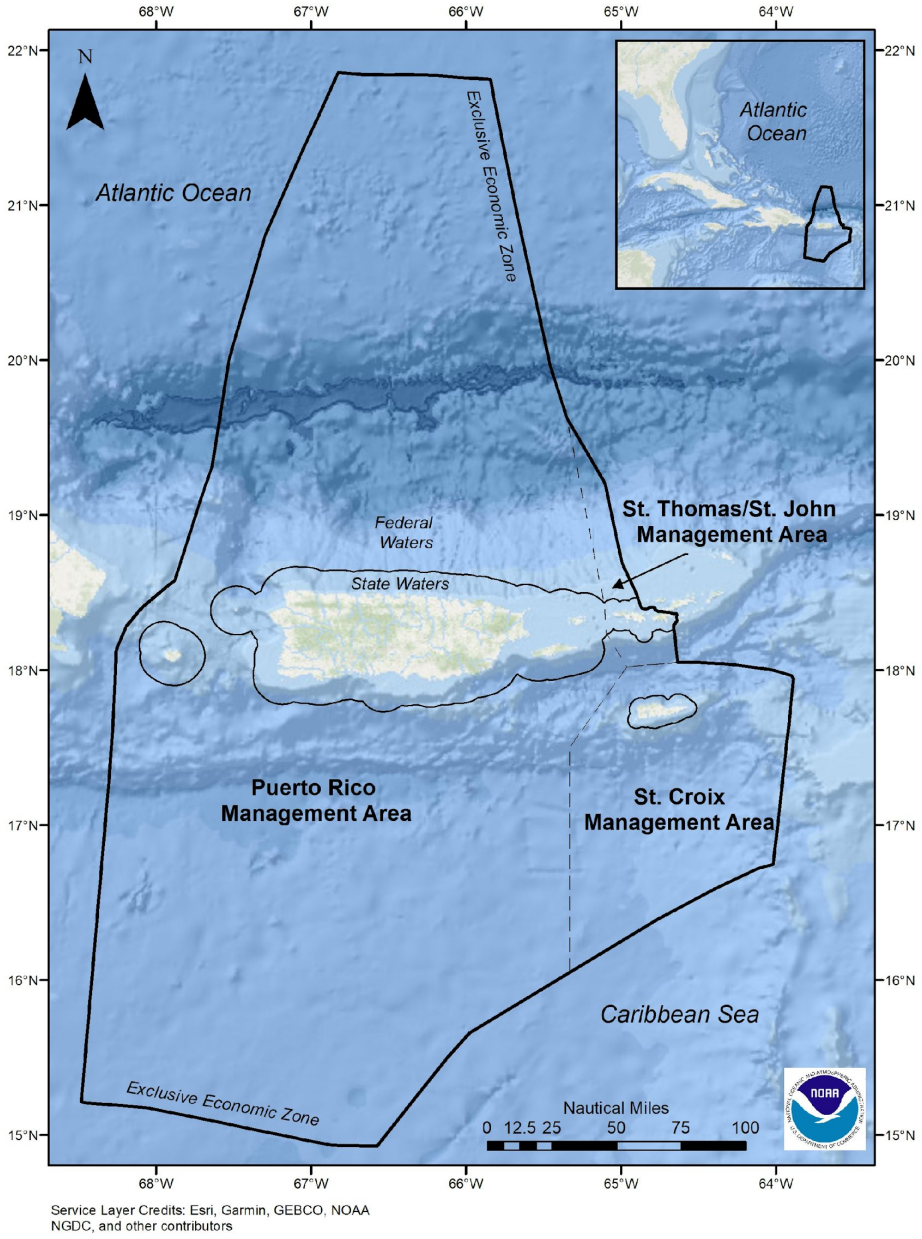
Developing a Fishery Ecosystem Plan for the U.S. Caribbean Region: Qualitative and quantitative approaches to set the stage for Ecosystem-based Fishery Management

J.J. Cruz-Motta- Dep. Marine Sciences. University of Puerto Rico - Mayaguez

Tarsila Seara- Dep. of Biology and Environmental Science, University of New Haven

Stacey Williams- Institute for Socio-Ecological Research

Bill Arnold-Caribbean Council EBFM Technical Advisory Panel Chair



NOAA/NMFS EBFM POLICY STATEMENT

NOAA's National Marine Fisheries Service (NOAA Fisheries) strongly supports implementation of Ecosystem-Based Fisheries Management (EBFM) to better inform and enable better decisions regarding trade-offs among and between fisheries (commercial, recreational, and subsistence), aquaculture, protected species, biodiversity, and habitats. Recognizing the interconnectedness of these ecosystem components will help maintain resilient and productive ecosystems (including the human communities on which they depend), even as they respond to climate, habitat, ecological, and other environmental changes.

First step in process: develop an implementation roadmap

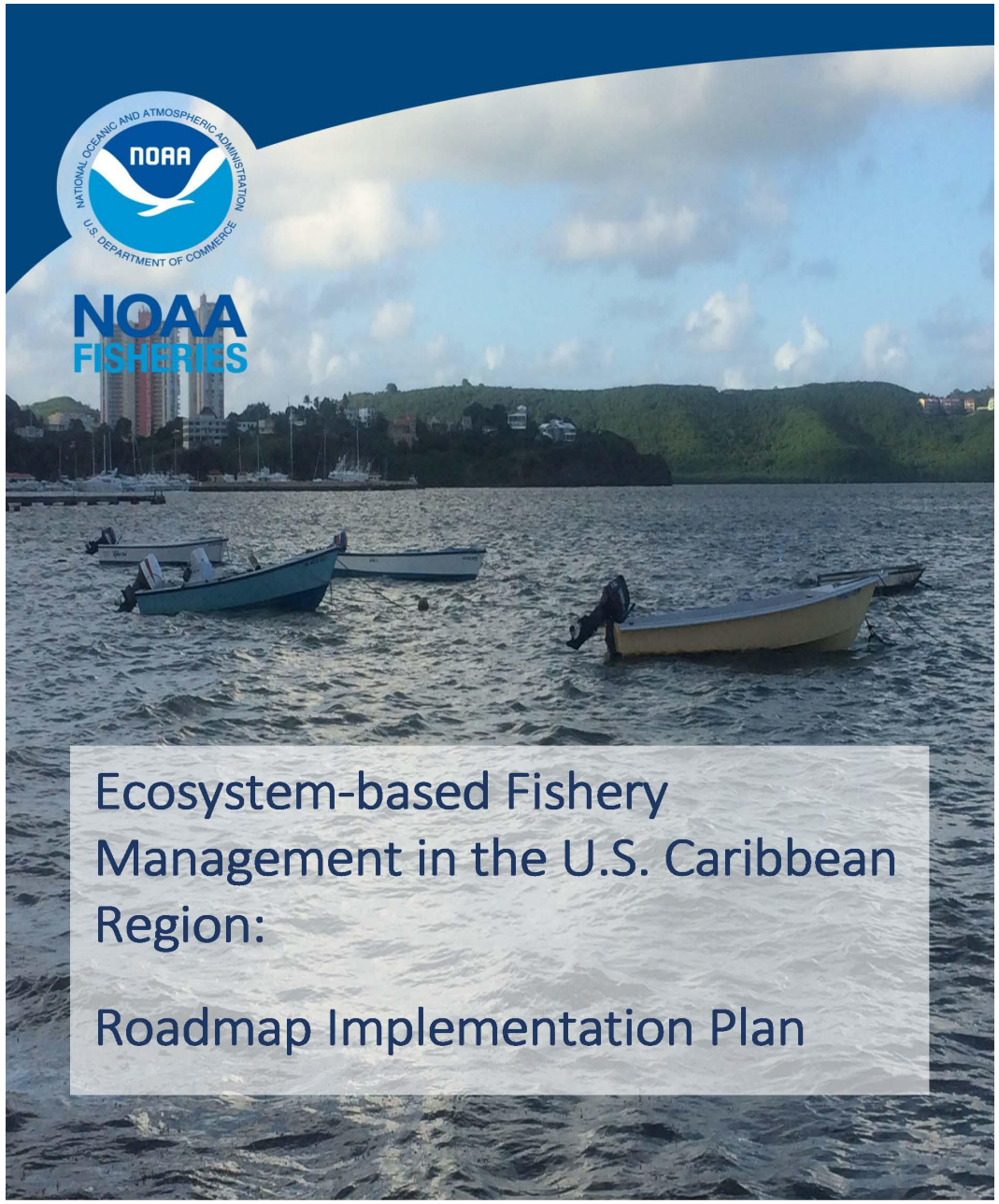
-Every U.S. fishery management region has developed and vetted an implementation roadmap

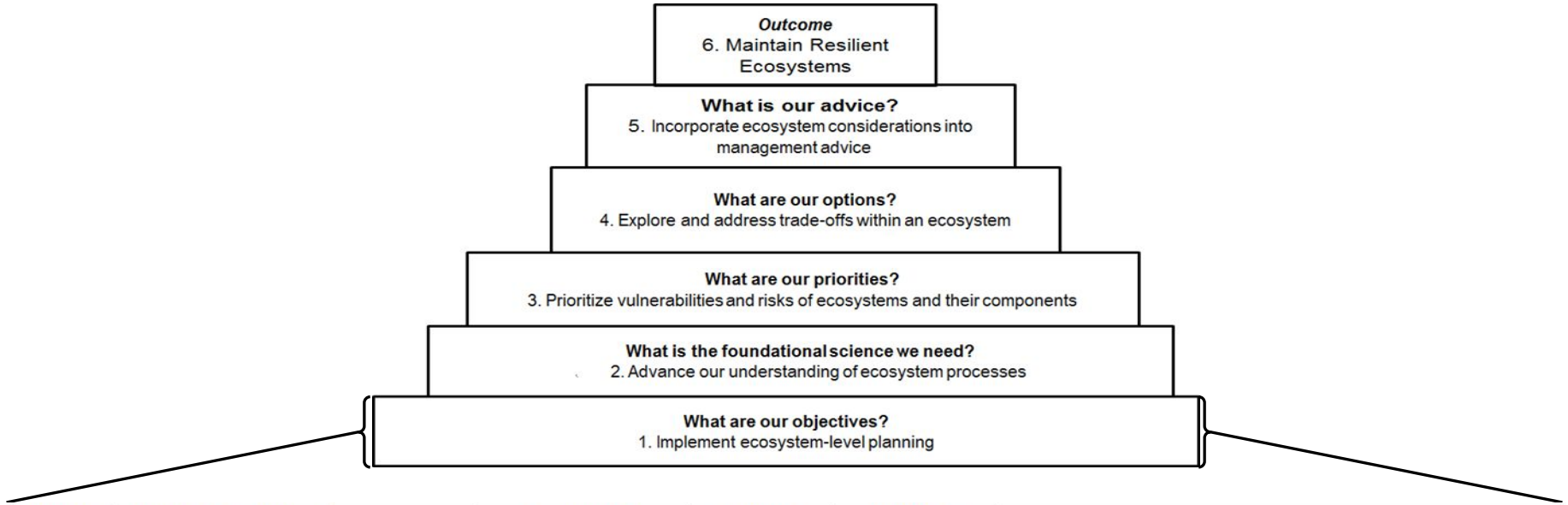
-Based on a 6-step development pyramid

-Roughly 35 roadmap action items distributed among the six steps

-Short-, medium-, and long-term milestones, with present emphasis on short-term milestones and those medium-term milestones for which resources are already committed

-Some regions are well along, others such as the U.S. Caribbean region are earlier in the process





Road Map #	Road Map Action Item	Timing	Associated Milestone	Target date	Point of Contact	SERO Organizational or Science Priorities
Guiding Principle 1: Implement ecosystem-level planning						
1a2	Develop U.S. Caribbean regional EBFM engagement strategies	Short	Draft strategy, for engaging participants and the public, approved by the Council	June 30, 2019	Caribbean Fishery Management Council	Org SFD 5 - Serve on and provide support services to the NMFS National and Regional Integrated Ecosystem Assessment Program. Org SFD 40- Engage stakeholders in the development of a Fishery Ecosystem Plan (FEP) in collaboration with the Council; specifically, develop a platform to integrate stakeholder data.
1a5	NOAA Fisheries support for Ecosystem Plan Development Teams and Ecosystem Committees (or equivalent groups) that Councils establish	Continuing	Council has established a Fishery Ecosystem Plan (FEP) team, included participation by NOAA Fisheries/SERO/SF Caribbean Branch	October 1, 2017 to establish initial plan team, but this is a continuing effort	SERO Sustainable Fisheries Division	Org SFD 40- Engage stakeholders in the development of an FEP in collaboration with the Council; specifically, develop a platform to integrate stakeholder data.

