Reef Fish Assemblages and Marine Protected Areas

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Some Issues

Regional surveys suggest that causes of declining catches include:

- overfishing,
- population growth,
- a shift from subsistence to commercial fishing,
- the use of more-efficient and in some cases: damaging fishing methods
- and environmental degradation (habitat and pollution).

Key environmental disturbances include:

- destruction of nursery areas (mangrove areas and corals) &
- shift from a coral phase to an algal phase, due from coastal development and poor land management practices.

During the last 10 to 15 years there has been a shift in emphasis in the management of fish stocks from "development" to "conservation."

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Uncertainty

Fog of War

"A general never knows anything with certainty, never sees his enemy clearly, and never knows positively where he is"

Napoleon

From: Appeldoorn 2010

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Uncertainty

Fog of Fisheries

A manager never knows anything with certainty, never sees the fishery clearly, and never knows positively where the stock is

From: Appeldoorn 2010

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FISHERIES MANAGEMENT

- Fisheries management aims to achieve the optimal and sustainable utilization of the fishery resource for the benefit of stakeholders, while maintaining biodiversity
- Conventional fisheries management is largely informed by scientific information, which is used to develop the rules under which a fishery operates to ensure its sustainability.

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Many types of fisheries management tools exist

- Input controls: access controls and fishing effort limits (e.g. restrictions on the number of boats/licenses, gear or trips);
- Output controls: catch limits such as total allowable catch (TAC) quotas;
- Technical measures: restrictions on the size of fish that can be caught or retained, or gear restrictions;
- Spatial-temporal measures: zoning and area-time-gear type closures.

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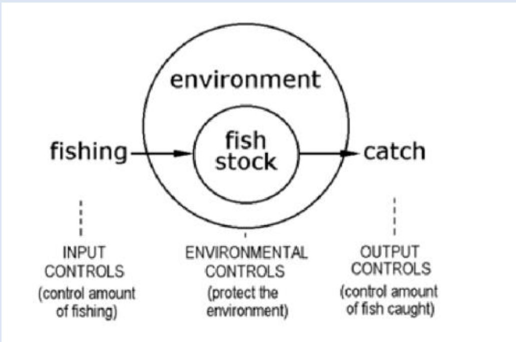

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Common fisheries management measures, their purpose and examples

PURPOSE	REGULATORY MEASURE	EXAMPLE
Reduce mortality of juveniles by letting free the smaller individuals	**Fishing gear restriction**	Mesh size in POTS, shrimp trawl nets. Excluding device in trawl nets
Protect the stock from overfishing by avoiding capture of immature animals	**Minimum legal size**	Minimum legal size for lobster, and reef fishes
Protect the stock during the reproduction period, or during recruitment	**Season closure**	Closure for snapper and Groupers. Closure during recruitment or spawning aggregation
Protect the individuals in the breeding zones	**Area closure**	Closure of breeding zones for lobster and reef fish
Resource conservation	**Total allowable catch**	Catch quota for lobster, queen conch and reef fishes
Avoid effort excess and make the fishery more profitable	**Fishing license**	Licenses for commercial boats and recreational vessels
Protect the rights of the fishing users and make the operations more efficient	**Territorial limit**	Zones in lobster and diving, recreational and commercial fisheries
Recovery of a fishery or a zone (emergency measure)	**Moratorium (temporary)**	Temporary closure to a fishery
Preserve a particular area, an specific habitat to serve as a compensatory element to the exploited areas surrounding	**Marine protected area**	Zones under special regime of use and protection, only open to lobster fishery

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Some indicators for sustainable fisheries Dimensions, criteria and indicators

DIMENSIONS	CRITERIA	INDICATORS
ECOLOGICAL	Stock biomass Harvest Fishing Pressure Stock structure Fishing capacity Effort	Catch per unit effort (CPUE) Catch Effort / No. of gear per fishing area Catch composition (size / species) No. of boats, gross tonnage, total effort No. of boats, fishing time
ECONOMIC	Harvest Harvest capacity Harvest value Exports Effort	Catch, by-catch No. of boats, gross tonnage, total effort Total value (prices) Export / catches value No. of boats, fishing time

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Fisheries Regulations and their enforcement

Enforcing regulations are needed and difficult because many users, large coastlines, many islands, many fishing methods, and a great variety of species in the catches.

- The cost of enforcement is often high and should be considered in all fisheries management plans.
- Involving fishers and other stakeholders in fisheries management is one way of ensuring public support and compliance with regulations and reduce cost.
- In many cases alternative regulations are easier to enforce.

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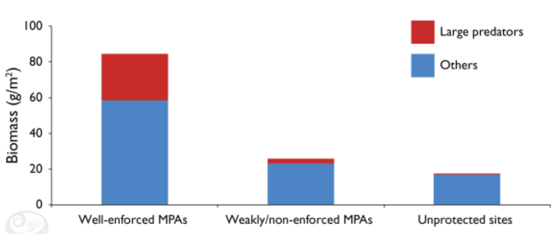
The role of enforcement



Biomass of large predatory fishes (red bars) and other fishes (blue bars) by protection level. Sala et al. (2012) *PLoS ONE*

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Are MPAs - THE ANSWER FOR FISHERIES?

- In many circumstances, MPAs will be inferior to an appropriate mix of other fisheries management tools in terms of the combined protection offered, potential yield and economic performance, as long as these tools are effectively implemented.
- MPAs can be a very useful component within the fisheries management toolbox.

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Are MPAs - THE ANSWER FOR FISHERIES?

•MPAs will generally have both biodiversity conservation and direct fisheries management outcomes, whether or not they have been established for both these purposes explicitly.

•To gain the most benefits, the two concepts need be bridged when planning and implementing MPAs.

