Characterizing a prespawning aggregation of bonefish, *Albula vulpes*

Quentin Andersen, Lily Bermel, Josie Cummings, Toby Ketchum, Andrew Muggia,
Ceci O'Marah, and Rob Titsworth
Advisor: Georgiana Burruss

Introduction

Spawning aggregations are temporary aggregations of a marine species that gather together at a predictable time and place for the purpose of broadcast spawning, or the mass release of gametes (Domeier 2012). These species, from small reef fish to humpback whales, migrate distances from a few meters to thousands of kilometers to their spatially distinct spawning sites. Spawning aggregations result in sudden, large increases in biomass, attracting piscivores and planktivores to feed on the spawning adults and gametes (Sadovy De Mitcheson and Colin 2012). Bonefish (*Albula vulpes*) are a species that form spawning aggregations, moving from their foraging grounds in shallow flats to prespawning aggregation locations, and then into deeper water to spawn, typically during full and new moons (Danylchuk *et al.* 2011).


Figure 1. A recently caught bonefish.

Bonefish are economically and ecologically important to The Bahamas. Catch-and-release bonefish angling contributes $141 million annually to the Bahamian economy (Fedler 2010). Bonefish feed on benthic invertebrates, and their feeding behavior reintroduces nutrients from the sediment back into the water column (Colton and Alevizon 1983). Great barracuda (*Sphyraena barracuda*) and some species of shark regularly prey on bonefish.

Bonefish migrate along coastlines to prespawning aggregation sites, exposing the species to coastal development. Bonefish experience high post-release predation (Cooke and Philipp 2004), and therefore angling creates a higher risk of predation, especially if these aggregations attract more predators.

In 2011, No Name Harbor (NNH) was discovered as a bonefish prespawning aggregation site (Danylchuk *et al.* 2011), where the aggregation resides during the day before nighttime spawning. At sunset, bonefish exhibit porpoising behavior, or gulping air at the surface. Porpoising is used as a metric for spawning behavior because after, porpoising bonefish were tracked moving from NNH to the drop-off of the Exuma Sound to spawn (Burruss, G., unpublished data). Commonly, aggregating species use the peaks in the lunar cycle as their spawning cue because these are the darkest and brightest nights of the month and have the strongest tides. Strong outgoing tides are important for bonefish as the tide would pull pelagic larvae offshore, decreasing the risk of egg predation and increasing dispersal.

The purpose of this study is to characterize NNH as a bonefish prespawning aggregation site by creating a bathymetric map, determining predator abundance around and interactions with the aggregation, and assessing the influence of abiotic factors on the aggregation.


Figure 2. Bonefish spawning aggregation.

By characterizing NNH by determining the influences of abiotic factors on the prespawning aggregation in NNH, bonefish reproductive cycles can be more understood. Understanding predator interactions with bonefish prespawning aggregations is integral to learning how coastal predators depend on these aggregations. This research is critical because this data will allow bonefish to be better managed and protected, through a potential marine protected area.

Methods

Bathymetric Mapping: In order to characterize NNH, a bathymetric map of the site was generated based on systematic depth measurements taken at specific GPS waypoints using a plumb line measuring in meters.

Surveys at Aggregation Site: Underwater Visual Consensus (UVC) surveys were conducted in order to assess predator density and number of fish in the aggregation. Video surveillance was conducted using a GoPro camera set in NNH for 90 minutes during incoming tide for best visibility. The cues that were studied were aggregation size, tide (specifically the number of hours of outgoing tide from 9 PM to 6 AM), and moon phase. Number of hours of outgoing tide at night was calculated using tide tables and moon phase was recorded for each survey conducted. Observation of porpoising is used as the metric of bonefish spawning but this metric has not been validated because bonefish spawning itself has not been observed due to the depths it occurs at. These observations were conducted at sunset on survey days; presence or absence of porpoising behavior was recorded.

