Functional eradication as a framework for invasive lionfish control

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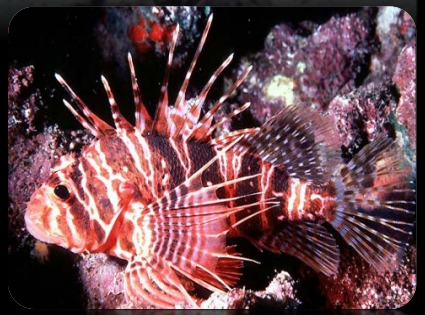
BEUCHAT

Invasive Indo-Pacific lionfish in the Western Atlantic













Raju Saravanan

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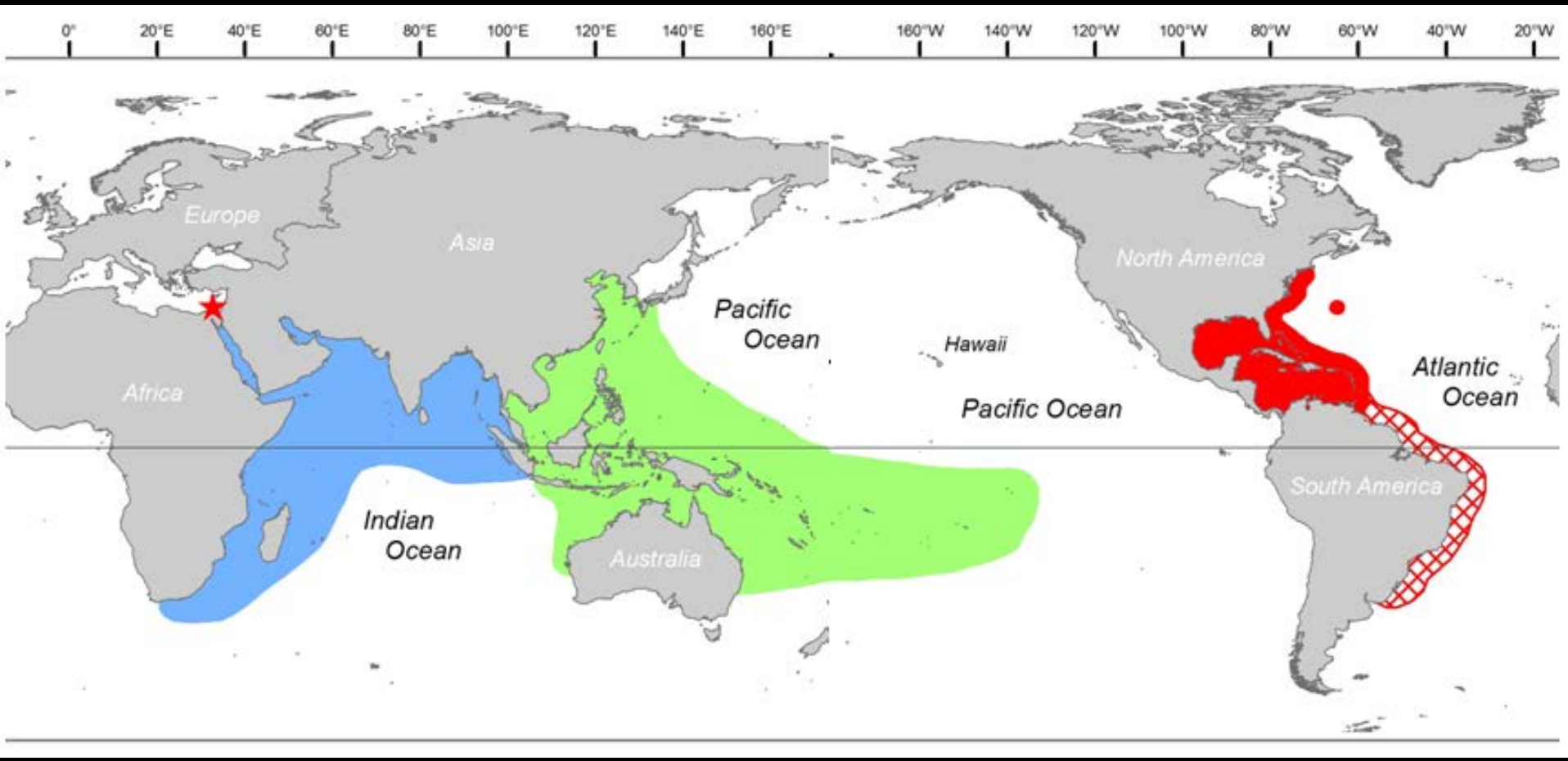
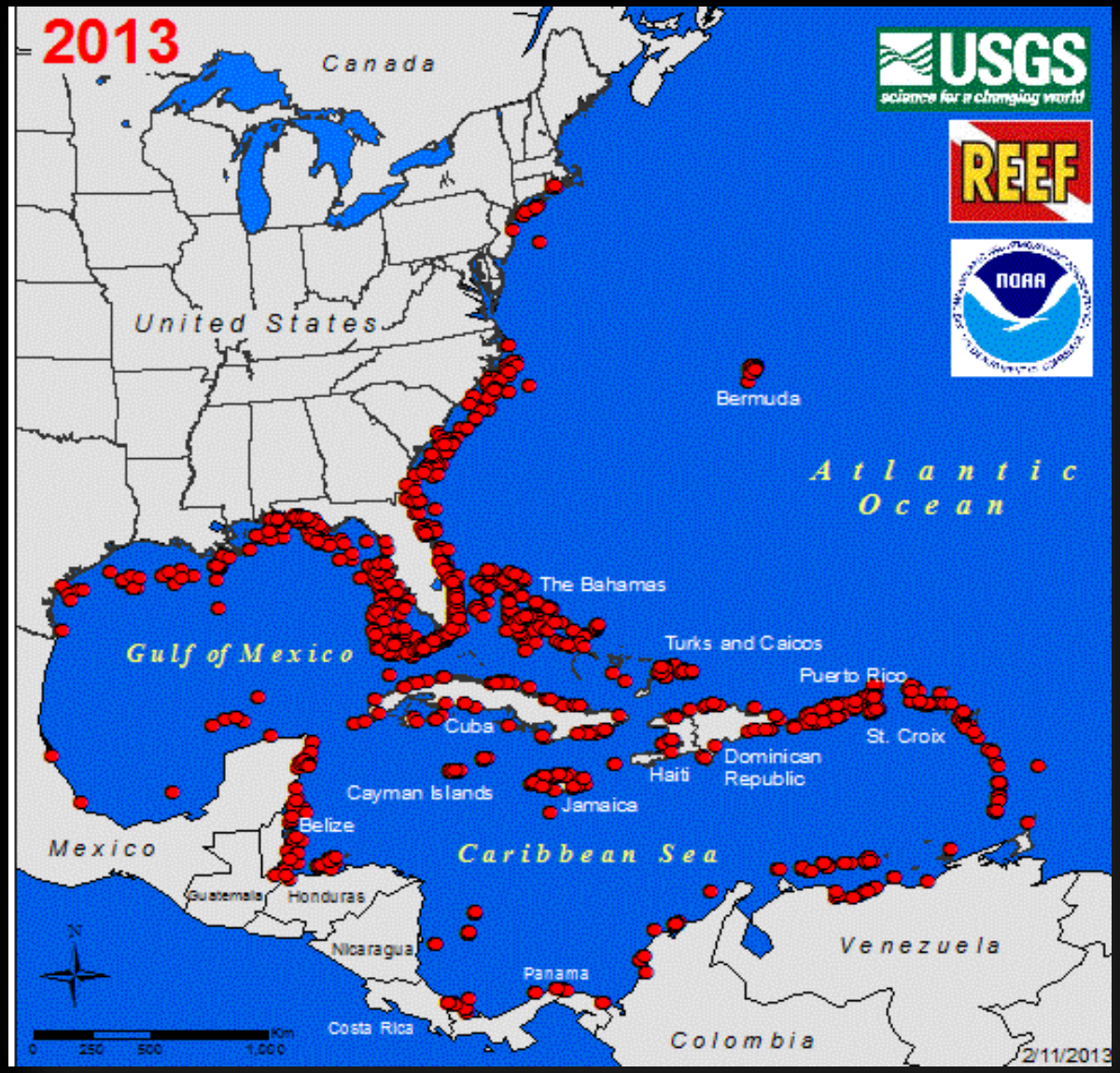
Lionfish Distribution