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Potential Fishery Benefits of MPAs

- Increase spawning stock biomass
- Spillover enhances local catches
- Offers insurance against uncertainty (precautionary principle)
- Increased predictability of catches
- Reduced problems of multi-species management
- Easier enforcement
- Greater equity among fishers
- Great public understanding of management

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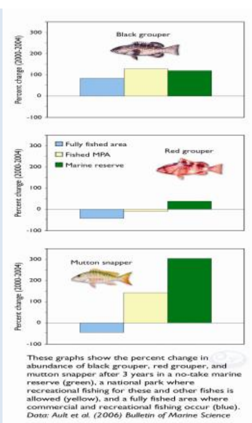

These graphs show the percent change in abundance of black grouper, red grouper, and mutton snapper after 3 years in a no-take marine reserve (green), a national park where recreational fishing for these and other fishes is allowed (yellow), and a fully fished area where commercial and recreational fishing occur (blue). *Data: Ault et al. (2006) Bulletin of Marine Science*

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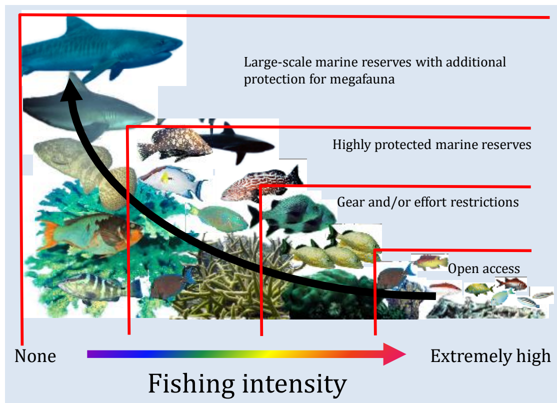

From: Roberts, 2010 GCFI

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Data Sources

Data used in stock assessments come from two sources: fishery-dependent (fishermen/dealers) and fishery-independent (scientific surveys).

Fishery-dependent data:

- Are collected from both commercial and recreational fishermen through observer programs, dealer reporting, phone surveys, etc.
- Give stock assessment scientists information about catch size, fishing effort, catch per unit effort, age structure, and other variables

Fishery-independent data:

- Are collected by scientists conducting long term surveys like Visual census or trawl surveys and other specific studies and programs
- Are independent of management measures
- Provide stock assessment scientists with biological data and other information
- describing juvenile and adult abundances, fish habitat characteristics, and environmental factors

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GCRMN-Caribbean Monitoring Guidelines

1. Key reef fish taxa (abundance and biomass)

Target: Species of economic and ecological importance + sensitive and invasive species

Level 1 - Density and size of core species only (snappers, groupers, parrotfishes & surgeonfishes)
Stationary point count, belt transects

Level 2 - Density and size of core species (snappers, groupers, parrotfishes & surgeonfishes), invasives & species of special interest
AGRRA protocol 30 x 2 m belts

Level 3 - Density and size of all fish species
AGRRA protocol 30 x 2 m belt, 5 per site, 8-12 min

Global Coral Reef Monitoring Network

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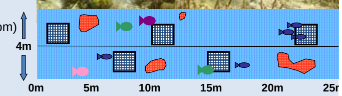
NOAA, Field Methods & Sample Design

Random stratified design
- inside vs. outside Park
- hard vs. soft bottom

Fish censuses
- One 25*4 m transect per site
- One point count (7.5 m radius)

Macroinvertebrate censuses
- Conch abundance & sexual maturity
- Lobster abundance

Habitat metrics
- Five 1-m^2 quadrats (stratified random)



Personnel
- Project manager & pool of trained biologists
- Low staff turnover

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FWC Fisheries Independent Program

To develop estimates of juvenile and adult abundance for reef fish species in the Florida Keys.

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Some of the goals are:

- Correlate juvenile and adult relative abundances
- Detect changes in size or age structure of fish populations
- Develop indices of recruitment for species as they enter the fishery
- Identify habitat utilization at different life stages (EFH), and movement patterns using Acoustic methods.
- Identification and monitoring of spawning aggregation sites

Current Research

RESEARCH TITLE:

- Stratified-random sampling (SRS) with Visual Point Counts
- Stratified-random sampling (SRS) with 21-m seines
- Keys Reef Fish Life History Studies, Acoustic Telemetry Studies

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Seine Survey

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Florida Keys Reef Fish Monitoring: Seine Program

Project Goals:

- Describe the distribution, abundance, species composition, size structure, and habitat usage of juvenile snapper species in nearshore seagrass areas of the middle Florida Keys.
- This information provides recruitment signals of snappers, which may be used as tuning indices for stock assessment and management.

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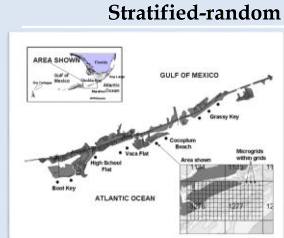
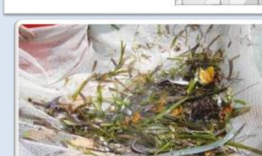
Stratified-random Seine sampling





Typical catch

Mutton snapper

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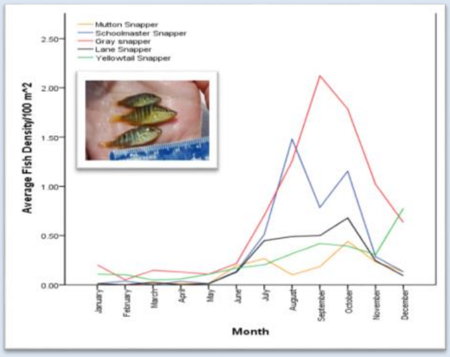
Seine Survey: Results



Average monthly densities of all snapper species collected between 2006 and 2014

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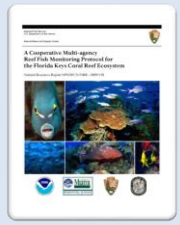
Reef Visual Census (RVC) Program

Goals

- Develop consistent protocols for underwater visual surveys
- Optimize sampling design and efficiency
- Establish a long-term dataset for monitoring reef fish species
- Track changes in reef fish abundance, distribution, and size structure



Multi-agency Monitoring

•Cooperative fisheries independent monitoring for the Florida Keys, Dry Tortugas, and SE Florida Reef ecosystem

–Partners: FWC, NOAA/NMFS, Univ. of Miami, National Park Service, Nova Southeastern University

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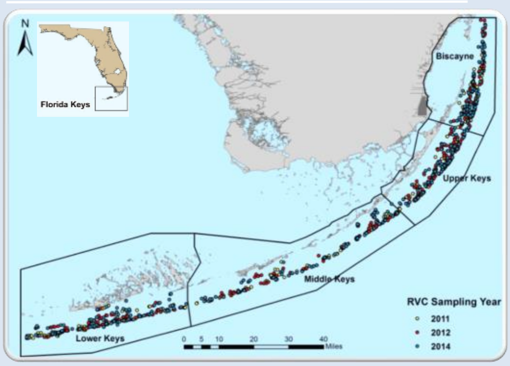
RVC Study Area



