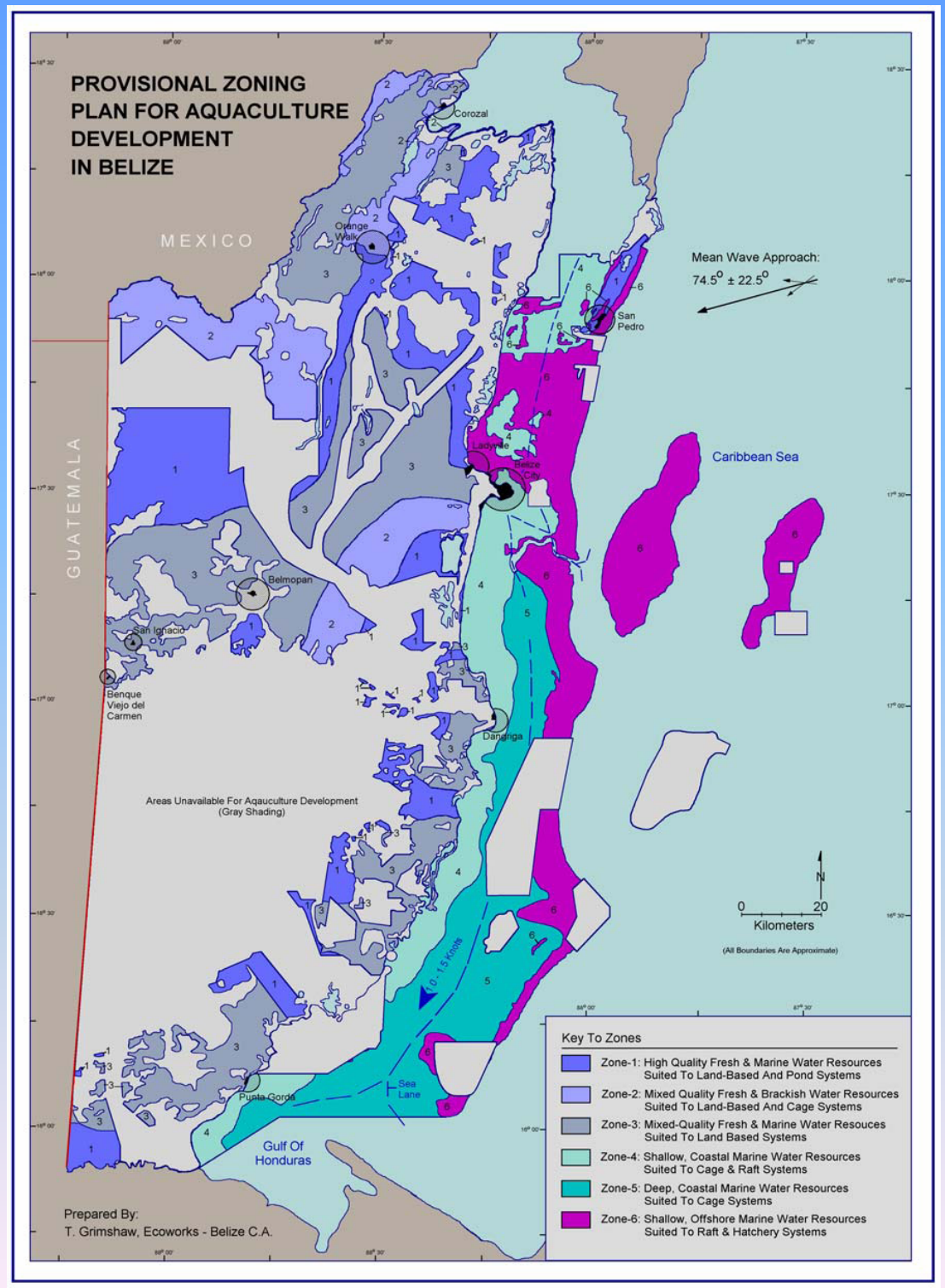
Recent technological advances in offshore cage systems allow for the development of aquaculture operations in the open ocean. This offshore industry is rapidly expanding throughout the world. Indeed, during the past 20–30 years, the salmon industry has driven such technological advances, reaching a point where state-of-the-art aquaculture cages with 100 m of diameter or more, capital cost under US$7/m^3, and widespread applications have been extensively exposed to high-energy environments (Scott and Muir, 2000). The technology is in place, as over the past decade a variety of modern submersible, semisubmersible, and floating cages have been designed and built to "conform" with waves and strong currents associated with the high-energy environment generally associated to offshore areas.

In addition to the attainable benefit of higher potential profits, offshore aquaculture may provide the benefits of (1) overall reduction in conflicts with other users and in objections from adjacent landowners, (2) avoidance of the ecological carrying capacity limitations of inshore waters, (3) access to larger volumes of high-quality water for finfish or filter-feeding organisms, (4) reduction of overall ecological impacts, (5) possible reduction of regulatory and permit requirements, and (6) ability to culture high-value, open ocean species (Stickney and McVey, 2002). Although the economical feasibility of such operations is still being evaluated, the potential benefits described signal the feasibility of raising a variety of marine finfish species in offshore environments to increase production while

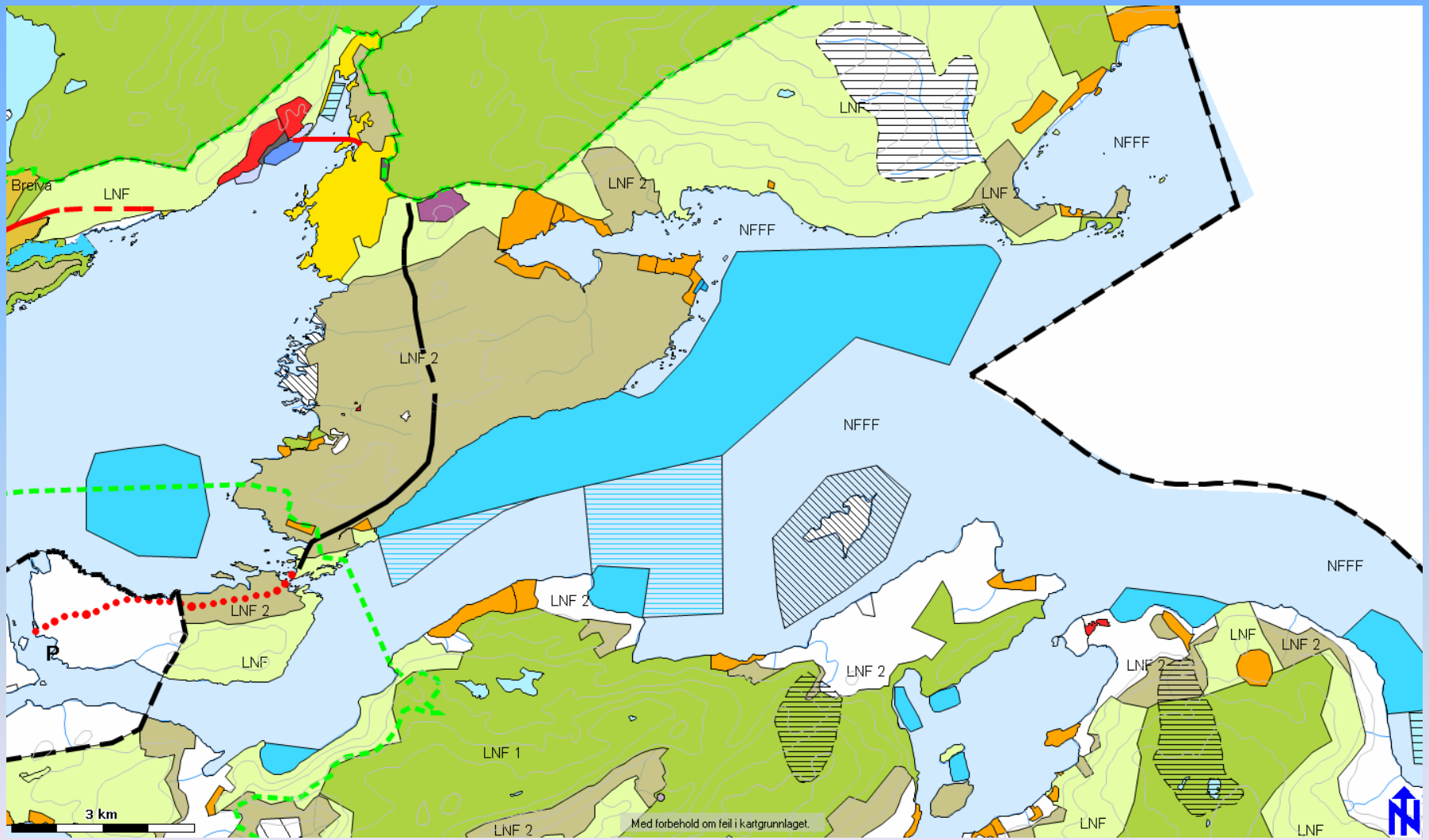

Alaska/Arctic
Great Lakes
Northeast
Mid-Atlantic
South Atlantic
West Coast
Gulf of Mexico
Caribbean
Pacific Islands
Legend
US Exclusive Economic Zone (EEZ)
Regional Planning Areas
Large Marine Ecosystems
Courtesy of NOAA