- Red Lionfish – Pterois volitans
- Devil Firefish – Pterois miles



Invasion status



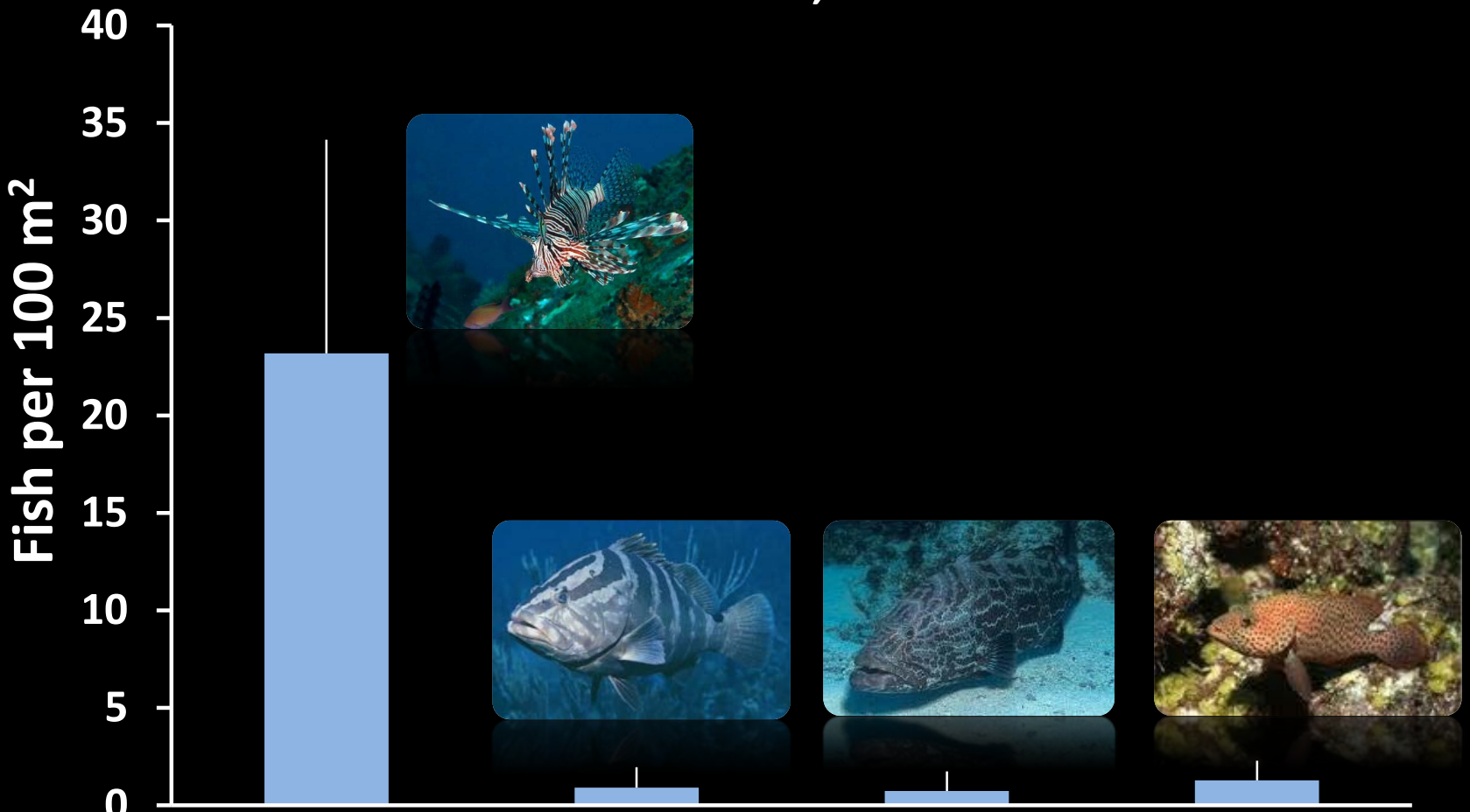
USGS Non-indigenous Aquatic Species Database 2013