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Reef Visual Census (RVC) Program

Year	Number of Fish	Number of Counts
2009	241,027	1004
2010	146,071	739
2011	195,352	786
2012	173,646	801
2014	198,843	826

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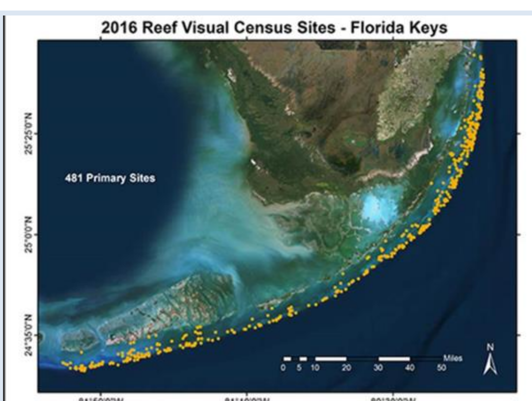

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Model board design and changing picture composition

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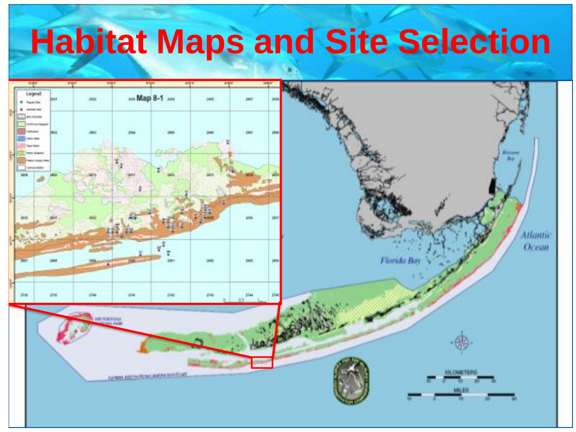

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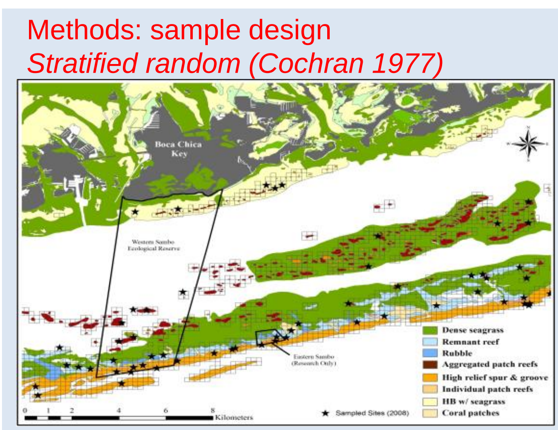

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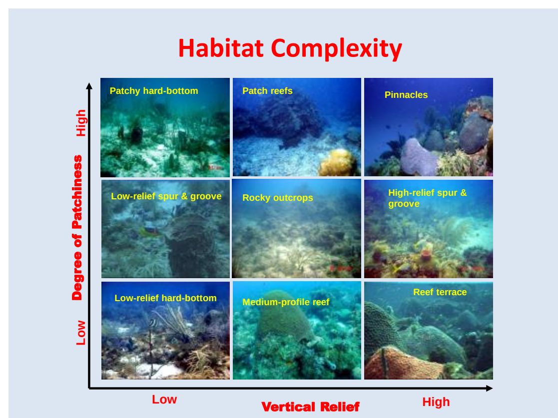

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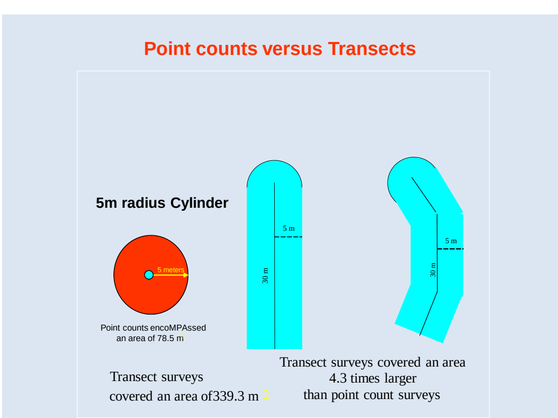

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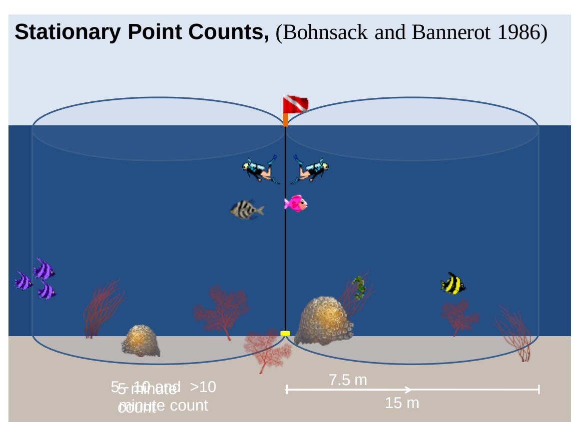

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Calculation Madness

Biomass Calculation

$$Bm = \frac{\sum_{0}^{n=x} m}{\pi r^2}$$

Shannon's Equitability

$$E_H = \frac{H}{H_{max}} = \frac{H}{\log S}$$

Fish Density Calculation

$$F_d = \frac{n}{\pi r^2}$$

Simpson's D

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

Proportion of Species "i"

$$p_i = \frac{n}{N}$$

Simpson's Equitability

$$E_p = \frac{D}{D_{max}} = \frac{1}{\sum_{i=1}^{S} p_i^2} \times \frac{1}{S}$$

Shannon's H

$$H = -\sum_{i=1}^{S} p_i \log p_i$$

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How is it used?