TASK FORCE MEMBERS

Timothy Essington, chair, University of Washington
Phillip Levin, co-chair, The Nature Conservancy, University of Washington (formerly NOAA Northwest Fisheries Science Center)
Lee Anderson, University of Delaware
Alida Bundy, Bedford Institute of Oceanography
Courtney Carothers, University of Alaska Fairbanks
Felicia Coleman, Florida State University
Leah Gerber, Arizona State University
Jonathan Grabowski, Northeastern University
Edward Houde, University of Maryland Center for Environmental Science
Olaf Jensen, Rutgers University
Christian Möllmann, University of Hamburg
Kenneth Rose, Louisiana State University
James Sanchirico, University of California, Davis
Tony Smith, CSIRO Australia

Caribbean Fishery Management Council

Progress with Developing an Ecosystem-based Fishery Management (EBFM) Approach

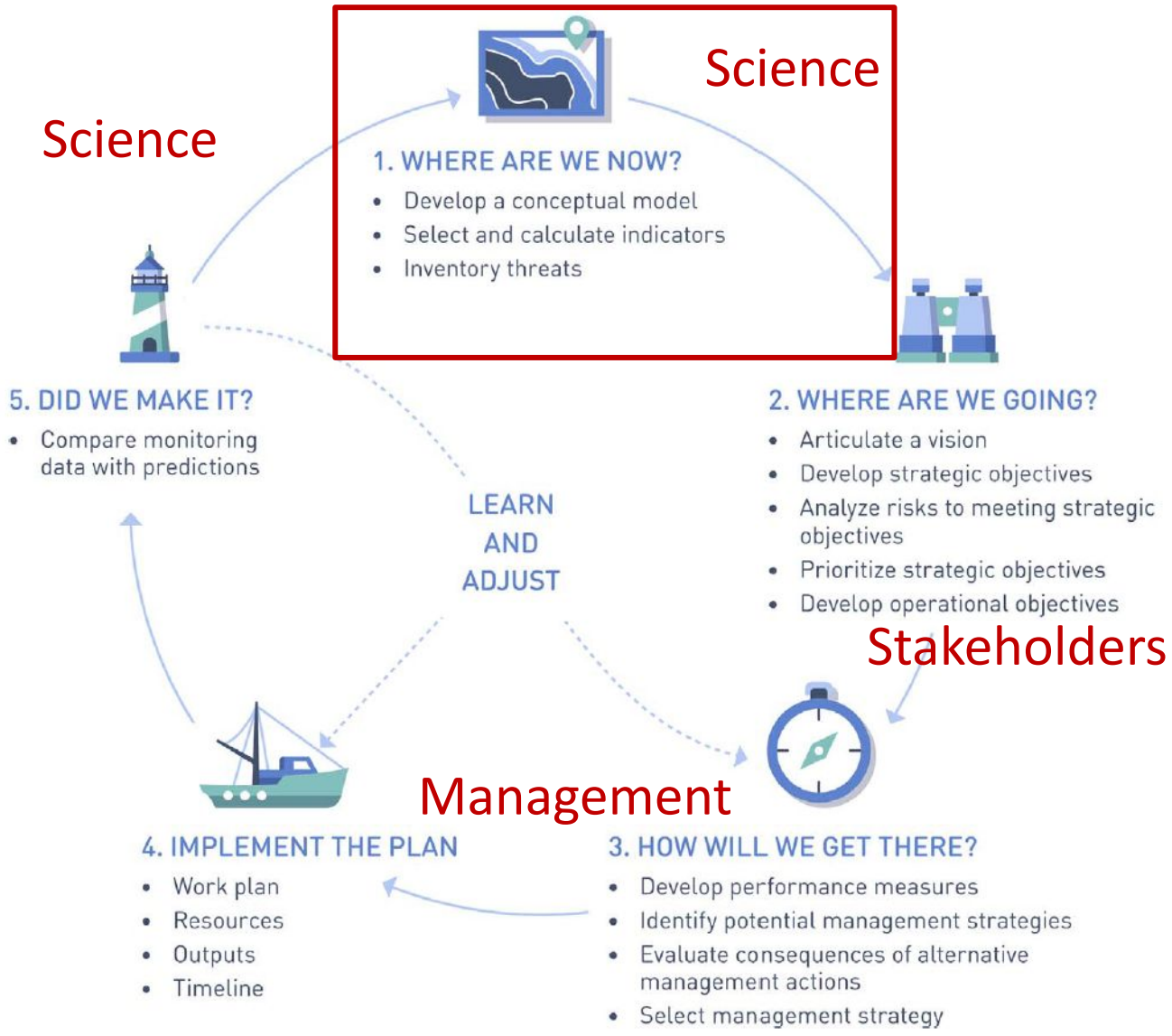
Island-based Fishery Management Plans set the stage for an ecosystem approach

- -Submitted to NOAA for Secretarial approval in Fall 2019
- -Creates three separate fishery management plans (= “place-based” approach)
  - -St. Croix: 3-200 nautical miles
  - -St. Thomas/St. John: 3-200 nm
  - -Puerto Rico: 9-200 nm
- -Revises e.g. species managed, allowable catch, but remains a ‘single-species’ approach

Emphasis has now shifted to FEP development

- -Each island group’s District Advisory Panel provides citizen science
- -Scientific and Statistical Committee oversees science, participates in Plan development
- -Technical Advisory Panel makes recommendations to Council on Plan development

Structure/Process of FEPs



Where are we? → Scientific question

1) Develop a Conceptual Model
2) Select and Calculate Indicators
3) Inventory threats

Stakeholder and expert opinion:
QUALITATIVE approach

1) Observations (e.g. temporal trends)
2) Models: explanations of those trends
3) Hypotheses: predictions if models/explanations are true

QUANTITATIVE approach

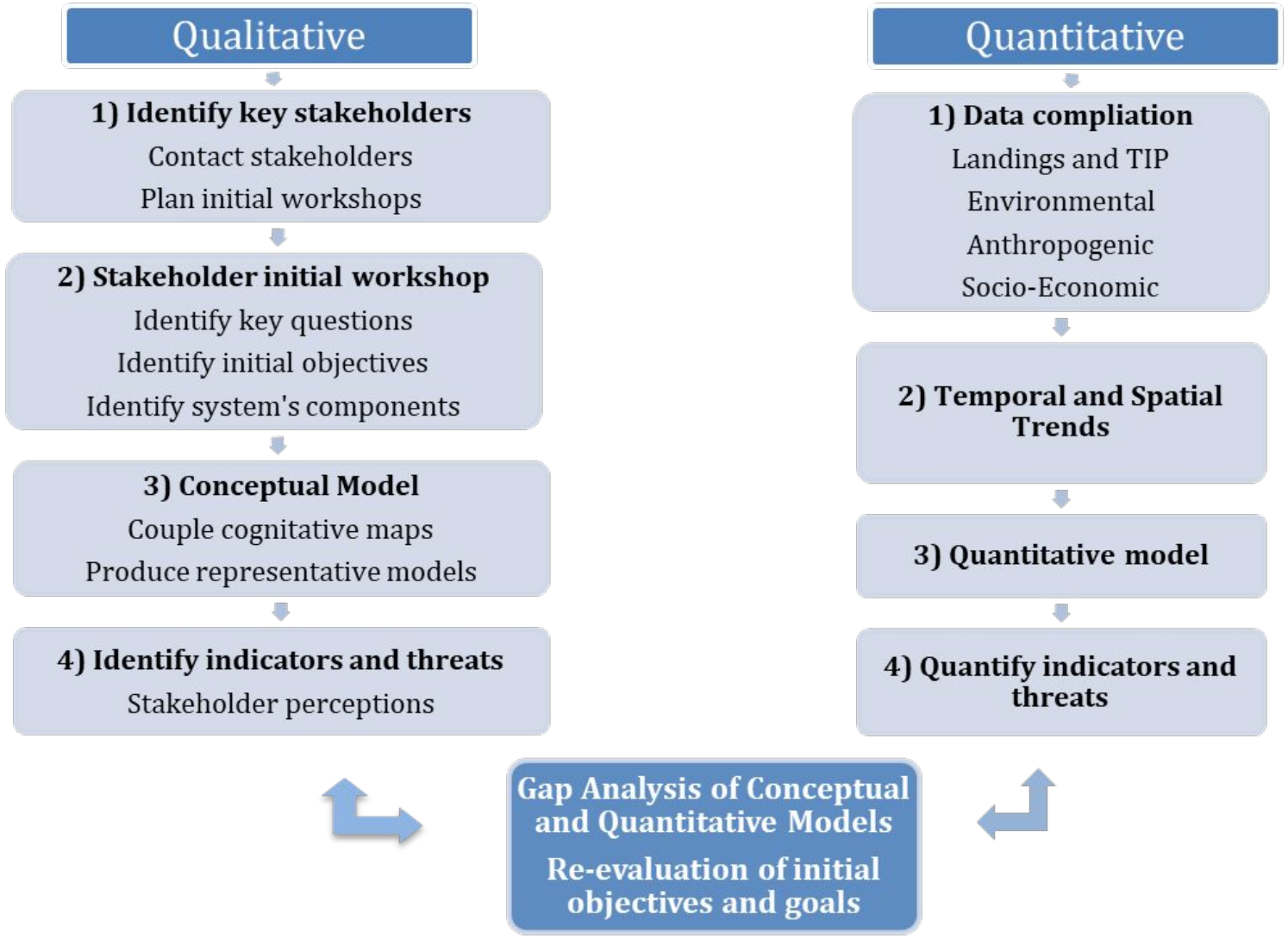
OBJECTIVES

1) To develop both a conceptual and quantitative model of Caribbean ecosystems within a fisheries context.

2) To select and estimate indicators of the performance of the model.

3) To integrate results from both models to identify threats.

General Structure



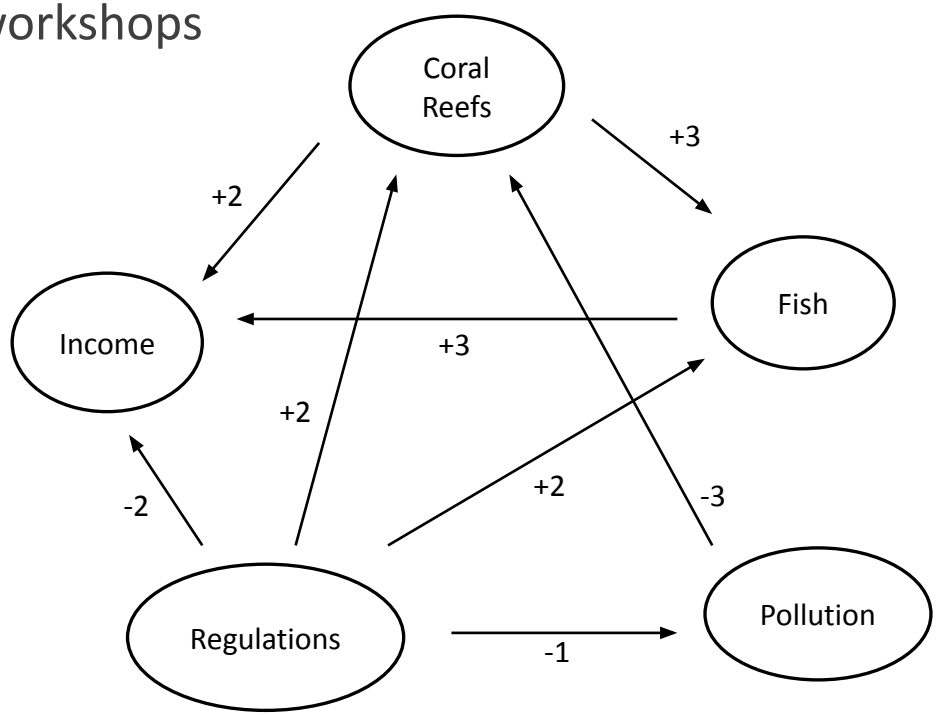
Qualitative Approach

Conceptual Models (Fuzzy Cognitive Maps):

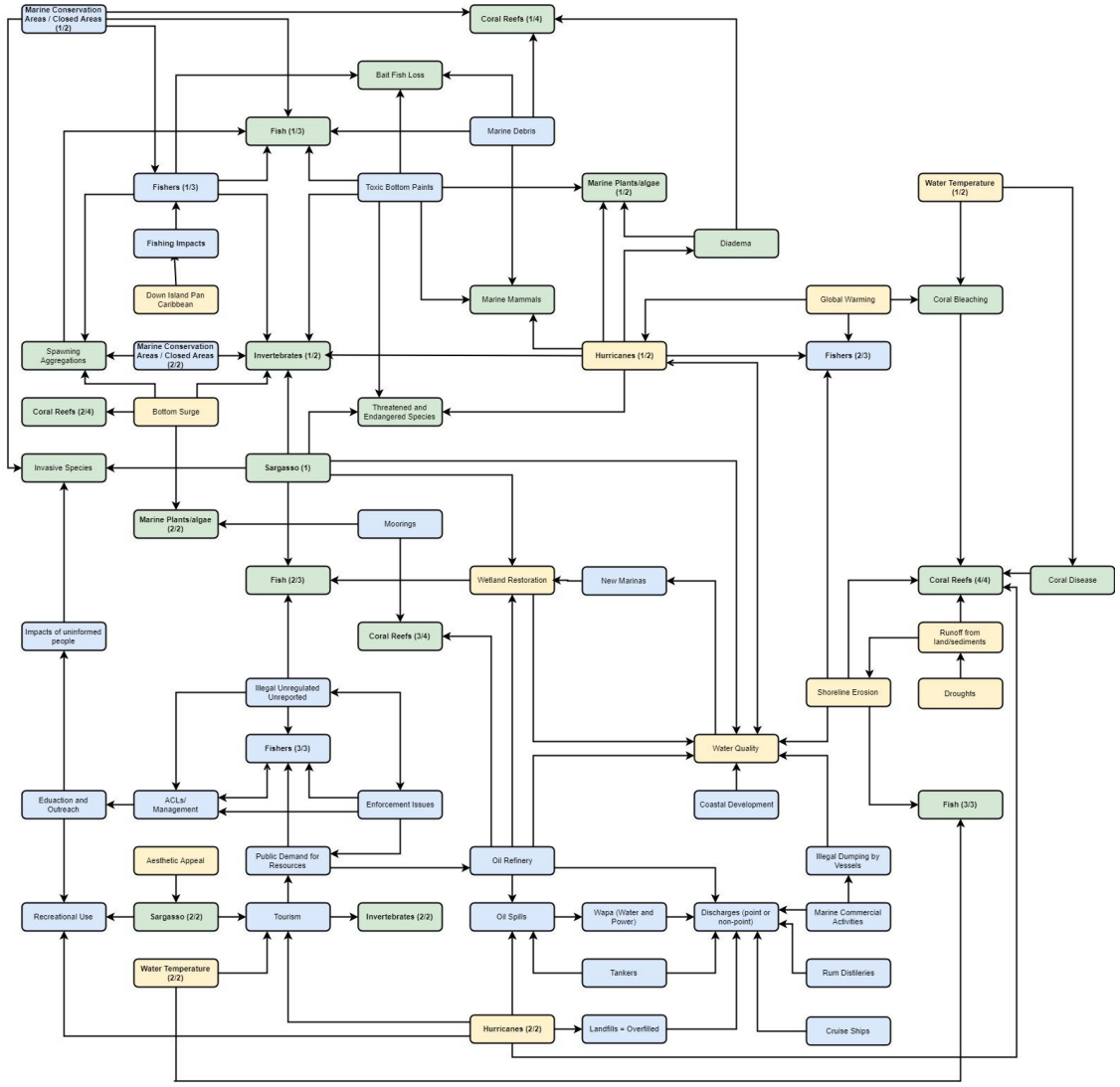
- DAPs, SSC, and additional CFCM efforts
- Additional models to be developed during stakeholder workshops