Lionfish abundance has increased rapidly

Green et al. 2012 PLoS ONE

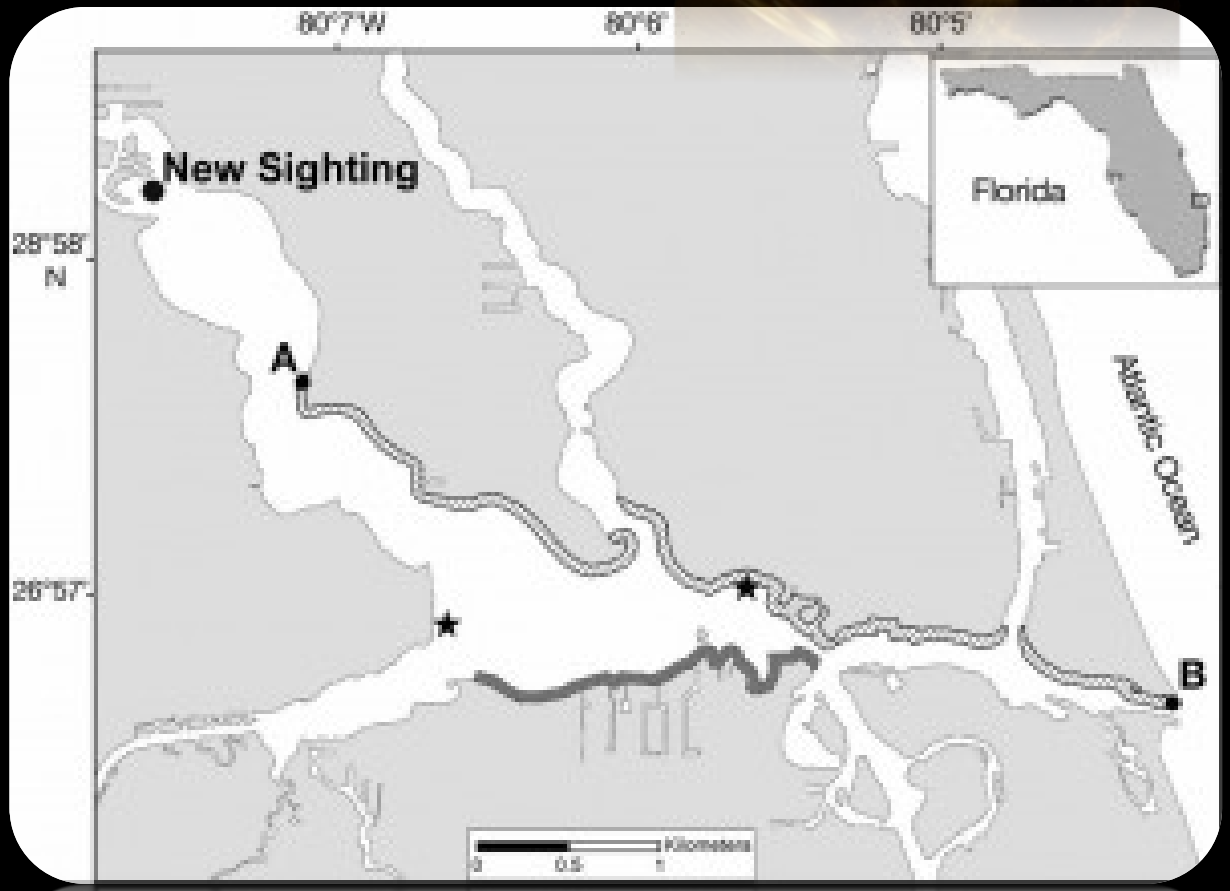
Relative predator abundance

Eleuthera, Bahamas



Green et al. 2012 PloS ONE

Lionfish in the Loxahatchee River

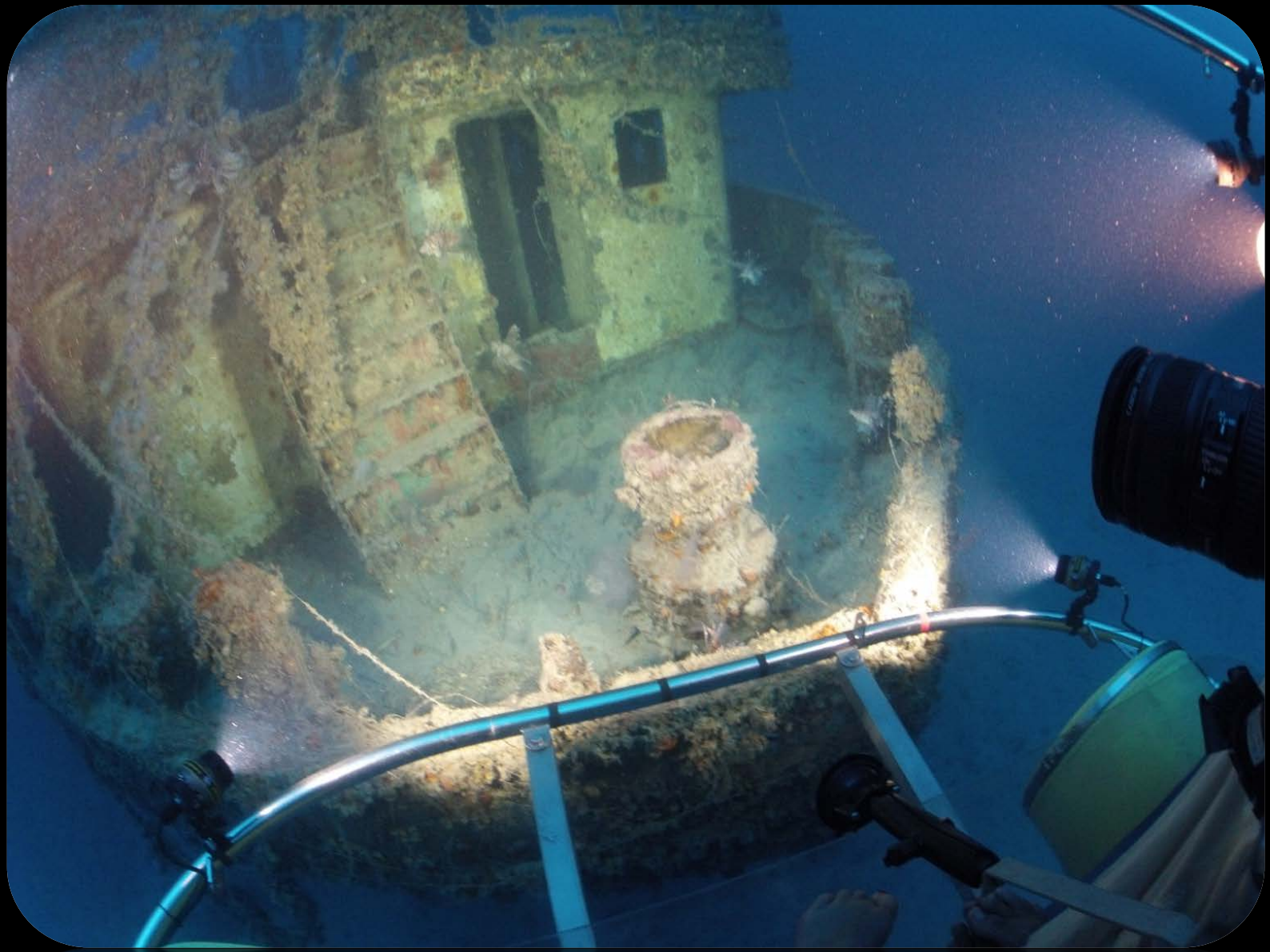


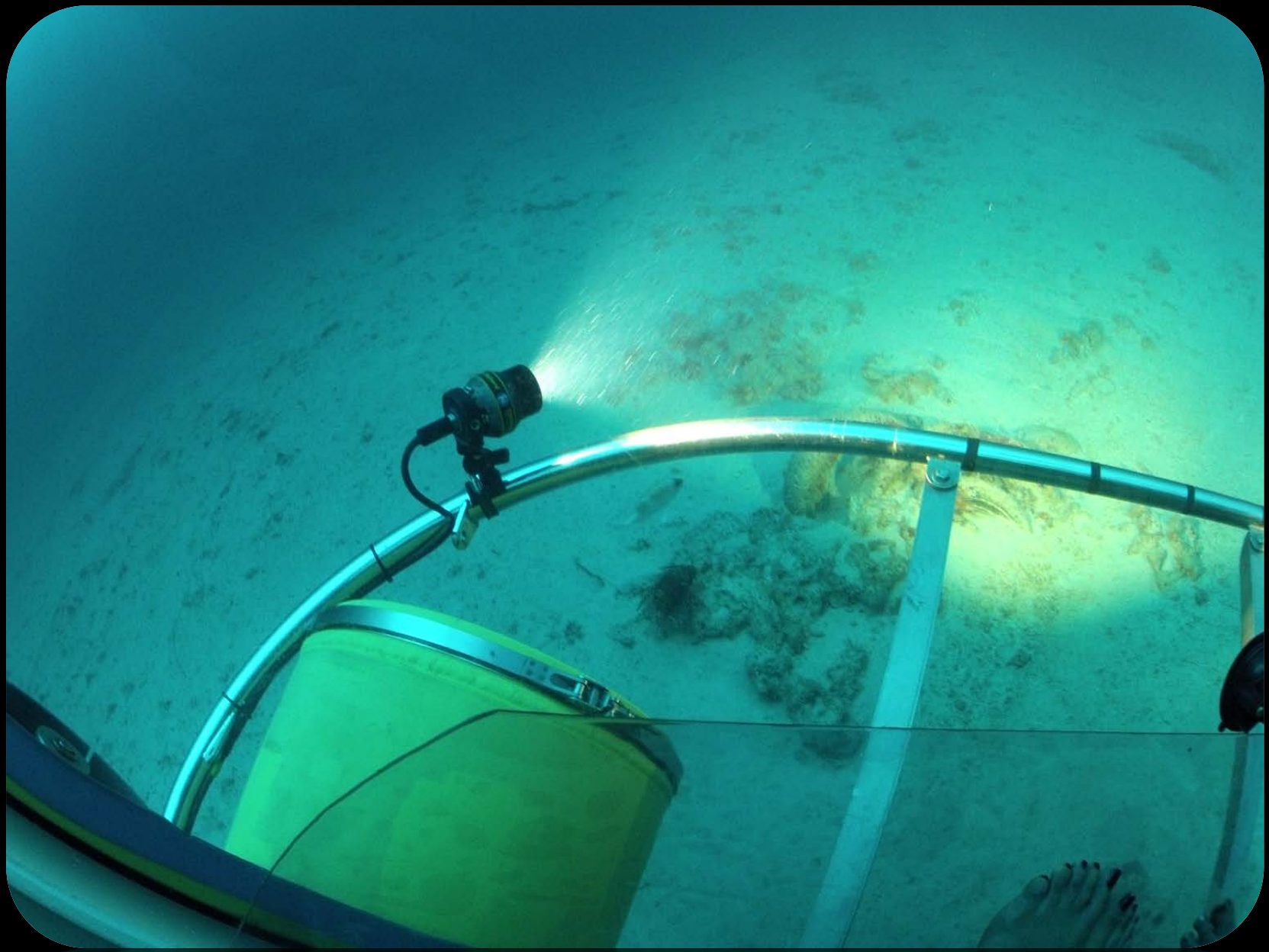
Judd and Layman 2012

The lionfish have invaded an area similar in size to which state?

Potential lionfish range

Morris & Whitfield 2009





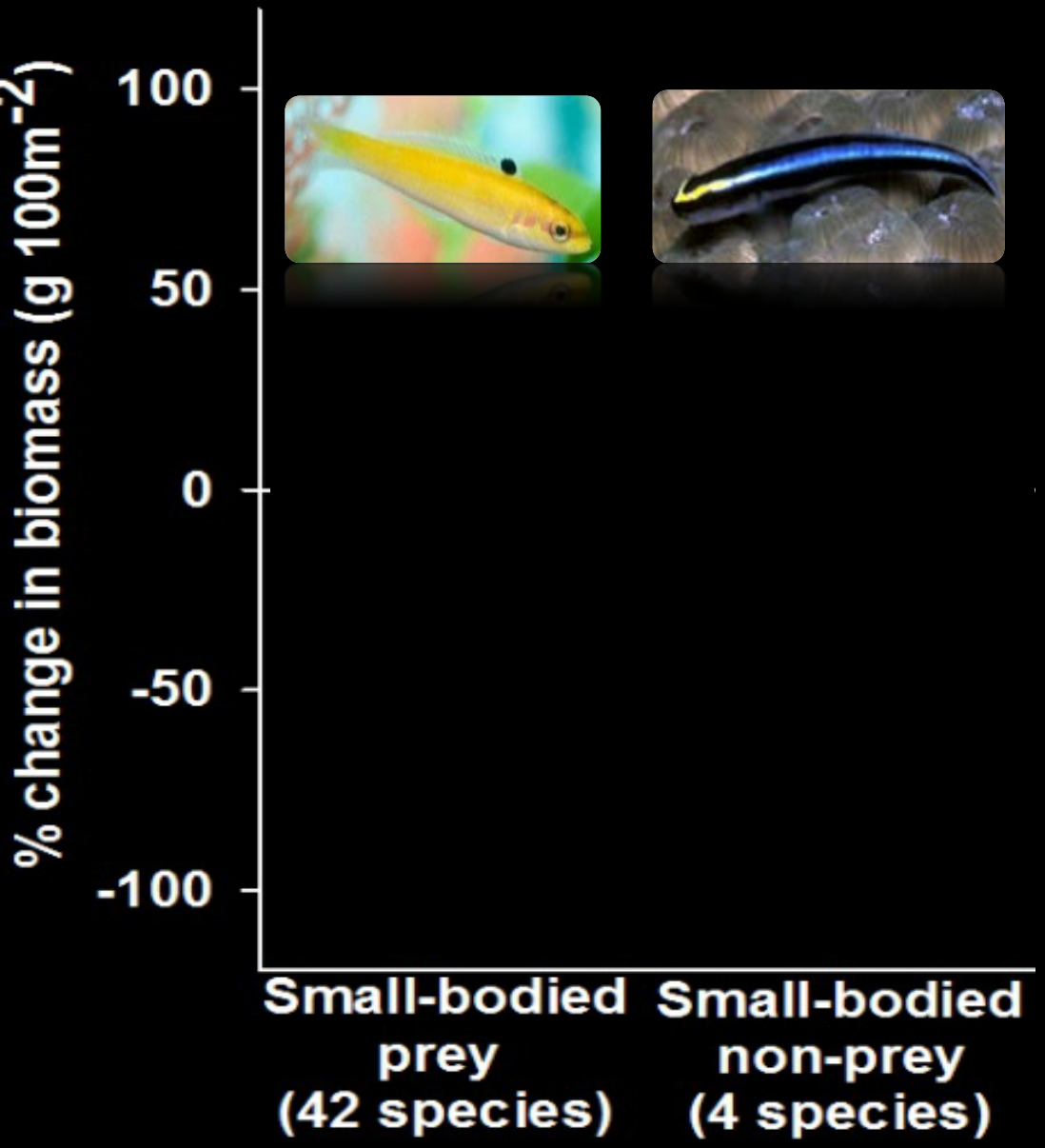
Gape-limited predators

Avoided

Preferred

Green & Côté J Animal Ecol in review

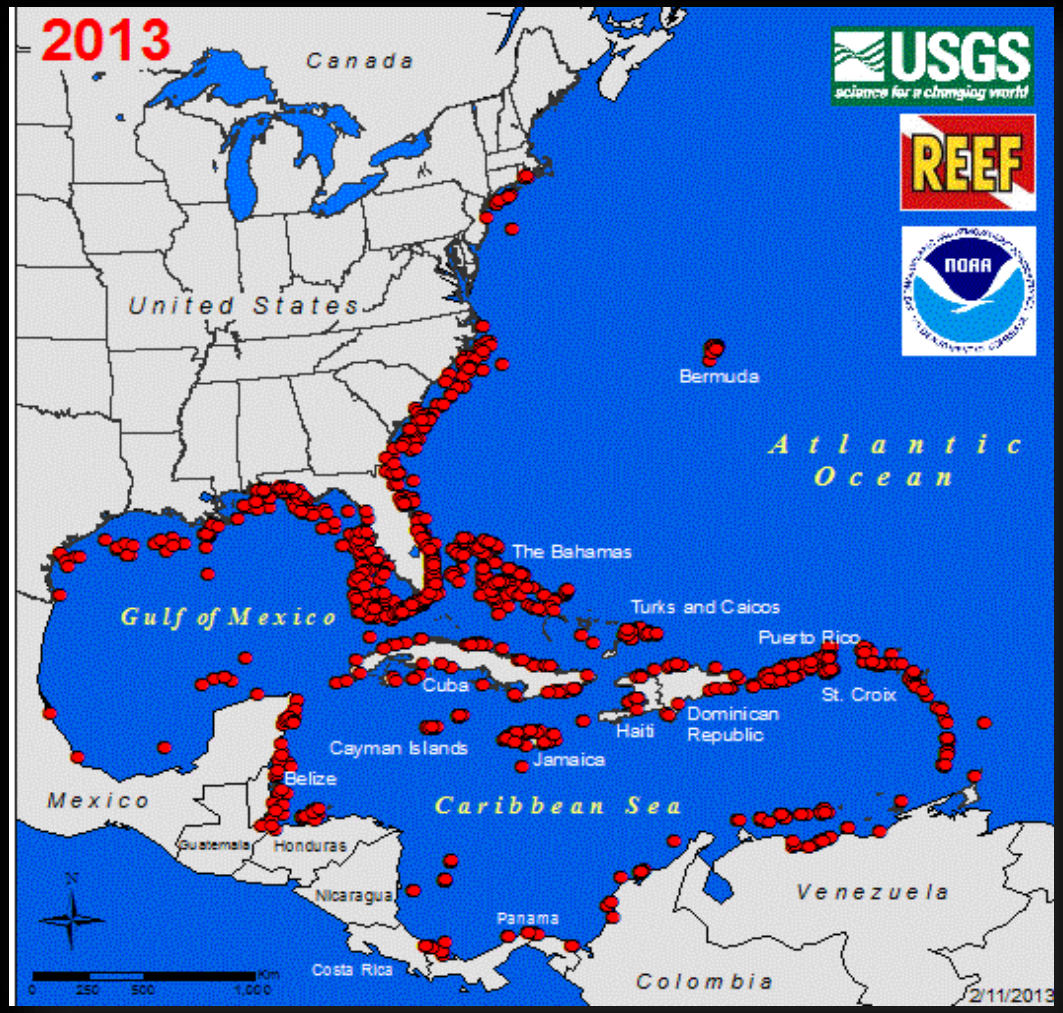
65% reduction in prey biomass over two years