- Stock assessments
- Responses to management actions
- Fish Habitat Assessment
- Spawning Aggregations

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Using RVC Data to Answer Management Questions

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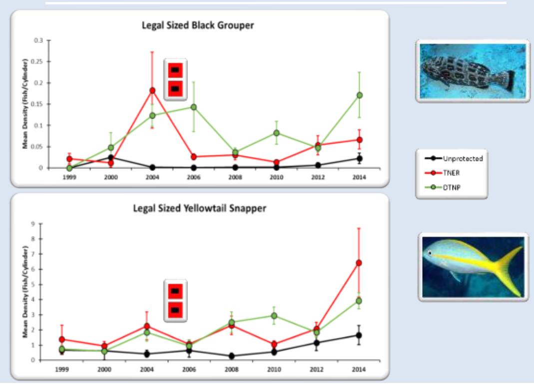
Mean Density within Tortugas Management Zones



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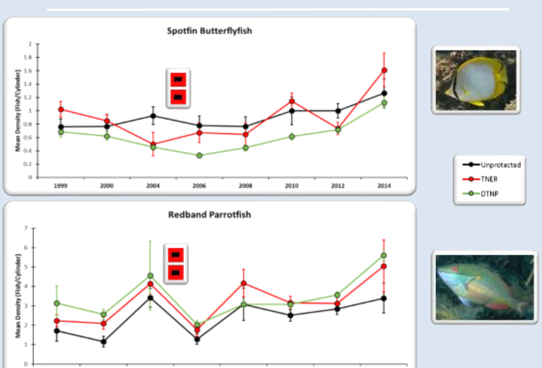
Mean Density within Tortugas Management Zones



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Reef Visual Census (RVC) Program

Percent occurrence for each species

Species	2009	2010	2011	2012	2014
Mutton Snapper	20.43%	15.16%	16.04%	22.38%	22.23%
Black Grouper	13.99%	17.70%	26.22%	18.35%	9.01%
Bicolor Damselfish	87.67%	84.58%	85.28%	83.82%	88.55%
Hogfish	68.01%	64.68%	68.62%	71.38%	64.25%
Gray Snapper	26.28%	31.88%	26.58%	24.72%	21.61%
Yellowtail Snapper	66.78%	56.62%	64.22%	69.16%	61.18%
White Grunt	79.59%	74.46%	77.69%	79.83%	68.46%
Bluestriped Grunt	41.96%	33.18%	30.86%	36.93%	30.51%

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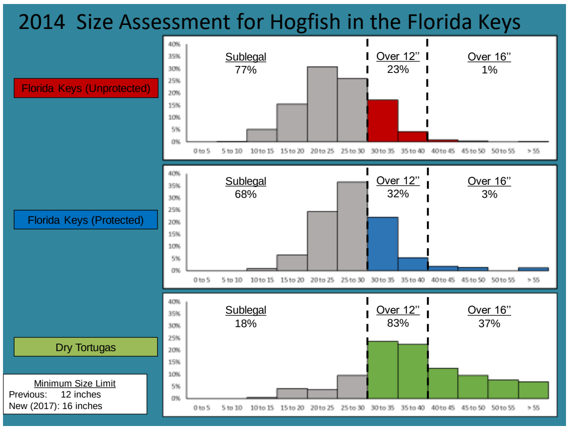

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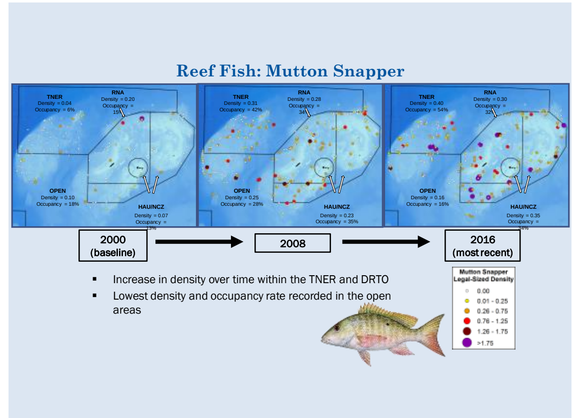

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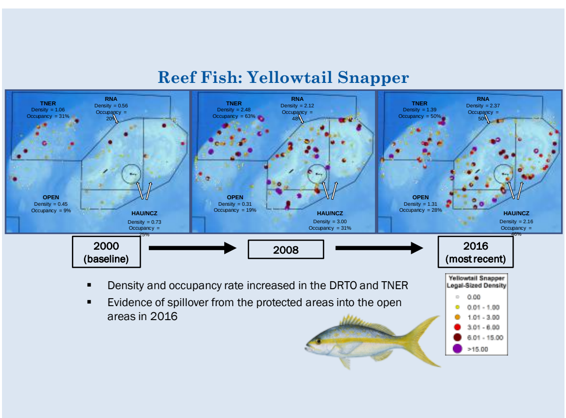

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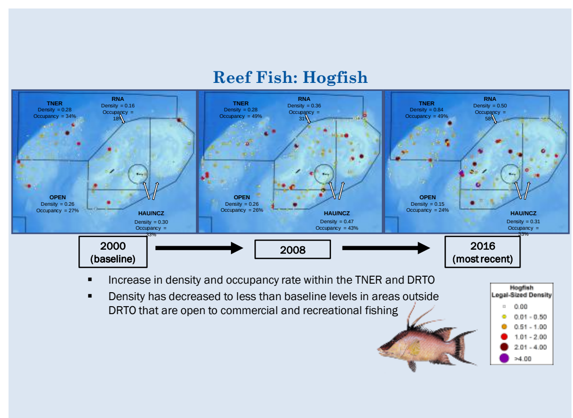

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Biological response within MPAs, such as the density, biomass, size of animals and trophic levels

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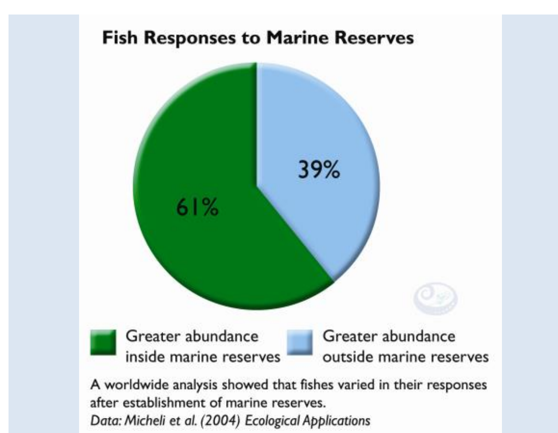