Questionnaires:

- Participant characteristics
- Further investigation of conceptual model outcomes

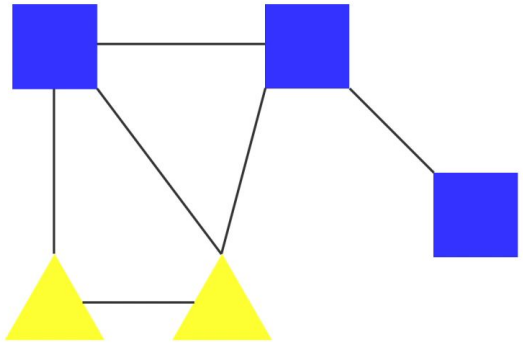


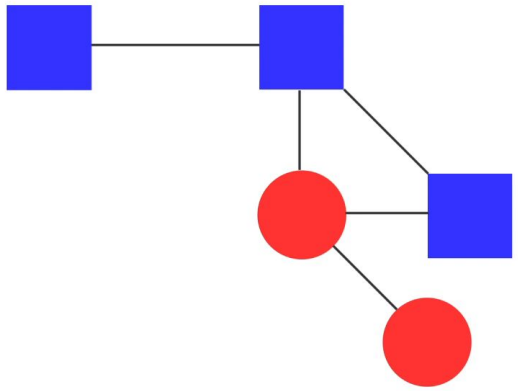
DAP conceptual model: St. Croix



Qualitative Approach

Social Cognitive Maps



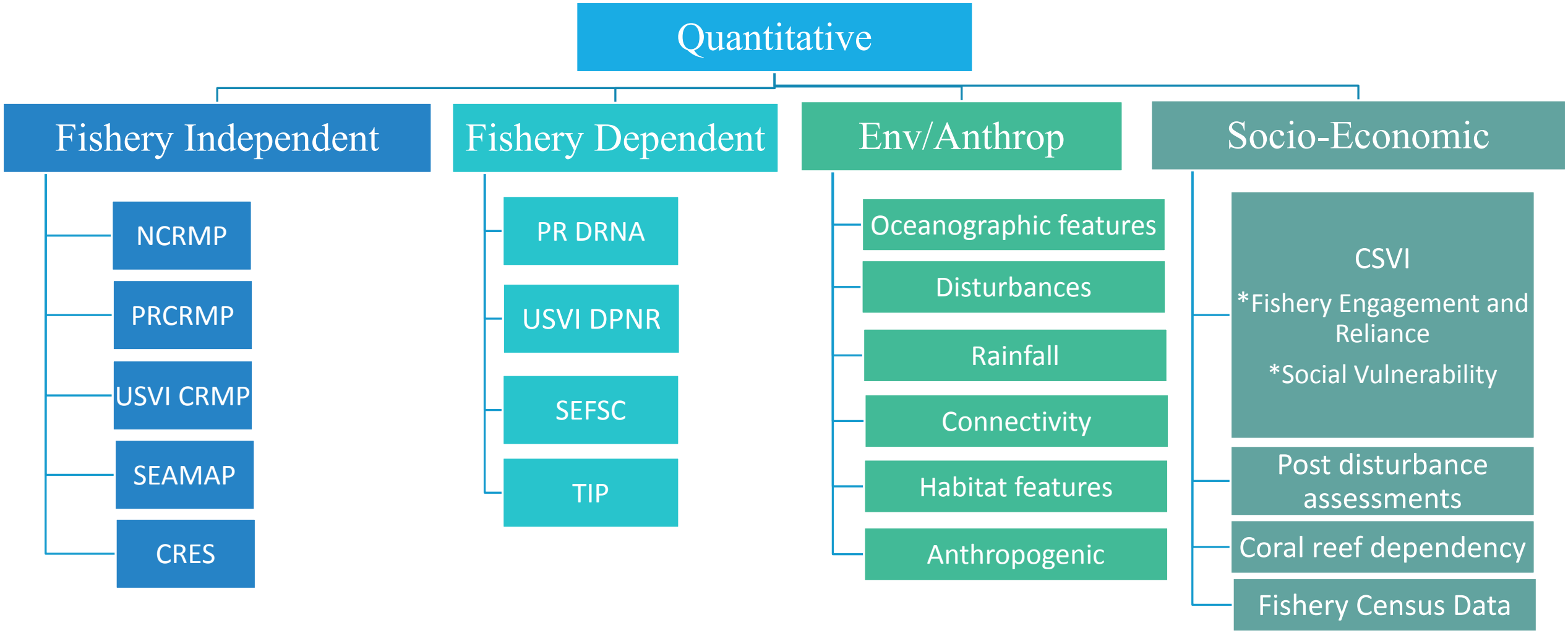


Qualitative Approach

Stakeholder Conceptual Models/Social Cognitive Maps, and information obtained through questionnaires by management region will be used to:

- Allow visualization and in-depth analyses of stakeholder perceptions (e.g. using graph theoretical approach)
- Help identify priorities and risk factors to guide management decisions
- Identify data gaps
- Guide the development of hypotheses to be tested using the quantitative approach