Green et al. 2012
PLoS ONE

What have we learned so far?

Complete eradication is unlikely



Controlling the lionfish invasion

~~Eradication~~ → Population suppression

The goal:

Make the most effective use of limited resources for control

Planning control

Minimize ecological impacts in priority areas

Planning control

Minimize ecological impacts in priority areas

Juvenile fish habitat

Marine Protected Areas

How many lionfish to remove?

How many lionfish can a reef tolerate?

How many lionfish can a reef tolerate?

$$P - C = N$$

Prey fish production ($kg\ ha^{-1}yr^{-1}$)	-	Lionfish prey consumption ($kg\ ha^{-1}yr^{-1}$)	=	Net prey fish production ($kg\ ha^{-1}yr^{-1}$)

Prey decline if $N < 0$

How many lionfish can a reef tolerate?

$$\overline{N}_x = \underbrace{\frac{1}{z}\sum_{\forall_z}\sum_{\forall_i}\sum_{\forall_v}\left(\frac{jW_{v,i,z}{}^{q}}{e^{\frac{E}{kT}}}\right)W_{v,i,z}}_{\text{Prey fish production}} - \underbrace{\overline{d}_x\overline{W}_x\overline{p}(0.006e^{0.16T}\overline{W}_x{}^{c})y}_{\text{Lionfish prey consumption}}$$

Green et al. *in press* Ecol. App.

How many lionfish can a reef tolerate?

$$\bar{N}_x = \frac{1}{z}\sum_{\forall_z}\sum_{\forall_i}\sum_{\forall_v}\left(\frac{jW_{v,i,z}{}^{q}}{e^{\frac{E}{kT}}}\right)W_{v,i,z} - \bar{d}_x\bar{W}_x\bar{p}(0.006e^{0.16T}\bar{W}_x{}^{c})y$$

Prey fish production (kg ha^{-1}yr^{-1})

Surveys of prey fish biomass

Green et al. *in press* Ecol. App.

How many lionfish can a reef tolerate?

$$\bar{N}_x = \frac{1}{z}\sum_{\forall z}\sum_{\forall i}\sum_{\forall v}\left(\frac{jW_{v,i,z}{}^{q}}{\frac{E}{e^{kT}}}\right)W_{v,i,z} - \bar{d}_x\overline{W}_x\bar{p}(0.006e^{0.16T}\overline{W}_x{}^{c})y$$

Lionfish prey consumption (kg ha^{-1}yr^{-1})

Predation rates
MEPS 2011

Diet composition
MEPS 2013

Lionfish densities and body sizes
Coral Reefs 2013

How many lionfish can a reef tolerate?

$$\bar{d}_x = \frac{\frac{1}{z}\sum_{\forall z}\sum_{\forall i}\sum_{\forall v}\left(\frac{jW_{v,i,z}{}^{q}}{\frac{E}{e^{kT}}}\right)W_{v,i,z}}{\overline{W}_x\overline{p}\left(0.006e^{0.16T}\overline{W}_x{}^{c}\right)y}$$

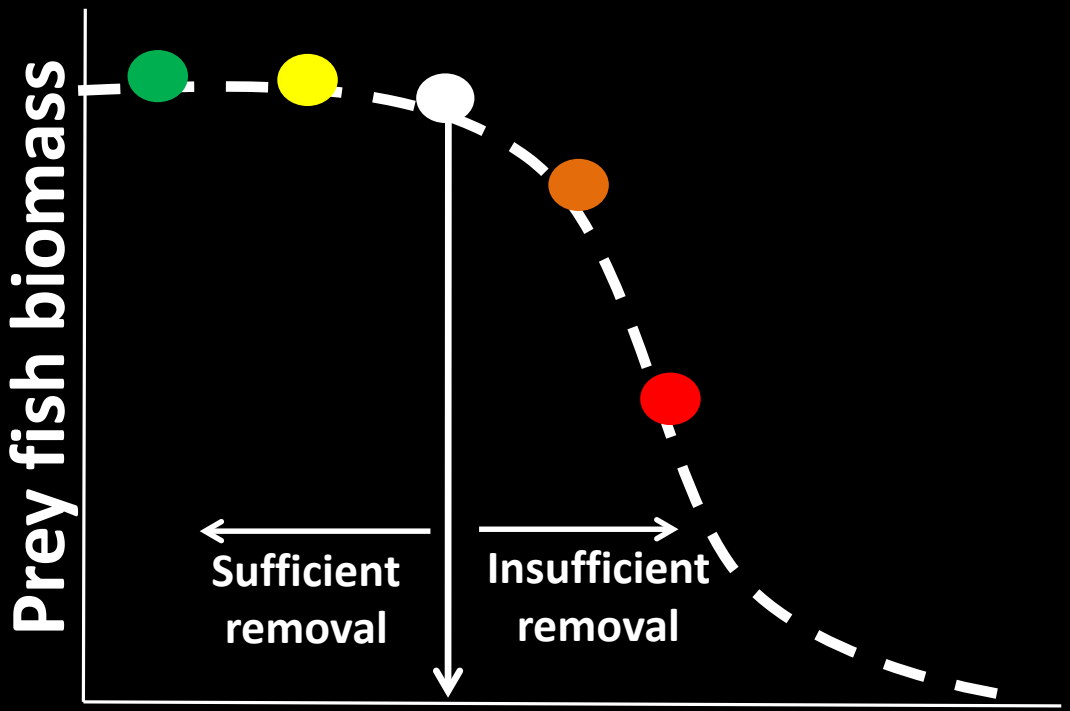
Surveys of fish biomass

Predation rates

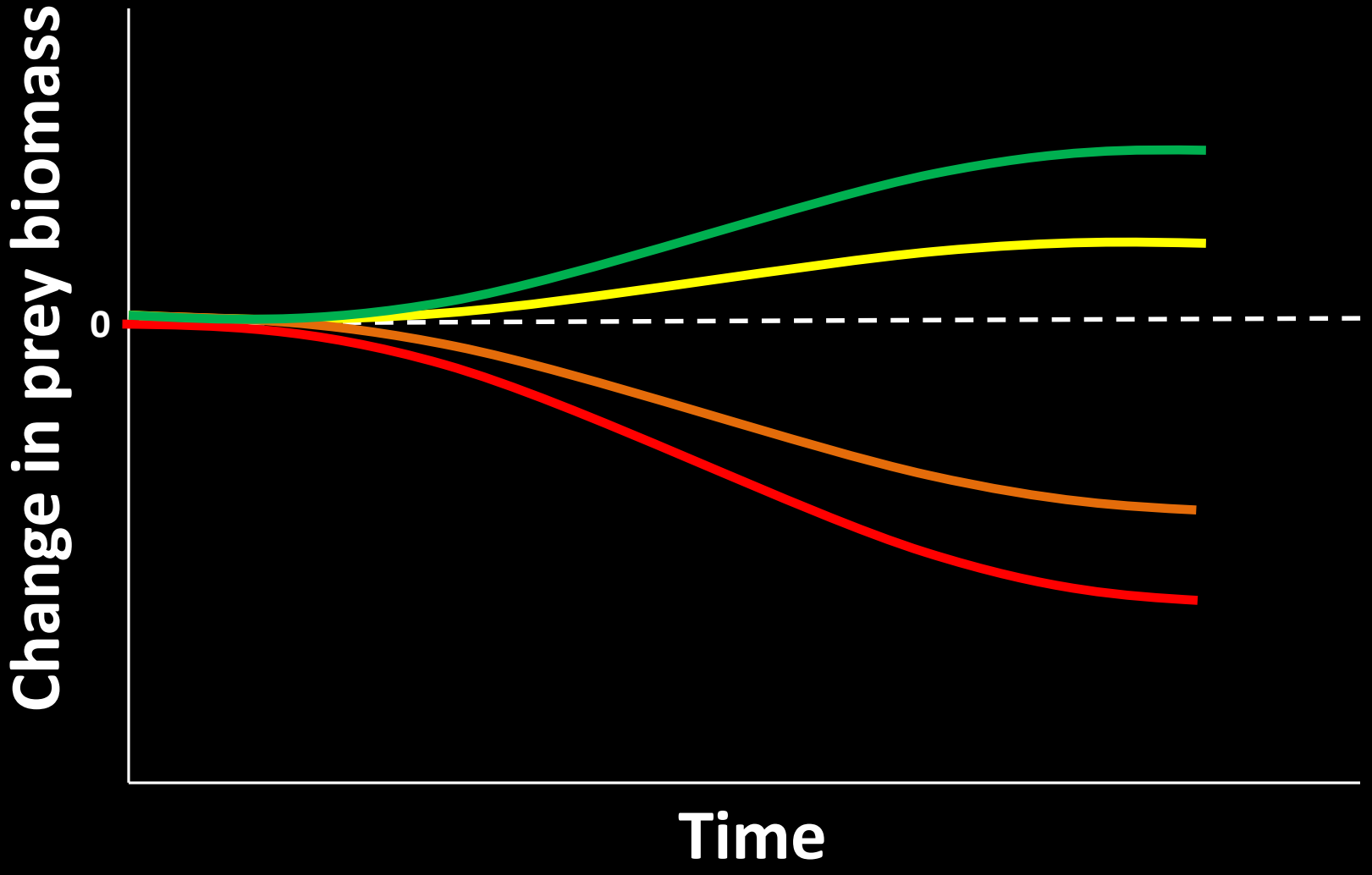
Lionfish densities and body sizes

How many lionfish to remove?