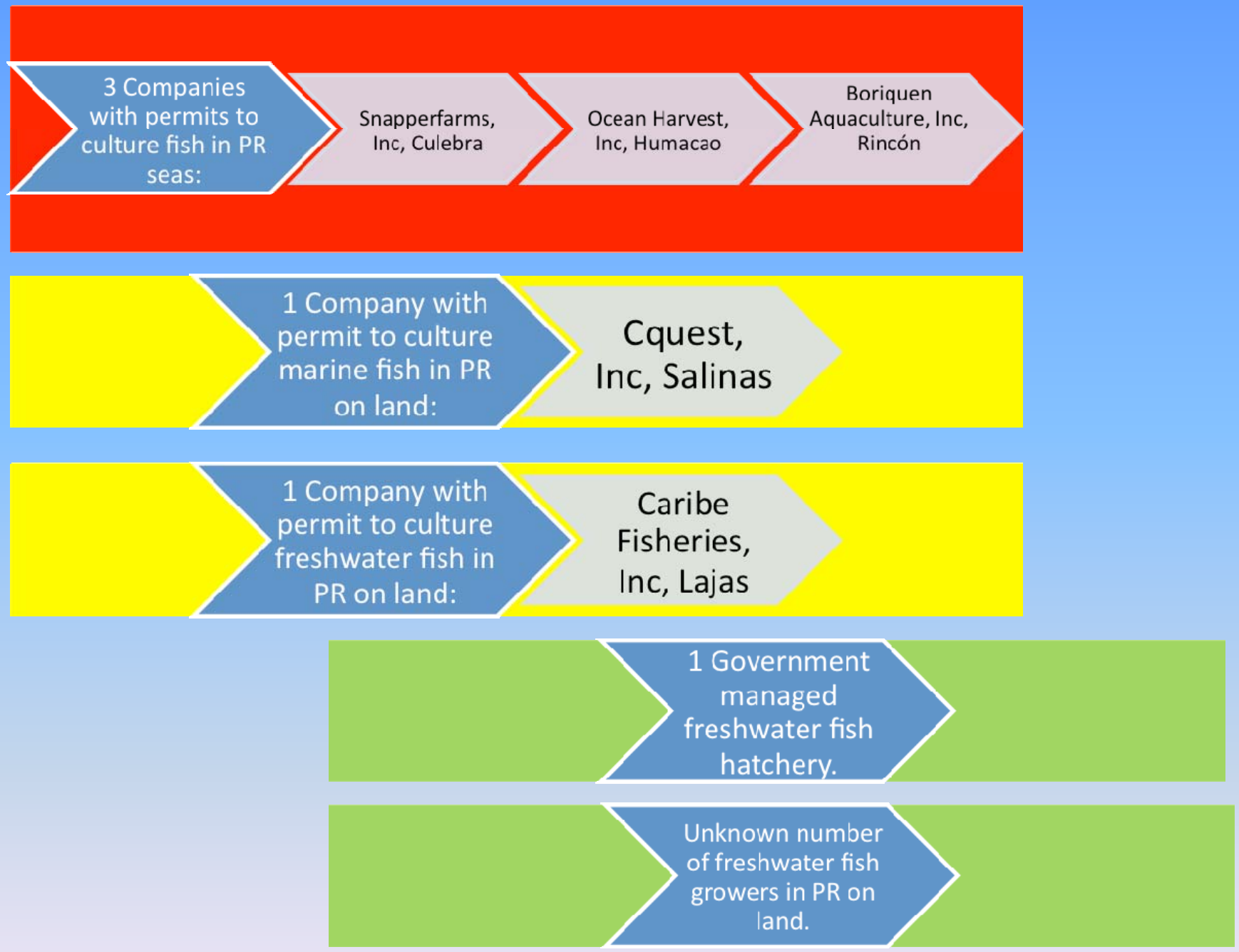
Coffin Bay, Australia




PROVISIONAL ZONING PLAN FOR AQUACULTURE DEVELOPMENT IN BELIZE
MEXICO
GUATEMALA
Corozal
Orange Walk
San Pedro
Ladyville
Belize City
Belmopan
San Ignacio
Benque Viejo del Carmen
Dangriga
Punta Gorda
Caribbean Sea
Gulf Of Honduras
Sea Lane
1.0 - 1.5 Knots
Mean Wave Approach:
74.5° ± 22.5°
Areas Unavailable For Aquaculture Development (Gray Shading)
N
0
20
Kilometers
(All Boundaries Are Approximate)
Key To Zones
Zone-1: High Quality Fresh & Marine Water Resources Suited To Land-Based And Pond Systems
Zone-2: Mixed Quality Fresh & Brackish Water Resources Suited To Land-Based And Cage Systems
Zone-3: Mixed-Quality Fresh & Marine Water Resouces Suited To Land Based Systems
Zone-4: Shallow, Coastal Marine Water Resources Suited To Cage & Raft Systems
Zone-5: Deep, Coastal Marine Water Resources Suited To Cage Systems
Zone-6: Shallow, Offshore Marine Water Resources Suited To Raft & Hatchery Systems
Prepared By:
T. Grimshaw, Ecoworks - Belize C.A.

Area planning Bodø municipality, Norway




3 Companies with permits to culture fish in PR seas:
Snapperfarms, Inc, Culebra
Ocean Harvest, Inc, Humacao
Boriquen Aquaculture, Inc, Rincón
1 Company with permit to culture marine fish in PR on land:
Cquest, Inc, Salinas
1 Company with permit to culture freshwater fish in PR on land:
Caribe Fisheries, Inc, Lajas
1 Government managed freshwater fish hatchery.
Unknown number of freshwater fish growers in PR on land.

Which criteria to base marine fish culture zoning ????

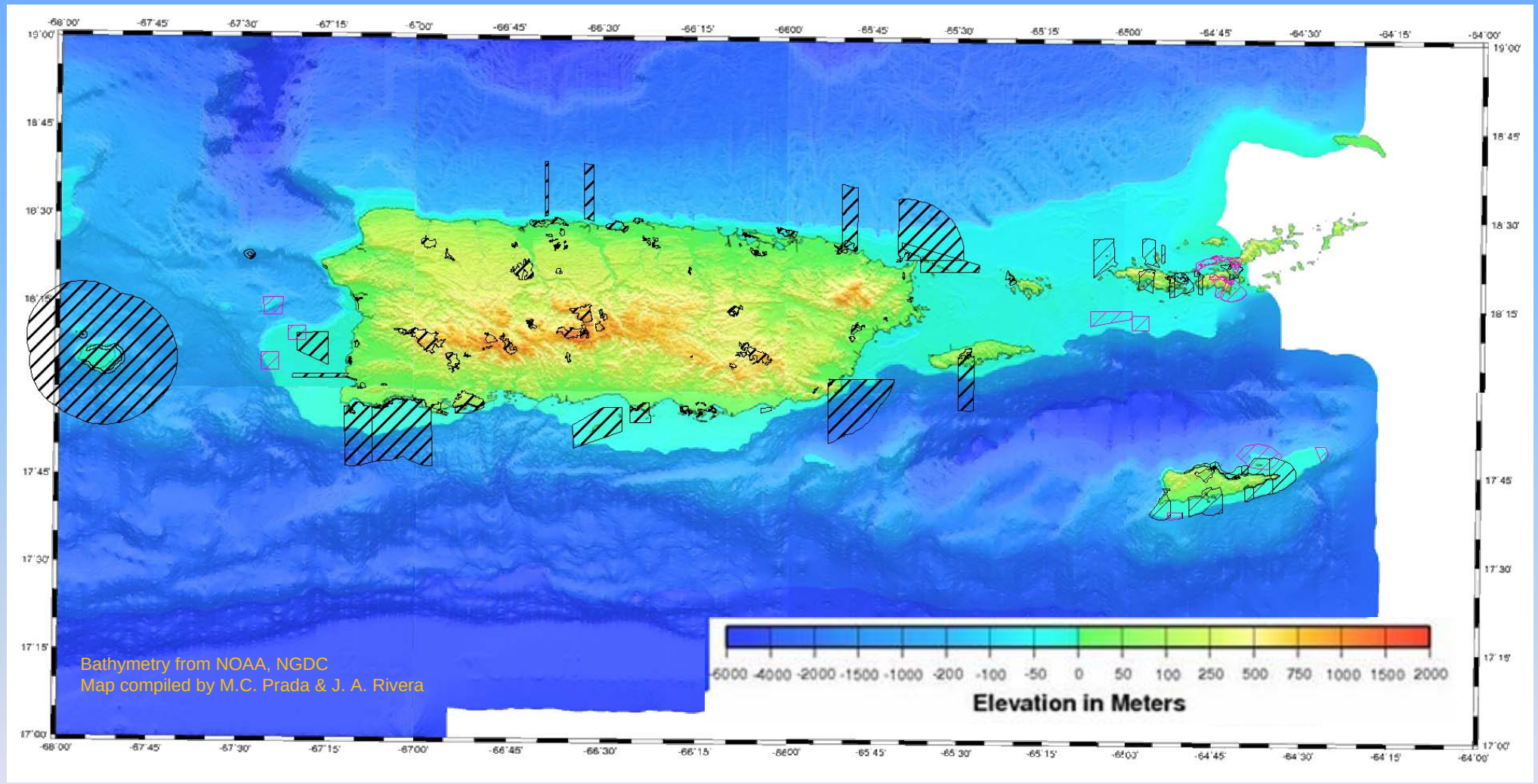
- Bathymetry based on ocean cage design, benthic environment
- Benign sea conditions, meteorological prediction zones
- No stakeholder conflict of use for area
- Good water quality and currents
- Quick access to sea, road and air transportation infrastructure

