Coral farming and reef rehabilitation in Puerto Rico: Recent progress and major needs


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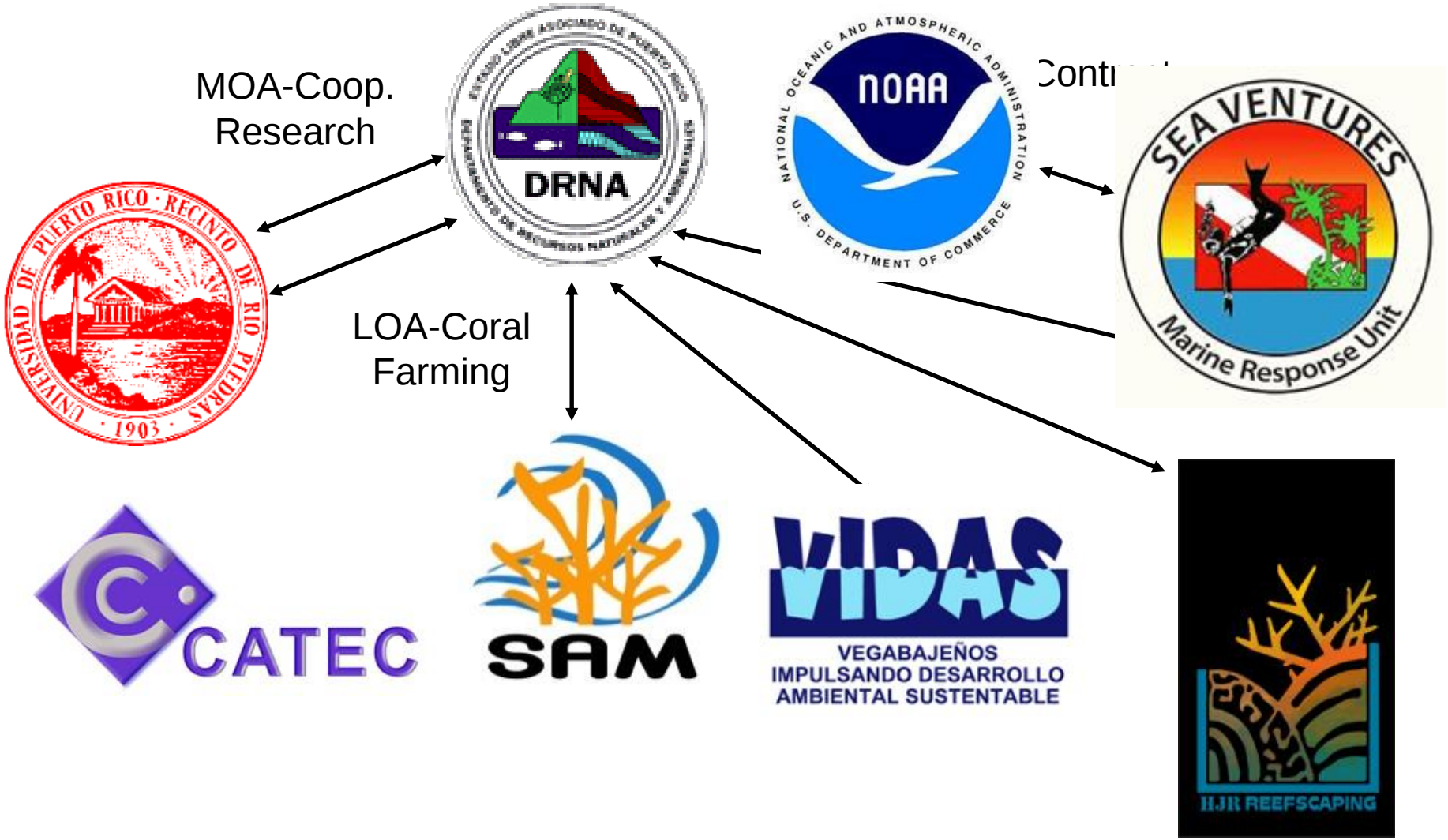
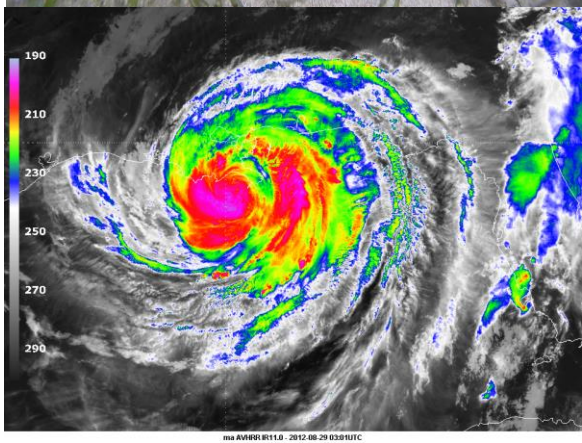
U.S. Coral Reefs Task Force Meeting
Fajardo, Puerto Rico
October 29, 2015

Puerto Rico National Coral Farming and Reef Rehabilitation Alliance

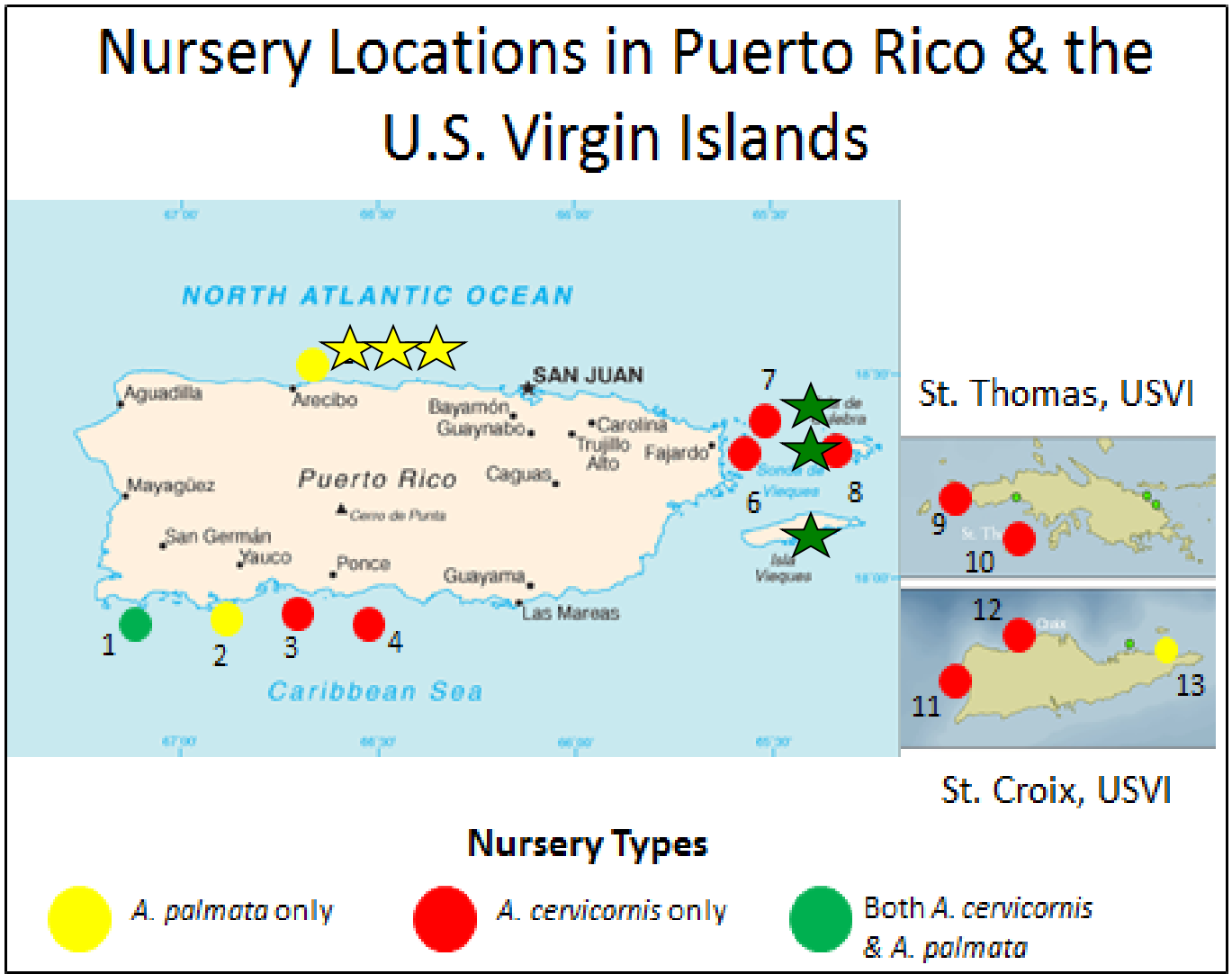


Objectives

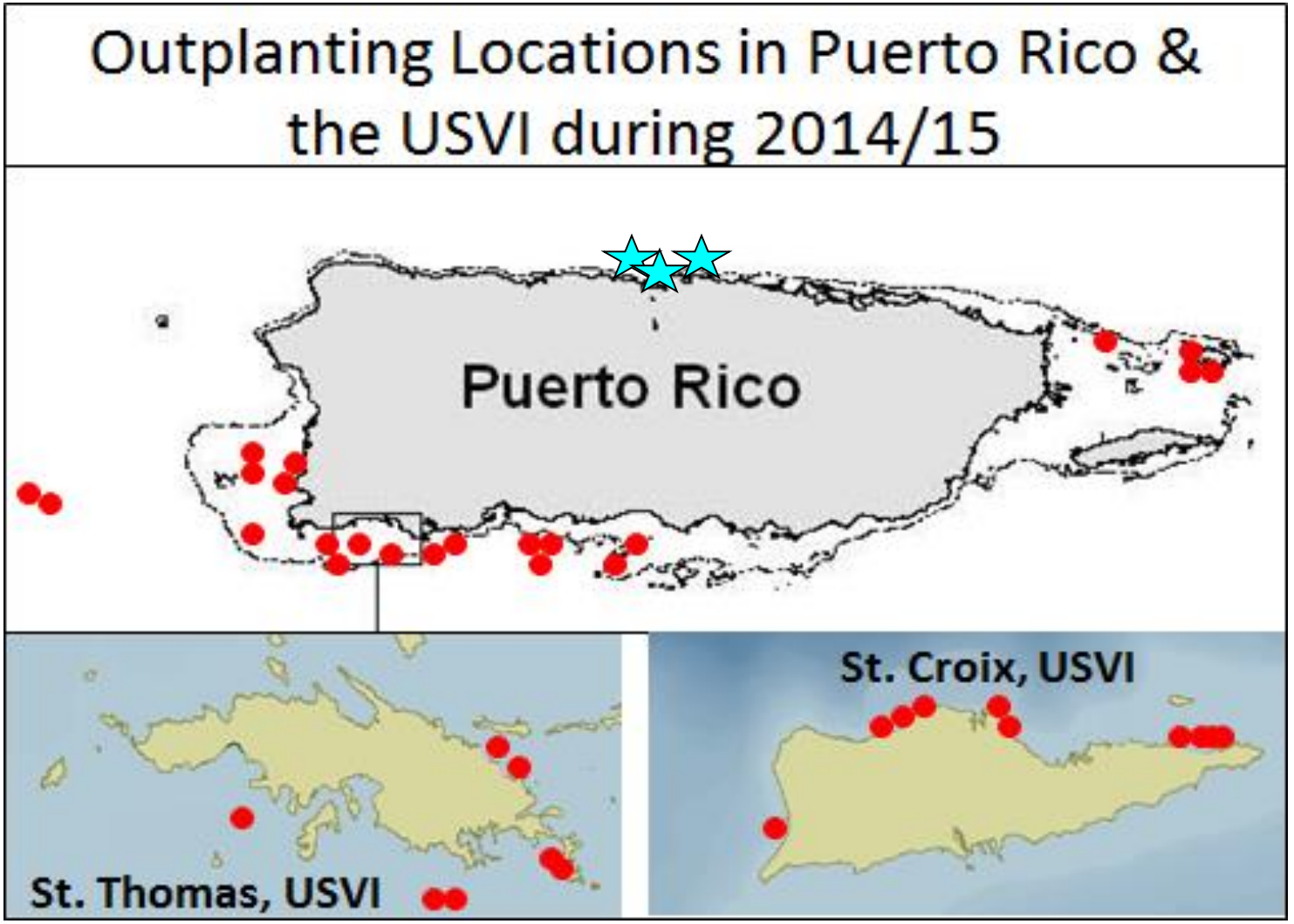
- Efforts by:
  - DNER
  - NOAA-RC and Sea Ventures
  - HJR ReefScaping
  - VIDAS
  - Sociedad Ambiente Marino and CATEC/UPR
- Recommendations for improving coral farming and reef rehabilitation