$$\overline{d_x} = \frac{\frac{1}{z}\sum_{\forall z}\sum_{\forall i}\sum_{\forall v}\left(\frac{jW_{v,i,z}{}^{q}}{e^{\frac{E}{kT}}}\right)W_{v,i,z}}{\overline{W}_x\overline{p}(0.006e^{0.16T}\overline{W}_x{}^{c})y}$$

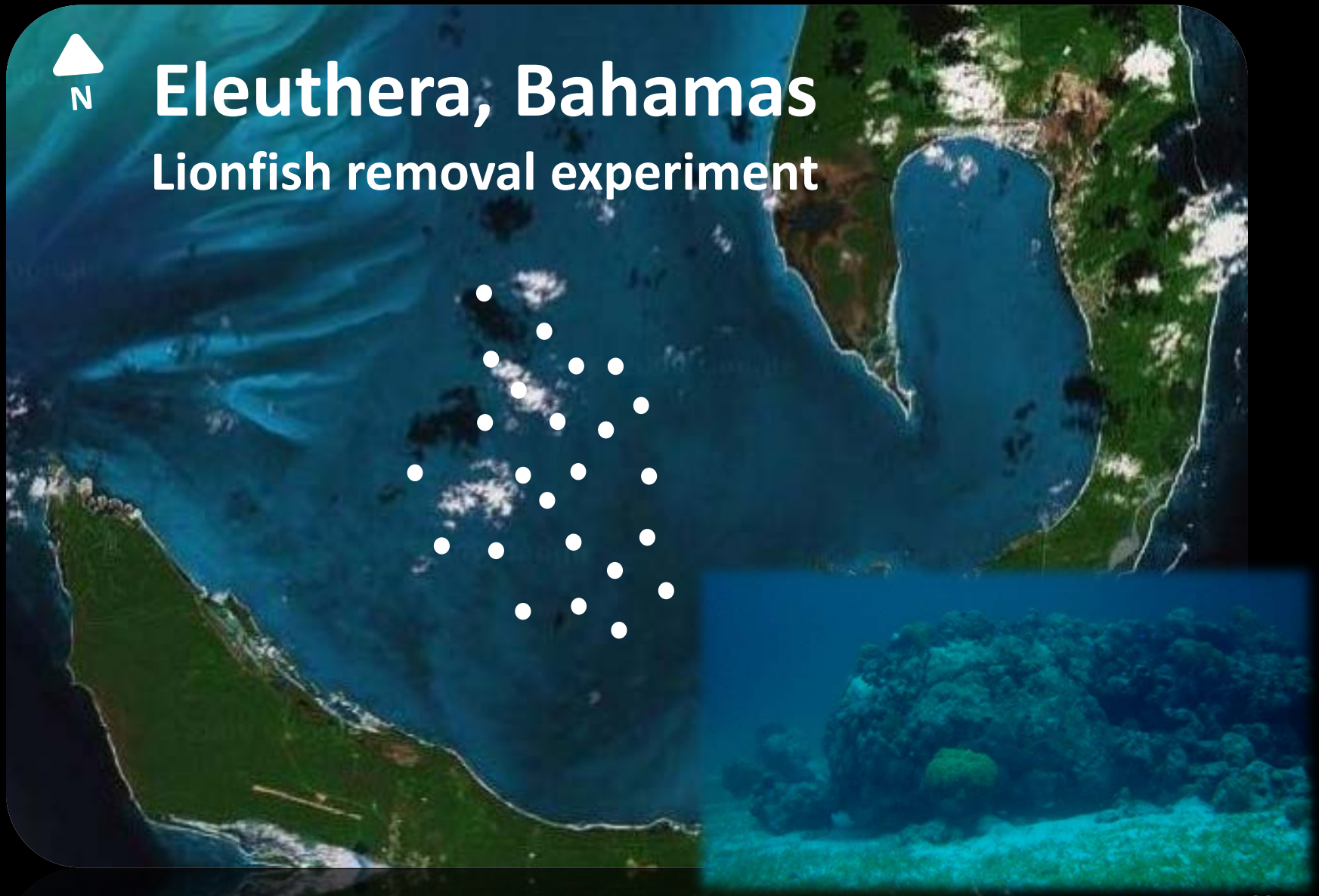


How many lionfish to remove?



The Bahamas

Testing targets for lionfish control



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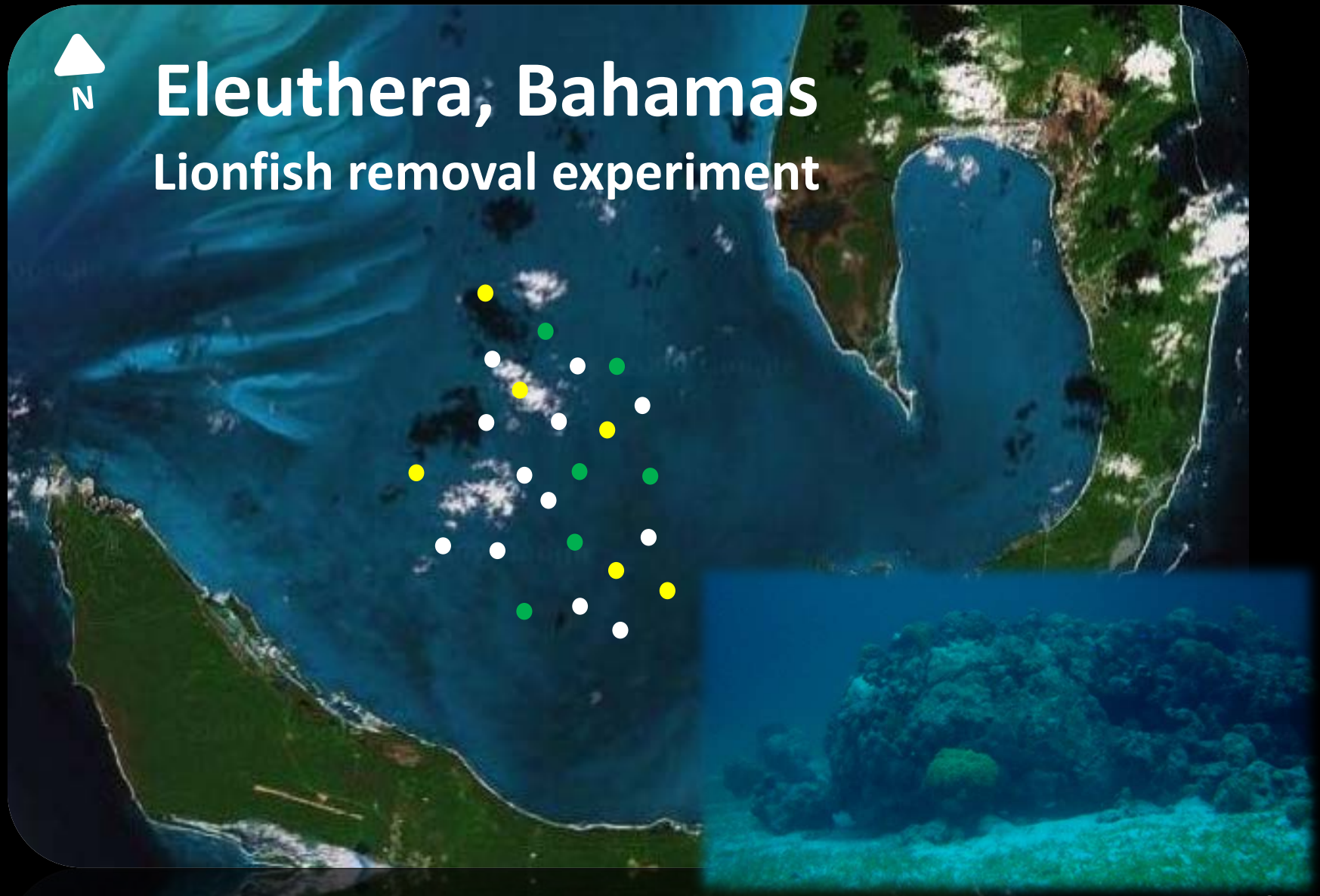
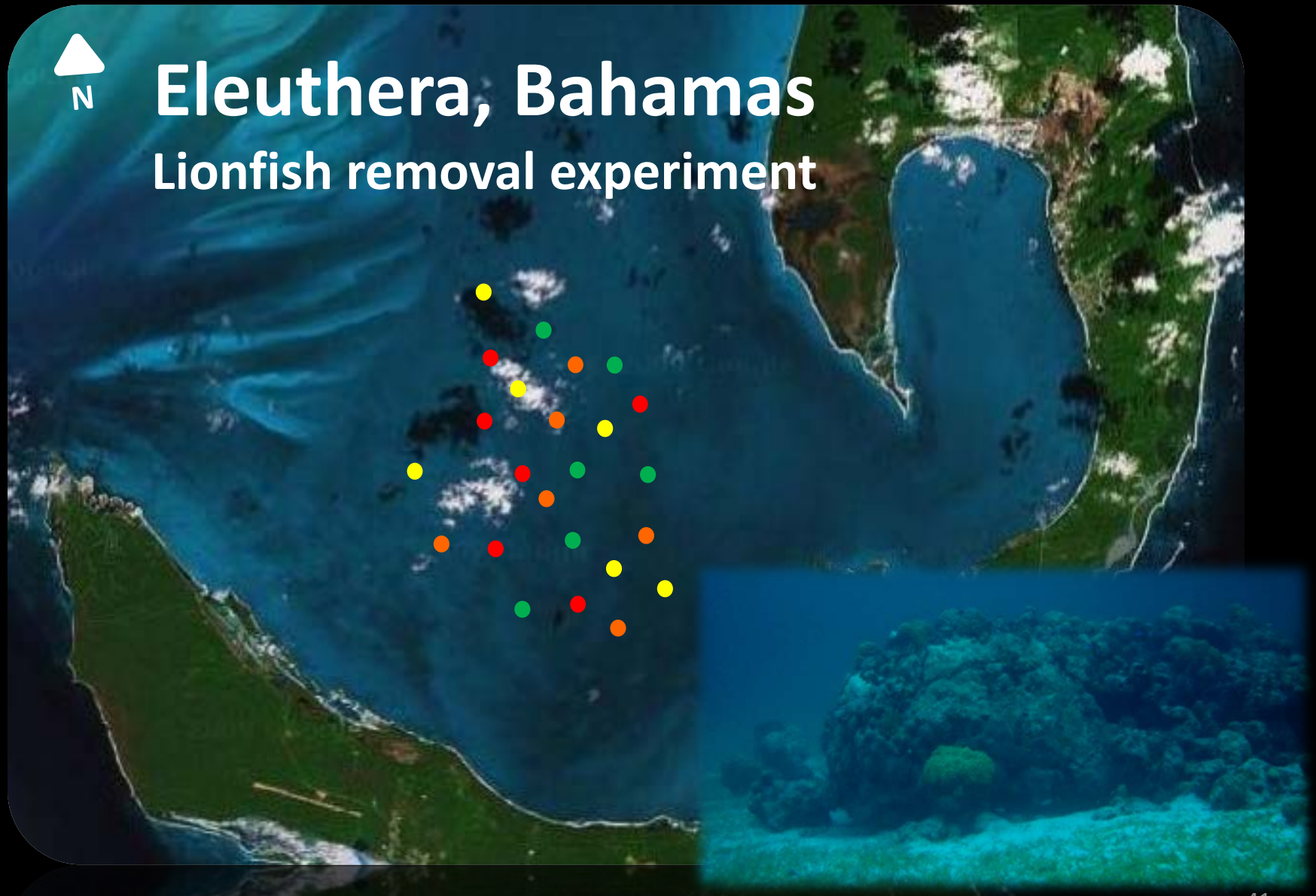