Predator Abundance: Predator interactions with the bonefish spawning aggregation were determined using passive acoustic telemetry. A VEMCO VR2W acoustic receiver was placed in NNH to receive the detections from the VEMCO V13 transmitters implanted in the predators, which produce a coded ping every 60-130 seconds. Fourteen barracuda were caught and surgically implanted with transmitters; seven were caught between Chub Rock and Bamboo Point, an area that the aggregation is frequently tracked at night, and seven were caught between Powell Point to the Schooner Cays, an area that the aggregation has not been tracked using. These areas were used to determine if predators track bonefish aggregations from a far distance or if they just overlap in home ranges.


Figure 3. Barracuda were caught using fast action trolling gear at 6-8 knots.


Figure 4. Barracuda were anaesthetized using clove oil and surgically implanted with an intermittent acoustic transmitter.

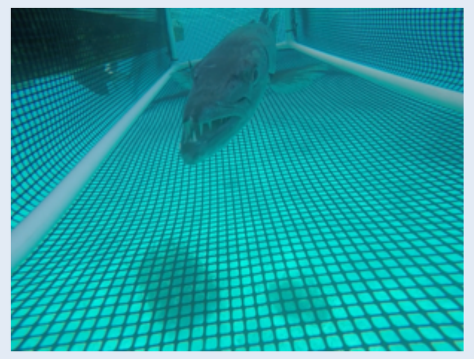
Figure 5. Barracuda were placed into a pen to recover for 45 minutes after surgery and then released close to their capture location.

Results

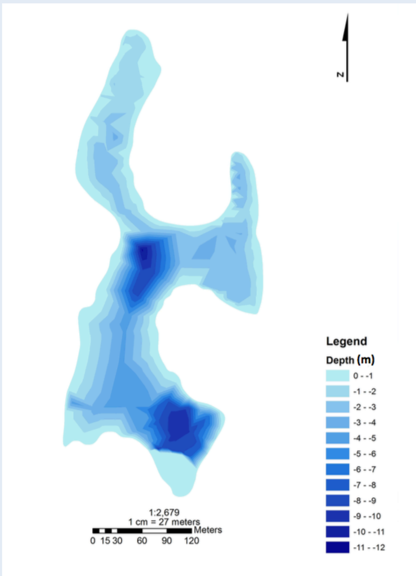

Figure 6. A bathymetric map of NNH was generated using QGIS with depths varying between 0 and 12 m. Depths were adjusted to be slack low tide based on local tide tables.

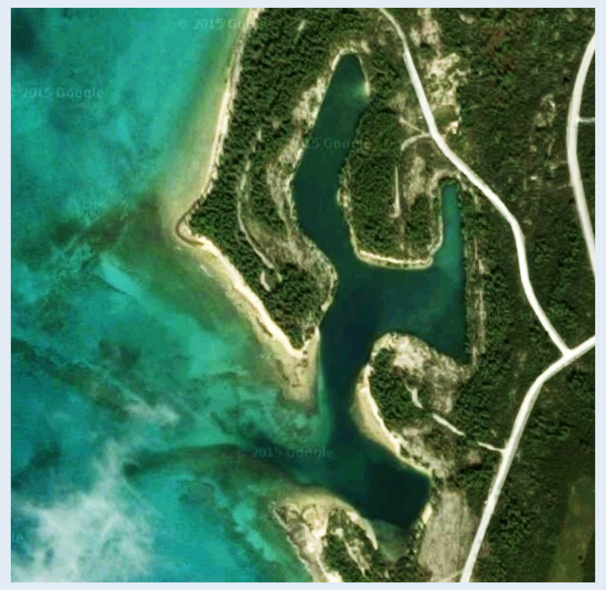
Figure 7. Aerial photo of NNH courtesy of Google Earth.