35,000 corals were outplanted during 2014/15 from nurseries in Florida, Puerto Rico and the USVI to assist in the recovery of ESA listed coral populations and restore degraded reefs (n=14 farms PR; n=5 USVI)



35,000 corals were outplanted during 2014/15 from nurseries in Florida, Puerto Rico and the USVI to assist in the recovery of ESA listed coral populations and restore degraded reefs (n=24 PR; n=16 USVI)

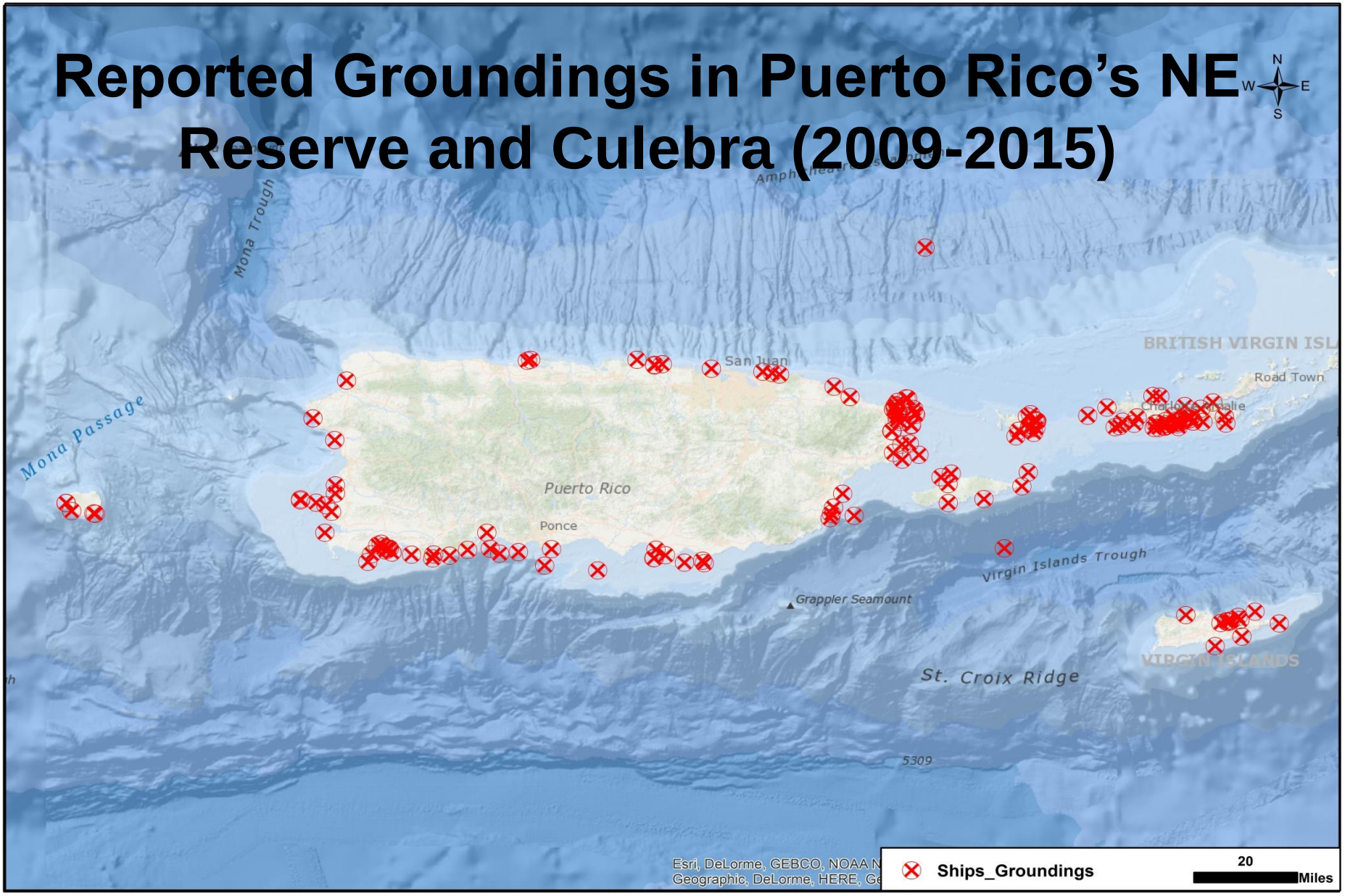


- Coordination of all coral farming and reef rehabilitation efforts in Puerto Rico
- Signed 3-year LOA with coral farmers (October 14, 2014)
  - Operation of coral farms
  - Establish uniform methods
  - Emergency restoration (i.e., groundings, major storm swells, hurricanes)
  - Support DNER/NOAA operations
- Unsuccessful seeking NOAA programatic funds to support and coordinate coral farming efforts

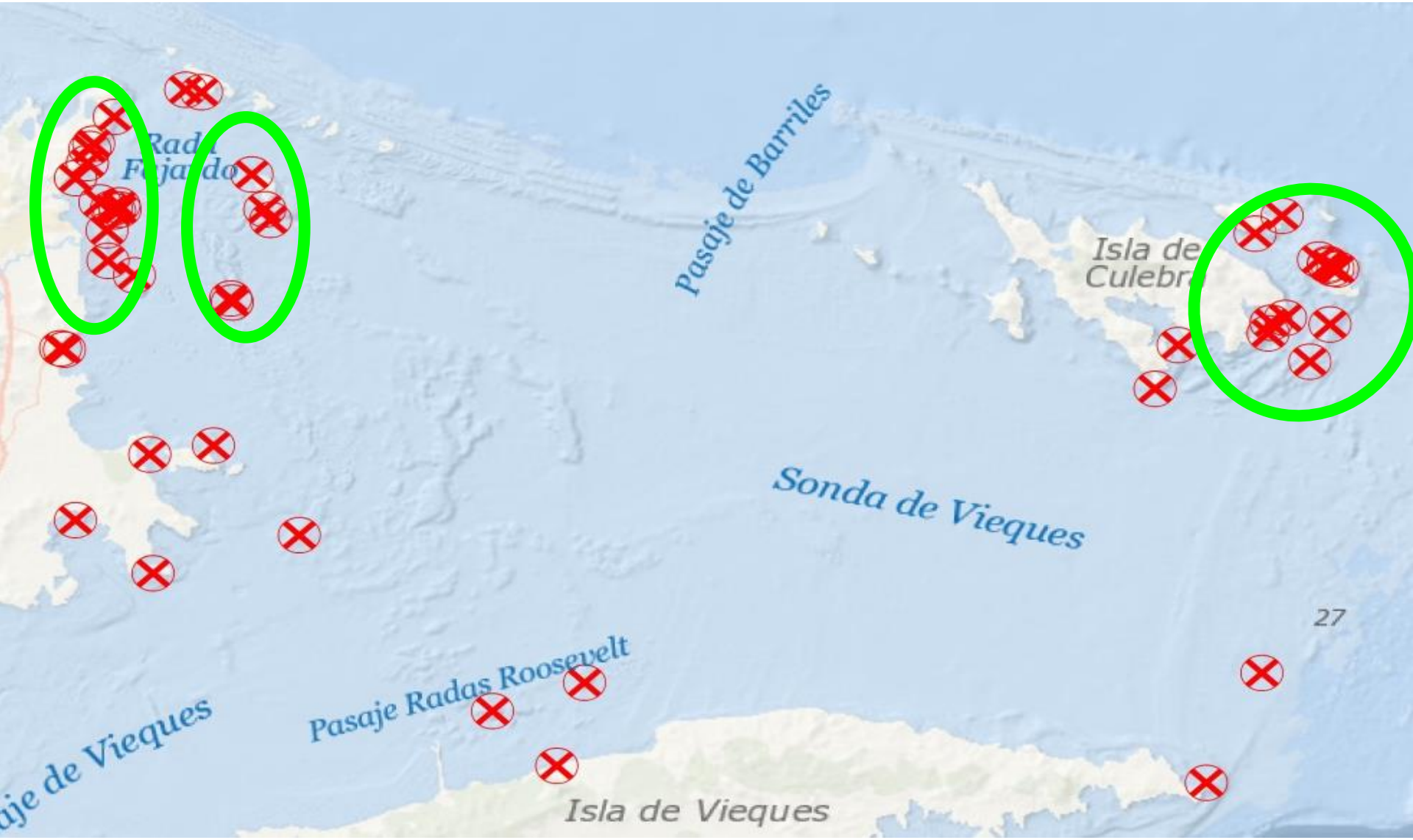
Time lapse series of stabilized *Acropora palmata* fragment in Vega Baja (10cm to over 1m in 6 years)

Storm generated fragments of *A. palmata* averaging 10-20cm in diameter were stabilized in 2008 in Vega Baja, PR in an area where there were no other colonies of *A. palmata.* In 2014 (shown below), many colonies were over 1 meter in diameter.