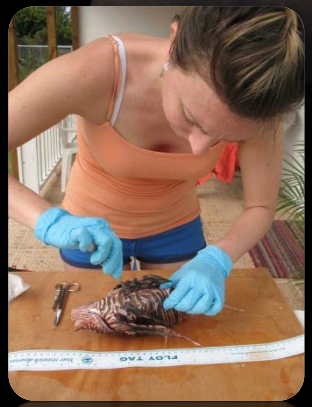
Testing targets for lionfish control

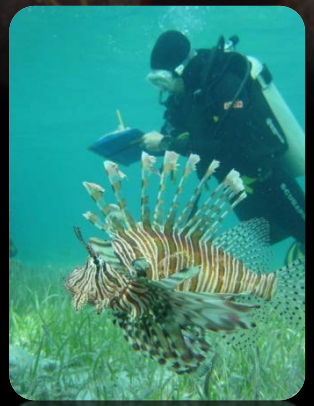


Testing targets for lionfish control

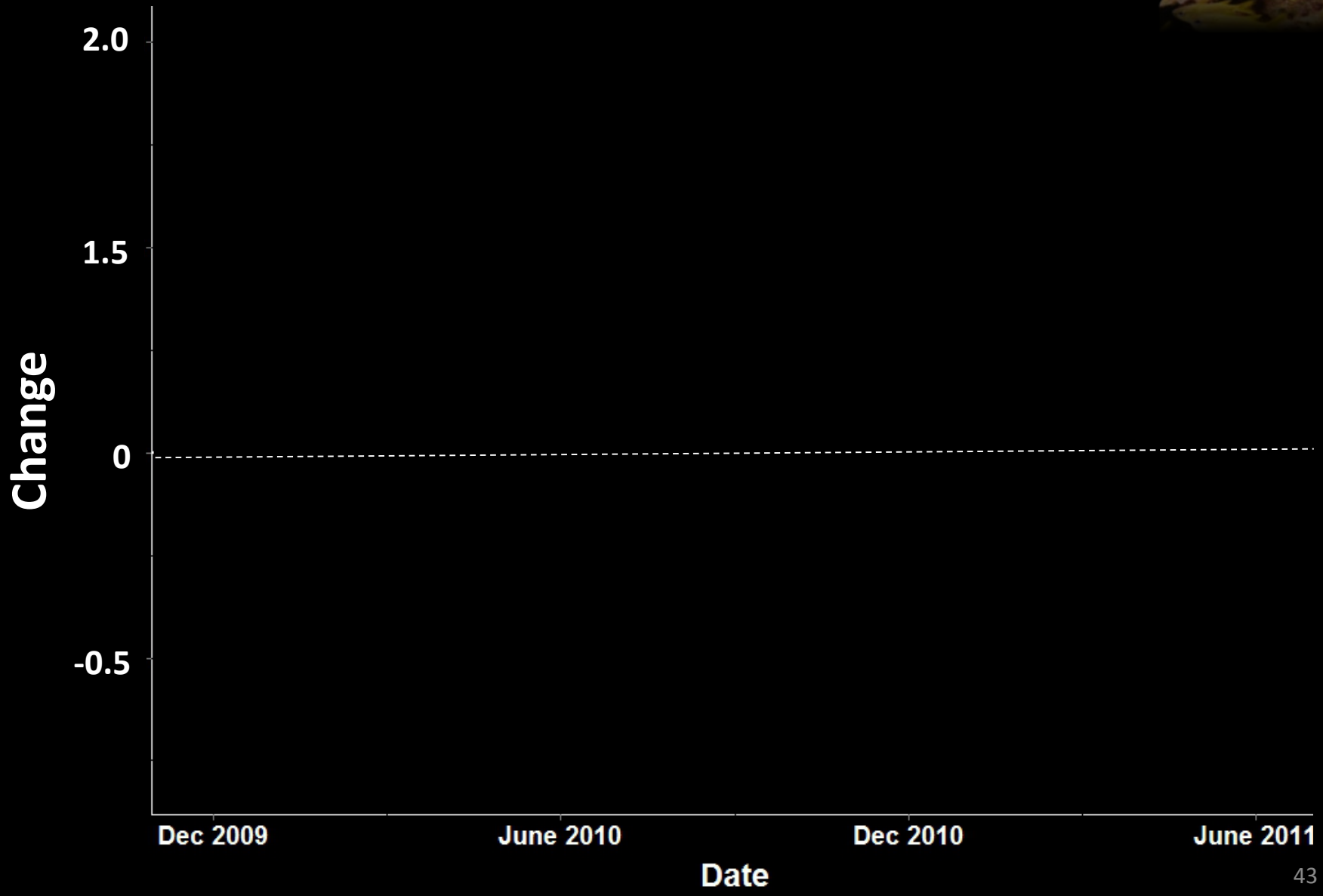
Two year removal experiment:

- **Removed lionfish monthly to maintain four treatment groups**
- **Surveyed native fish community every six months**