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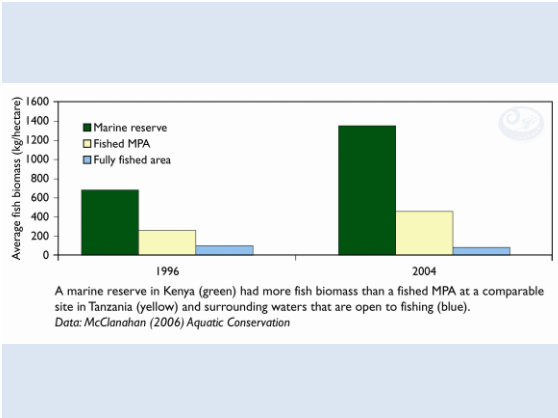

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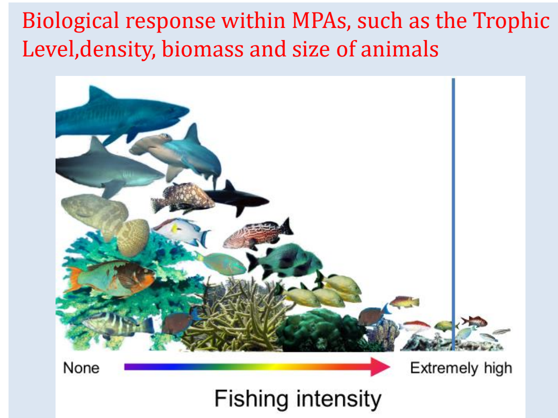

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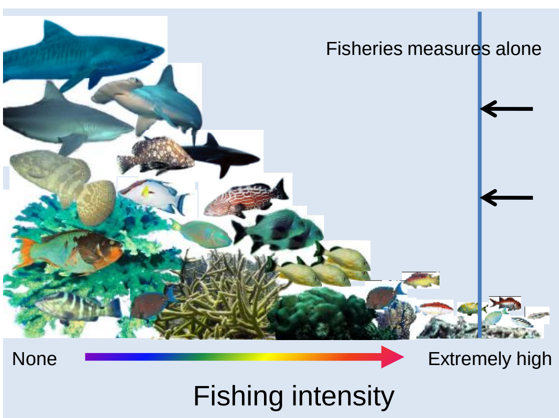

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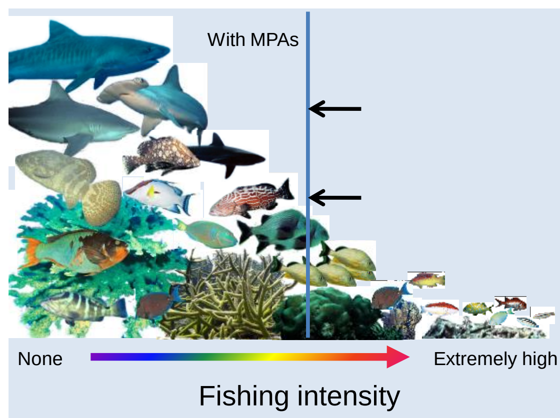

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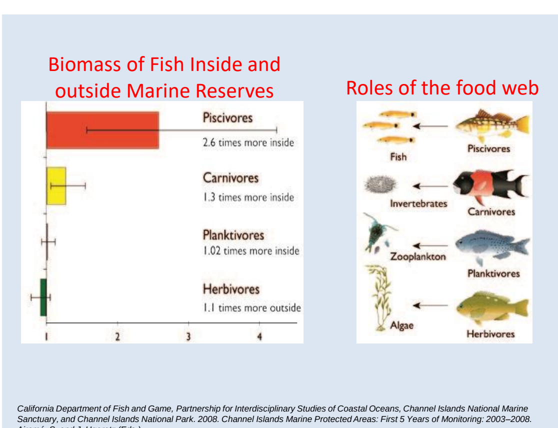

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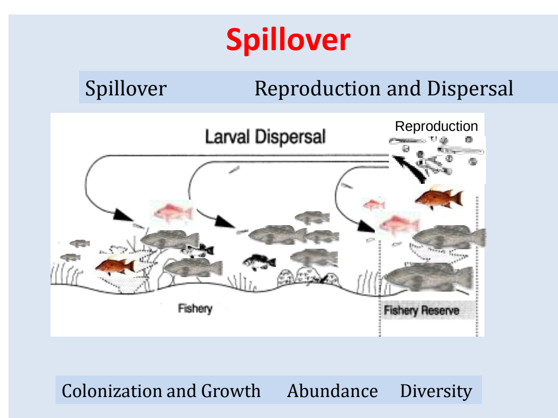

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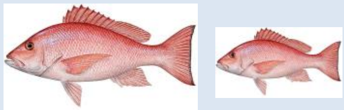
Fecundity

Example: red snapper



Length:	60 cm	40cm
Weight:	12.5 kg	1.1kg
Number:	1	212

9,300,000 eggs

Non-linear relationship between fish size and larval production

From: Grimes 1987

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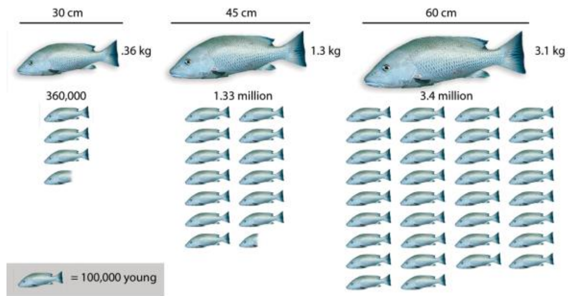

Average numbers of young produced by three different sizes of gray snapper.
Data: Bortone & Williams (1986) US Fish and Wildlife Service Biological Report

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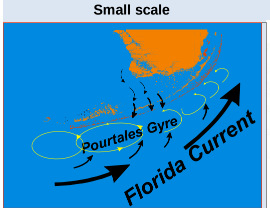
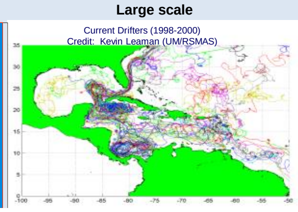
Connectivity