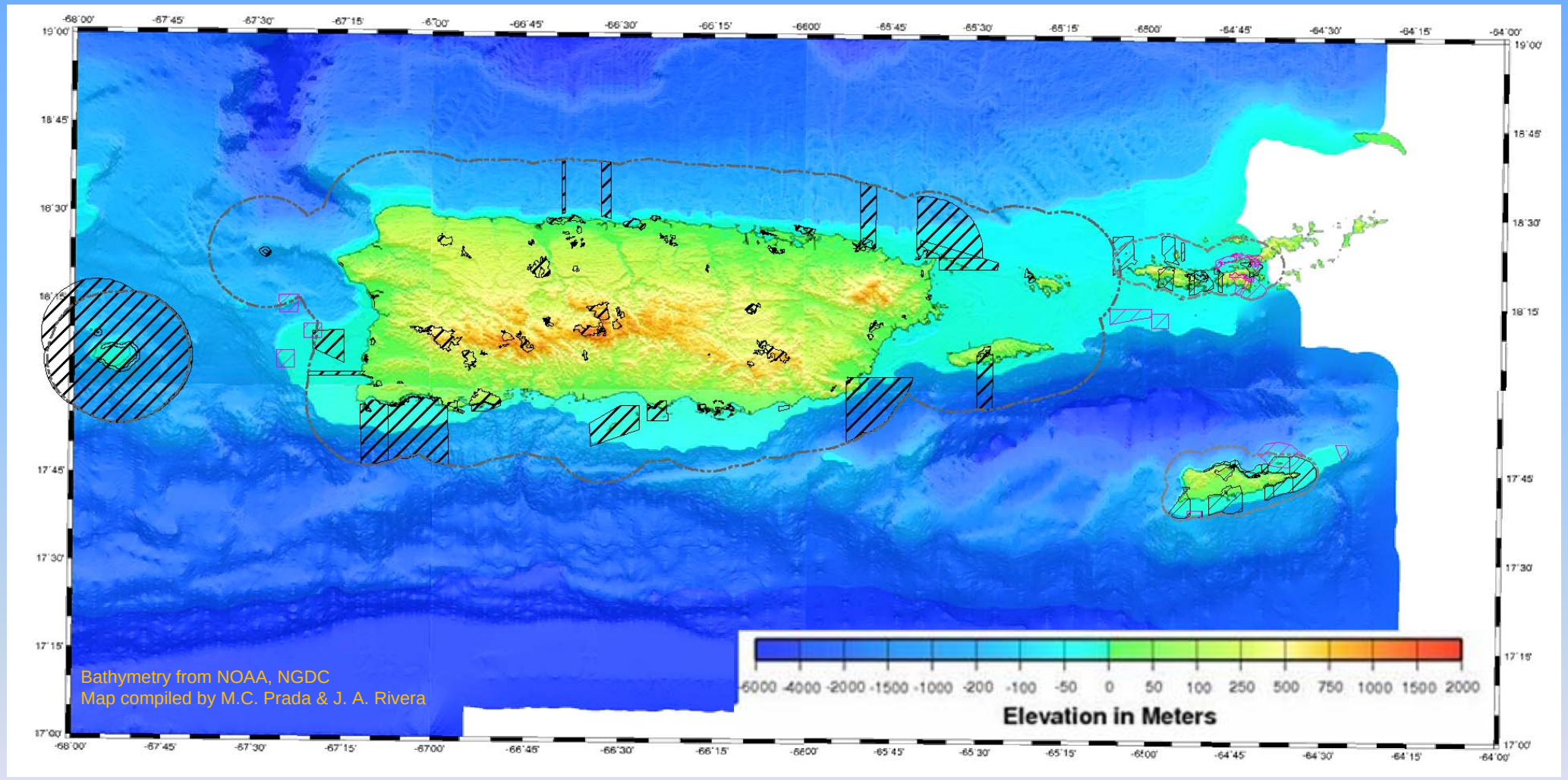
Potential areas for zoning as marine fish culture in PR

(prioritized in order of importance)

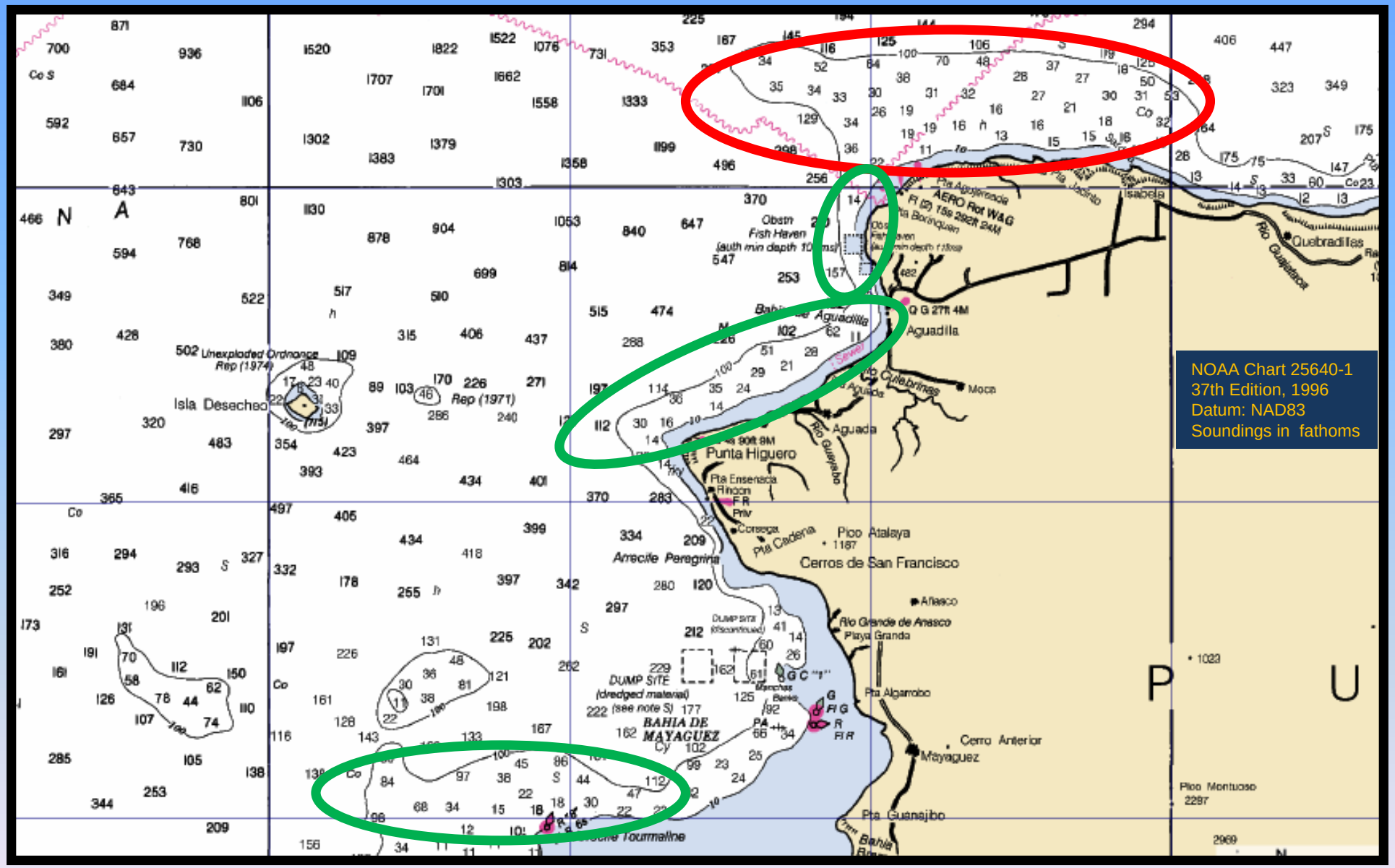
- West coast: 5 areas
- East coast: 2 areas
- South coast: 5 areas
- North coast: 4 areas

Weather Observations and Prediction Zones , Buoy Location

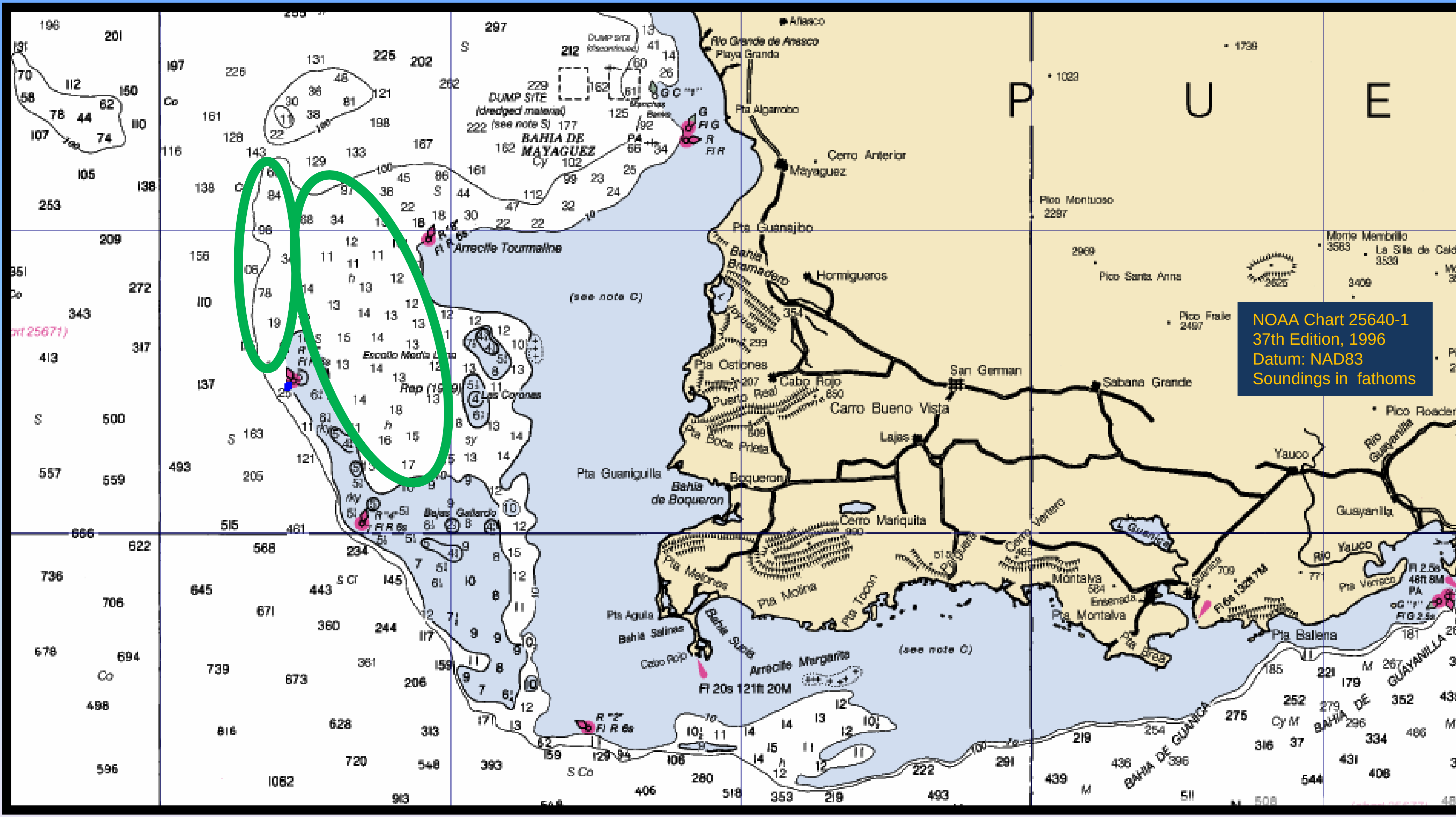

Bathymetry from NOAA, NGDC
Map compiled by M.C. Prada & J. A. Rivera
-6000 -4000 -2000 -1500 -1000 -200 -100 -50 0 50 100 250 500 750 1000 1500 2000
Elevation in Meters