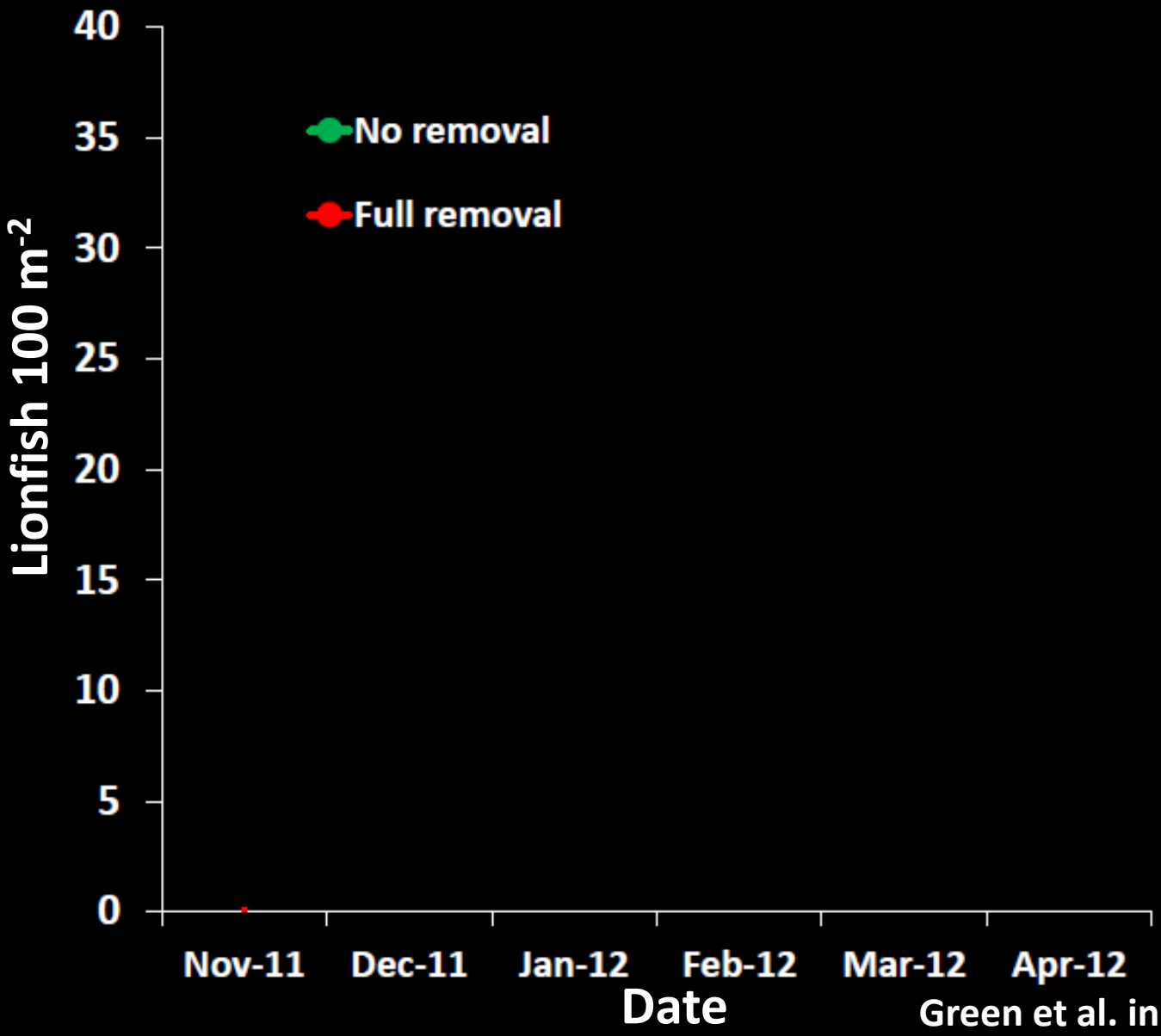




Change in prey-sized fish (<15cm)



Recolonization happens rapidly



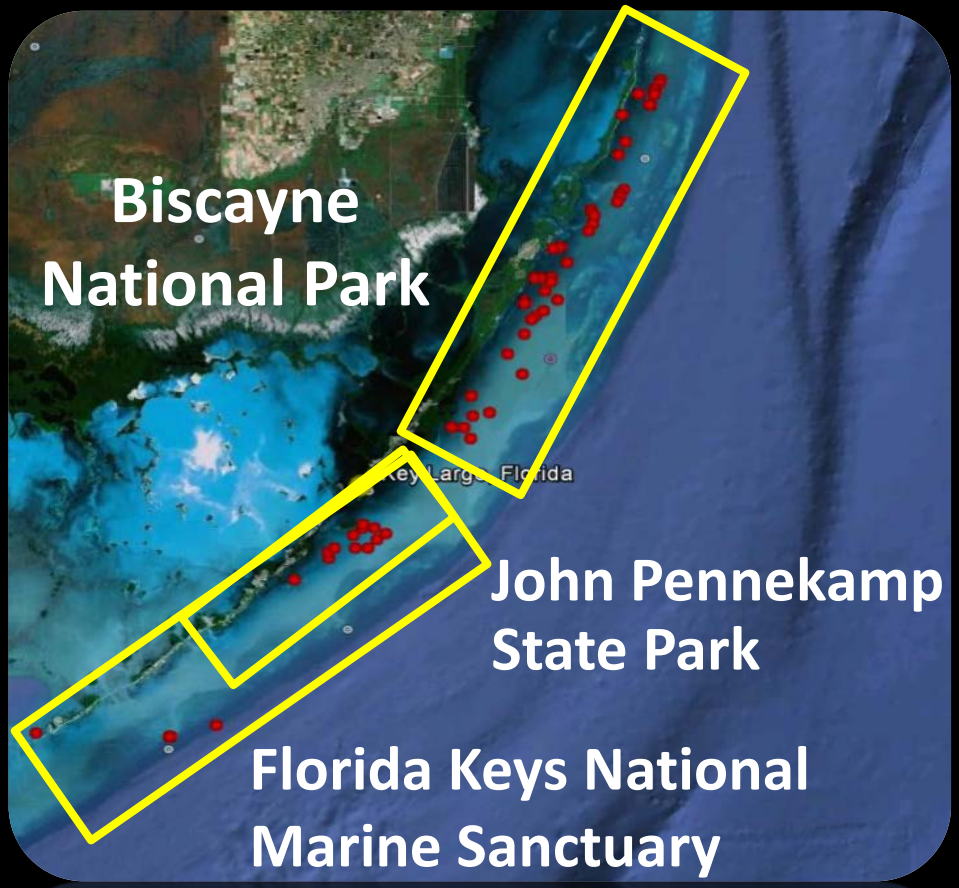
Green et al. in review Ecol App

How often to remove?

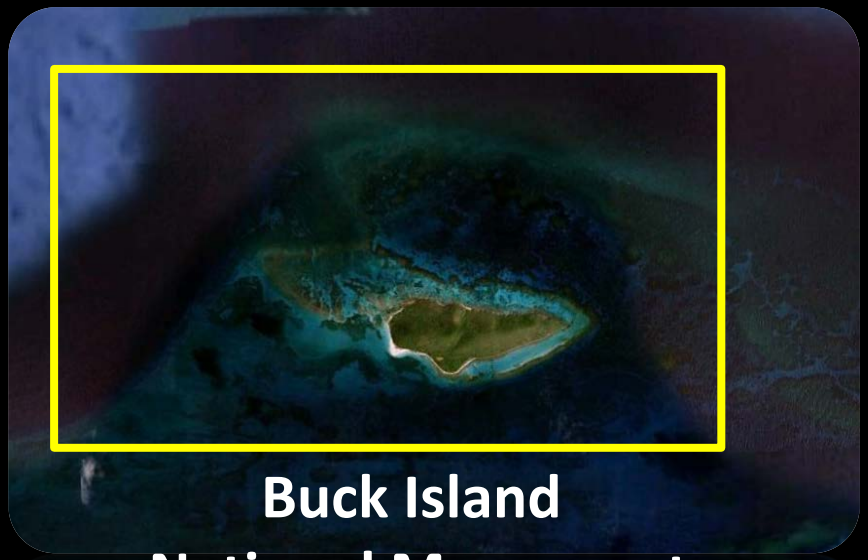
What is the cost and effort needed for control?

Lionfish removal project

Florida Keys



St Croix, USVI



FLORIDA 4 REEF Protect Our Reefs

Sea Grant Florida

NOAA CORAL REEF CONSERVATION PROGRAM

National Marine Sanctuaries

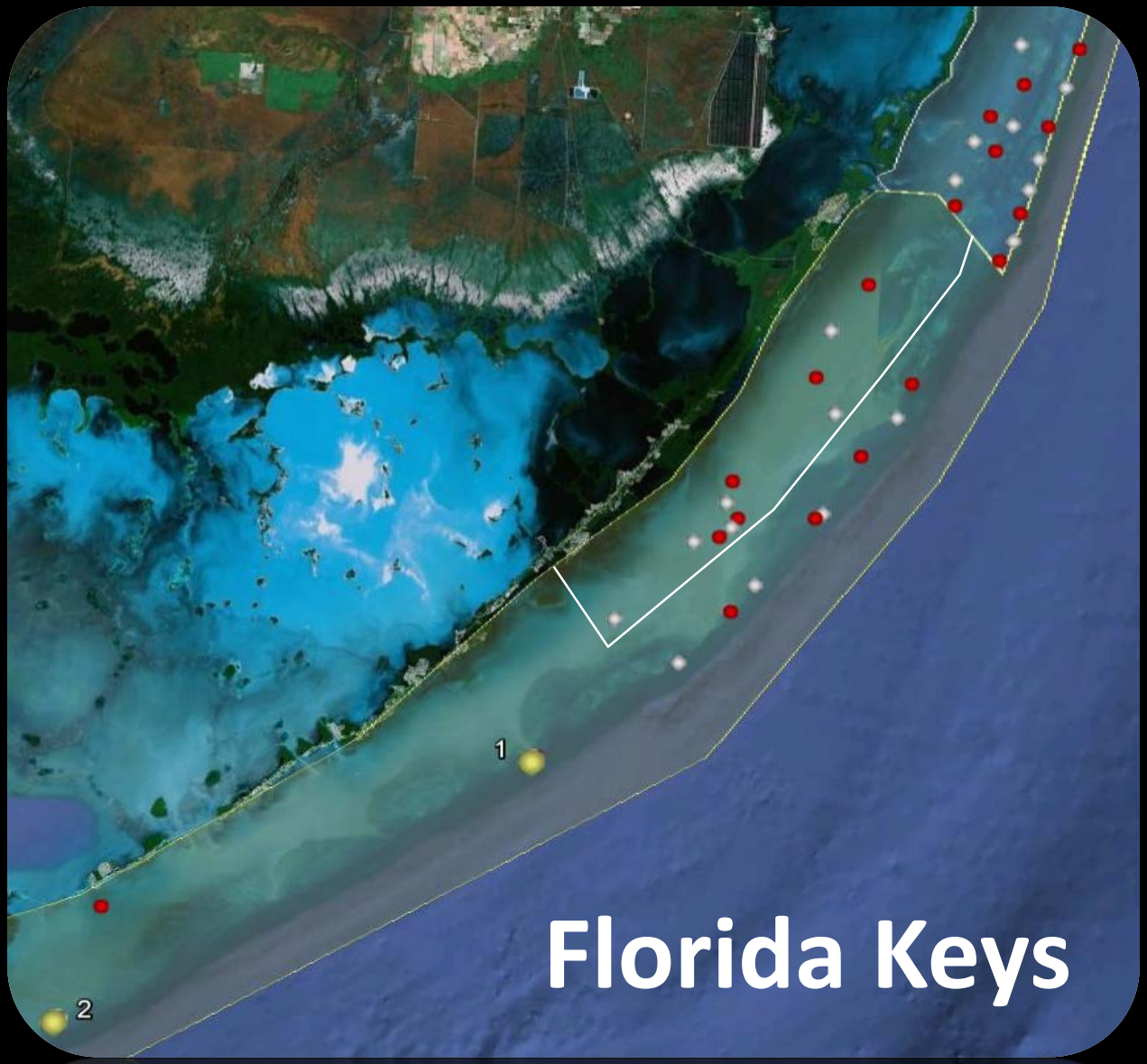
Florida Park Service Environmental Protection

National Park Service

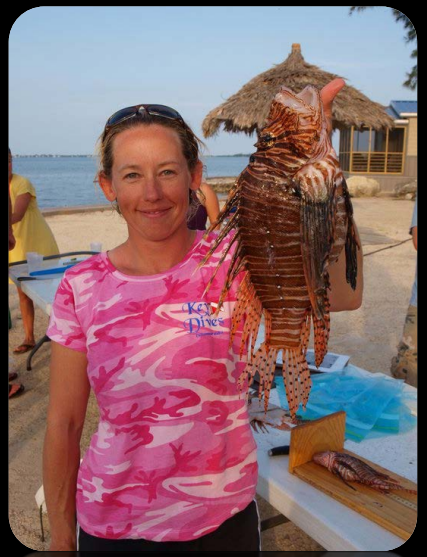
OSU Oregon State University

NOVA Southeastern University

REEF


1
2
Florida Keys

Tools to achieve control



Derbies

Diver removal

Traps

(…..Robots?)