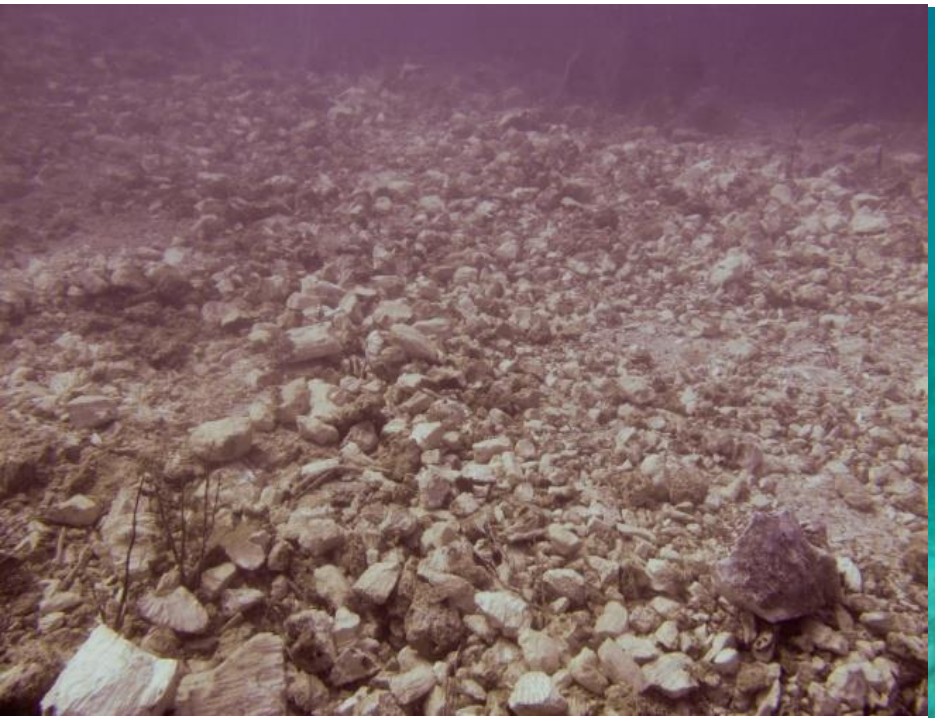
Reported Groundings in Puerto Rico's NE Reserve and Culebra (2009-2015)



NE Reserve hotspots (Fajardo, Palominos, Cayo Largo)
Culebra hotspots (Las Pelas and Culebrita)



LNG-C Matthews Grounding
Guayanilla, Puerto Rico; Dec. 2009



Post Grounding: 3,200 m^2 of reef were damaged. Most of the reef was flattened by vessel (resembled a parking lot)

LNG-C Matthews Grounding
Guayanilla, Puerto Rico; Dec. 2009

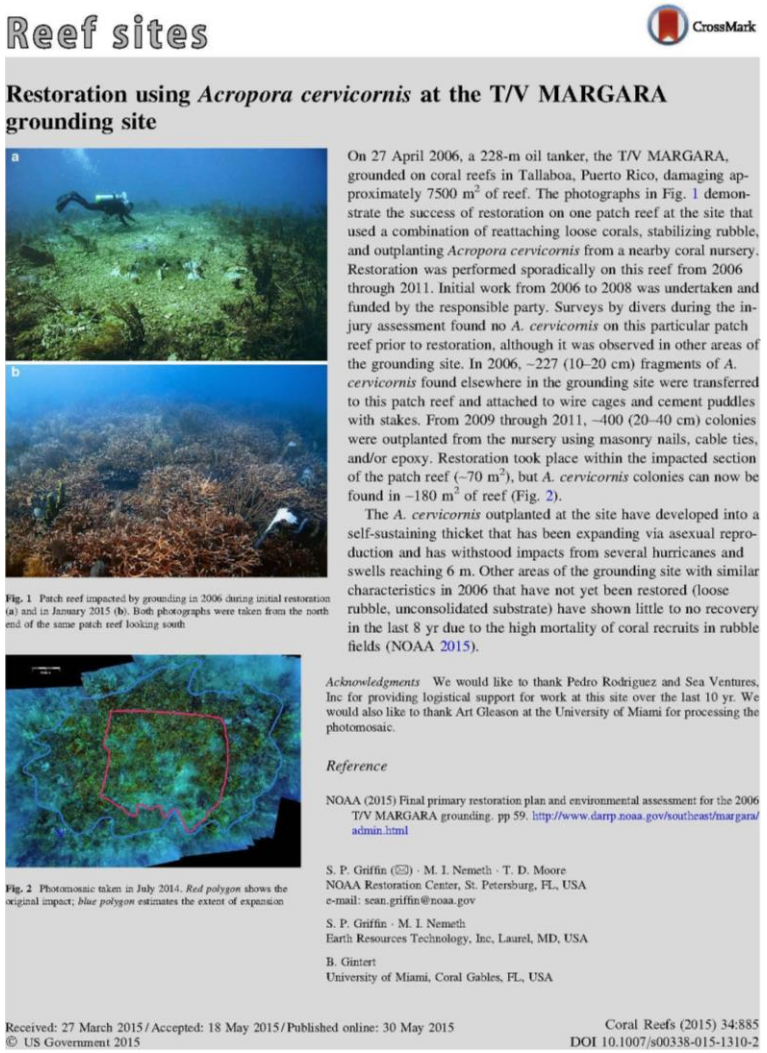
Comprehensive restoration focused on reattaching corals, stabilizing rubble and reconstructing lost topography.
7,000 corals were reattached during restoration.
Rugosity restored similar to unimpacted reef.

LNG-C Matthews Grounding
Guayanilla, Puerto Rico; Dec. 2009

Although 7,000 corals were saved during the restoration, 65,000 corals were unable to be recovered which left a lot of empty space. 1,100 *Acropora cervicornis* colonies were outplanted from the nursery at Margara to help accelerate recovery.

New publications by NOAA-RC

- Griffin et al. (2015)
- Description of *Acropora cervicornis* recovery trends at *T/V Margara* grounding site, PR
- 227 fragments (10-20 cm) in 2006
- 400 fragments (20-40 cm) in 2009-2011



Reef sites

CrossMark

Restoration using *Acropora cervicornis* at the T/V MARGARA grounding site

Fig. 1 Patch reef impacted by grounding in 2006 during initial restoration (a) and in January 2015 (b). Both photographs were taken from the north end of the same patch reef looking south

On 27 April 2006, a 228-m oil tanker, the T/V MARGARA, grounded on coral reefs in Tallaboa, Puerto Rico, damaging approximately 7500 m^2 of reef. The photographs in Fig. 1 demonstrate the success of restoration on one patch reef at the site that used a combination of reattaching loose corals, stabilizing rubble, and outplanting *Acropora cervicornis* from a nearby coral nursery. Restoration was performed sporadically on this reef from 2006 through 2011. Initial work from 2006 to 2008 was undertaken and funded by the responsible party. Surveys by divers during the injury assessment found no *A. cervicornis* on this particular patch reef prior to restoration, although it was observed in other areas of the grounding site. In 2006, ~227 (10–20 cm) fragments of *A. cervicornis* found elsewhere in the grounding site were transferred to this patch reef and attached to wire cages and cement puddles with stakes. From 2009 through 2011, ~400 (20–40 cm) colonies were outplanted from the nursery using masonry nails, cable ties, and/or epoxy. Restoration took place within the impacted section of the patch reef (~70 m^2), but *A. cervicornis* colonies can now be found in ~180 m^2 of reef (Fig. 2).

The *A. cervicornis* outplanted at the site have developed into a self-sustaining thicket that has been expanding via asexual reproduction and has withstood impacts from several hurricanes and swells reaching 6 m. Other areas of the grounding site with similar characteristics in 2006 that have not yet been restored (loose rubble, unconsolidated substrate) have shown little to no recovery in the last 8 yr due to the high mortality of coral recruits in rubble fields (NOAA 2015).

Fig. 2 Photomosaic taken in July 2014. *Red polygon* shows the original impact; *blue polygon* estimates the extent of expansion

Acknowledgments We would like to thank Pedro Rodriguez and Sea Ventures, Inc for providing logistical support for work at this site over the last 10 yr. We would also like to thank Art Gleason at the University of Miami for processing the photomosaic.

Reference

NOAA (2015) Final primary restoration plan and environmental assessment for the 2006 T/V MARGARA grounding. pp 59. http://www.darrp.noaa.gov/southeast/margara/admin.html

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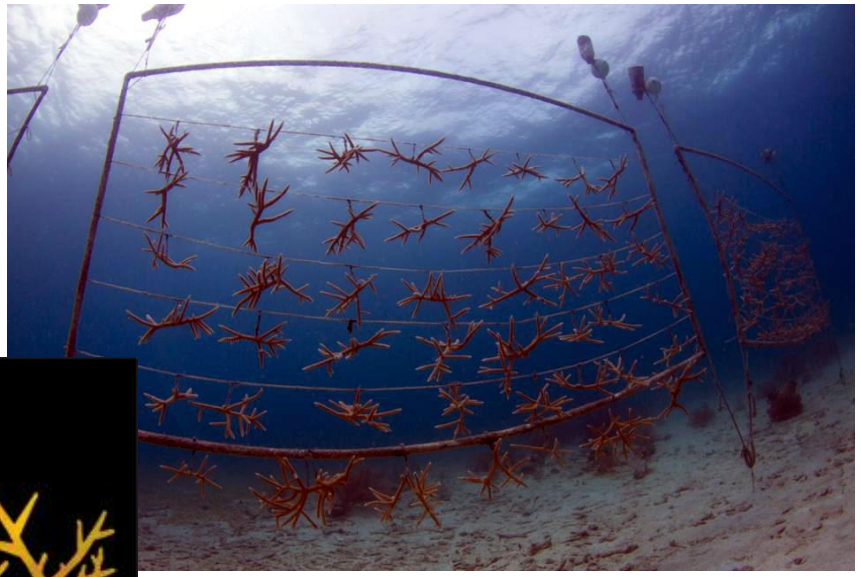
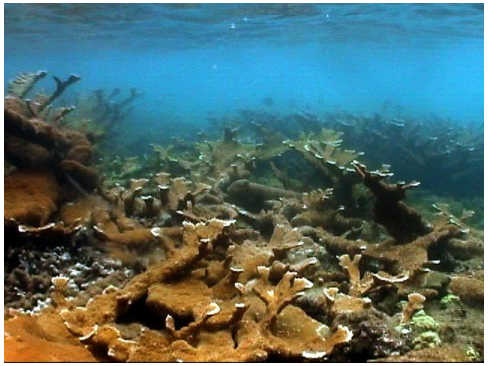
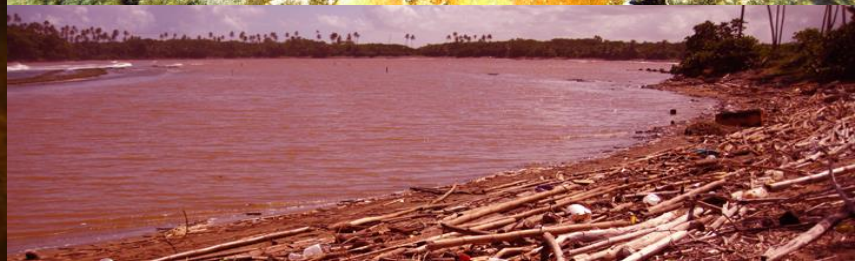
HRJ-ReefScaping