-68°00'
-67°45'
-67°30'
-67°15'
-67°00'
-66°45'
-66°30'
-66°15'
-66°00'
-65°45'
-65°30'
-65°15'
-65°00'
-64°45'
-64°30'
-64°15'
-64°00'
19°00'
18°45'
18°30'
18°15'
17°45'
17°30'
17°15'
17°00'
-6000 -4000 -2000 -1500 -1000 -200 -100 -50 0 50 100 250 500 750 1000 1500 2000
Elevation in Meters
Bathymetry from NOAA, NGDC
Map compiled by M.C. Prada & J. A. Rivera

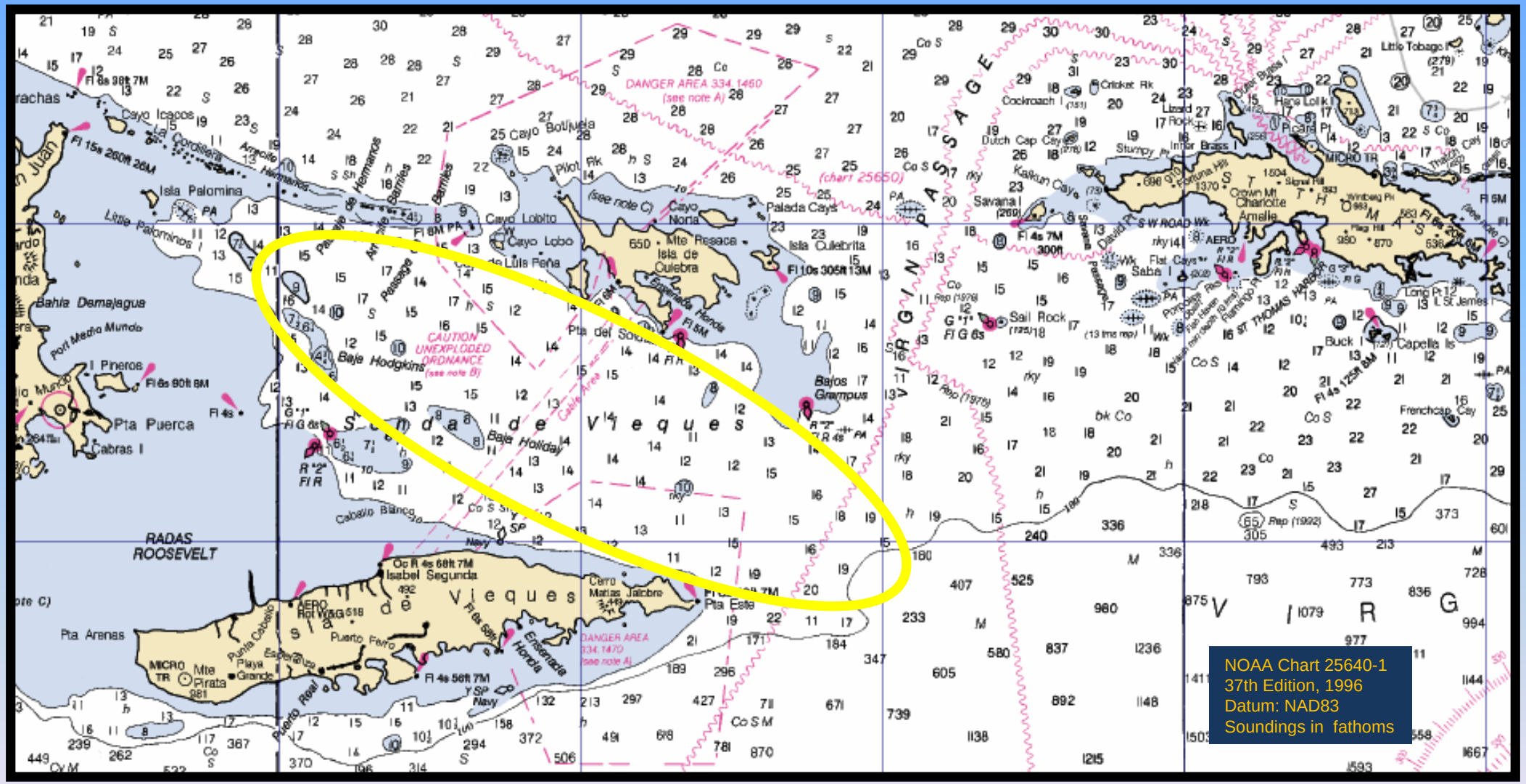
NW Coast


Isla Desecheo
Punta Higuero
Aguadilla
Aguada
Isabela
Quebradillas
Cerros de San Francisco
Pico Atalaya
1187
Arrecife Peregrina
BAHIA DE MAYAGUEZ
DUMP SITE
(dredged material)
(see note S)
Mayaguez
Cerro Anterior
Pico Montuoso
2287
Pta Guanajibo
Pta Algarrobo
Aflasco
Río Grande de Anasco
Playa Grande
Río Guajataca
Río Guayabo
Unexploded Ordnance
Rep (1974)
Rep (1971)
Obstn
Fish Haven
AERO Rot W&G
Fl (2) 15s 292ft 24M
Fl G 27ft 4M
NOAA Chart 25640-1
37th Edition, 1996
Datum: NAD83
Soundings in fathoms