Quantitative Approach

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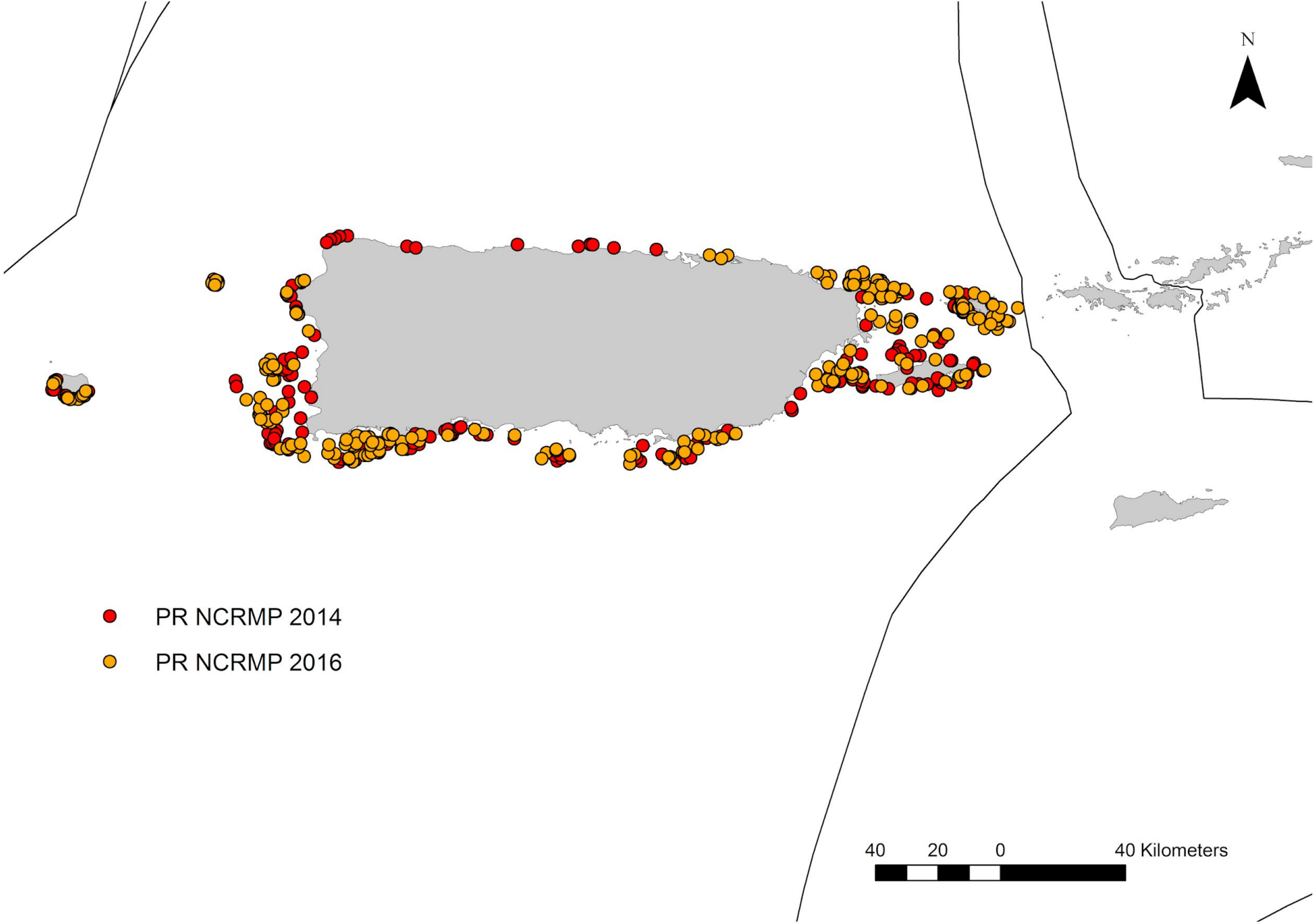
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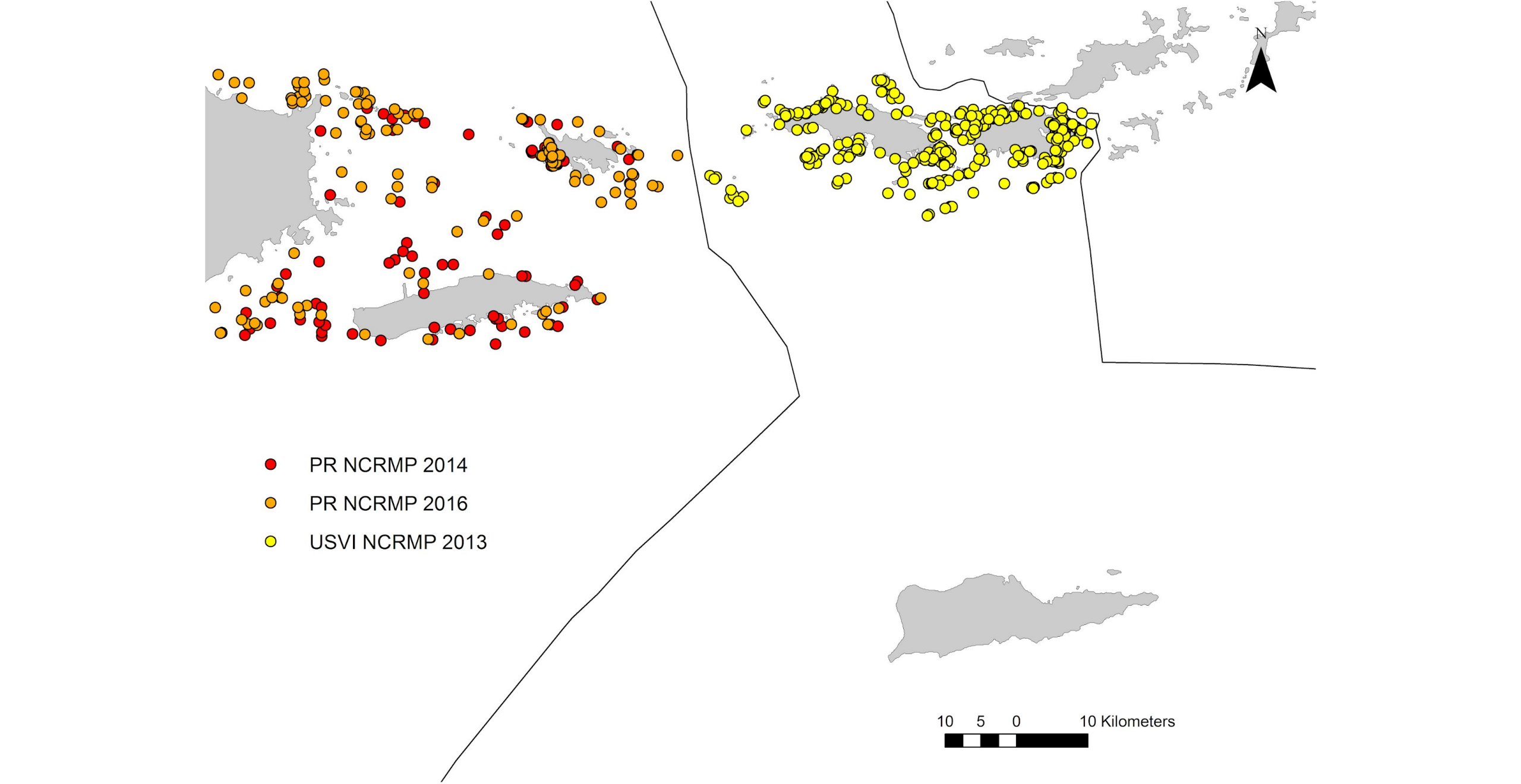
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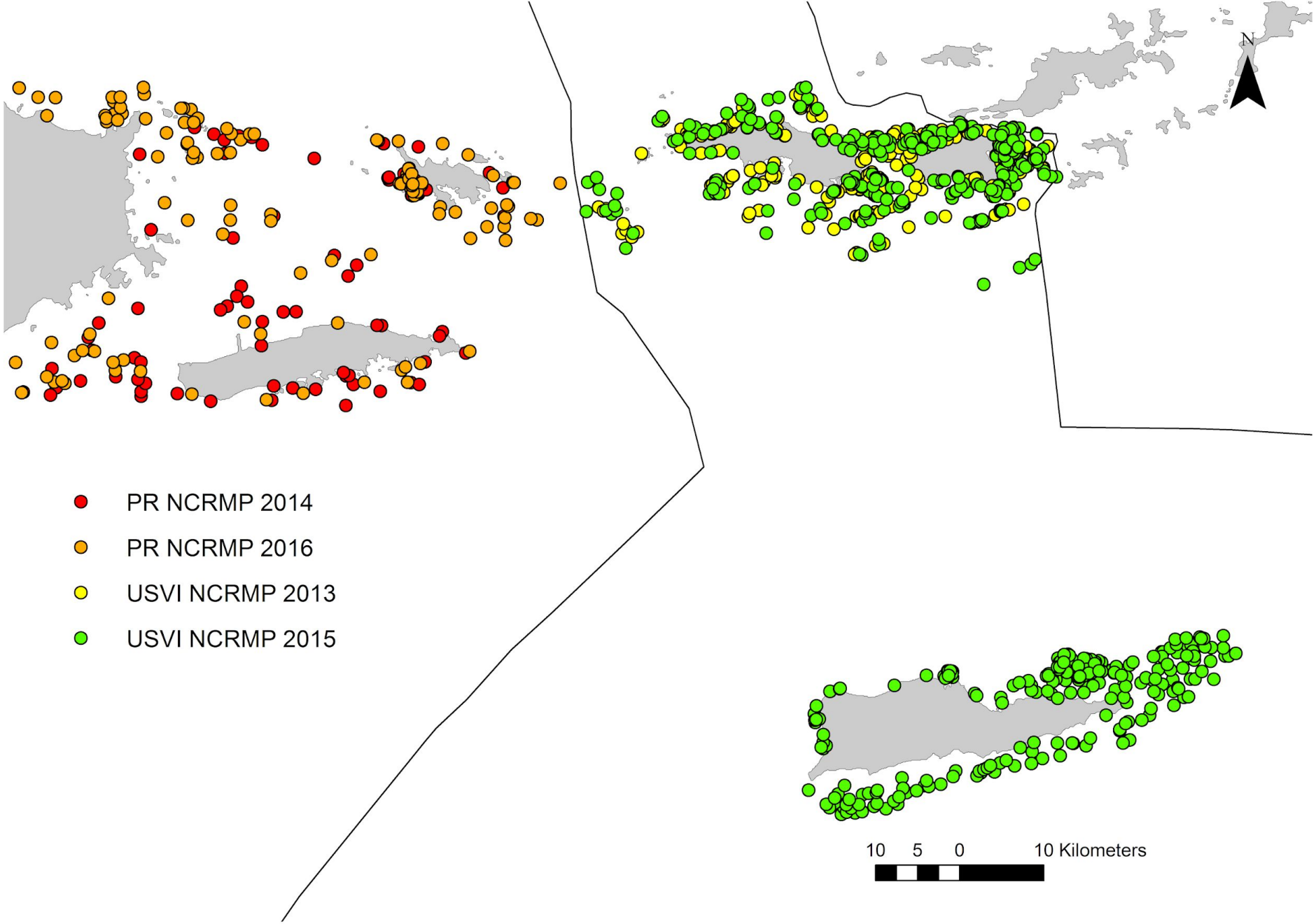
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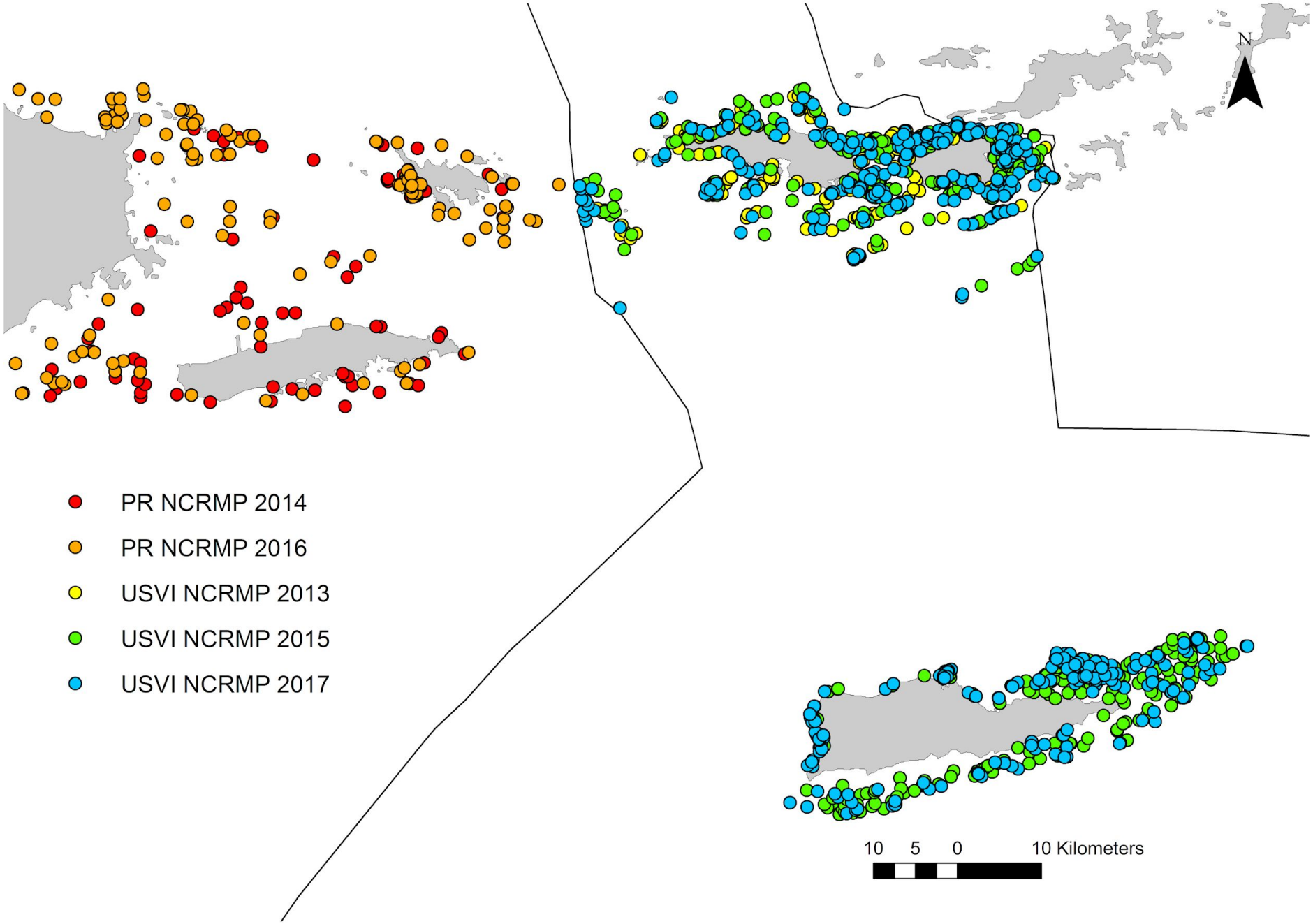
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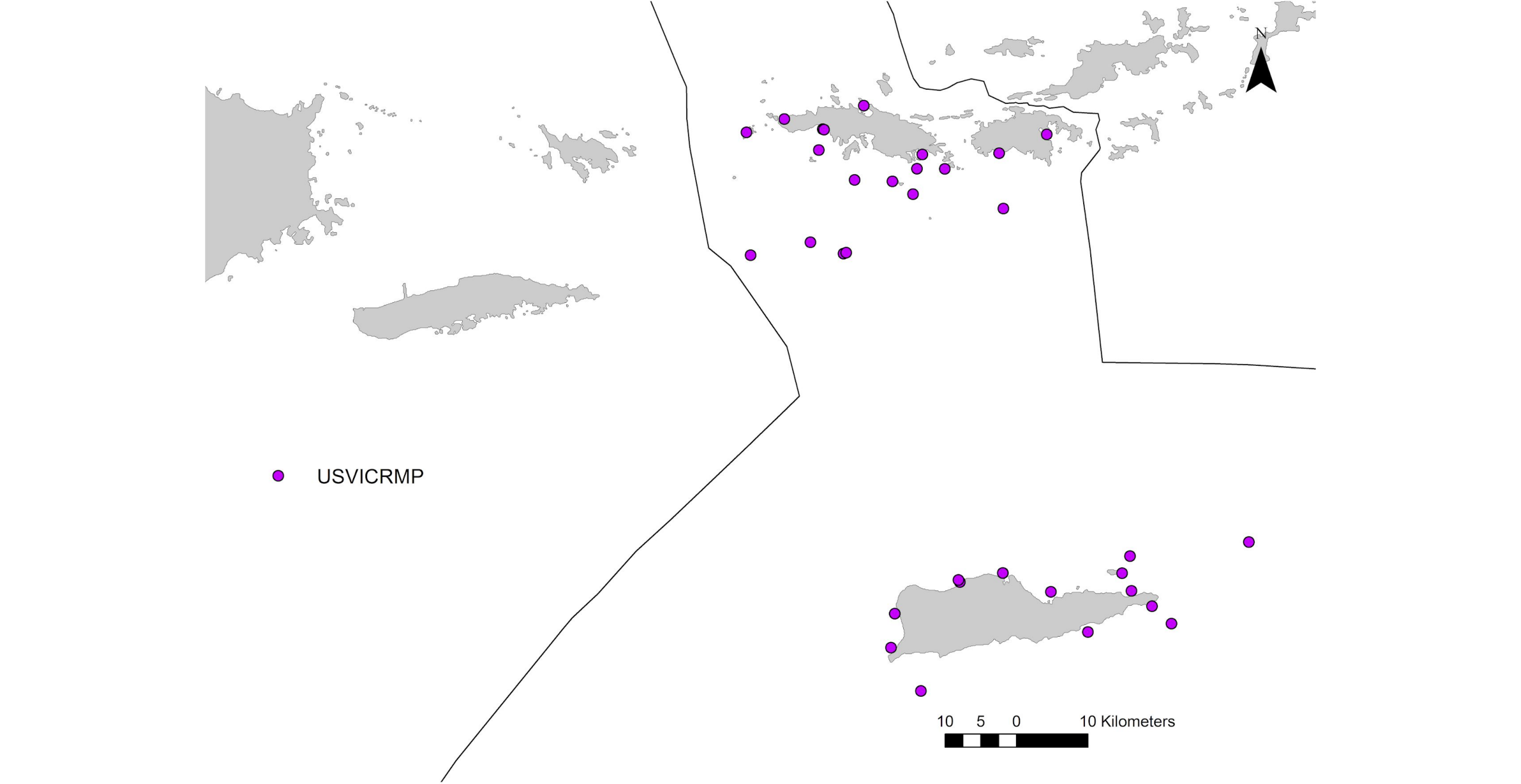
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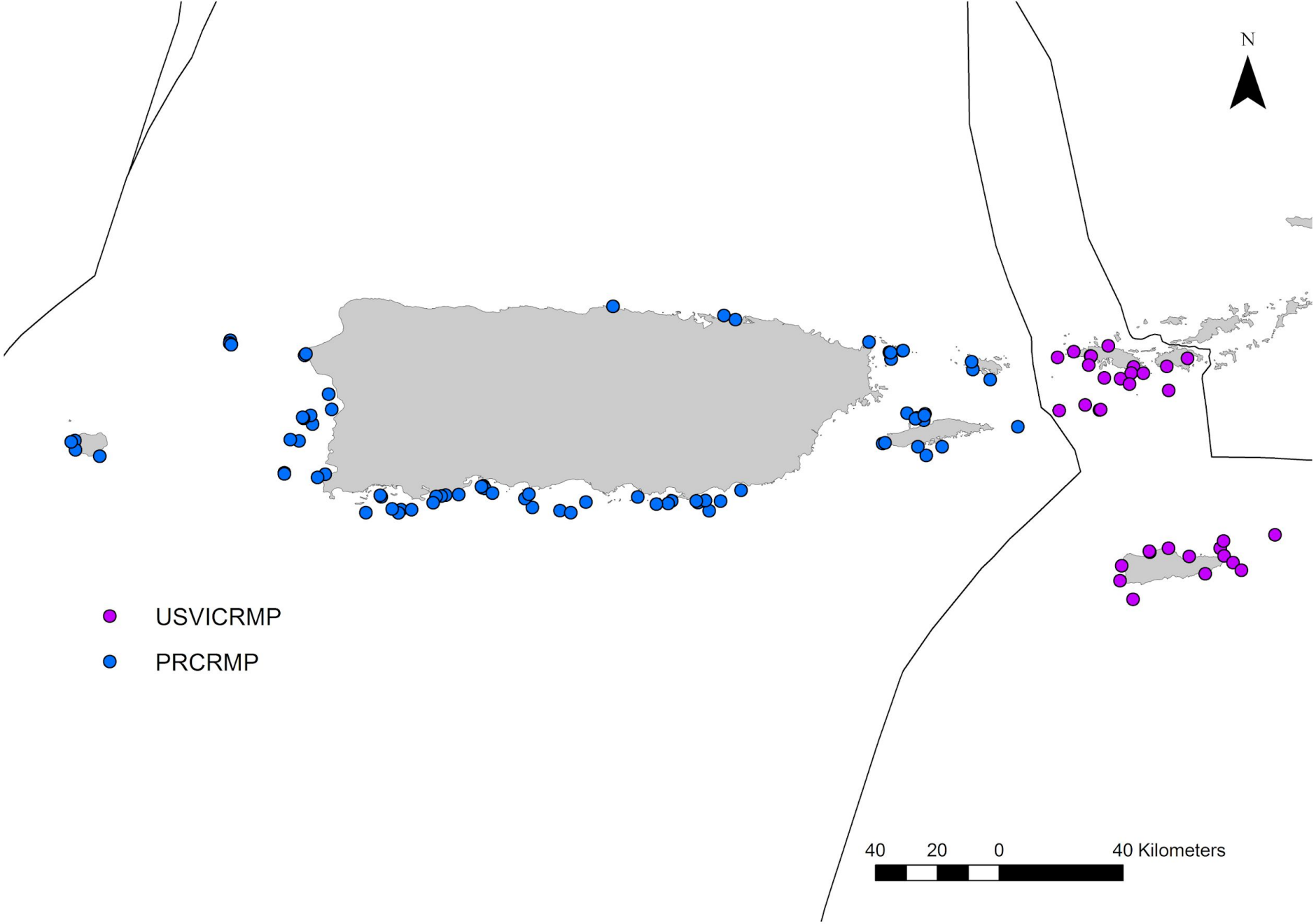
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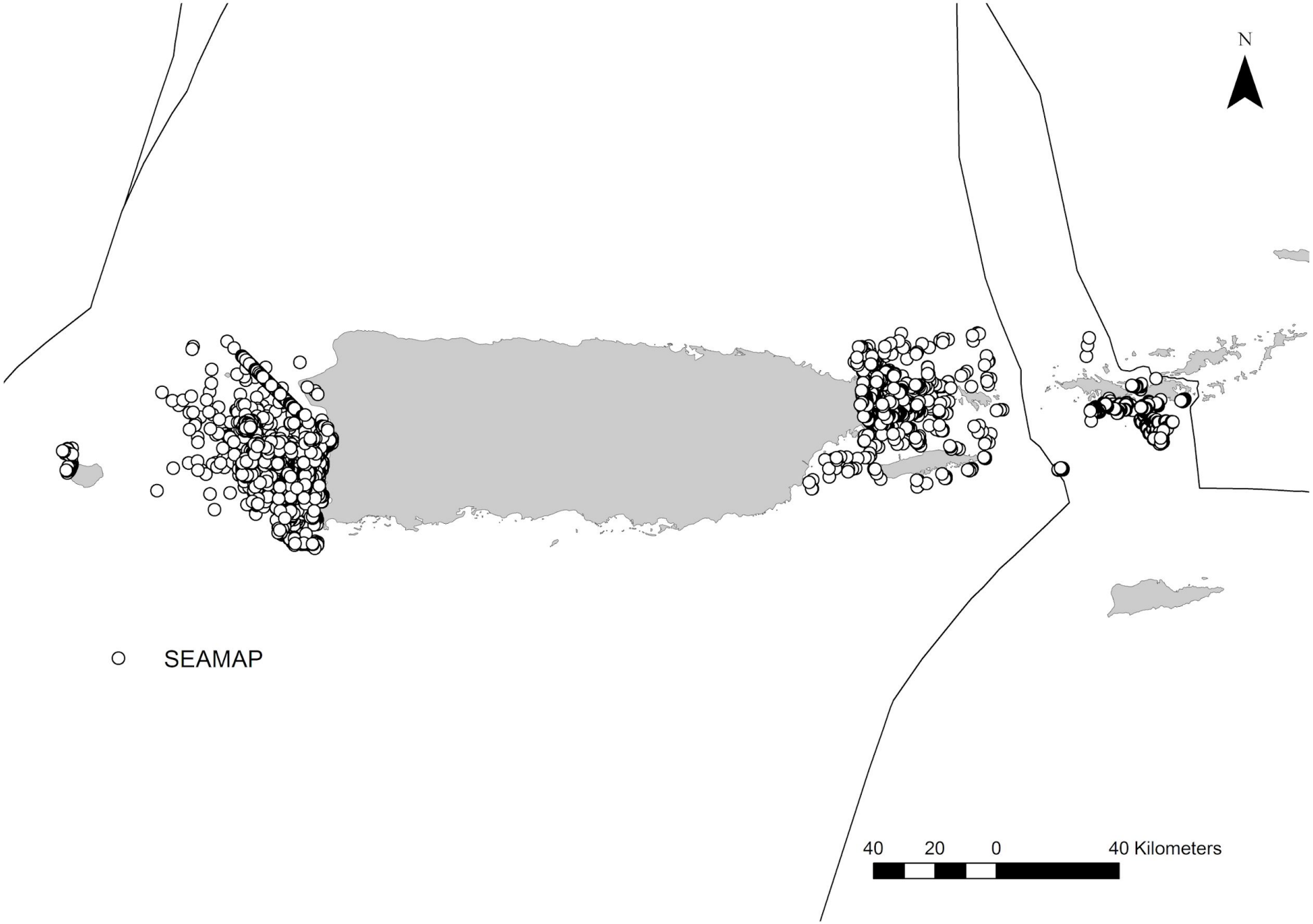
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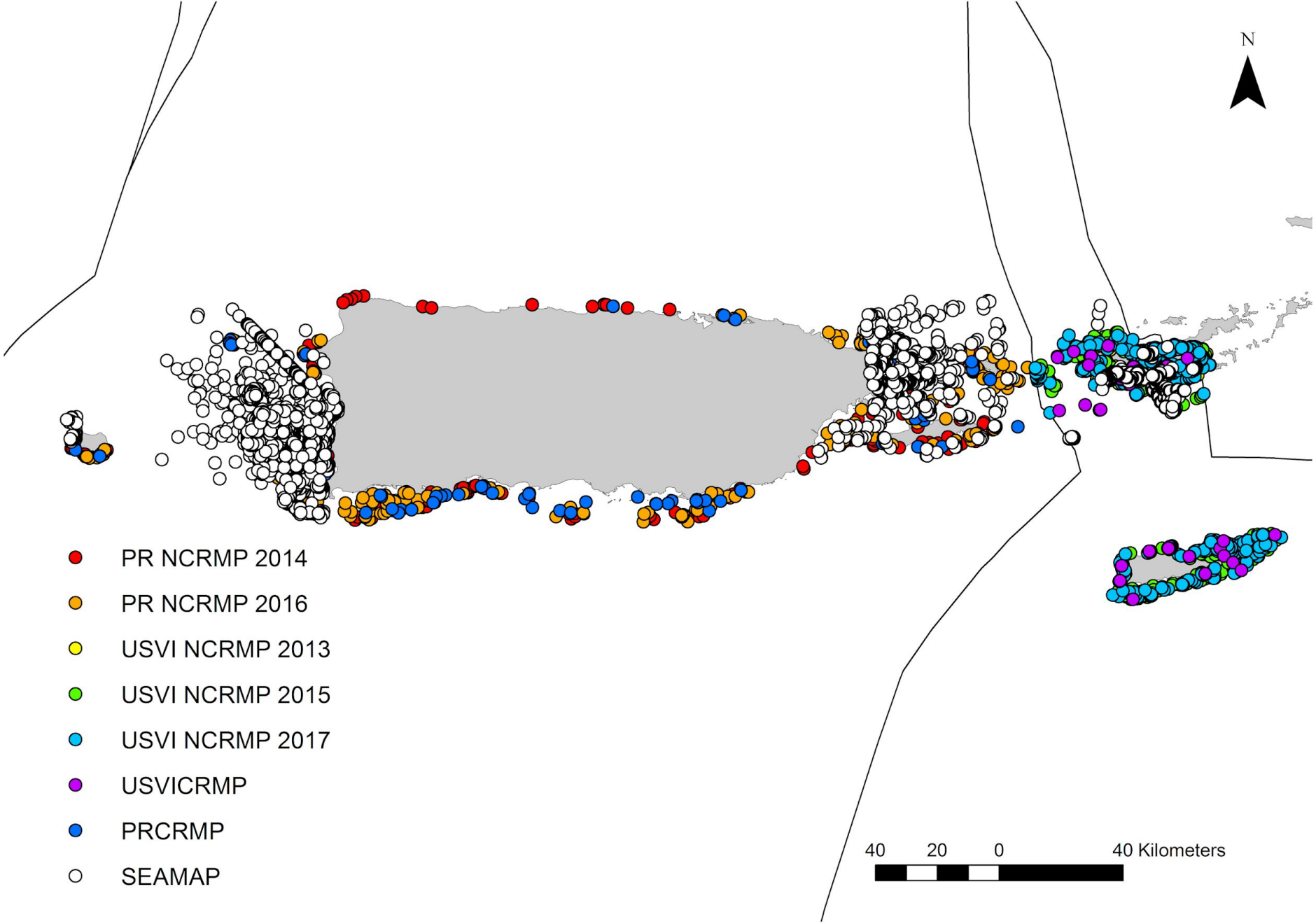
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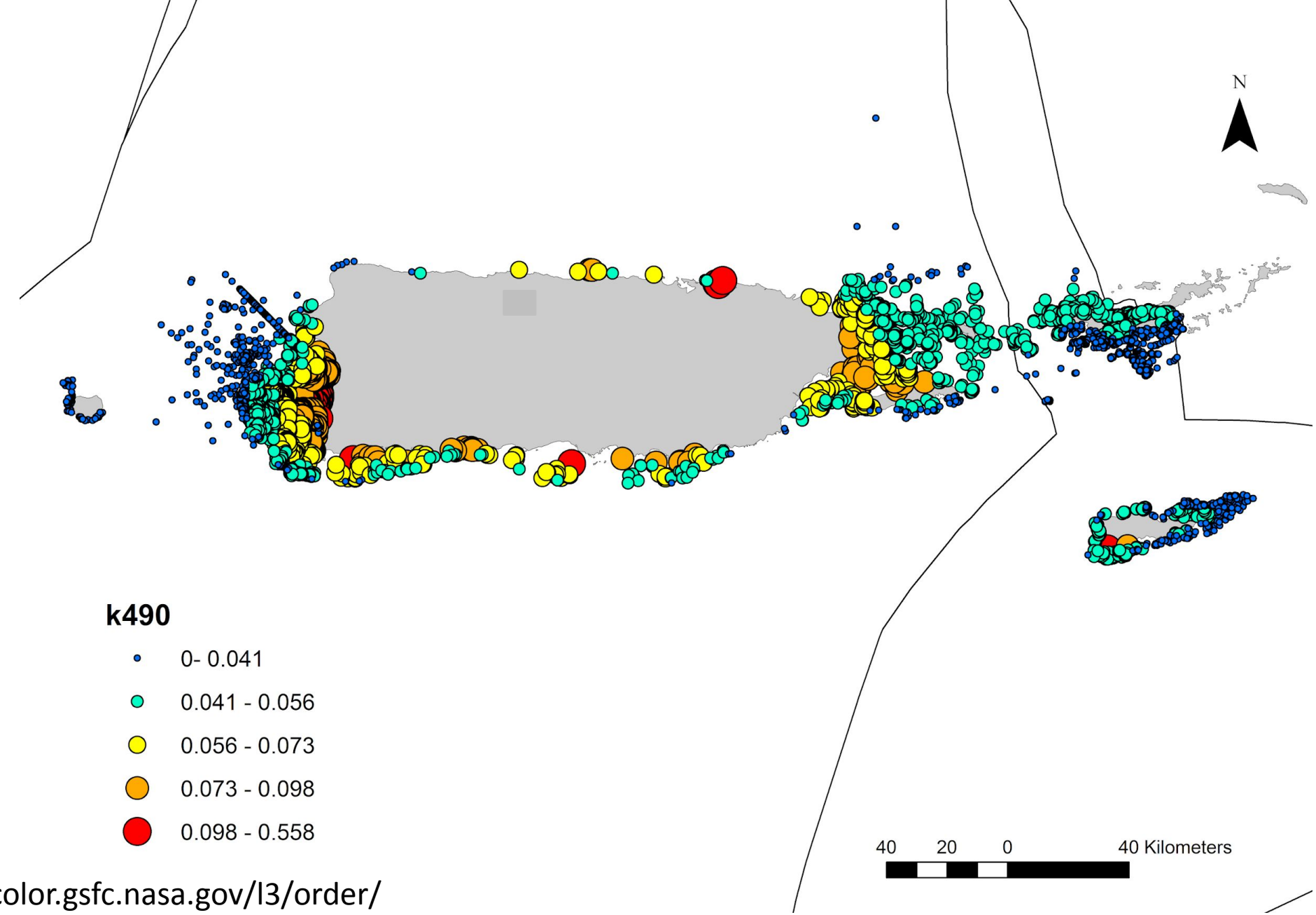