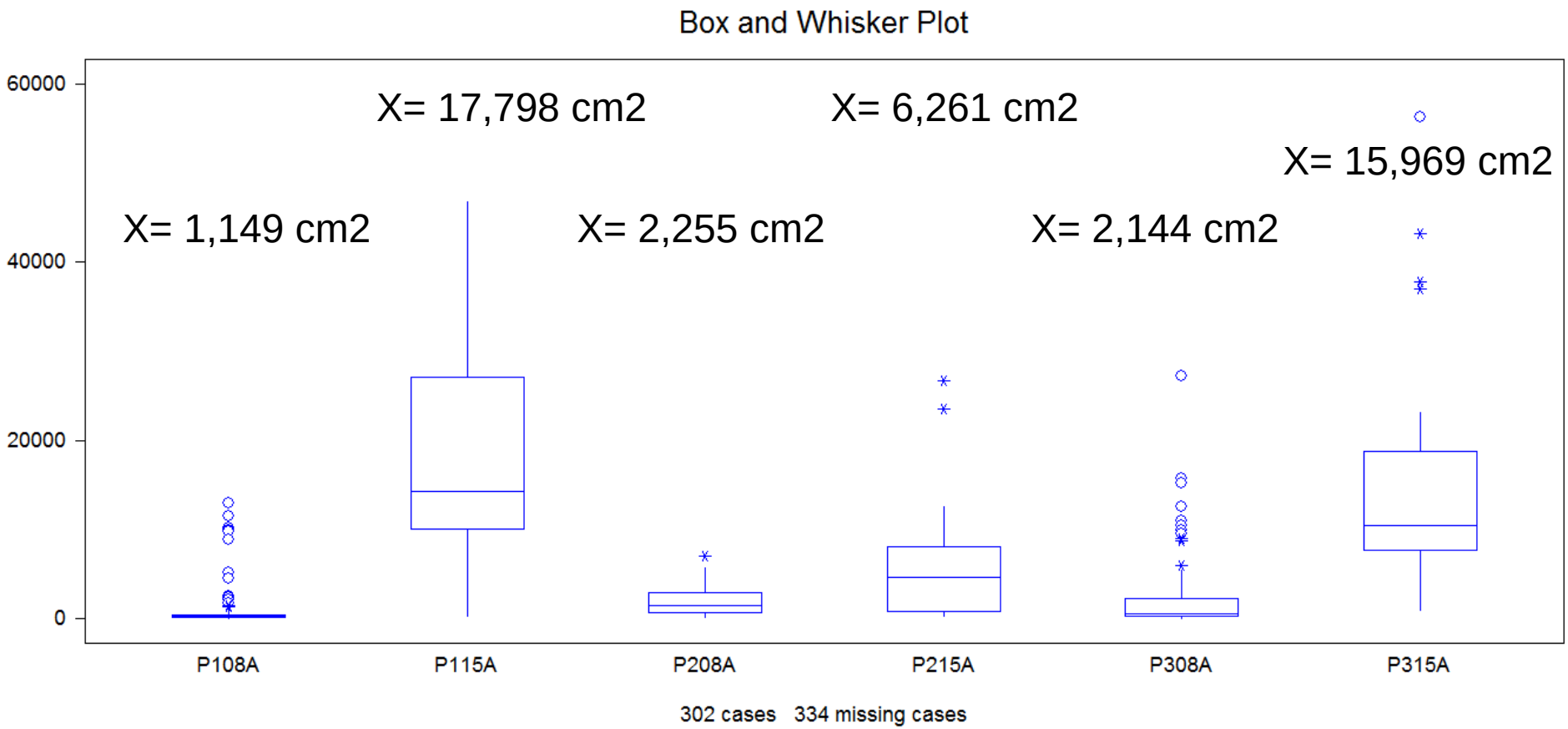


VIDAS + UPR/CATEC + SAM +DNER lead a massive Elkhorn coral (*Acropora palmata*) emergency restoration effort following a severe winter swell (March 18-21, 2008)



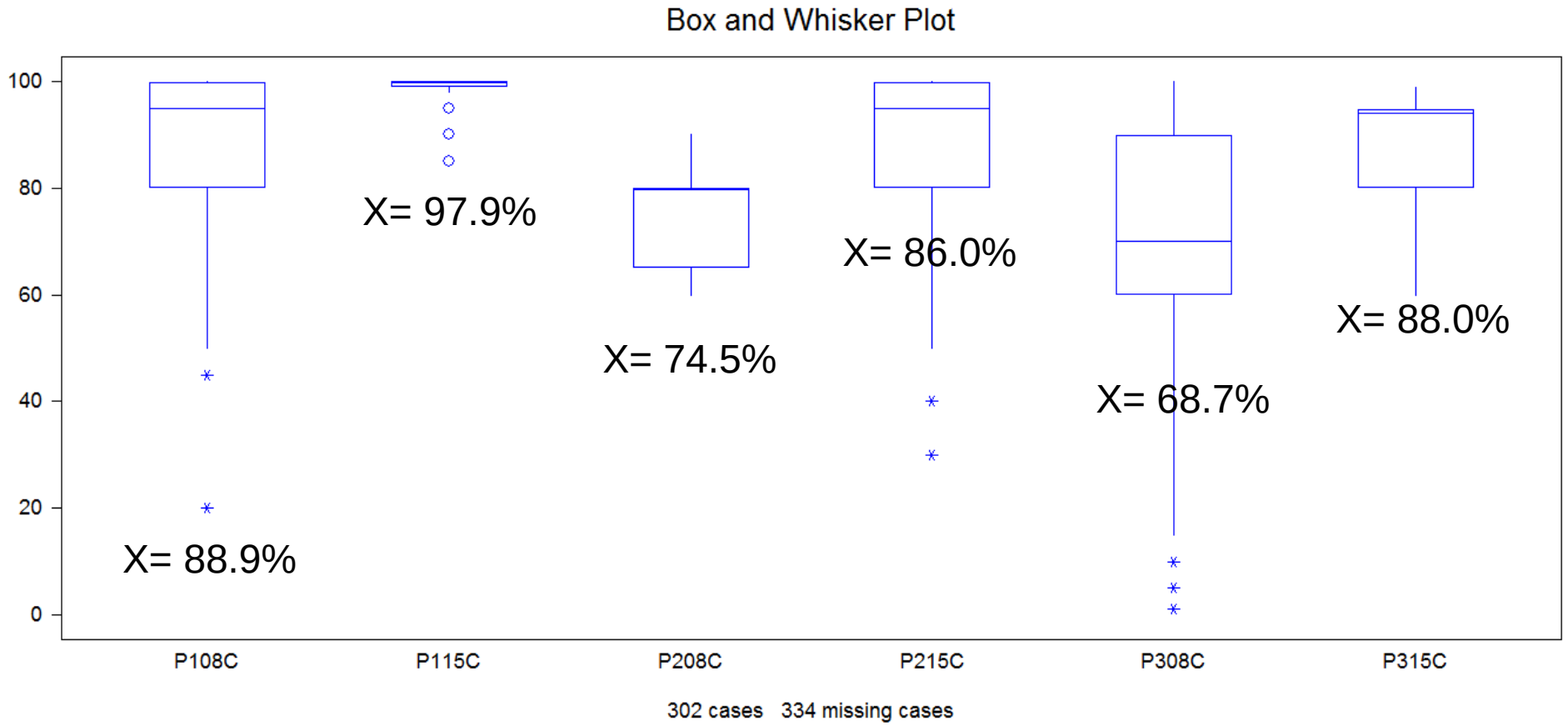


Outstanding restored *A. palmata* growth at Vega Baja (2008-2015)



2008 Plot 1	2015 Plot 1	2008 Plot 2	2015 Plot 2	2008 Plot 3	2015 Plot 3

Outstanding restored *A. palmata* growth at Vega Baja (2008-2015)