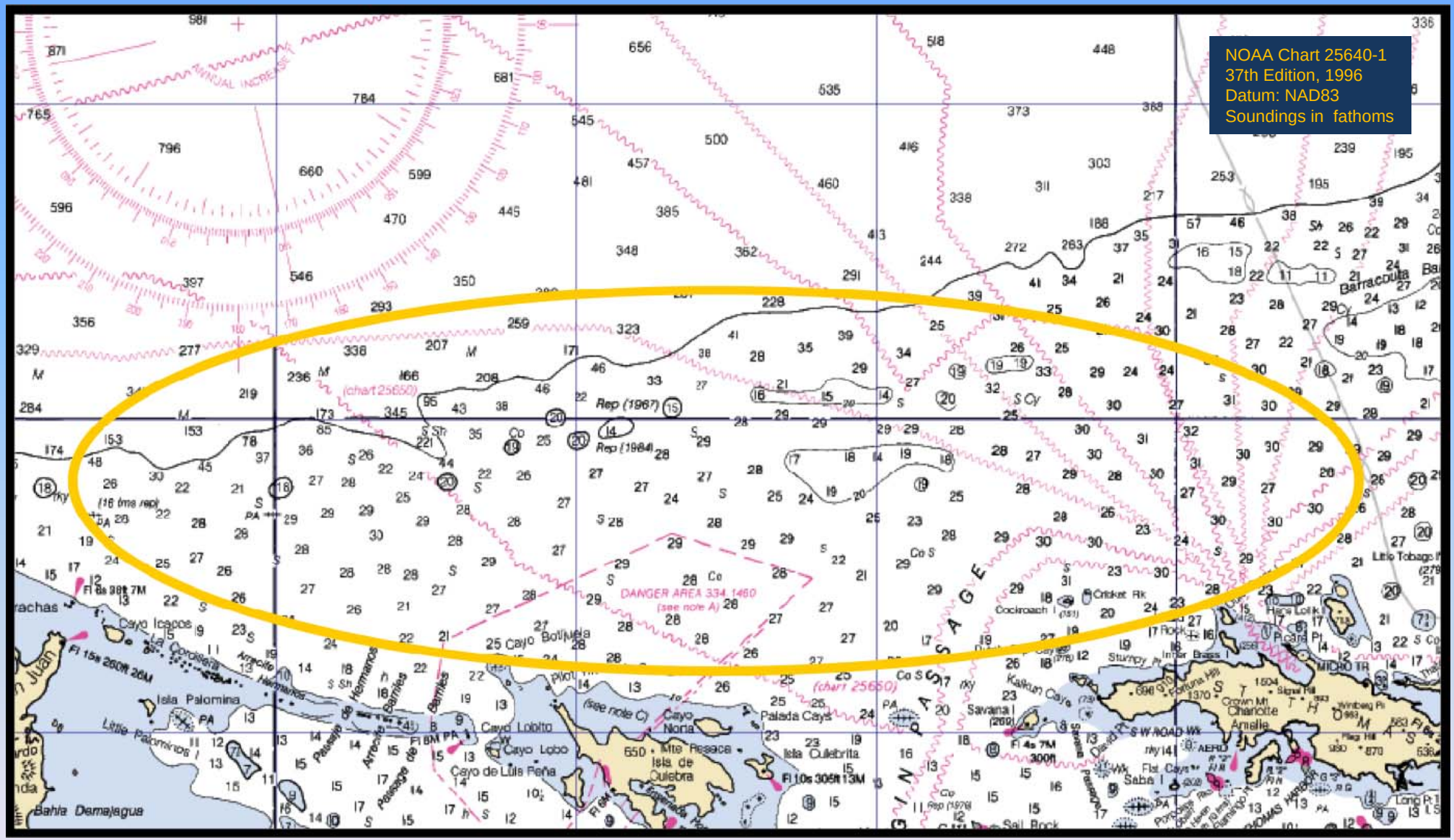
SW Coast


NOAA Chart 25640-1
37th Edition, 1996
Datum: NAD83
Soundings in fathoms
P
U
E
Rio Grande de Anasco
Playa Granda
Pta Algarrobo
DUMP SITE
(dredged material)
(see note S)
BAHIA DE
MAYAGUEZ
Cerro Anterior
Mayaguez
Pico Montuoso
Pta Guanajibo
Arrecife Tourmaline
Bahia Bramadero
Hormigueros
(see note C)
Pico Santa Anna
Pico Fraile
Monte Membrillo
Pta Ostiones
Cabo Rojo
Puerto Real
San German
Sabana Grande
Carro Bueno Vista
Escollo Media Luna
Las Coronas
Lajas
Yauco
Pta Guaniguilla
Bahia de Boqueron
Boqueron
Bajas Gallardo
Cerro Mariquita
Guayanilla
Pta Melones
Pta Molina
Pta Aguila
Bahia Salinas
Cabo Rojo
Bahia Sucia
Arrecife Margarita
Fl 20s 121ft 20M
Montalva
Ensenada
Pta Montalva
Pta Brea
Pta Ballena
Pta Verraco
BAHIA DE GUANICA
BAHIA DE GUAYANILLA