- •Connectivity is considered a critical component in the design of Marine reserves.
- •For most reef species, connectivity occurred on small and large scales

Small scale



Large scale



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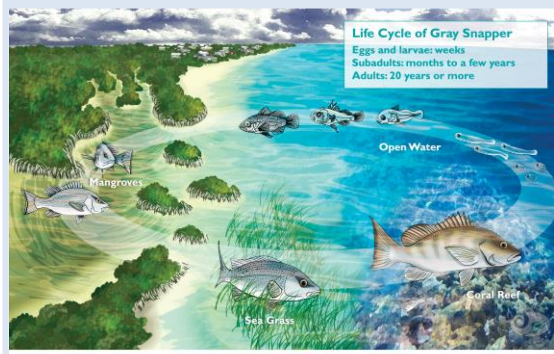

The gray snapper uses many habitats throughout its life. Open water, mangroves, sea grass, and coral reef are important for growth and survival during different life stages of this fish. *Art by Ryan Kleiner* In PISCO 2007

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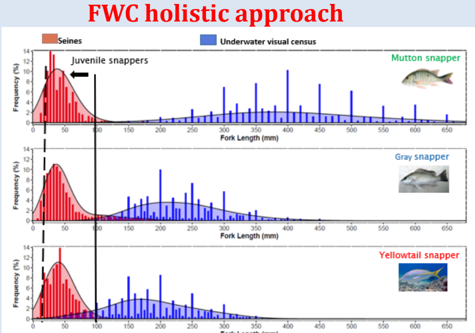
FWC holistic approach



Comparison of length frequency distributions between seines and visual census) for the three snapper collected. Solid line indicated young juvenile snapper (< 100mm SL) and dashed line indicated settlement stage individuals (< 40 mm).

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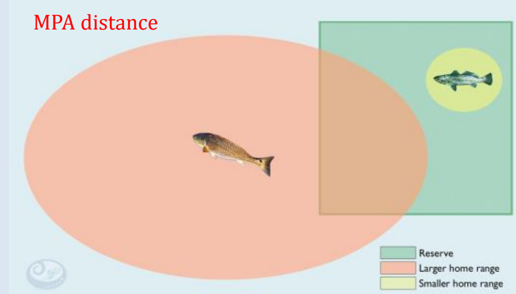
MPA distance



The size of a marine reserve determines which species will benefit the most based on how far the adults move. Adults of some species can be protected entirely by the hypothetical reserve (green box) in the figure because they move only short distances (yellow oval) and may never leave the reserve. However, other species move farther (orange oval) and would likely benefit less from a marine reserve of this size. *Data: Johnson et al. (1999) North American Journal of Fisheries and Aquatic Sciences*

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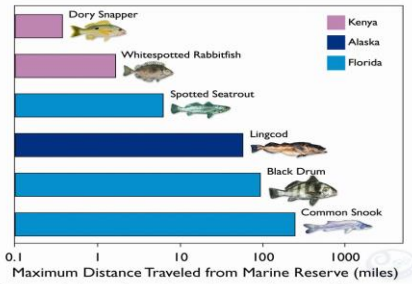

This graph shows the maximum distances that tagged fishes traveled from marine reserves in Kenya (violet), Alaska (navy), and Florida (turquoise). These studies provide direct evidence that fishes spill over from marine reserves into surrounding waters. *Data: Kaunda-Arara & Rose (2004) Environmental Biology of Fishes; Johnson et al (1999) North American Journal of Fisheries Management; Starr et al. (2006) Canadian Journal of Fisheries and Aquatic Sciences*

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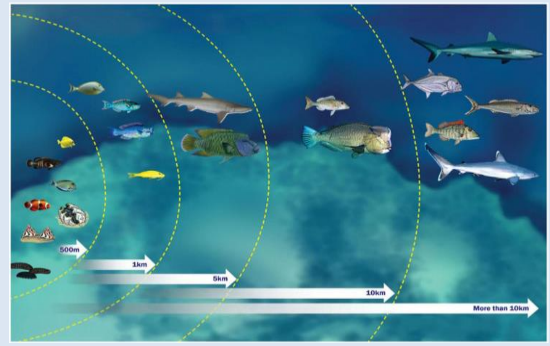

Different species have home ranges of different sizes (modified from Maypa 2012), so they need different sized marine reserves. To maintain healthy populations of focal species, marine reserves should be larger than their home ranges. (From Green et al 2014.

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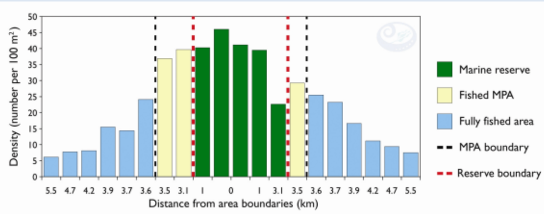

The abundance of 8 commercially important fishes is highest in the middle of the marine reserve and declines beyond the reserve boundary in a fished MPA and a fully fished area.
Data: Guidetti (2007) Conservation Biology

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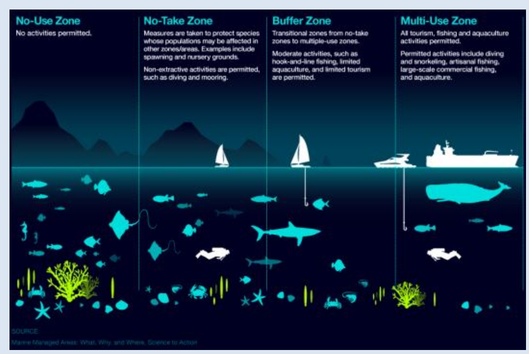

The figure illustrates the different types of zones that may be designated within an MPA to manage the different activities and also shows what the likely state of the biodiversity will be in the different zones.

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How Long Will It Take for MPAs to Produce Benefits?