2008 Plot 1	2015 Plot 1	2008 Plot 2	2015 Plot 2	2008 Plot 3	2015 Plot 3

2 Years

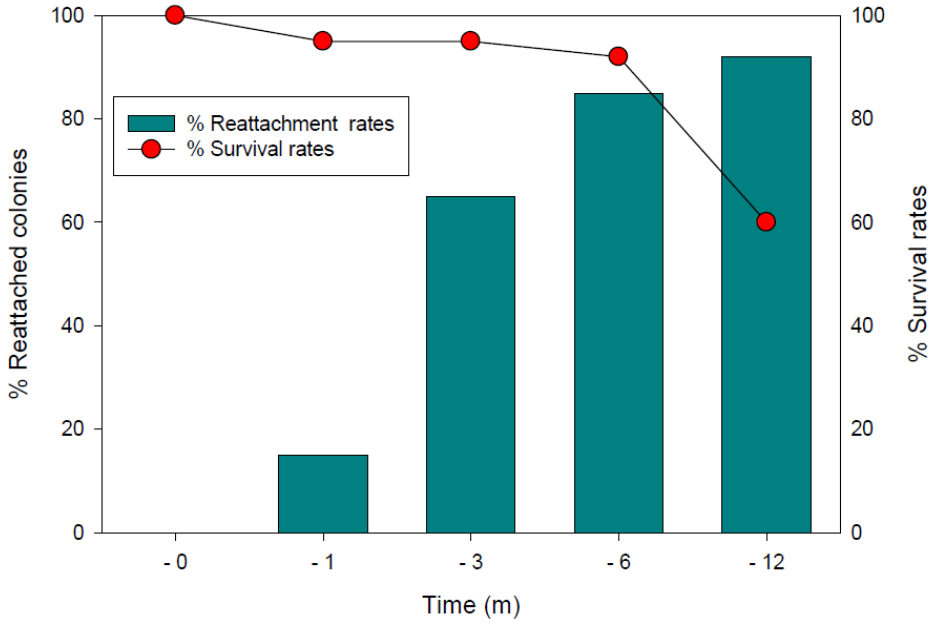
7 Years

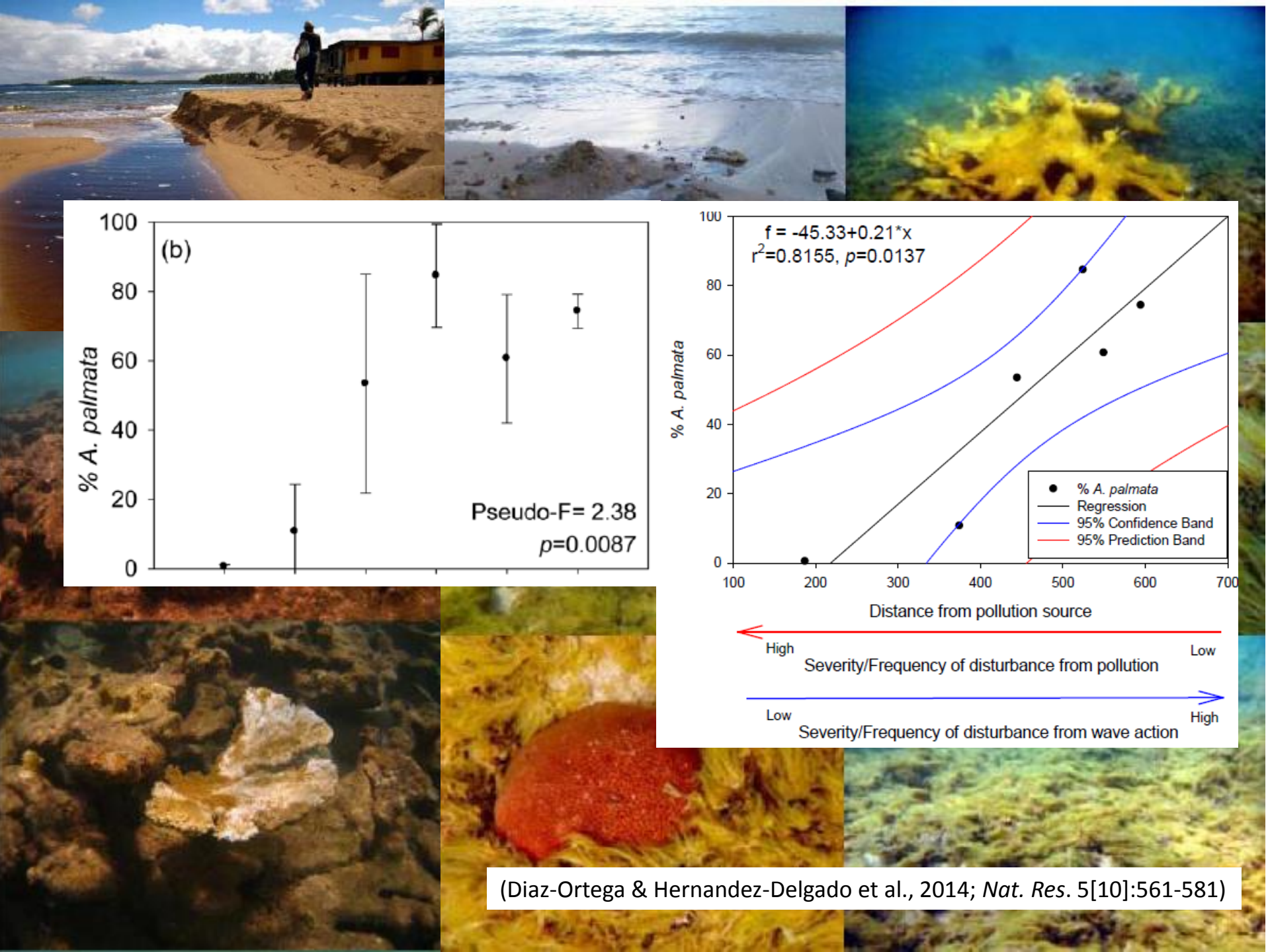
3 Y

Vega Baja still supports impressive remnant populations of *Acropora palmata*

There is still illegal sewage dumping at Vega Baja

- Rapid recovery of low-tech replanted coral fragments (VIDAS, UPR, DNER) (n=645)
- High colony survival rates, skeletal growth and branching production
- But sewage and sediment bedload impacted survival across some reef segments!





(Diaz-Ortega & Hernandez-Delgado et al., 2014; *Nat. Res*. 5[10]:561-581)

Need of immediate action from Commonwealth and Federal regulatory agencies to stop raw sewage dumping along the Vega Baja coast

Community-based (VIDAS) collaboration with academia (CATEC/UPR), DNER and the Commonwealth Legislature for the designation of the Vega Baja and Manati Submarine Gardens Natural Reserve

ESTADO LIBRE ASOCIADO DE PUERTO RICO

17ma. Asamblea Legislativa — 6ta. Sesión Ordinaria

SENADO DE PUERTO RICO

P. del S. _____

___ de octubre de 2015

Presentado por los señores *Tirado Rivera y* ____________

LEY

académicas para el manejo conjunto de la reserva, incluyendo a Vegabajeños Impulsando Desarrollo Ambiental Sustentable (VIDAS), la Sociedad Ambiente Marino (SAM), el Grupo de Investigación de Arrecifes de Coral (GIAC) del Centro para la Ecología Tropical Aplicada y Conservación (CATEC) de la Universidad de Puerto Rico; fijar la obligación del DRNA de rendir informes anuales a la Asamblea Legislativa; asignar fondos para la implantación de las disposiciones de esta Ley; y para otros fines relacionados.

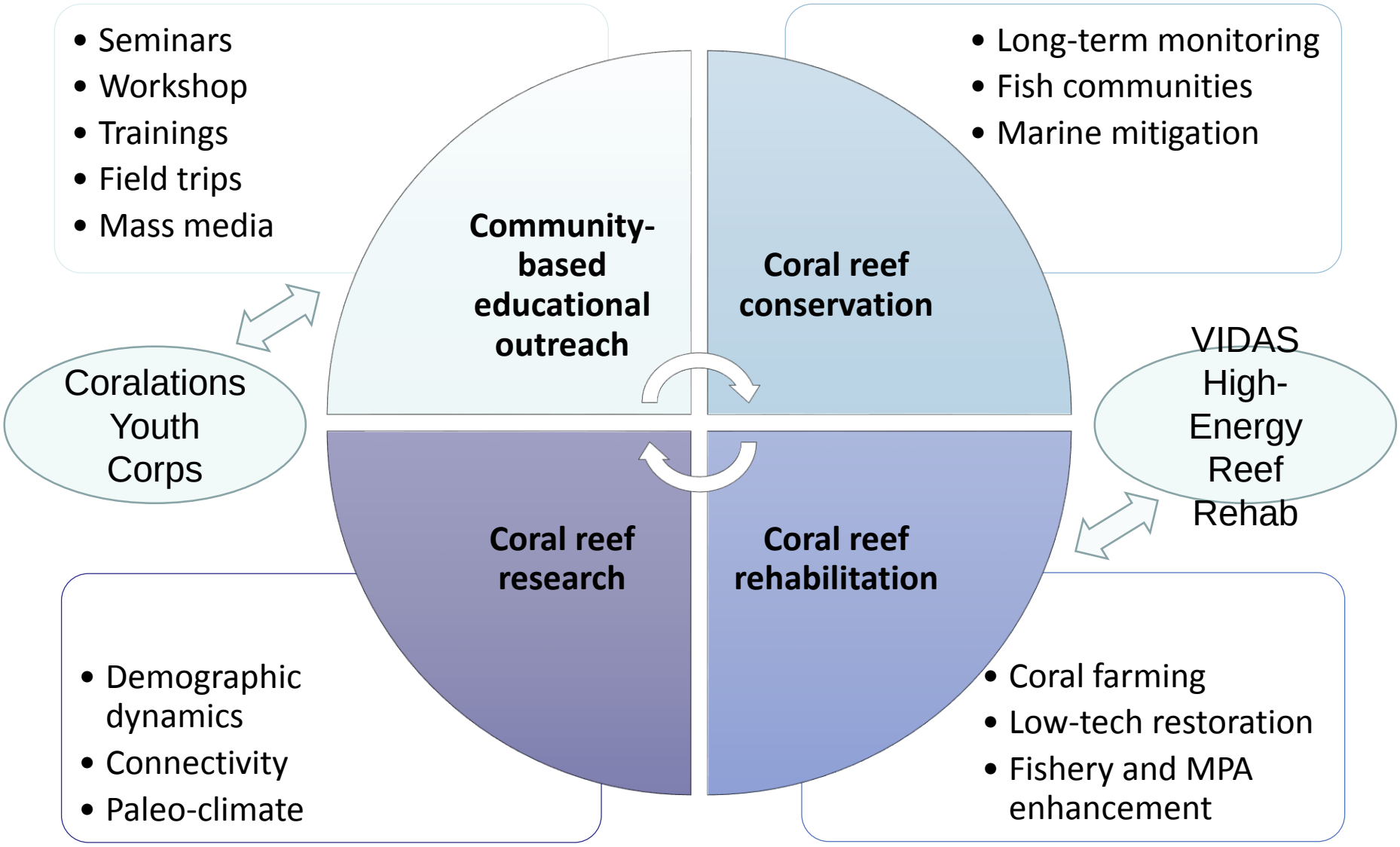
EXPOSICIÓN DE MOTIVOS

La protección y conservación del medio ambiente y los recursos naturales es una labor que adquiere progresivamente mayor importancia, ante la presión creciente a las que la naturaleza puertorriqueña se ve sometida por el desarrollo desmedido, así como por las realidades geográficas, demográficas, económicas y sociales. Las exigencias del poder