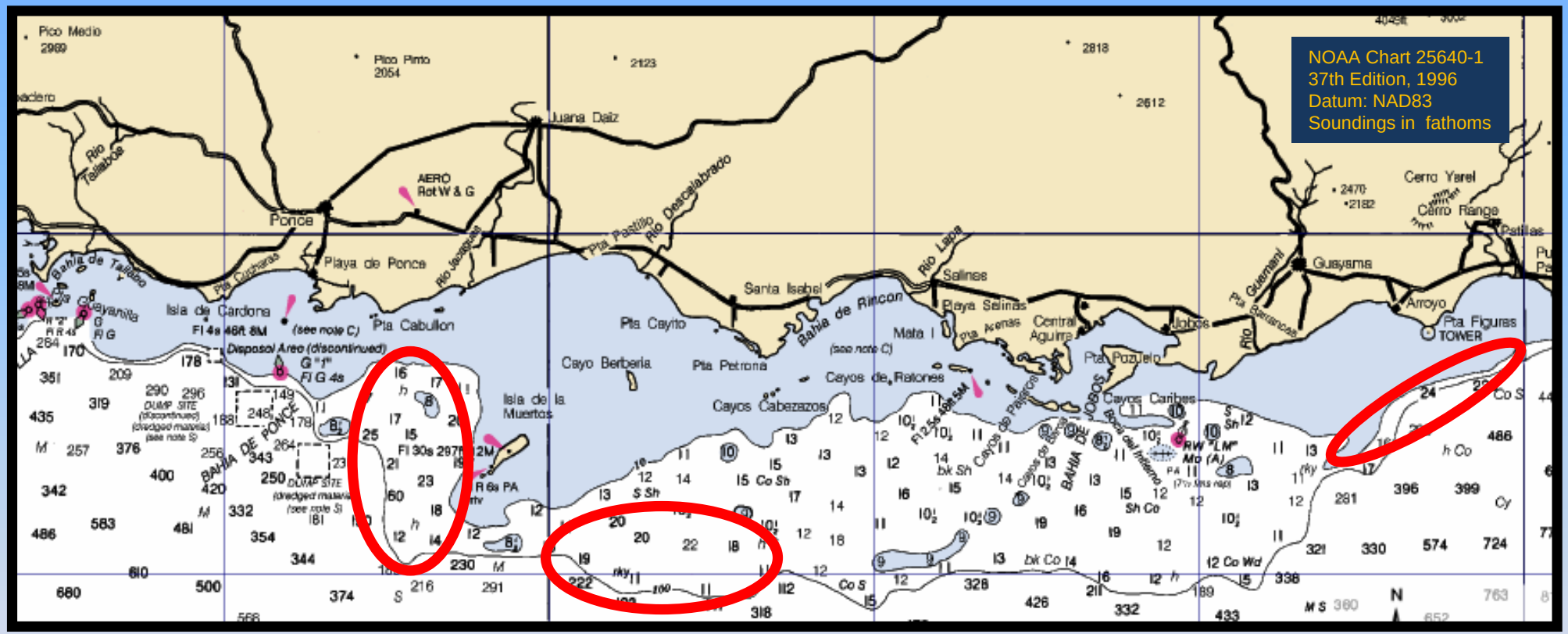
East Coast, Vieques Sound



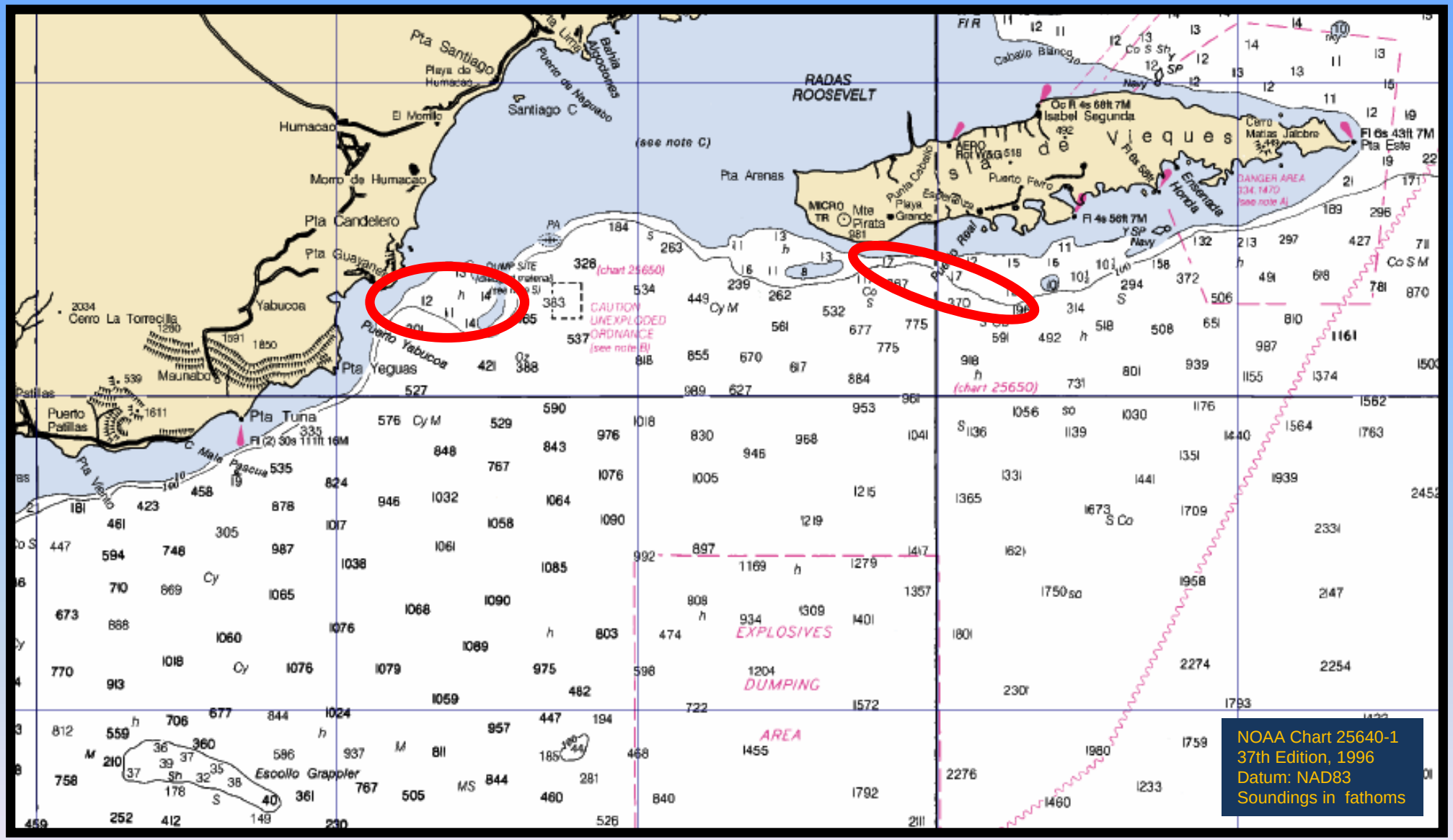
NE Coast, N of Culebra Island



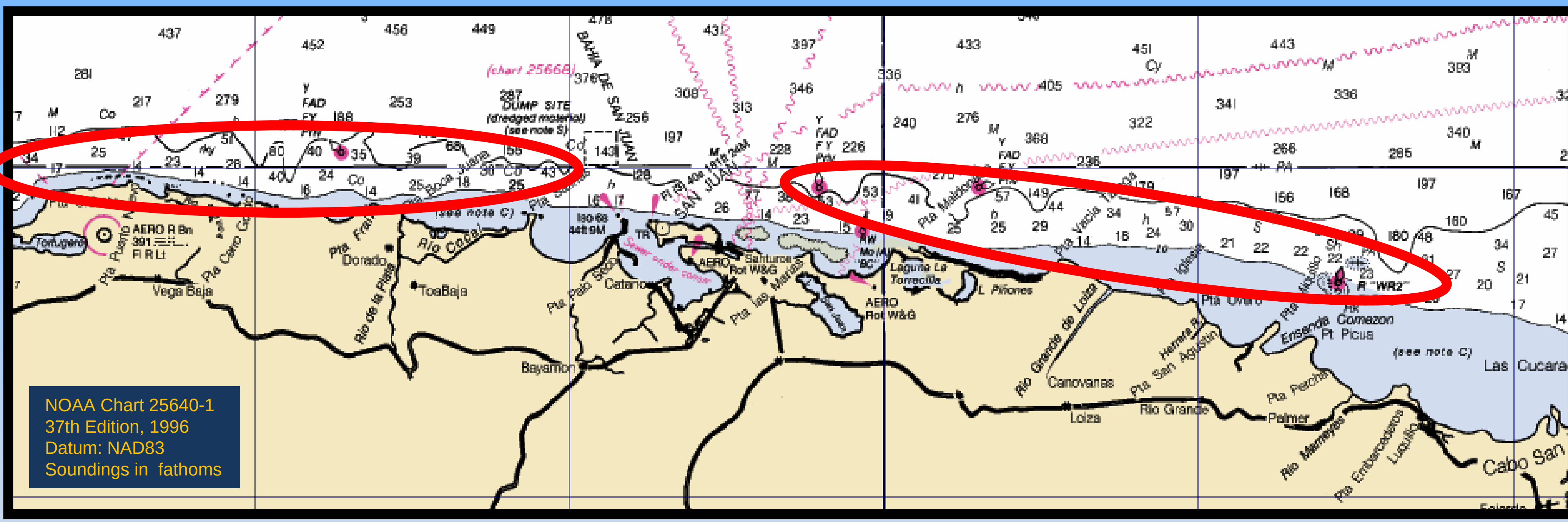
South Coast


NOAA Chart 25640-1
37th Edition, 1996
Datum: NAD83
Soundings in fathoms
Pico Medio
2969
Pico Pinto
2054
2123
2818
2612
Juana Diaz
Río Tallaboa
AERO
Rot W & G
Ponce
Playa de Ponce
Río Cuchara
Río Jacaguas
Pta Pastillo
Río Descalabrazo
Cerro Yarel
2470
2182
Cerro Range
Patillas
Guayama
Río Lapa
Salinas
Santa Isabel
Bahía de Rincon
Playa Salinas
Central Aguirre
Arroyo
Pta Figuras
TOWER
Río Guamani
Pta Serrano
Jobos
Mata I
Pta Pozuelo
Bahía de Jobos
Cayos Caribes
Cayos de Barca
Cayos de Pargos
Bocas del Infierno
Isla de Cardona
Fl 4s 46ft 8M
(see note C)
Pta Cabullon
Disposal Area (discontinued)
G "1"
Fl G 4s
Bahía de Tallaboa
Guayanilla
Pta Cayito
Cayo Berberia
Pta Petrona
Cayos de Ratones
Cayos Cabezazos
Isla de la Muertos
BAHIA DE PONCE
DUMP SITE
(dredged material)
(see note S)
Fl 30s 29ft 12M
R 6s PA
RW "LM"
Mo (A)
PA
(see note C)