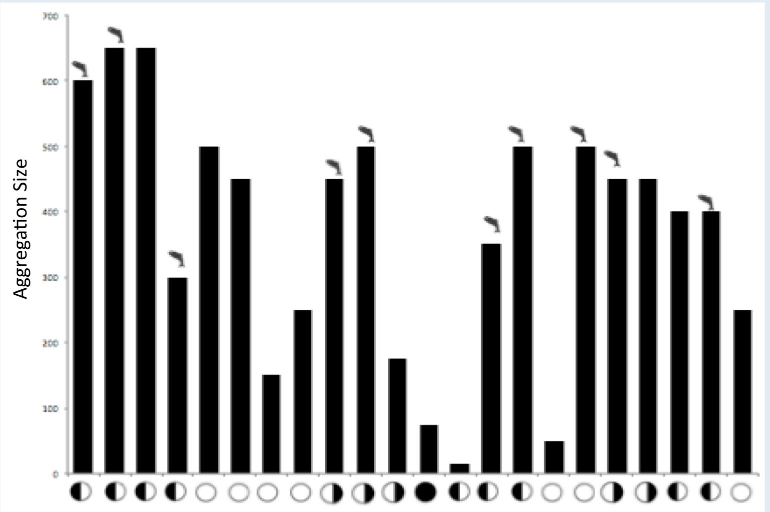

Figure 8. Size of the bonefish aggregation in number of fish in the bonefish aggregation as estimated by using UVC surveys compared with moon phase (open circles represent full moons and closed circles represent new moons). The fish symbol at the top of the bar indicates that porpoising was observed on the same day as the survey.

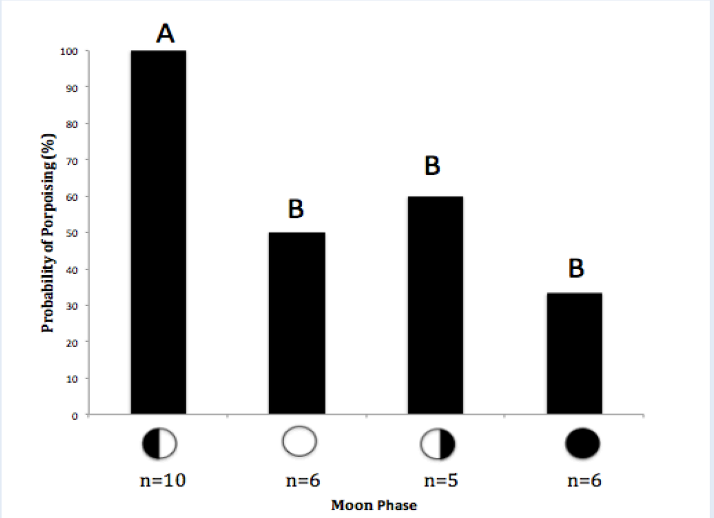

Figure 9. The probability of porpoising occurring during each moon phase was determined by categorizing each observation day into the moon phase (First Quarter, Full, Last Quarter, New moons) within 3 days before or after the observation date. Different letters denote significant differences.

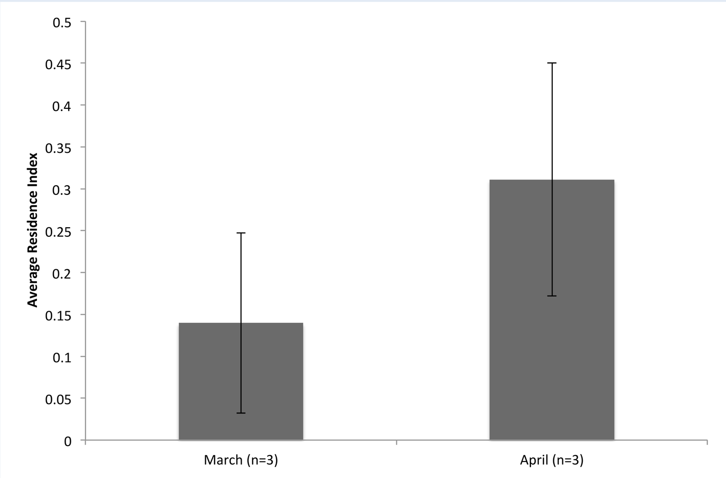

Figure 10. The average residence index of barracuda in NNH in March and April was calculated as the proportion of the number of days a predator was detected by the VR2W receiver in NNH to the number of days in that month.