Community-Based Coral Aquaculture and Reef Rehabilitation Program


SAM

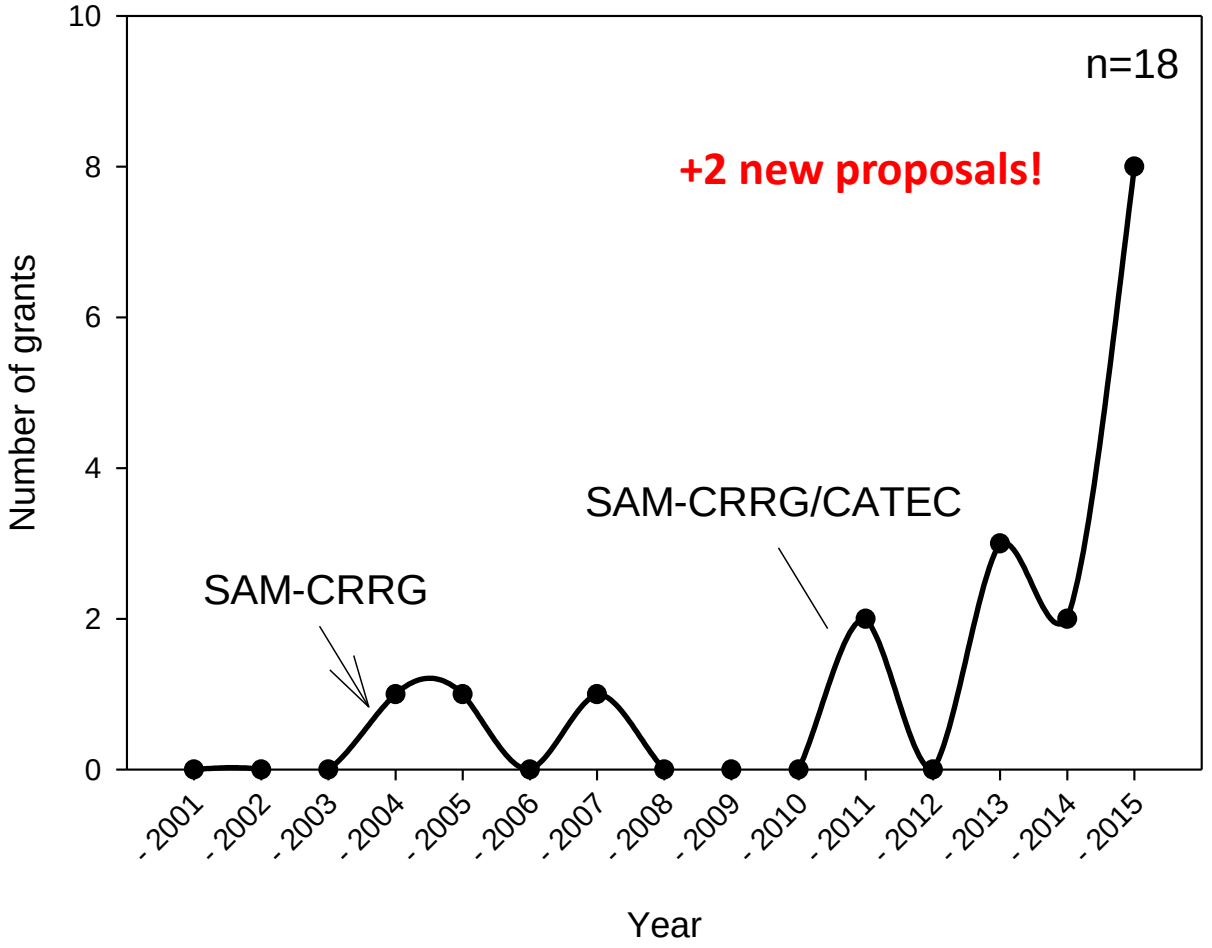
CATEC-SAM collaboration

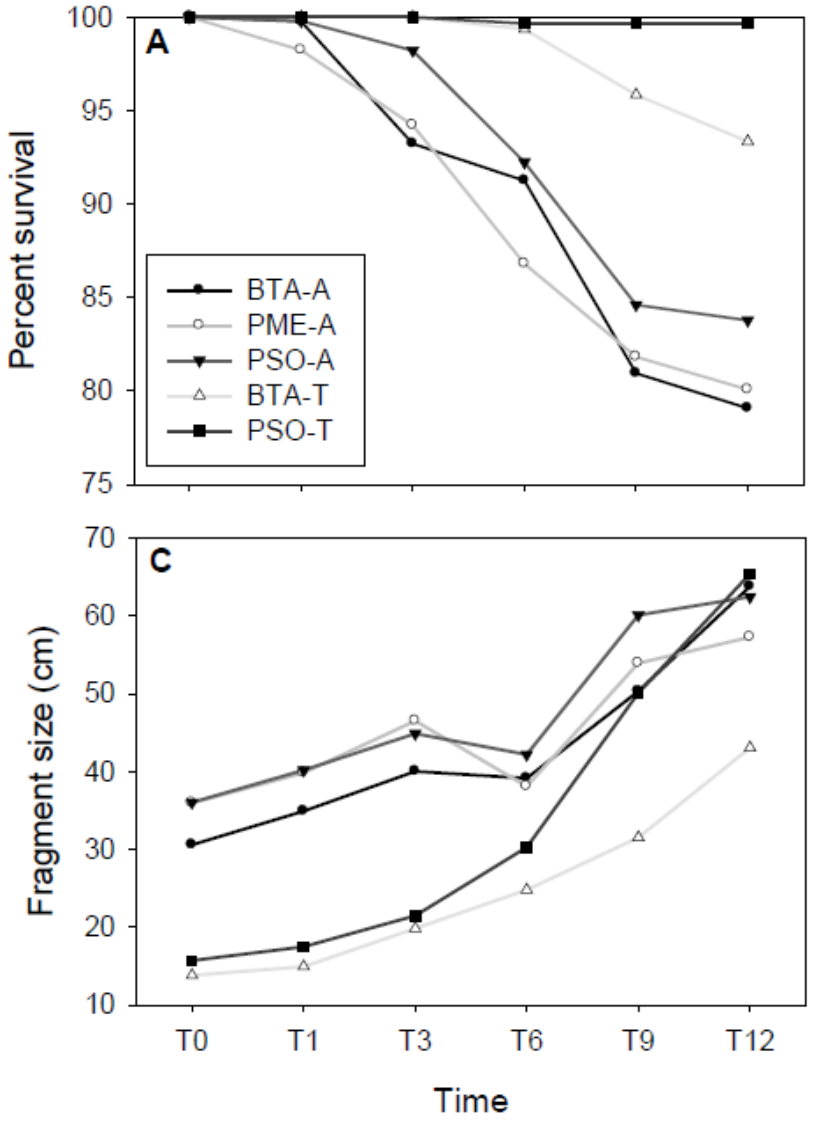


UPR/CATEC + SAM produced 16 peer-reviewed publications during 2014-2015

Some of these peer reviewed publications address elements critical for guiding future coral reef conservation, farming, and rehabilitation efforts (i.e., coral farming, demographic dynamics, LBSP impacts, land use change, coral immunology, climate change)

CATEC+SAM=
Reversing the equation!





(Hernandez-Delgado et al., 2014a; *Open J. Ecol*. 4[14]:918-944)

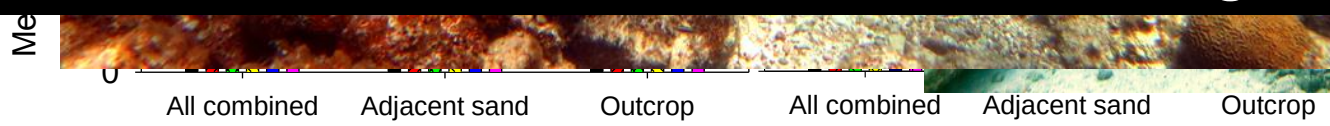
Coral farming and rehabilitation of reefs in Culebra Island

SAM-UPR/CATEC and Colectivo Cayo La Yayi are launching in 2015 the Bieke Community-Based Reef Rescue Project

But there is still a need to fully remove all unexploded ordnance from Vieques and Culebra islands

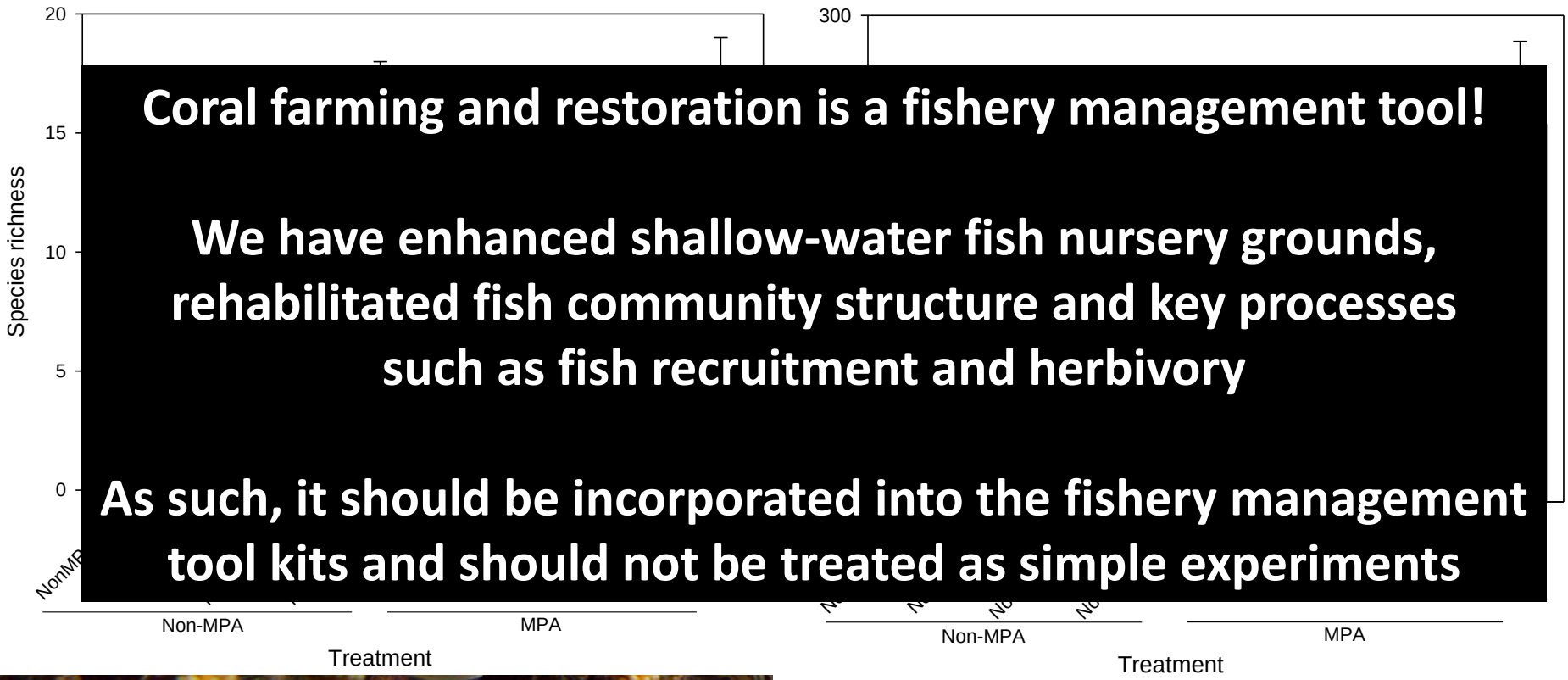
The U.S. Navy must pay all cleaning and all ecological restoration of Vieques and Culebra coral reefs within impacted areas

Return all cleaned lands to the Commonwealth government



(Hernandez-Delgado et al., 2014b; *Rev. Biol. Trop*. 62[Suppl. 3]:183-200)

Juvenile reef fish habitat rehabilitation

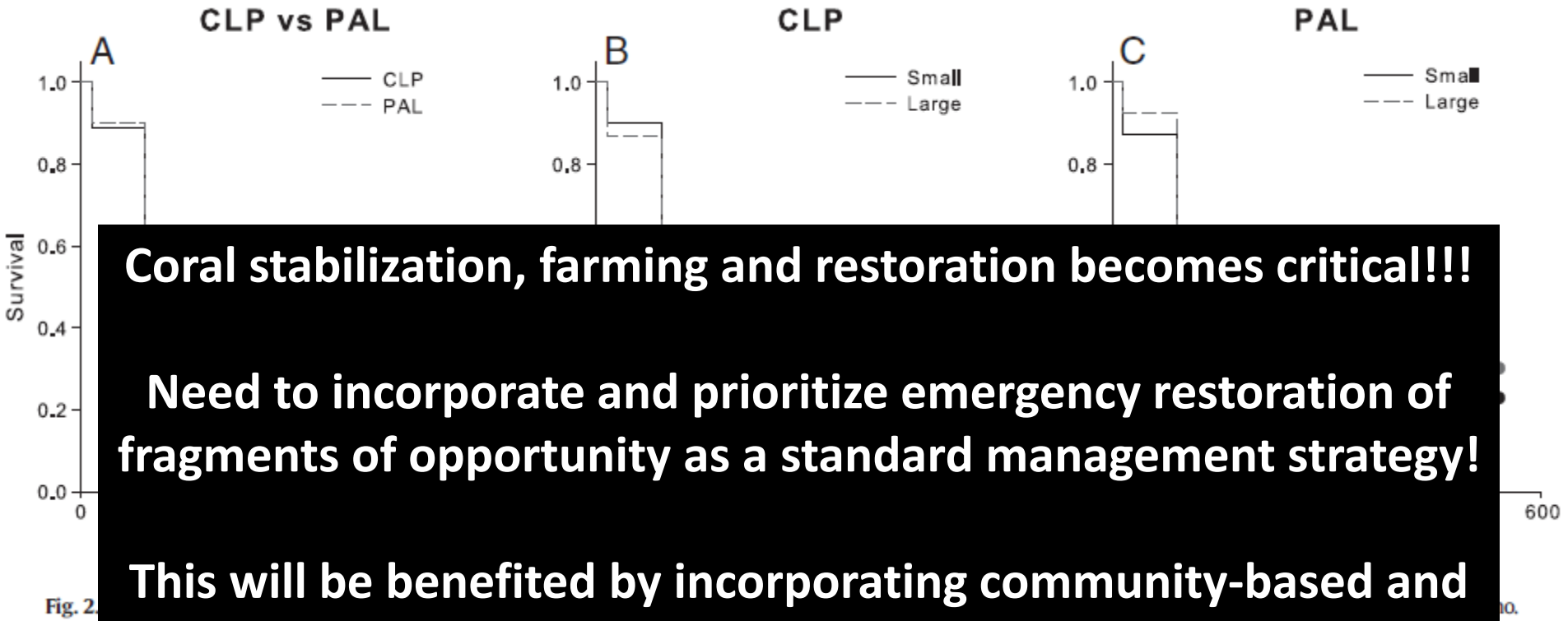


Coral farming and restoration is a fishery management tool!