SE Coast & SW Vieques Island

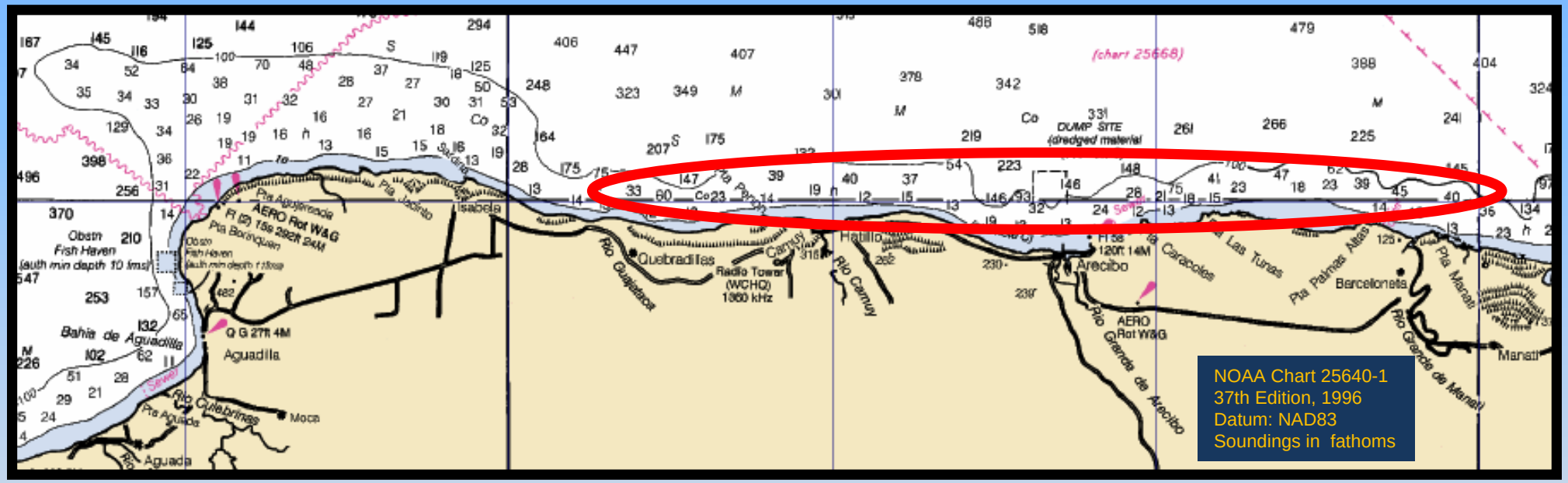


North Coast

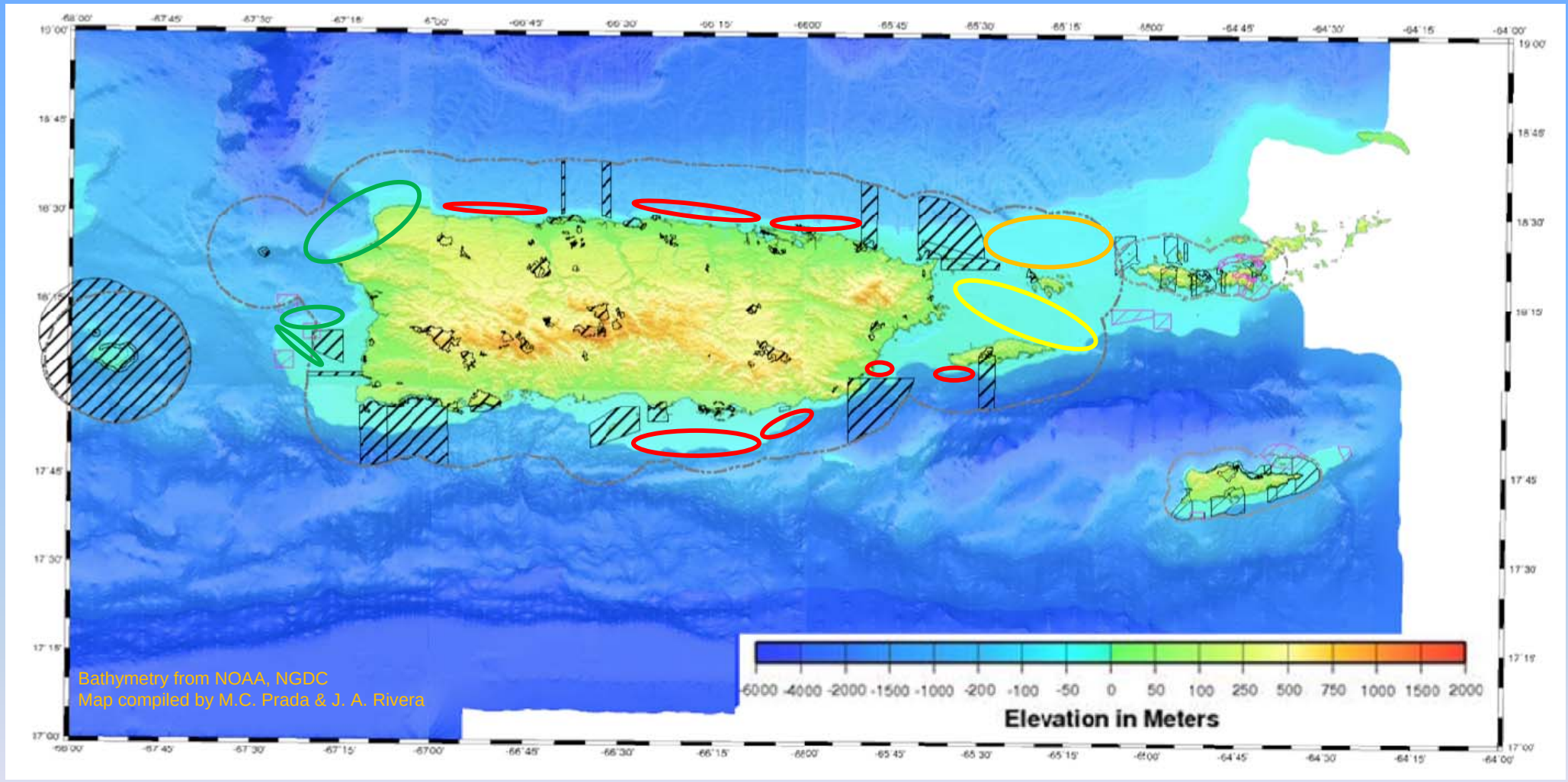


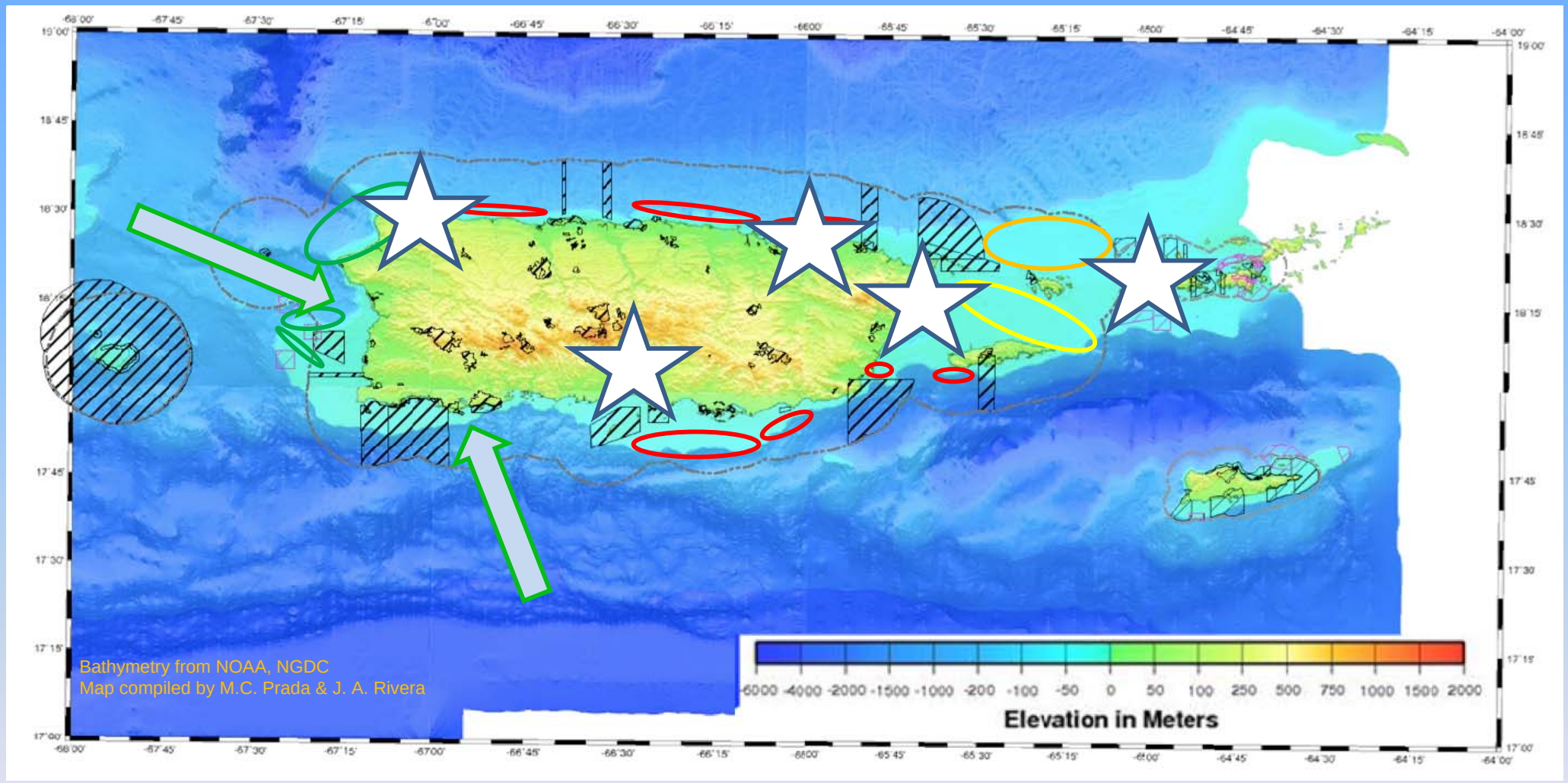
NOAA Chart 25640-1
37th Edition, 1996
Datum: NAD83
Soundings in fathoms

North Coast



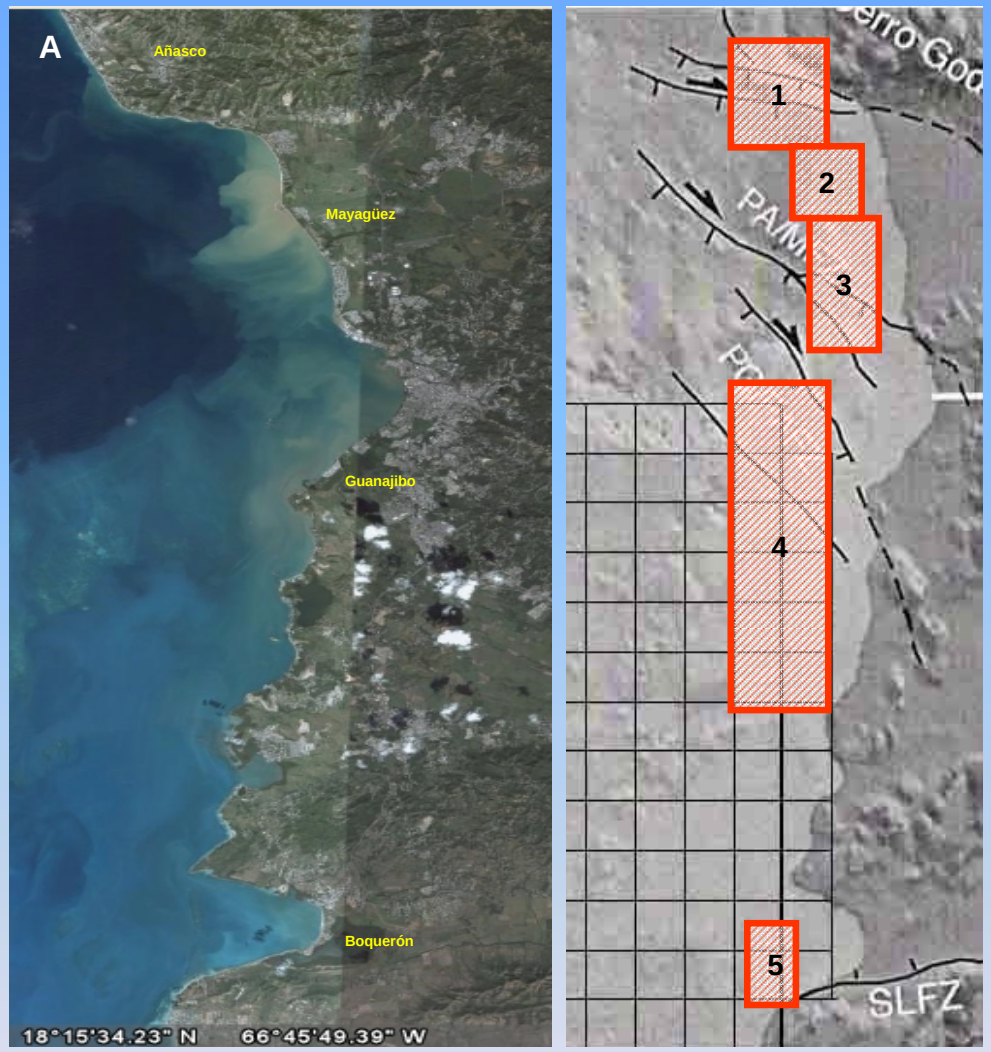
NOAA Chart 25640-1
37th Edition, 1996
Datum: NAD83
Soundings in fathoms


Bathymetry from NOAA, NGDC
Map compiled by M.C. Prada & J. A. Rivera
-6000 -4000 -2000 -1500 -1000 -200 -100 -50 0 50 100 250 500 750 1000 1500 2000
Elevation in Meters


Bathymetry from NOAA, NGDC
Map compiled by M.C. Prada & J. A. Rivera
-6000 -4000 -2000 -1500 -1000 -200 -100 -50 0 50 100 250 500 750 1000 1500 2000
Elevation in Meters

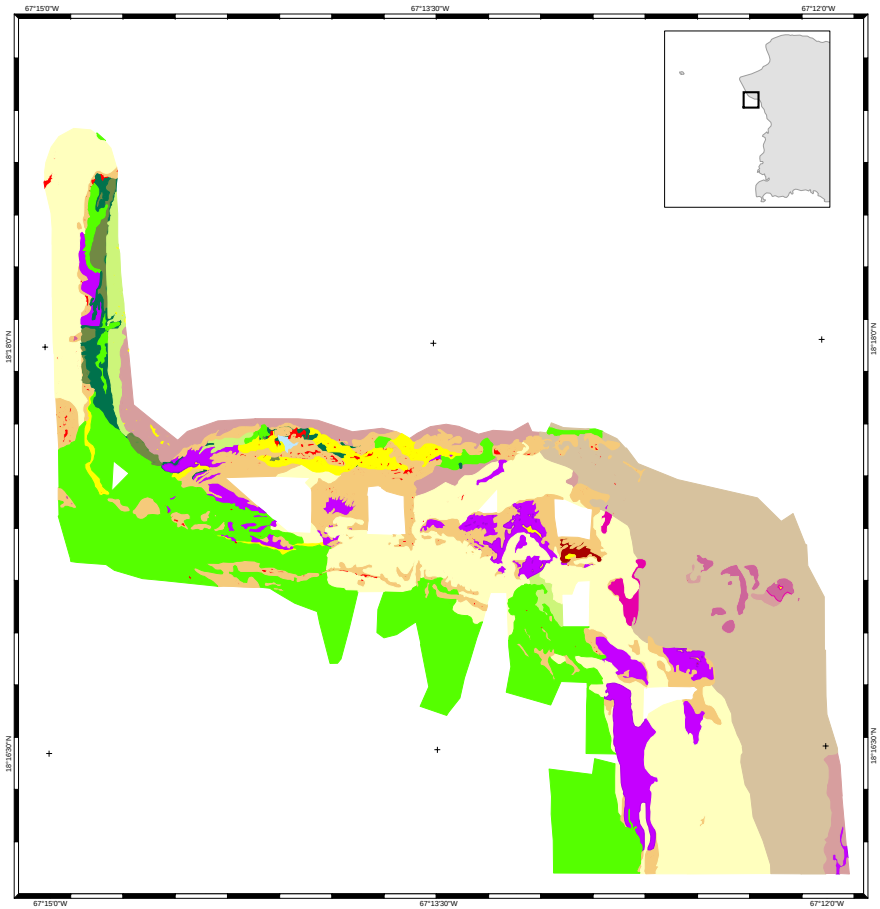
Advantages of Zoning

- Selects best environment for proposed activity “a priori”
- Reduce permit evaluation time frames
- Prevent conflict between stakeholders
- Stimulates and increases efficiency of local economy
- Can help provide economic activity where it is needed
- Facilitates Coastal Zone Management



Habitat Mapping of the West Coast Shelf of PR: Results of the Analysis of Existent Sonar Imagery. Report to CCRI, March 25, 2008 by M. C. Prada & J. A. Rivera.