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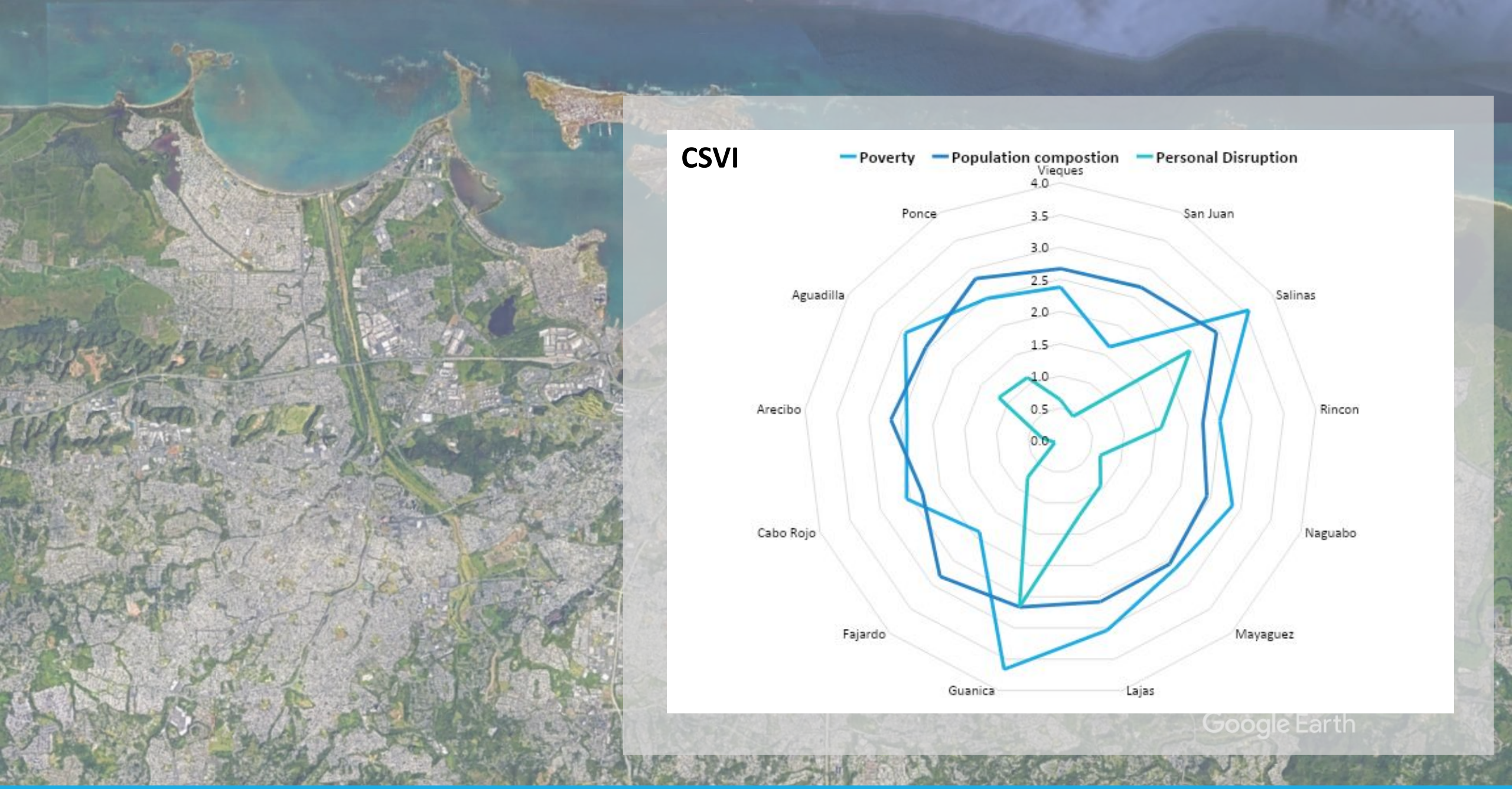
CSVI
Poverty
Population compostion
Personal Disruption
Vieques
San Juan
Salinas
Rincon
Naguabo
Mayaguez
Lajas
Guanica
Fajardo
Cabo Rojo
Arecibo
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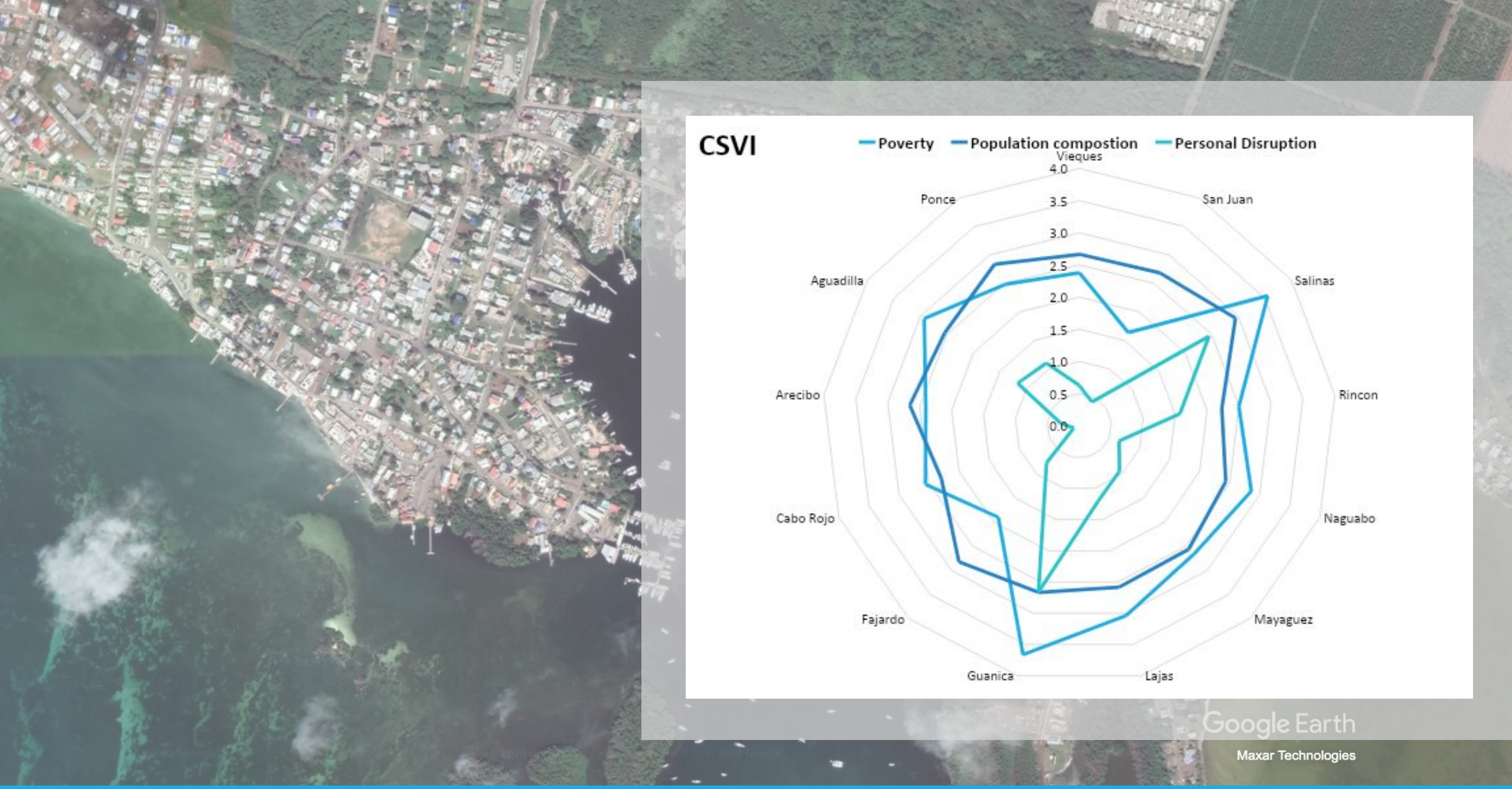
Google Earth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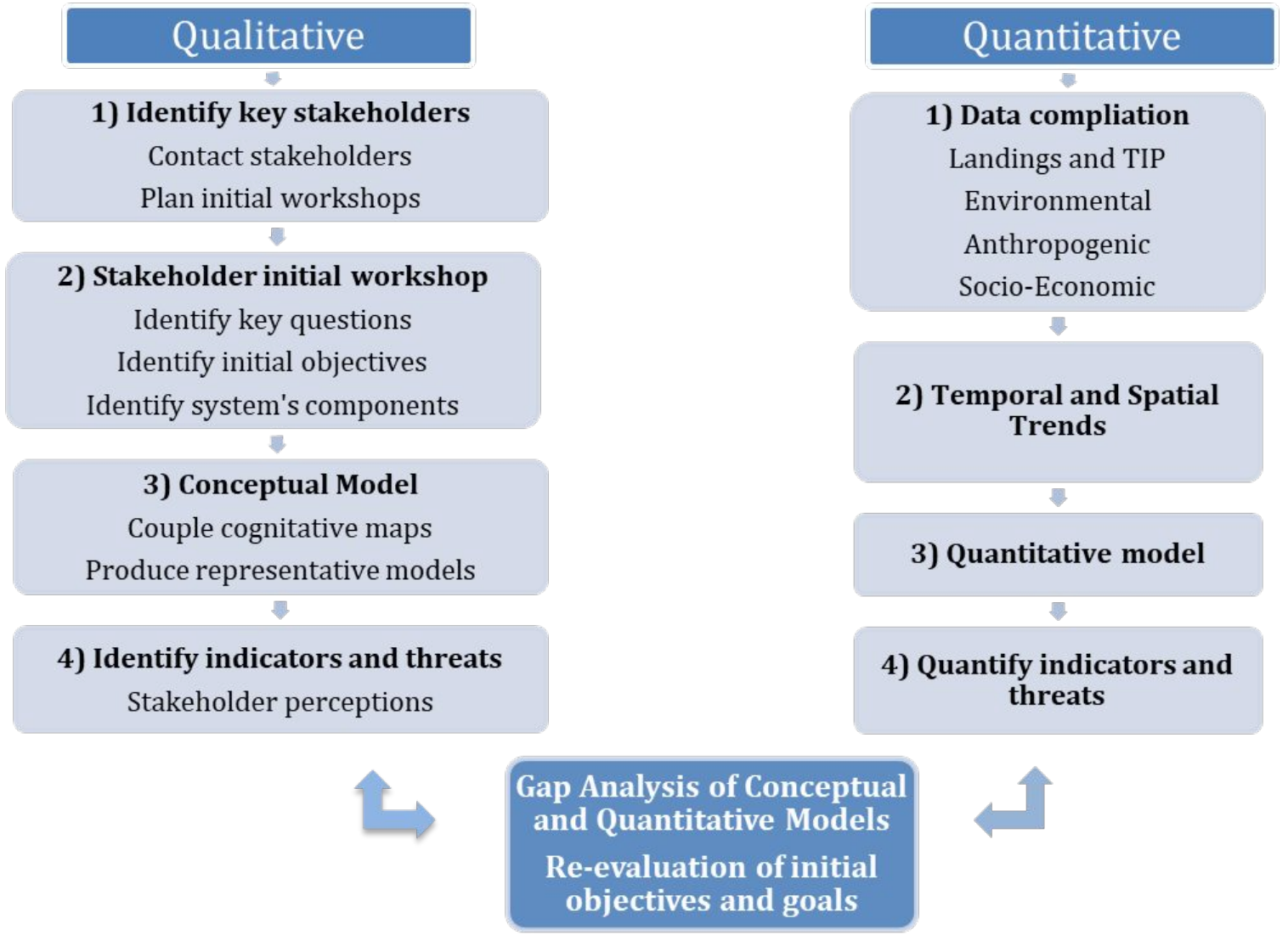
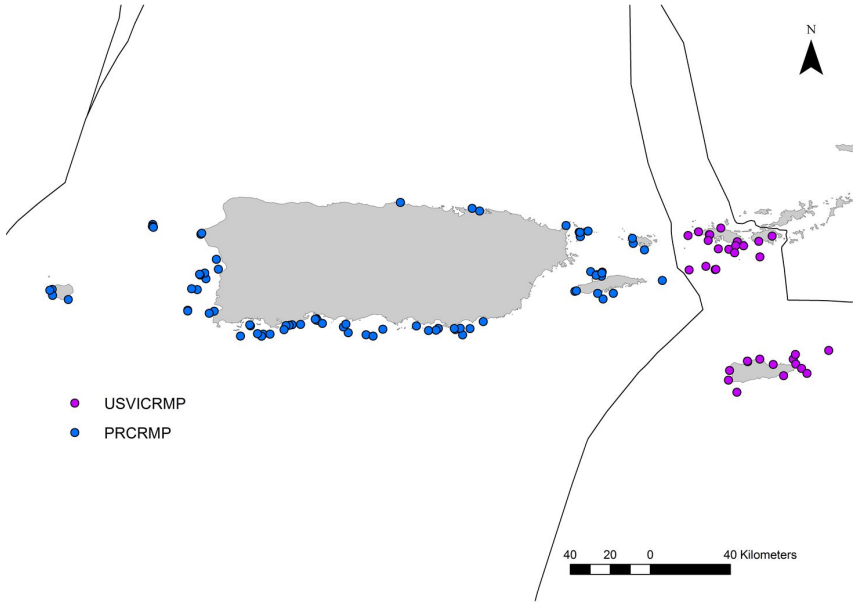
General Structure