- Stocks of many exploited species can be expected to increase by 2 to 4 times in 5 years
- Spillover should become significant within 5 years
- Net gains will come faster the more over fished the stocks are to begin with

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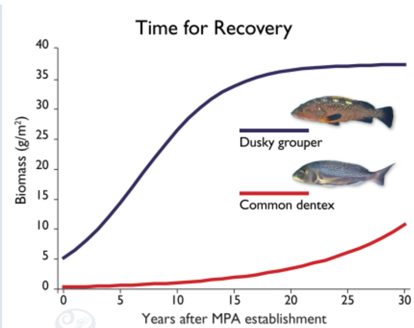

Recovery of biomass for the common dentex (red line) and dusky grouper (blue line) in the Medes Islands MPA in Spain. Garcia-Rubies et al. (2013) *PLoS ONE*

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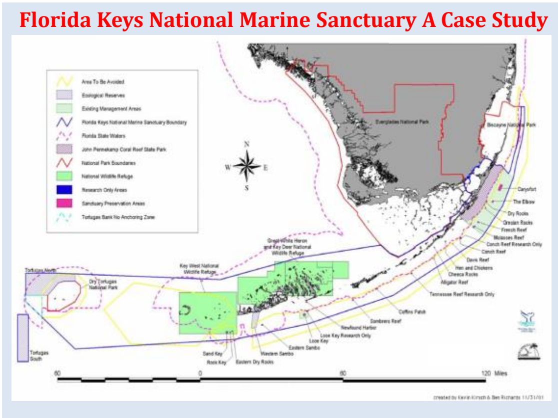

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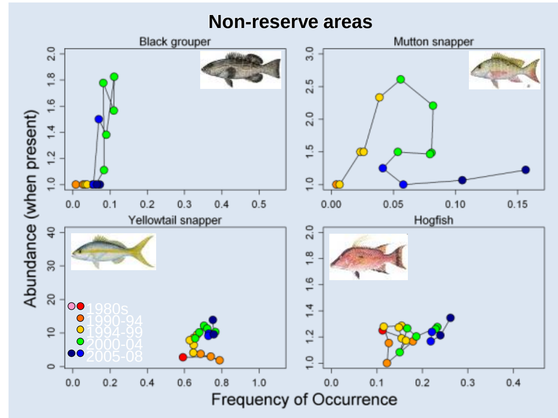

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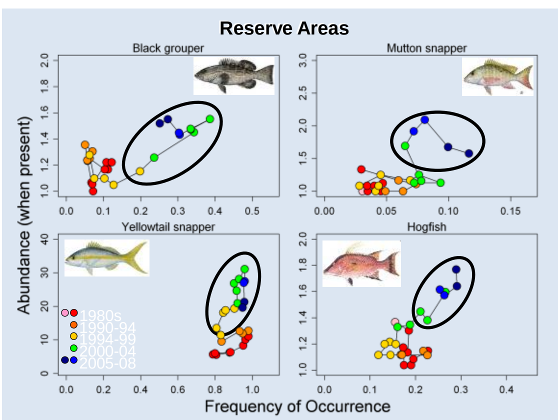

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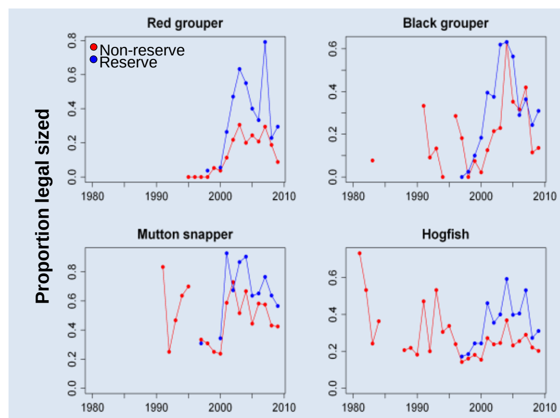

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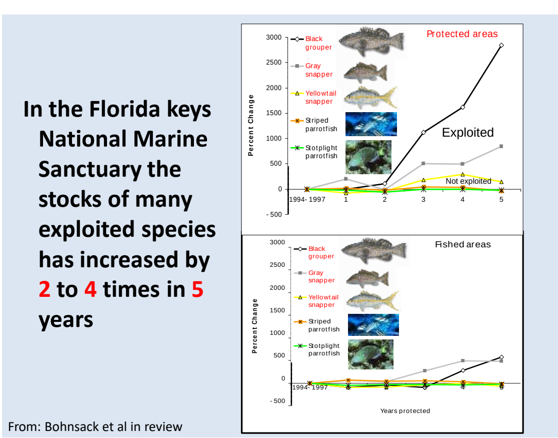

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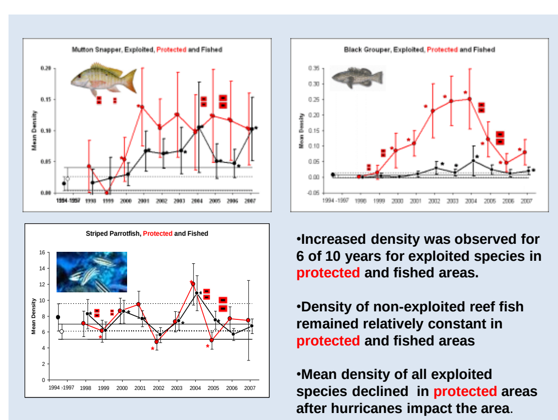

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Maturity size of fish

Species	Common Name	Maturity Size
Mycteroperca bonaci	Black Grouper	67.7
Cephalopholis fulva	Coney	14.7
Lutjanus cyanopterus	Cubera Snapper	65
Lutjanus cyanopterus	Cubera Snapper	65
Lutjanus jocu	Dog Snapper	31
Lutjanus griseus	Gray Snapper	21
Cephalopholis cruentata	Graysby	16
Lutjanus synagris	Lane Snapper	16
Lutjanus mahogoni	Mahogany Snapper	14
Lutjanus analis	Mutton Snapper	28
Epinephelus striatus	Nassau Grouper	48
Epinephelus guttatus	Red Hind	25
Epinephelus adscensionis	Rock Hind	25
Lutjanus apodus	Schoolmaster	25
Mycteroperca tigris	Tiger Grouper	46
Mycteroperca venenosa	Yellowfin Grouper	51
Mycteroperca interstitialis	Yellowmouth Grouper	42
Ocyurus chrysurus	Yellowtail Snapper	15

What is average size of fish in your MPA?

Are they getting large enough to reach maturity?