We have enhanced shallow-water fish nursery grounds, rehabilitated fish community structure and key processes such as fish recruitment and herbivory

As such, it should be incorporated into the fishery management tool kits and should not be treated as simple experiments

Compromised demographic dynamics of *Acropra cervicornis* lose fragments



Coral stabilization, farming and restoration becomes critical!!!

Need to incorporate and prioritize emergency restoration of fragments of opportunity as a standard management strategy!

This will be benefited by incorporating community-based and NGOs training, certification and participation

(Mercado-Molina et al., 2014; *J. Exp. Mar. Biol. Ecol*. 457:215-219)

Projected collapse of *Acropora cervicornis* restored populations

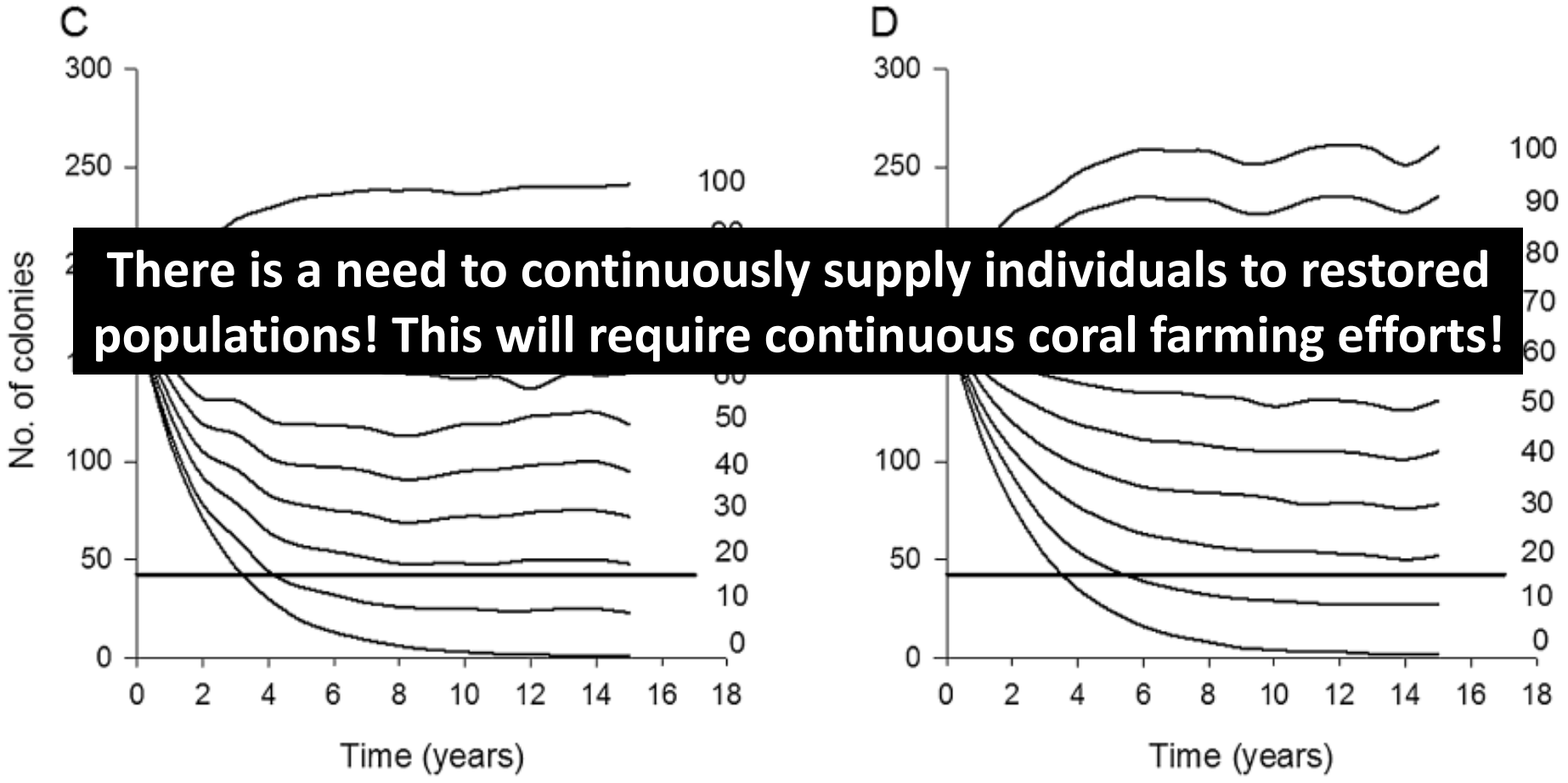
Corals need to be sustainably propagated and added to restored populations. Otherwise, restored populations (from single shot efforts) may go to extinction within less than two decades

Coral farming and restoration must be sustainably financed and should not be disregarded simply as non-priority case by case projects!

Coral farming and reef restoration must be one of the top management priorities!

Programmatic funding through DNER should be the most simple and logical way to support most operations

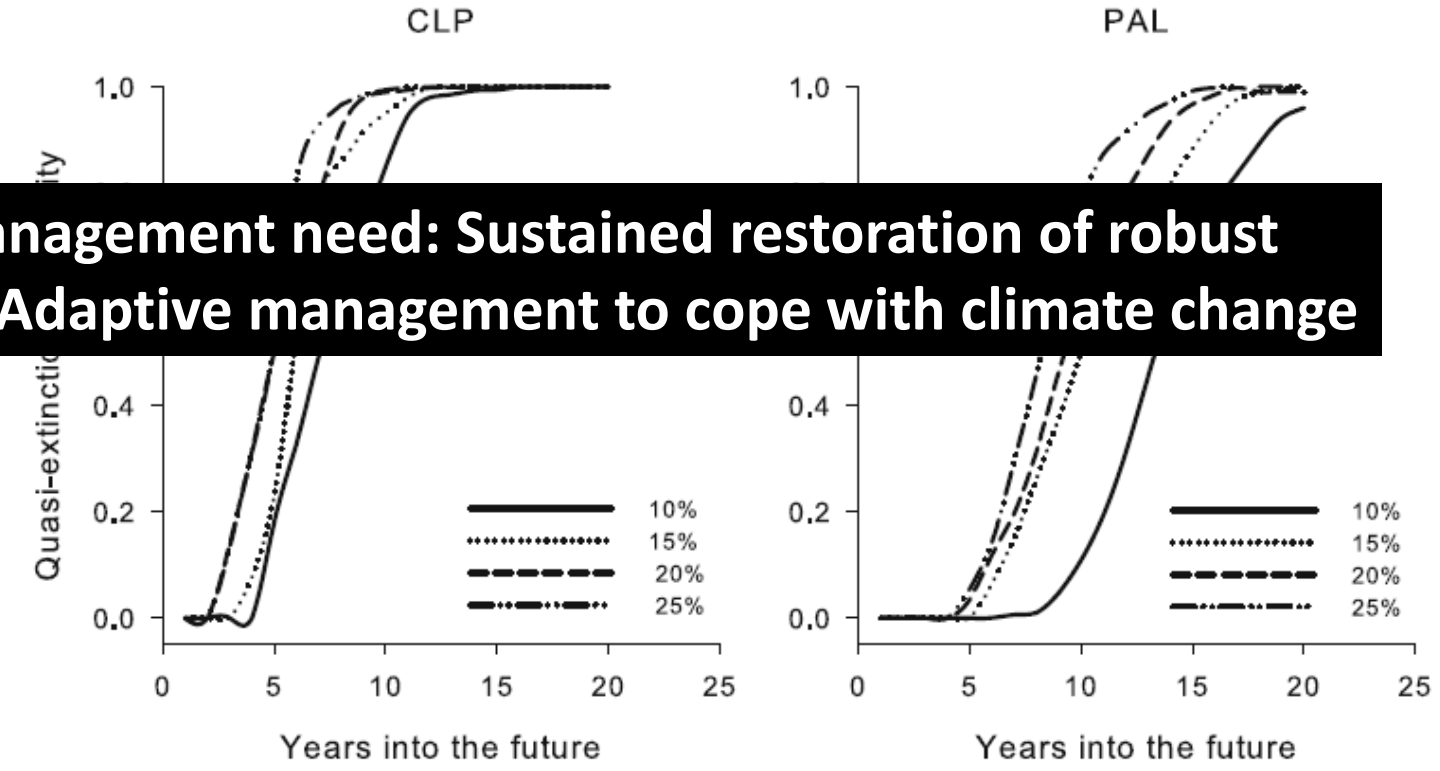
Sustained addition of *Acropora cervicornis* colonies to restored populations



There is a need to continuously supply individuals to restored populations! This will require continuous coral farming efforts!

