Reef fish spawning aggregations: a rather brief love story

This presentation is brought to you today through the cooperation of the following institutions:
Reef Fish Spawning Aggregations (FSAs)

Why do fish form FSAs?

• Many reef fish species use spawning aggregations
  – Increases chances of finding mates
  – Increases genetic diversity in the population
  – Protect adults and eggs from predation
• Many species forming spawning aggregations (www.scrfa.org)

• Timing and size of the FSA vary greatly. Ex: wrasse vs. grouper
Reef Fish Spawning Aggregations (FSAs)

Why should we be concerned about the status of FSAs?

• There are species that use spawning aggregations as their only means of reproduction
  – These aggregations occur at predictable locations and times of the year.
  – This predictability increases the chances that these aggregations could be depleted due to over exploitation.

Photo credit: Douglas David Seifert
Reef Fish Spawning Aggregations (FSAs)

How do fish know where to form FSAs?

• One theory: young fish learn from older fish
  – The same individual fish return year after year, sometimes covering great distances.
Reef Fish Spawning Aggregations (FSAs)

What happens if an aggregation is fished out?

- If it is completely fished out, there is not much evidence that they can return.
  - However, if there are some remnants of the population left, with time, it may recover.

From: Sedovy de Mitcheson et al, 2008
Reef Fish Spawning Aggregations (FSAs)

How are FSAs studied?

• A variety of techniques:
  – Both fishery-dependent and fishery-independent

• Fishery-dependent:
  – Collect reproductive samples
  – Interview people fishing

• Fishery-independent:
  - Direct observation
  - Tag and release
  - Remote Operating Vehicles
  - Acoustics
Reef Fish Spawning Aggregations (FSAs)

How we study the aggregations here in the Keys

Objectives:

1. Identify potential FSA sites
2. Assess reef fish utilization of the sites using sonar, diver surveys and telemetry (acoustic tagging)
3. Assess and compare geomorphological characteristics of the sites
   - Similar geomorphological characteristics across sites?
4. Communicate results to FKNMS and other management entities
Reef Fish Spawning Aggregations (FSAs)

What did we know about aggregations in the Keys?

From: Lindeman et al. 2000
# Reef Fish Spawning Aggregations (FSAs)

<table>
<thead>
<tr>
<th>Species</th>
<th>D</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
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<th>Source</th>
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<tbody>
<tr>
<td>Scamp</td>
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<td>Domeier and Colin 1997</td>
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<td>Gag grouper</td>
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<td>Domeier and Colin 1997, Hood and Schlieder 1992</td>
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<tr>
<td>Yellowtail snapper</td>
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<td>Lindeman et al. 2000, Claro et al 2009</td>
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<tr>
<td>Dog snapper</td>
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<td>Lindeman et al. 2000, RNA report</td>
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<tr>
<td>Schoolmaster</td>
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<td>Lindeman et al. 2000</td>
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<td>Ault et al 2006, RNA report</td>
</tr>
</tbody>
</table>
Best available bathymetry

NOAA Chart 11463
• Contours only

NGDC (National Geophysical Data Center) gridded Bathymetry
• Digital, 90m resolution

= Carysfort Lighthouse
Reef Fish Spawning Aggregations (FSAs)

How did we know where to start?

• Site selection:
  – Gathered information from many sources: fishermen, divers, managers
  • Still an ongoing process

• Sites are mapped during the ‘off’ season using sonar to determine benthic structures

• Surveys were conducted during the predicted spawning moons of the targeted species
Reef Fish Spawning Aggregations (FSAs)

How do we currently study aggregations in the Keys?

- **Upper Keys**
  - Initiated in 2007
  - FSA sites previously “fished out”

- **Lower Keys**
  - Initiated in 2009
  - Status of FSA sites unknown

- **Middle Keys**
  - Initiated in 2011
  - Mapping currently in progress
Reef Fish Spawning Aggregations (FSAs)

How did we map the FSAs?

• Using acoustic sonar
  – Project began using a single beam and split-beam system.
  – Currently, we use a multi-beam system.

• Transects were driven while acoustics ‘pinged’ the bottom
  – Mowing the lawn
Reef Fish Spawning Aggregations (FSAs)

How did we conduct surveys?

- Using sonar equipment
  - Previously mapped areas were surveyed during predicted spawning times
Reef Fish Spawning Aggregations (FSAs)

Diver surveys to groundtruth sonar observations

- Divers were deployed when a large fish mark was detected by the sonar equipment
- Sometimes it was a target species, sometimes not.
Reef Fish Spawning Aggregations (FSAs)

Aerial Surveys:
• Examine boating pressure on known sites
• Used to identify potential FSAs
Reef Fish Spawning Aggregations (FSAs)

What have we discovered about aggregations in the Keys?