Temporal trends: Multivariate approach

EXAMPLE: PR Coral Reef Monitoring Program

42 Stations
5 belts per Station
1999 - 2019



	2004/Enrique	2004/Enrique	2004/Enrique/Cl	2004/Enric	2004/Enric	2004/Enric	2004/Enric	2004/Enric	2004/Enric	2004/Pelo
Abudefduf saxatilis	507.7	0	0	710.836	0	0	317.312	0	0	0
Abudefduf taurus	0	0	0	0	0	0	0	0	0	0
Acanthostracion polygonius	0	0	0	0	0	0	0	0	0	0
Acanthostracion quadricornis	0	0	0	0	0	0	0	0	0	0
Acanthurus bahianus	0	118.246	118.246	43.457	236.492	249.742	1626.533	0	0	0
Acanthurus chirurgus	0	0	0	0	0	0	0	0	0	0
Acanthurus coeruleus	0	0	0	1766.617	0	0	3698.602	0	0	0
Aetobatus narinari	0	0	0	0	0	0	0	0	0	0
Alphestes afer	0	0	0	0	0	0	0	0	0	0
Aluterus monoceros	0	0	0	0	0	0	0	0	0	0
Aluterus scriptus	0	0	0	0	0	0	0	0	0	0
Amblycirrhitus pinos	0	0	0	0	0	0	0	0	0	0
Anisotremus surinamensis	0	0	0	0	0	0	0	0	0	0
Anisotremus virginicus	0	0	0	0	0	0	0	0	283.546	0
Apogon townsendi	0	0	0	0	0	0	0	0	0	0
Archosargus rhomboidalis	0	0	0	0	0	0	0	0	0	0
Aulostomus maculatus	0	0	0	96.697	0	0	105.063	0	0	0
Balistes vetula	0	0	0	0	0	0	0	0	0	0
Bodianus rufus	0	0	0	0	0	0	0	0	0	0
Calamus bajonado	0	0	0	0	0	0	0	0	0	0
Calamus calamus	0	0	0	0	0	0	0	0	0	0
Calamus penna	0	0	0	0	0	0	0	0	0	0
Cantherhines macrocerus	0	0	0	0	0	0	0	0	0	0
Cantherhines pullus	0	0	0	0	0	0	0	0	0	0
Canthidermis sufflamen	0	0	0	0	0	0	0	0	0	0
Canthigaster rostrata	0	10.535	11.369	0	21.486	0.417	0	32.438	10.535	10.535