(Mercado-Molina et al., 2015a; *J. Nat. Conserv*. 24:17-23)

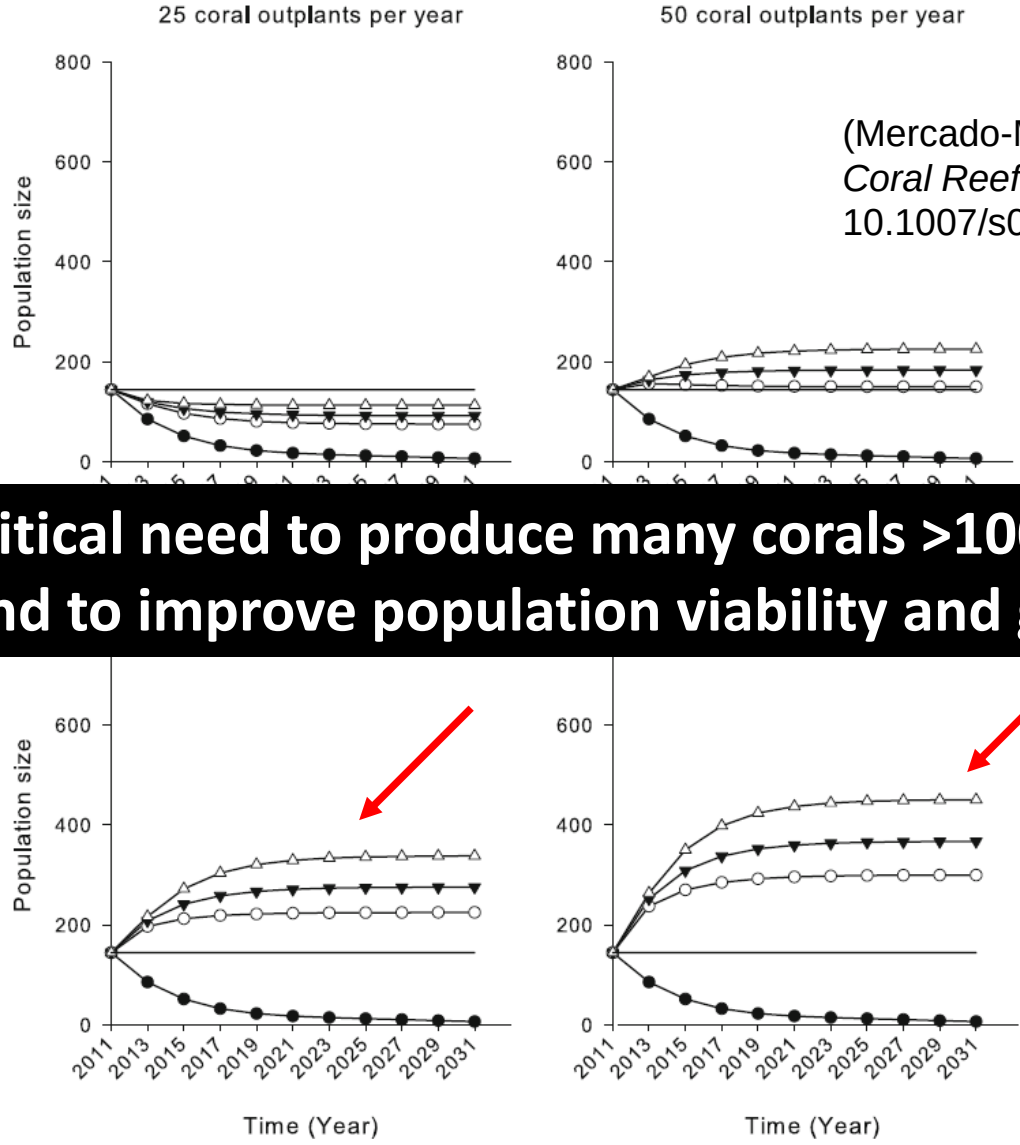
Population viability analysis of wild *Acropora cervicornis* populations suggest rapid potential of extinction



Critical management need: Sustained restoration of robust populations; Adaptive management to cope with climate change

(Mercado-Molina et al., 2015b; *Coral Reefs* DOI 10.1007/s00338-015-1341-8)

Size does matter in *Acropora cervicornis*!!!



(Mercado-Molina et al., 2015b; *Coral Reefs* DOI 10.1007/s00338-015-1341-8

There is a critical need to produce many corals >100 cm TL for outplanting and to improve population viability and growth (λ>1)

Fig. 4 Simulated trajectories of the *Acoprora cervicornis* population size over time at Canal Luis Peña using different numbers and sizes of transplanted colonies based on the stochastic mean matrix. *Solid line* = initial population size (N_0 = 144); *closed circles* = population trajectory with no outplants; *open circles* = small-sized outplants; *closed triangles* = medium-sized outplants; *open triangles* = large-sized outplant

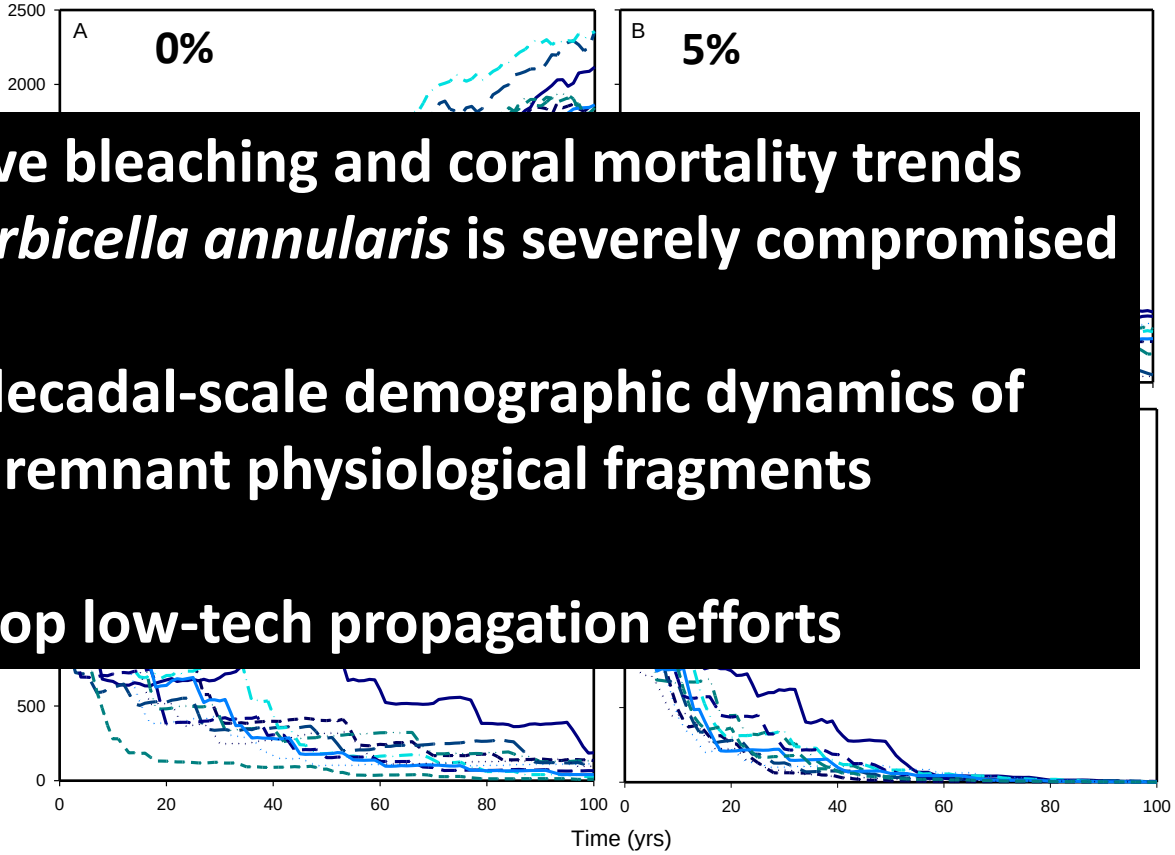
Stochastic trajectory of an *Orbicella annularis* population through diverse massive bleaching and mass mortality probabilities

Population growth under no bleached conditions

5 p

1 si

2 population collapse (30-40y)



Under current massive bleaching and coral mortality trends population viability of *Orbicella annularis* is severely compromised

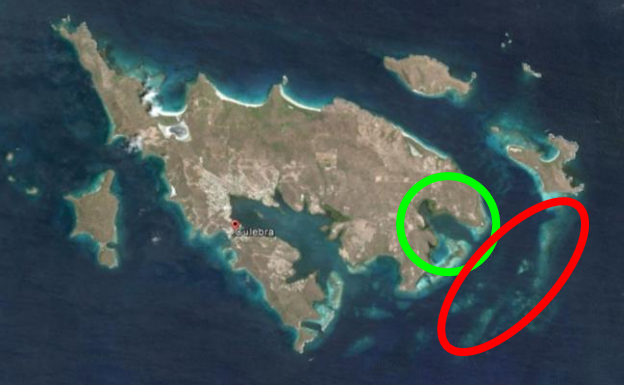
Currently analyzing decadal-scale demographic dynamics of post-bleaching remnant physiological fragments

Need to develop low-tech propagation efforts

(Hernández-Pacheco et al., 2011;*Ecosphere* 2(1):art9. 1-13)

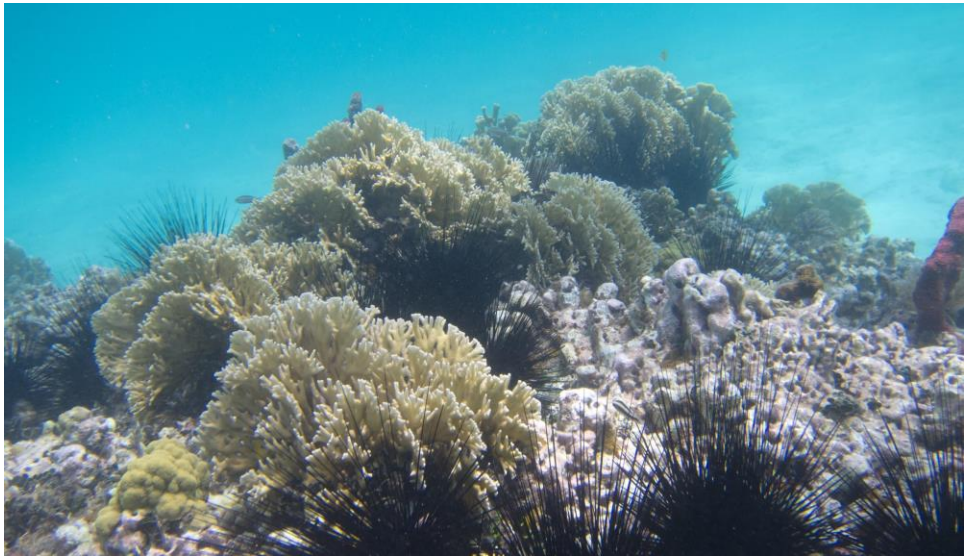
Anchoring impacts

- Destruction by accidental anchoring, even in the presence of mooring buoys
- Requires rapid emergency restoration responses
- Need to designate all coral farming and reef rehabilitation sites as Coral Reef Recovery Zones (Law 147, 1999)



Frequent Recreational Vessel Groundings at Las Pelas Reef and Los Corchos Reefs System, Culebra

Repeated grounding impacts to reef jutting out into channel at Las Pelas through Los Corchos reef system could be avoided through installation of Aids to Navigation



Final recommendations

- Need to strengthen support to coral farmers
- Support needs to become continuous and sustained
- DNER should be the leading coordinating institution in PR – Requires continuous support through Programmatic Funding from NOAA
- The U.S. Navy must support coral farming and reef restoration efforts in Vieques and Culebra

Final recommendations

- Coral farming and reef rehabilitation is a proven fishery management tool
- Program priorities need to be reviewed to incorporate coral farming and reef rehabilitation as management tools
- Need to improve the spatial scale of reef rehabilitation efforts

Final recommendations

- Incorporate coral population modeling into coral farming and reef rehabilitation management

  - Improve decision-making and management priorities
  - Improve site selection decisions (in coordination with oceanographic modeling)
  - Address multiple ecological questions, such as impacts by:

    - LBSP
    - Outcompetition by encrusting red algae *Ramicrusta textilis*
    - Diseases
    - Physiological dynamics

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