Keep in mind
- Keys aggregation research: began 5 years ago...
- Other areas of the Caribbean began in the 1990s and early 2000s

What has not been done:
- Other than the Tortugas South Ecological Reserve, have not successfully documented spawning at these aggregations
  - Spawning is implied: fisheries dependent data, timing of observations, condition of fishes observed
  - Aggregating fish will still attract higher levels of exploitation
Reef Fish Spawning Aggregations (FSAs)

What have we found in the Keys?

NGDC bathymetry (left) vs. QTCV bathymetry (right)

SER = Shelf Edge Reef
FOR = Forereef
IOR = Incipient Outlier Reef
Reef Fish Spawning Aggregations (FSAs)

In the Upper Keys:

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Species Observed</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whistle Buoy</td>
<td>Cubera Snapper</td>
<td>Several visual observations of 15-34 schooling cubera snapper (60-85 cm), June and July 2009</td>
</tr>
<tr>
<td>Carysfort</td>
<td>Black Grouper</td>
<td>Several observations of 6-11 large black grouper (50-85 cm), Feb &amp; March 2010</td>
</tr>
<tr>
<td>Watson Reef*</td>
<td>Mutton Snapper</td>
<td>Visual observation of 35-45 mutton snapper (60-65 cm) swimming in water column</td>
</tr>
</tbody>
</table>

* Watson Reef was also reported as a location for black and yellowtail snapper, but direct observations for those species have yet to be confirmed.
# Reef Fish Spawning Aggregations (FSAs)

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Species Observed</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Dry Rocks</td>
<td>Mutton snapper, gray snapper, yellow goatfish, mahogany snapper, spadefish, striped grunts</td>
<td>Dozens of mutton snapper observed by divers May 2011, observations of 38 fishing boats on site in May 2011; Hundreds to over 1000 gray snapper observed over several months (June, July, and/or August) 2010 and 2012, with additional species</td>
</tr>
<tr>
<td>Mangrove Toppino</td>
<td>Gray snapper</td>
<td>Over 1000 gray snapper swimming in tight school over two successive days, August 2012</td>
</tr>
<tr>
<td>Eyeglass Bar</td>
<td>Gray snapper, mutton snapper</td>
<td>Hundreds of gray snapper observed over three consecutive months (June, July, August) 2010: Fishing boats observed catching mutton snapper in May 2012, no visual observation by divers</td>
</tr>
<tr>
<td>Maryland Shoal</td>
<td>Gray snapper, yellowtail snapper</td>
<td>Numerous schools of 12-25 fish, large (30-50 cm) fish, swimming in close formation. Observations of 10 fishing boats (1 commercial, 9 recreational) fishing on gray snapper in July 2010</td>
</tr>
</tbody>
</table>
SPAs do not contain reef fish aggregation sites

SER = Shelf Edge Reef
BRT = Back Reef Trough
FOR = Forereef
IOR = Incipient Outlier Reef
UST = Upper Slope Terrace
Aerial Surveys - Boating Pressure

Morning Flights

Afternoon Flights

Photo credit: FWC, Robert Glazer
Reef Fish Spawning Aggregations (FSAs)

How have FSAs fared in other locations?

Over here guys! I think I see some fish!
Of the 140 aggregation sites for which there is information on their current and past status, the great majority are in decline. Increases are typically associated with some form of protection.
## Reef Fish Spawning Aggregations (FSAs)

### Observations of Mutton snapper (*Lutjanus analis*) on Riley’s Hump

<table>
<thead>
<tr>
<th>Date and Station</th>
<th>Numbers observed</th>
<th>Moon phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 May–1 June 1999</td>
<td>1 fish in 3 of the 11 dives</td>
<td>Full moon May 30*</td>
</tr>
<tr>
<td>31 July–3 Aug 2000</td>
<td>1 fish in 5 of the 6 dives</td>
<td>New moon July 30*</td>
</tr>
<tr>
<td>17 July 2001 Station 2</td>
<td>10</td>
<td>3 days before new moon*</td>
</tr>
<tr>
<td>27 May 2002 Station 2</td>
<td>75 -100</td>
<td>1 day after full moon*</td>
</tr>
<tr>
<td>15 June 2003 Station 2</td>
<td>75 -100</td>
<td>1 day after full moon*</td>
</tr>
<tr>
<td>15 June 2003 Station 12</td>
<td>200 +</td>
<td>1 day after full moon*</td>
</tr>
<tr>
<td>4 July 2004 Station 12</td>
<td>300</td>
<td>2 days after full moon*</td>
</tr>
<tr>
<td>3 July 2007 Station 12</td>
<td>100 +</td>
<td>3 days after full moon**</td>
</tr>
<tr>
<td>12 June 2009 (1415-1715 hrs)</td>
<td>~4000</td>
<td>5 days after full moon***</td>
</tr>
</tbody>
</table>


** Mike Burton’s Trip report

*** FWC current study
Reef Fish Spawning Aggregations (FSAs)

What about FSA work in other parts of the Caribbean?