Global Invasive Species Database 2012

Population control




Single-species population models identify mortality rate needed to cause population decline

Population control




ERADICATION

When is eradication successful?

Restricted geographic range

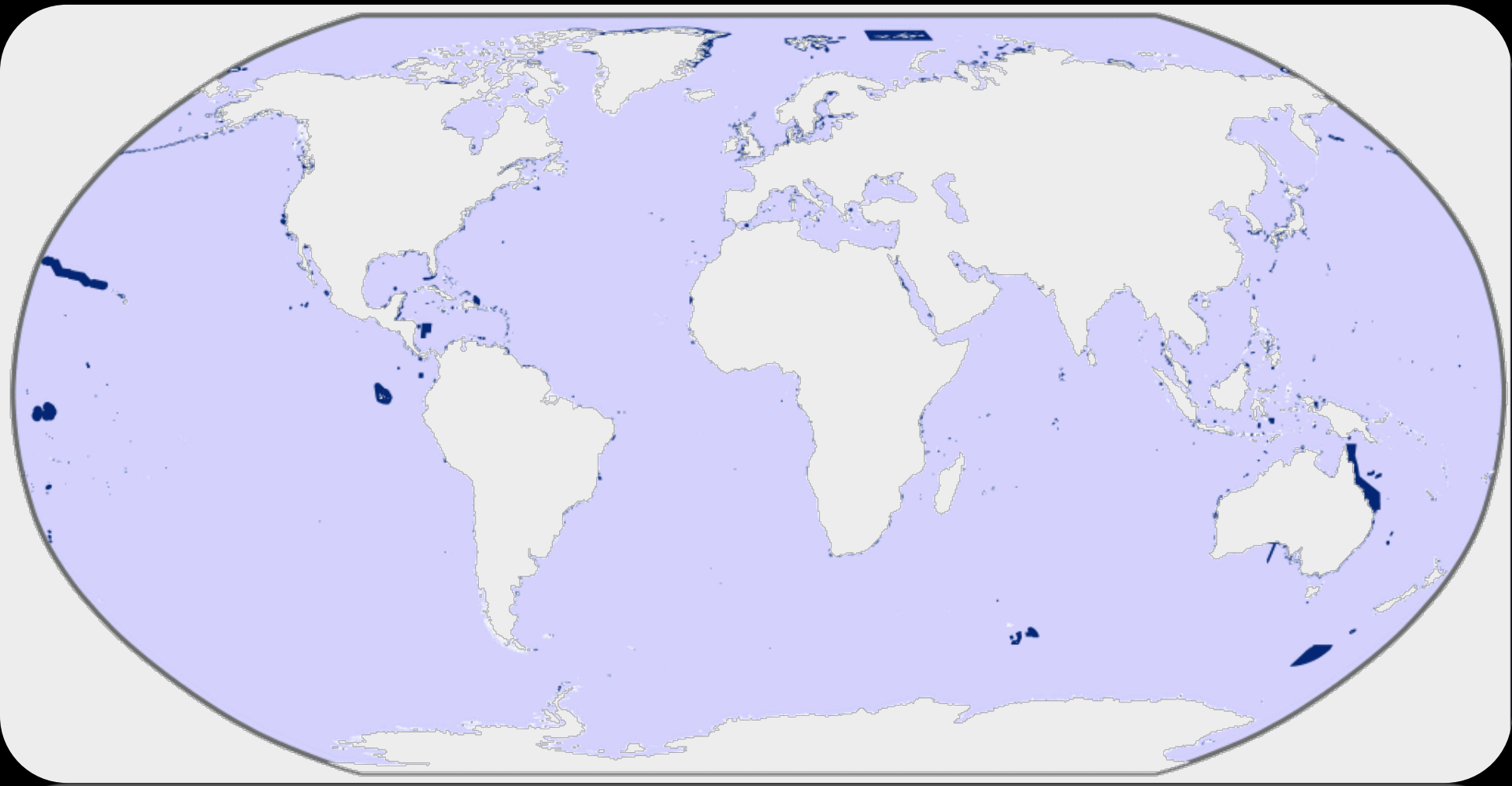
Small population size

Occupied habitats readily accessible

Invader easily removed

Invasions in the sea

Marine conservation occurs at a local scale



MPA Global
A database of the world's Marine Protected Areas

SEA AROUND US PROJECT · WWF · UNEP · WCMC · IUCN The World Conservation Union

A new approach to invasive species management

Numerical eradication

A new approach to invasive species management

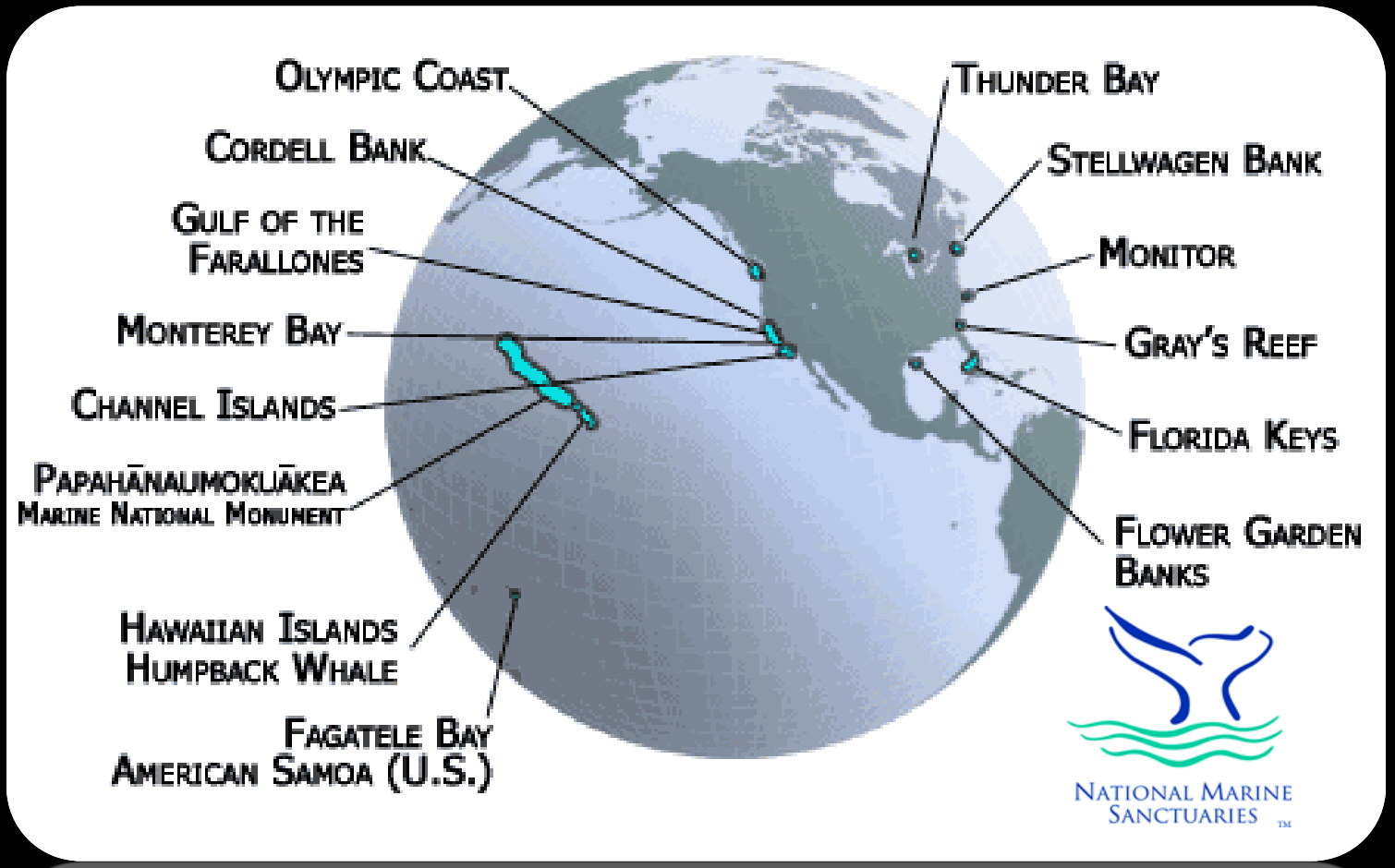
Numerical eradication

‘Functional’ eradication

A new approach to invasive species management

Three steps:

Invasion & US marine protected areas



Many ongoing invasions in US waters




GLOBAL INVASIVE SPECIES DATABASE

IUCN SSC Species Survival Commission ISSG Invasive Species Specialist Group

Which marine invasions can be functionally eradicated?




OSU Oregon State University

NATIONAL PARK SERVICE

NATIONAL MARINE SANCTUARIES

REEF www.REEF.org

Thank you

- stephanie.green@science.oregonstate.edu

Lionfish abundance has increased rapidly

Green et al. 2012 PLoS ONE

64 prey fish plus a shrimp!

Impact of lionfish on Bahamian reef fishes