Benthic Habitats of the Añasco Shelf
Añasco 1 Section



Habitat type

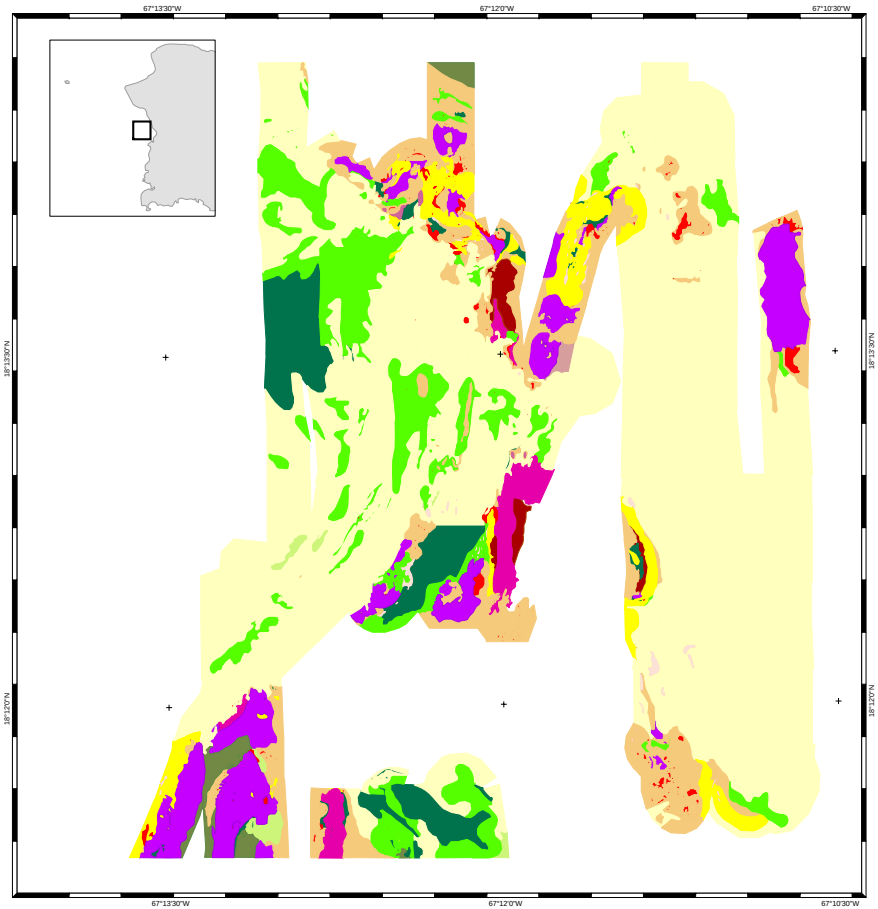
- corals_high relief
- coral_patch
- corals_low relief
- gorgonian_patch
- gorgonian_plain
- elevated_gorgonians
- grass_coral
- grass_invertebrates
- dense_grass
- grass_sparse
- dense_algae
- sparse_algae
- sand_invertebrates
- sand_noripple
- fine_sand
- mud_bare
- mud_invertebrates

Map generated from visual interpretation of SSS images collected in May, 2000 and processed at 1 m resolution.

Datum: WGS 84

NOAA Award NA04NOS4260206
UPRM Award R-PUPR-05 and R-PUPR 1-06

Benthic Habitats of the Mayagüez Shelf
Mayagüez Section



Habitat type

- corals_high relief
- coral_patch
- corals_low relief
- gorgonian_patch
- gorgonian_plain
- elevated_gorgonians
- grass_coral
- grass_invertebrates
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- grass_sparse
- dense_algae
- sparse_algae
- sand_invertebrates
- sand_noripple
- fine_sand
- mud_bare
- mud_invertebrates

Map generated from visual interpretation of SSS images collected in May, 2000 and processed at 1 m resolution.

Datum: WGS 84

NOAA Award NA04NOS4260206
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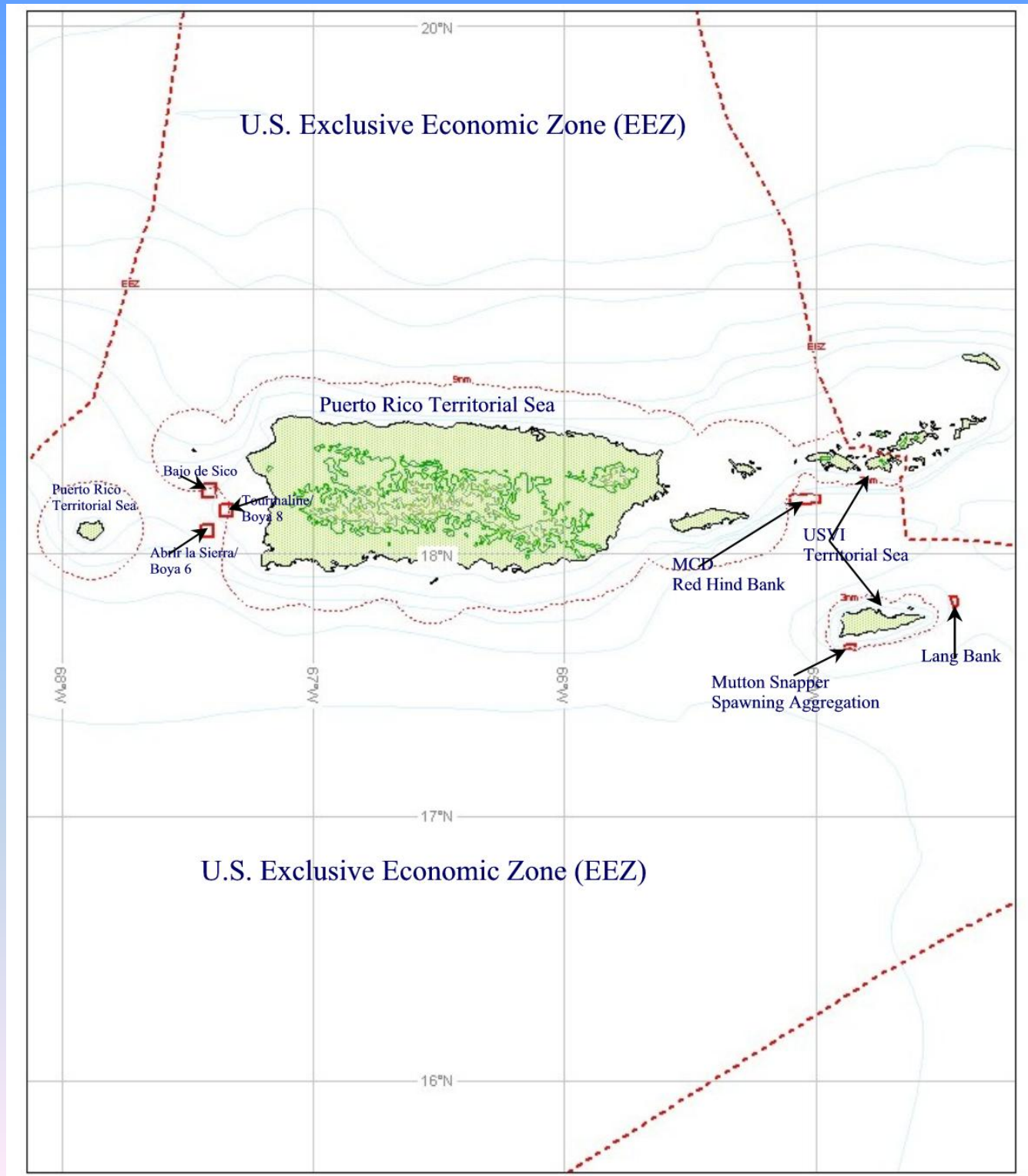
SUMMARY

- Marine zones for the culture of fish in open ocean cages have been identified in the 100-200 ft depth zone around the PR shelf
- These marine zones have been prioritized in order of preference in the following order; West, East, South and North coasts
- The priority preference is based on the sea and wind condition zones used by the NOAA-NWS
- Benthic habitat maps are available for some PR shelf areas and should be used in helping decide marine zone delineation
- Areas of the PR shelf lacking benthic habitat maps should be prioritized for mapping

CONCLUSIONS

- Coastal and ocean spatial data is available to help enable zoning, these data should be used in the creation of zoning maps
- Some coastal and ocean areas are spatial data deficient, efforts to acquire these data is needed
- Zonification of the marine environment helps us comply with the new National Ocean Council policy
- Zonification of the marine environment is a stakeholder collaborative effort

QUESTIONS ????


U.S. Exclusive Economic Zone (EEZ)
Puerto Rico Territorial Sea
Bajo de Sico
Puerto Rico
Territorial Sea
Tourmaline/
Boya 8
Abrir la Sierra/
Boya 6
MCD
Red Hind Bank
USVI
Territorial Sea
Lang Bank
Mutton Snapper
Spawning Aggregation
20°N
18°N
17°N
16°N
U.S. Exclusive Economic Zone (EEZ)

World capture and aquaculture production