Case studies:

How they study aggregations in Belize and U.S. Virgin Islands
Timing and occurrence of multi-species reef fish spawning aggregations

Hypothesis: multi-species reef fish spawning aggregations occur predictably at:

- shelf edges (20-60 m water depth)
- adjacent to deep water (>200 m)
- reef promontories (convex shelf-edge bend, or “submerged capes”)
- ledges, humps or high-relief structure
CHARACTERIZATION OF TRANSIENT MULTI-SPECIES REEF FISH SPAWNING AGGREGATIONS AT GLADDEN SPIT, BELIZE

William D. Heyman and Björn Kjerfve

Table 2. Direct and indirect evidence of possible transient spawning aggregations at Gladden Spit. Spawning was observed (S) for 17 species, constituting direct evidence.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species name</th>
<th>Seasonal peak spawning period</th>
<th>Lunar abundance peak</th>
<th>Evidence for spawning aggregations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lutjanidae</td>
<td>Lutjanus analis</td>
<td>Mar–Jun</td>
<td>–2 to 7 dafm</td>
<td>R 3 S 3 G C F</td>
</tr>
<tr>
<td></td>
<td>L. cyanopterus</td>
<td>Apr–Sep</td>
<td>–2 to 12 dafm</td>
<td>R 3 G C F</td>
</tr>
<tr>
<td></td>
<td>L. jocu</td>
<td>Apr–Jun</td>
<td>–2 to 7 dafm</td>
<td>R 3 C F</td>
</tr>
<tr>
<td></td>
<td>Ocypodeus clypeus</td>
<td>Feb–Mar</td>
<td>No data</td>
<td>R 3 S 3 F</td>
</tr>
<tr>
<td>Serranidae</td>
<td>Epinephelus striatus</td>
<td>Dec–Feb</td>
<td>2–10 dafm</td>
<td>R 3 G C F</td>
</tr>
<tr>
<td></td>
<td>Mycteroperca bonaci</td>
<td>Jan–Mar</td>
<td>5–14 dafm</td>
<td>R 3 G C F</td>
</tr>
<tr>
<td></td>
<td>M. tigris</td>
<td>Dec–Jan</td>
<td>2–10 dafm</td>
<td>G C F</td>
</tr>
<tr>
<td></td>
<td>M. venenosa</td>
<td>Jan–Apr</td>
<td>6–14 dafm</td>
<td>R 3 G C F</td>
</tr>
<tr>
<td>Carangidae</td>
<td>Seriola dumerili</td>
<td>Apr–Jun</td>
<td>No data</td>
<td>R 3 C F</td>
</tr>
<tr>
<td></td>
<td>Carangoides ruber</td>
<td>Apr–May</td>
<td>0–7 dafm</td>
<td>3 S 3 A C</td>
</tr>
<tr>
<td></td>
<td>Caranx hios</td>
<td>Apr–Jun</td>
<td>0–7 dafm</td>
<td>3 S 3 A C</td>
</tr>
<tr>
<td></td>
<td>Caranx laius</td>
<td>Apr–Jun</td>
<td>0–7 dafm</td>
<td>3 S 3 A C</td>
</tr>
<tr>
<td></td>
<td>Carangoides barbulae</td>
<td>Jun–Jul</td>
<td>0–7 dafm</td>
<td>3 S 3 A C</td>
</tr>
<tr>
<td></td>
<td>Trachurus falcatus</td>
<td>Apr–Jun</td>
<td>0–7 dafm</td>
<td>3 S 3 A F F</td>
</tr>
<tr>
<td></td>
<td>Decapterus macculatus</td>
<td>Jun</td>
<td>No data</td>
<td>3 S 3 C F</td>
</tr>
<tr>
<td>Scombridae</td>
<td>Scomberomorus cavalla</td>
<td>Apr–May</td>
<td>No data</td>
<td>R 3 S 3 A C</td>
</tr>
<tr>
<td>Erophidae</td>
<td>Chaetodipterus faber</td>
<td>Feb–Jul</td>
<td>0–7 dafm</td>
<td>A C</td>
</tr>
<tr>
<td>Labridae</td>
<td>Lachnolaimus maximus</td>
<td>Apr–May</td>
<td>0–7 dafm</td>
<td>S 3 A C</td>
</tr>
<tr>
<td>Haemulidae</td>
<td>Haemulon album</td>
<td>Apr–Jul</td>
<td>No data</td>
<td>R 3 S 3 C</td>
</tr>
<tr>
<td>Balistidae</td>
<td>Canthidermis maximus</td>
<td>Apr–Jun</td>
<td>0–7 dafm</td>
<td>3 S 3 A C</td>
</tr>
<tr>
<td></td>
<td>Xenichthys ringens</td>
<td>Mar–Aug</td>
<td>0–7 dafm</td>
<td>3 S 3 A C</td>
</tr>
<tr>
<td>Sparidae</td>
<td>Calamus bajonado</td>
<td>Dec–Jan</td>
<td>0–7 dafm</td>
<td>R 3 C</td>
</tr>
<tr>
<td>Ostraciidae</td>
<td>Lactophrys trigonus</td>
<td>Feb–Mar</td>
<td>0–7 dafm</td>
<td>S 3 A C</td>
</tr>
<tr>
<td></td>
<td>L. triqueter</td>
<td>Jan–May</td>
<td>0–7 dafm</td>
<td>3 S 3 A C</td>
</tr>
</tbody>
</table>