1424 Observations
247 Species

Temporal trends: Multivariate approach

	2004/Enrique	2004/Enrique	2004/Enrique/Cl	2004/Enri	2004/Enri	2004/Enri	2004/Enri	2004/Enri	2004/Enri	2004/Pelo
Abudefduf saxatilis	507.7	0	0	710.836	0	0	317.312	0	0	0
Abudefduf taurus	0	0	0	0	0	0	0	0	0	0
Acanthostracion polygonius	0	0	0	0	0	0	0	0	0	0
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Acanthurus bahianus	0	118.246	118.246	43.457	236.492	249.742	1626.533	0	0	0
Acanthurus chirurgus	0	0	0	0	0	0	0	0	0	0
Acanthurus coeruleus	0	0	0	1766.617	0	0	3698.602	0	0	0
Aetobatus narinari	0	0	0	0	0	0	0	0	0	0
Alphestes afer	0	0	0	0	0	0	0	0	0	0
Aluterus monoceros	0	0	0	0	0	0	0	0	0	0
Aluterus scriptus	0	0	0	0	0	0	0	0	0	0
Amblycirrhitus pinos	0	0	0	0	0	0	0	0	0	0
Anisotremus surinamensis	0	0	0	0	0	0	0	0	0	0
Anisotremus virginicus	0	0	0	0	0	0	0	0	283.546	0
Apogon townsendi	0	0	0	0	0	0	0	0	0	0
Archosargus rhomboidalis	0	0	0	0	0	0	0	0	0	0
Aulostomus maculatus	0	0	0	96.697	0	0	105.063	0	0	0
Balistes vetula	0	0	0	0	0	0	0	0	0	0
Bodianus rufus	0	0	0	0	0	0	0	0	0	0
Calamus bajonado	0	0	0	0	0	0	0	0	0	0
Calamus calamus	0	0	0	0	0	0	0	0	0	0
Calamus penna	0	0	0	0	0	0	0	0	0	0
Cantherhines macrocerus	0	0	0	0	0	0	0	0	0	0
Cantherhines pullus	0	0	0	0	0	0	0	0	0	0
Canthidermis sufflamen	0	0	0	0	0	0	0	0	0	0
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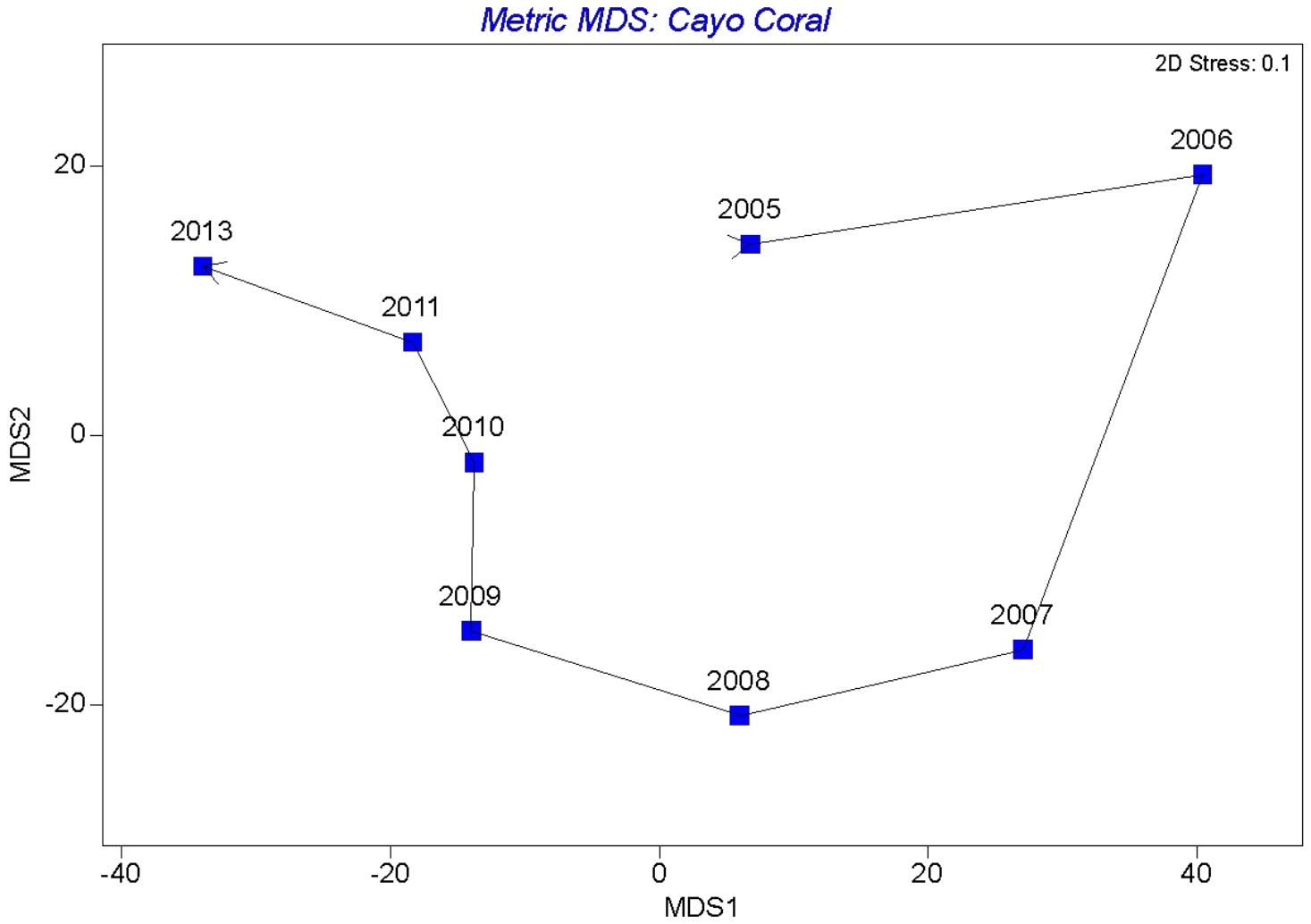
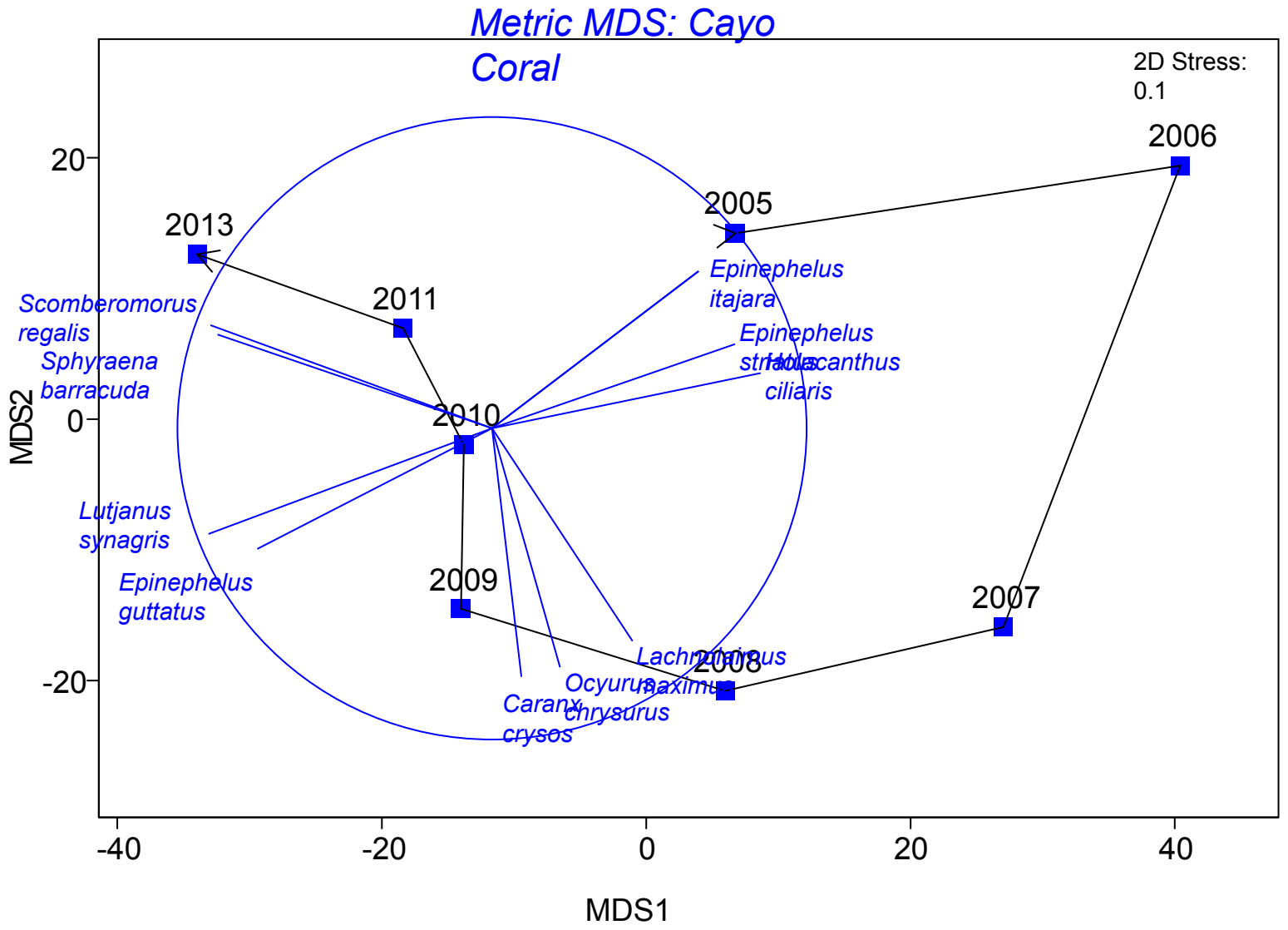
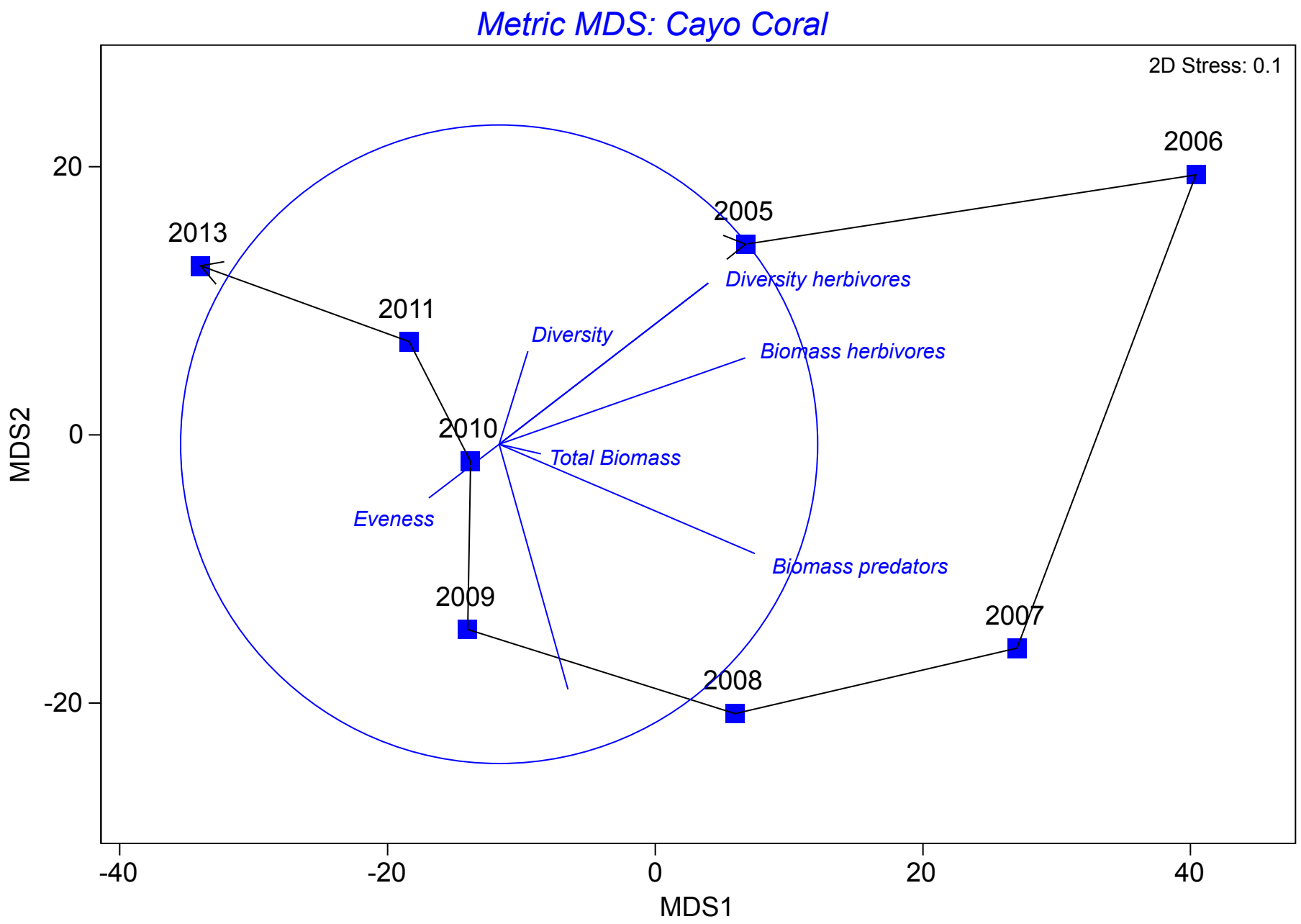


Indicators: Multivariate approach



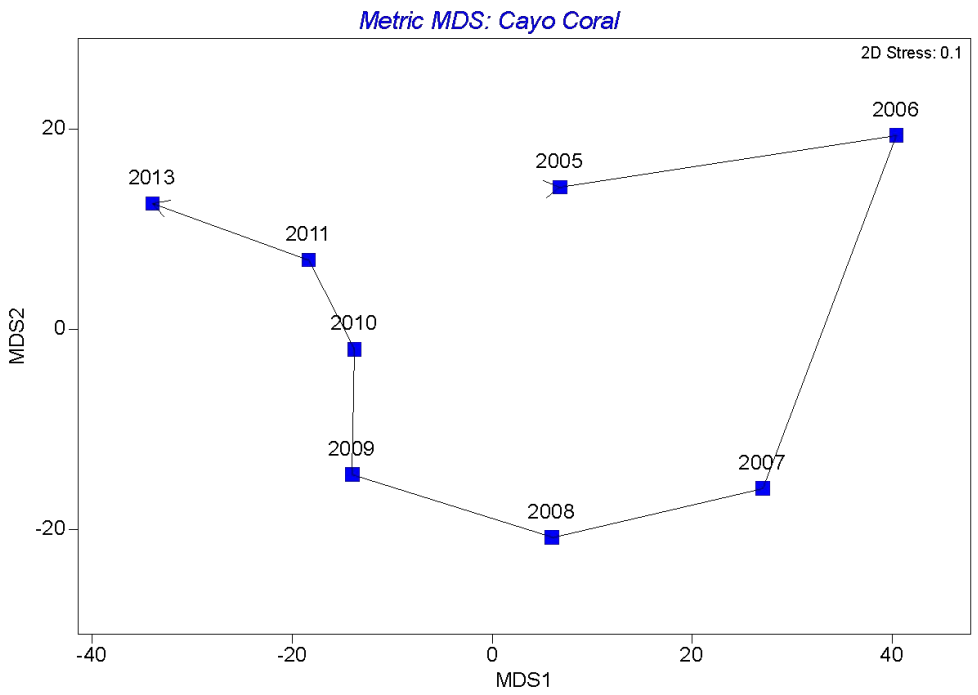


Indicators:

- Biomass herbivores
- Diversity herbivores
- Biomass top predators
- Total Biomass
- Diversity
- Eveness

Biotic-Environment Relationships: Multivariate approach

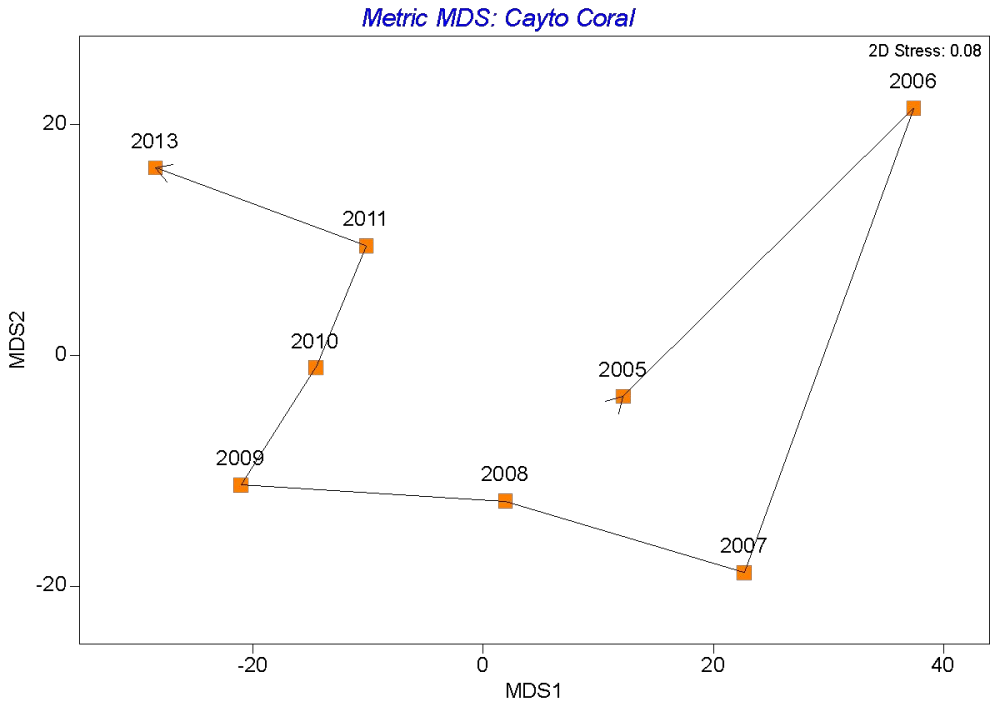
Fish Assemblages (Actual data)



247 Species

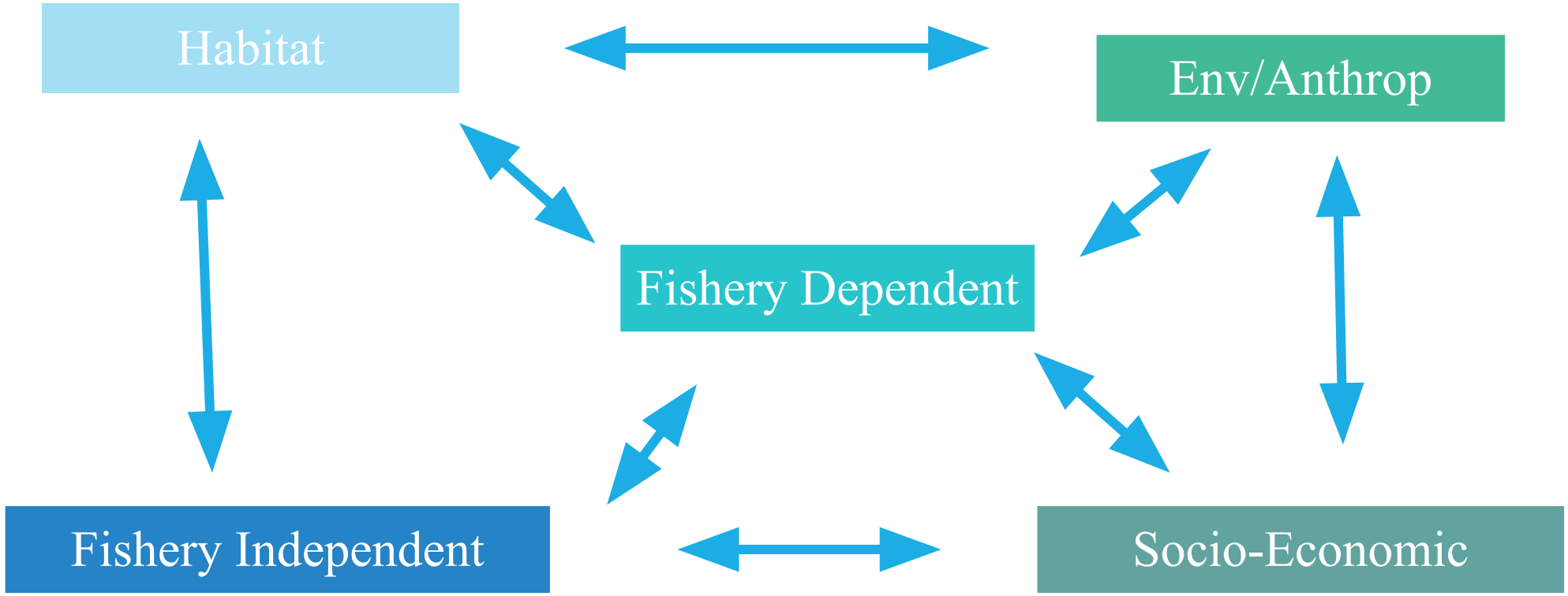
Rho

Environmental Variables (Hypothetic result)



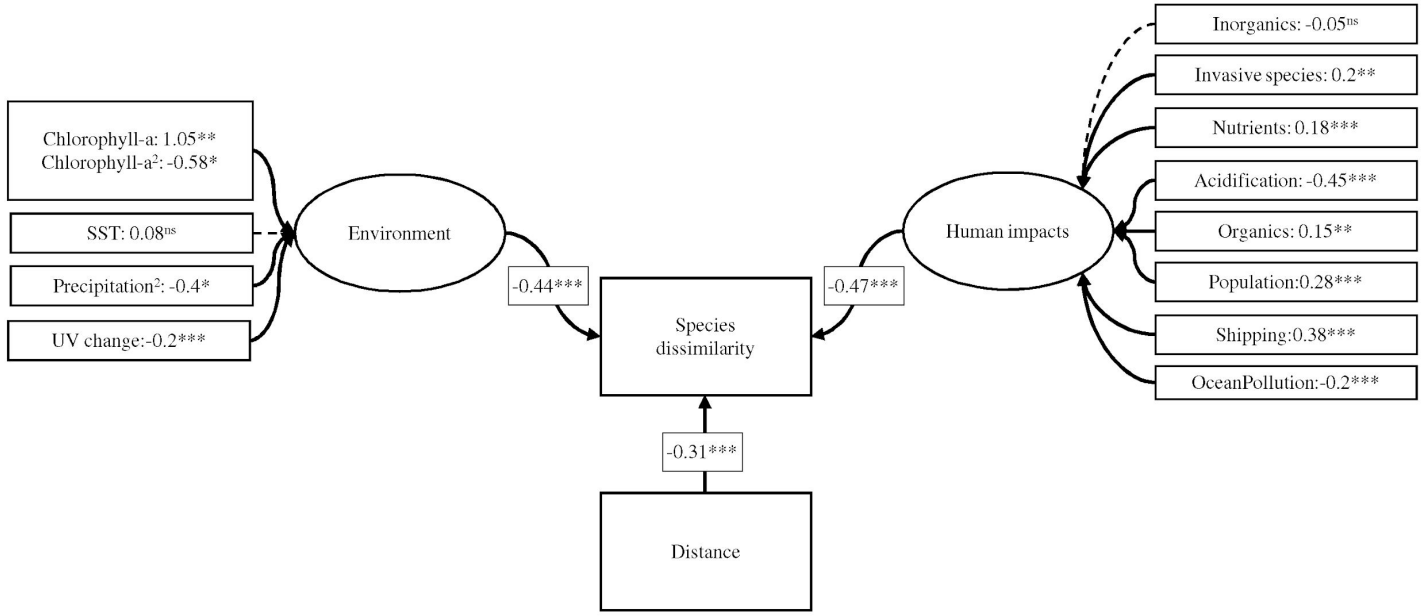
19 Environmental variables

Multiple Relationships: ??



Quantitative Approach: Structural Equation Modelling (**SEM**)

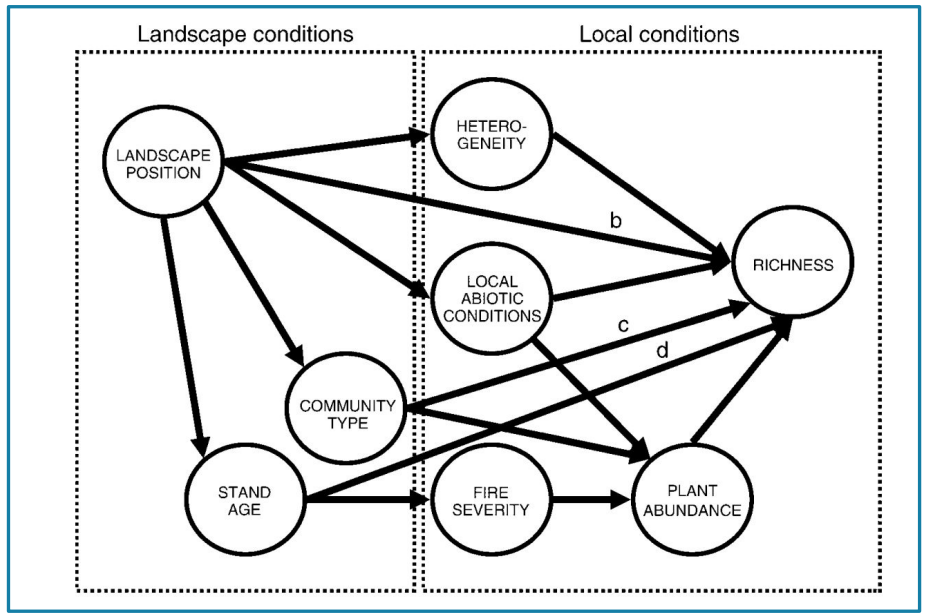
A form of graphical modelling that combine multiple variables in a single **causal** network:



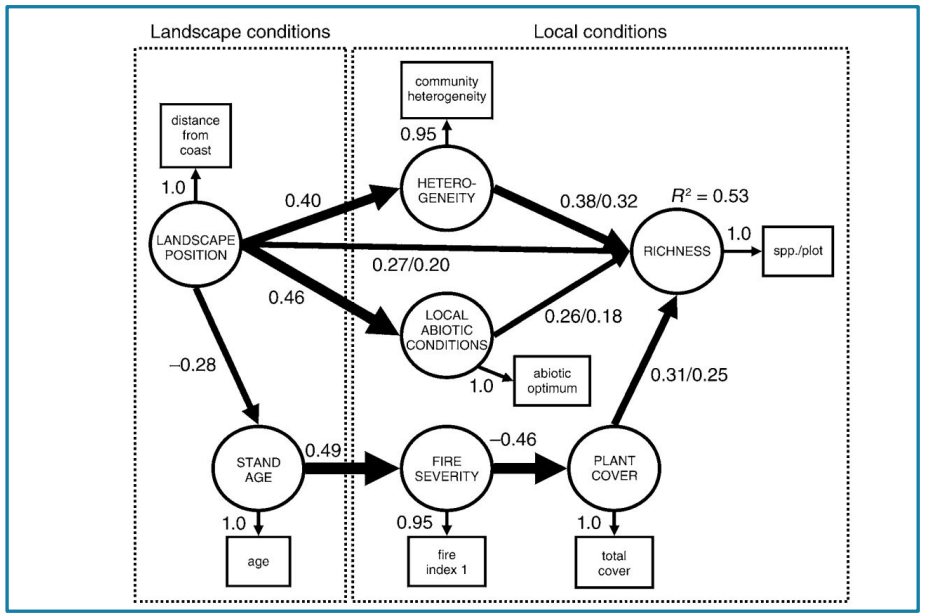
SEM allows to represent the interaction of multiple hypotheses, and then evaluate them quantitatively with data. The importance of the relationship is extracted from statistical modelling, mainly linear models.

Quantitative Approach: Qualitative + Quantitative

Conceptual model



SEM



Analysis of postfire plant diversity in California shrublands (Grace & Keeley, 2006)

Final considerations:

1) CFCM moving forward to build a FEP
2) Conceptual models are a key component of the FEP
3) Three-year project:
    1) Stacked conceptual model
    2) Quantitative model
    3) Gap analysis
    4) Testing of stacked conceptual model
4) Integrate with corollary projects (e.g. ESR Caribbean)

THANK YOU

QUESTIONS?

Extra Slides

Piecewise - SEM

pSEM expands upon traditional **SEM** by introducing a flexible mathematical framework that can incorporate a wide variety of model structures, distributions, and assumptions.

- Interactions
- non-normal responses
- Random effects
- Hierarchical models
- Alternate correlation structures

SEM (and **pSEM**) are useful tools for quantifying direct and indirect (cascading) effects, with great potential to support ecosystem-based management decisions

CFMC EBFM Technical Advisory Panel

-Derived from ad-hoc EBFM planning team

-set the stage for U.S. Caribbean EBFM development

-worked closely with Lenfest and their FEP development team to build foundation

-set the stage for Pew Charitable Trusts grant funds to support quantitative analyses

-Eight formal members, all with technical and science backgrounds, but dependent on contributions from a host of federal, state and academic partners, DAPs, others

-Presently addressing several key aspects of EBFM preparation:

-development of conceptual models (and submodels) for each island group

-identification, acquisition and organization of pertinent and accessible data

-statistical analyses, focus on understanding influence of historic habitat change

-3-year Lenfest project to conduct quantitative analyses

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