Maturity size of fish data are from Courtney Cox (RARE) and Heathy Reefs Initiative

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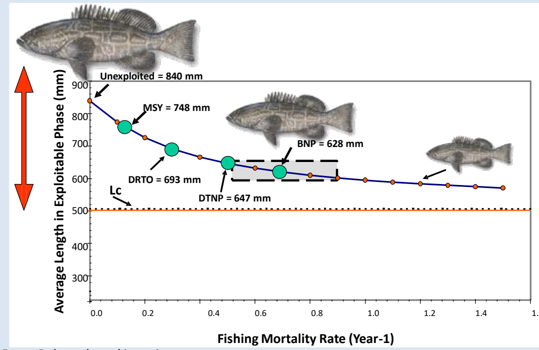
Fish are Larger Inside a Marine Reserve



From: Bohnsack et al in review

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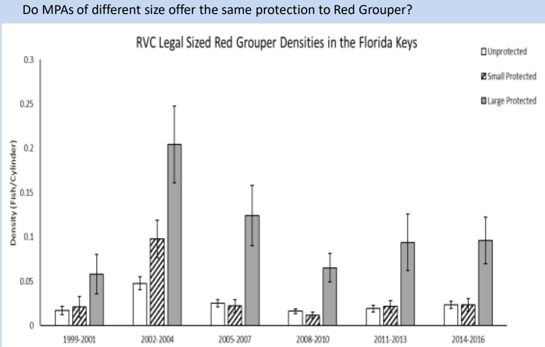
Incorporating RVC with Acoustic Telemetry

Do MPAs of different size offer the same protection to Red Grouper?



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FWC using Telemetry in the Keys

Over the last decade, the FWC Program has employed fish telemetry as a standard research tool to address information gaps.

Ultrasonic telemetry is an ideal tool to address questions related:

a) Activity patterns and habitat use of highly mobile and resident fishes
b) to quantify the movements of fishes, often relative to marine reserve boundaries and
c) to validate Fish Spawning Aggregation sites

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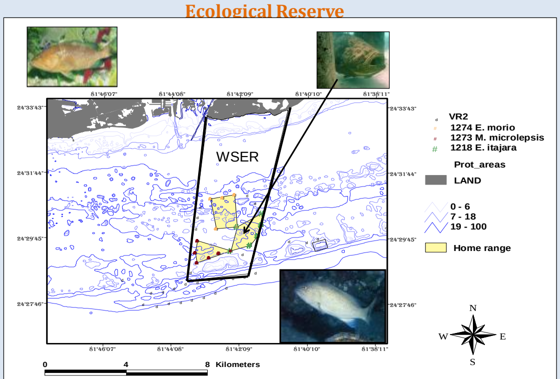
Home ranges for selected groupers in Western Sambos Ecological Reserve



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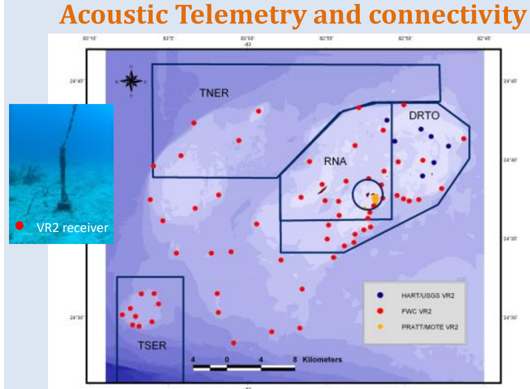
Acoustic Telemetry and connectivity



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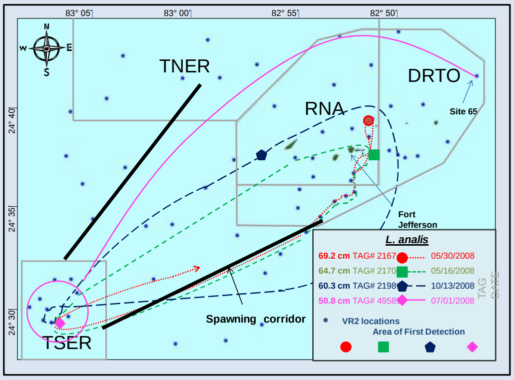

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Summary

For Stock assessment:
Fishery-independent surveys offer the best choice for achieving a reliable index of abundance

Surveys need to be designed with respect to: location, timing, gear, and other statistical survey design

For Marine Reserves:

- The combination of several independent sampling methods allows the estimation of fish density by habitat, and this is a valuable tool for evaluating the performance of the reserve.
- If these protected areas to be effective, they must include the diversity of habitats necessary to accommodate a wide range of fish species.

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Potential Management Actions

1. Reef monitoring plans (ideally every 2 years unless disturbance event like hurricanes, bleaching, disease then survey after event).
2. Review zoning of MPA (are there sensitive areas that would benefit from more protection (shallow reefs, FSA, nursery areas?)
3. Review regulations and enforcement
4. Minimize human impacts (land-based pollution, boat damage, coastal development or erosion, etc).
5. Active restoration (are there areas that would benefit from intervention –seagrass/mangrove restoration, coral enhancement, shoreline rebuilding)?

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Will redirected fishing effort undermine the benefits of reserve?

- Problems caused by redirection of fishing effort following reserve creation are highly unlikely to outweigh the benefits of reserves.
- Problems can be caused by changes in fishing effort.
- It is important to protect sites where populations and habitats are highly vulnerable to fishing.

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Some Final Thoughts

- An imperfect reserve is better than no reserve
- Need for conservation cannot be separated from the need for resource use
- Socioeconomic considerations usually determine the success or failure of MPA

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Steps for monitoring and assessment of the human dimensions of an LME, and of the use of its resources

1. Identify principal uses of LME resources
2. Identify LME resource users and their activities
3. Identify governance mechanisms influencing LME resource use
4. Assess the level of LME-related activities
5. Assess interactions between LME-related activities and LME resources
6. Assess impacts of LME-related activities on other users
7. Assess the interactions between governance mechanisms and resource use
8. Assess the socioeconomic importance of LME-related activities and economic and sociocultural value of key uses and LME resources
9. Identify the publics priorities and willingness to make tradeoffs to protect and restore key natural resources
10. Assess the cost of options to protect or restore key resources
11. Compare the benefits with the costs of protection and restoration options
12. Identify financing alternatives for the preferred options for protecting/restoring key LME resources

From: Sutinen et al 2000

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