dafm: days after full moon; negative numbers are days before full moon
S: spawning observed
R: ripe gonads found in high proportion (~70%) of fishery-landed individuals
3: at least 3x increase in abundance over non-aggregating time
G: gravid individuals observed underwater
Δ: color changes associated with spawning observed underwater
C: courtship behaviors observed underwater
F: reported by fishermen
CHARACTERIZATION OF TRANSIENT MULTI-SPECIES REEF FISH SPAWNING AGGREGATIONS AT GLADDEN SPIT, BELIZE

William D. Heyman and Björn Kjerfve

Gladden Spit example

Key
Belize spawning aggregation sites

USVI Nassau Grouper FSA site. From Kadison et al 2010 GCFI presentation

Grammanik Bank

Staging areas

South Bank

From Kovara and Heyman 2008 GCFI presentation

Grand Cayman SPAG site

From Heyman and Kobara 2012
FSA near outlier reefs

SER = Shelf Edge Reef
BRT = Back Reef Trough
FOR = Forereef
IOR = Incipient Outlier Reef
UST = Upper Slope Terrace
Most of the 36 documented and verified FSA sites in the Caribbean were found near shelf edges (29 sites or 81%) and dropoffs (23 sites or 64%).

From: Heyman and Kobara 2012.
Reef Fish Spawning Aggregations (FSAs)

- U.S. Virgin Islands – using the geomorphology and acoustic tagging to examine grouper aggregations
Defining spatial and temporal scales of movement of spawning aggregations

Spawning site (hourly)
• gamete release

Courtship arena (daily)
• spawning coloration
• courtship behaviors
• aggression

Staging area (weekly or monthly)
• feeding
• cleaning stations
• guiding first-time spawners

Catchment area (annually)
100 to > 1000 km²

1 km²
< 5 km²
25 km
5 to 100 km²

Functional Migration Area
Staging area
• feeding
• cleaning stations
• guiding first-time spawners

Courtship arena
• spawning coloration
• courtship behaviors
• aggression

Spawning site (hourly)
• gamete release

Nassau grouper
n = 37

Yellowfin grouper
n = 11

Tiger grouper
n = 6

n = 9
Other Spawning Aggregations - Conch

- Eastern Dry Rocks SPA
- Western Sambo Ecological Reserve
- Eastern Sambo Research Only
- Looe Key SPA
- Sombrero SPA
- Conch SPA
- Alligator SPA
- Molasses SPA
- French SPA
- Grecian SPA
- Elbow SPA

From: Glazer and Delgado report
Reef Fish Spawning Aggregations (FSAs)

Home ranges of conch: adapted from Delgado and Glazer 2007
Reef Fish Spawning Aggregations (FSAs)

Communicating the importance of FSAs

- Providing information to the community
  - Outreach and education
- Providing information to managers
  - Presentations to SAC, Sanctuary staff and FWC
Thank you montage slide...

• Project co-PIs:
  • Todd Kellison (NOAA)
  • Chris Taylor (NOAA)
  • Art Gleason (University of Miami)
• And a huge tip of the hat to Mike Feeley, Rick Nemeth, Will Heyman, the numerous FWC, NOAA personnel, and the community members who have provided both field support and their vast knowledge.
Any Questions?

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