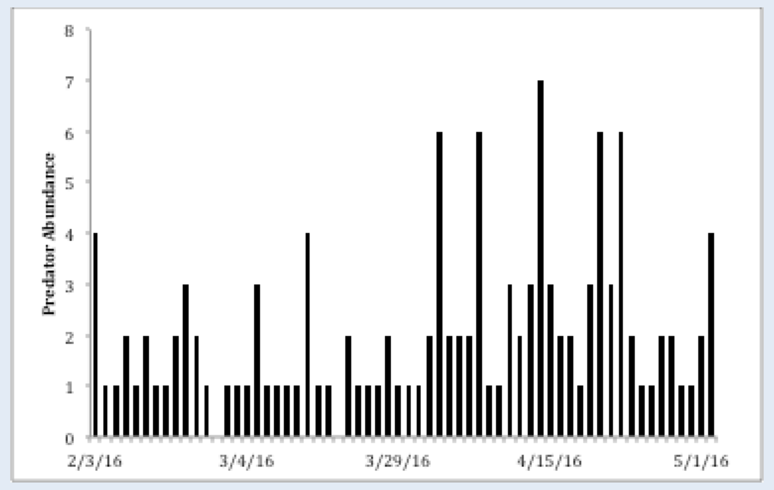

Figure 11. The predator abundance was determined by combining observations from Underwater Visual Consensus (UVC), video surveillance, and acoustic telemetry data from a VR2W receiver placed in NNH. Days during which no surveys were conducted are not included in the figure

All of the data collected was non-parametric; therefore Wilcoxon signed rank tests were conducted to determine significance. Surveys were conducted between February 3rd and May 4th, 2016. Based on all of the survey data, the aggregation size did not vary significantly with moon phase (Wilcoxon signed-rank test, *p*-values > 0.05). The number of fish in the aggregation compared with the probability of porpoising was also not significant (Wilcoxon signed-rank test, *p*=0.0985) (Figure 8). The probability of porpoising occurring in the First Quarter moon was statistically greater than the probabilities of porpoising occurring during the Full, Last Quarter, and New moon phases (Wilcoxon signed-rank test, *p*=0.0202, *p*=0.0486, and *p*=0.0270, respectively) (Figure 9).

The average residence indices did not differ significantly between the months of March and April (Wilcoxon sign-rank test, *p*=0.184). Out of the 14 barracuda tagged, 5 were detected on the receiver in NNH, all of which were from the overlapping range (Figure 10). The average predator abundance across the survey period from February 3rd to May 4th, 2016 was 2.03 +/- 0.19 predators observed. Predator abundance did not vary significantly in relation to the size of the aggregation (Wilcoxon signed-rank test, *p*= 0.1347) (Figure 11).

The size of the aggregation did not differ significantly when compared to tides, specifically the number of tidal hours between 9 PM and 6 AM (Wilcoxon signed-rank test, *p*-values > 0.05).

Discussion

This study aimed to characterize NNH by determining predator abundance and assessing the influence of abiotic factors on bonefish prespawning behavior. According to previous studies, the whole aggregation was believed to stay in NNH for four to seven days, leave, and return, throughout the spawning season (Danylchuk *et al.* 2011; Murchie *et al.* 2015). While individual fish might be moving back and forth between NNH and their foraging ground, this data suggests that as a whole, the aggregation remains in NNH during the bonefish spawning season.

The probability of porpoising occurring during the First Quarter moon is significantly greater than the probability during the other moon phases (Figure 8), meaning that bonefish are most likely spawning during the First Quarter moon, contrary to what previous studies have claimed (Danylchuck *et al.* 2011; Murchie *et al.* 2015). This is atypical compared to other spawning species, like the Nassau Grouper (*Epinephelus striatus*), who use the peaks in the lunar cycle as their spawning cue (Sadovy De Mitcheson and Colin 2012). The results from the data suggest that aggregation size and tide are not cues for bonefish spawning. Therefore, there are most likely other spawning cues that bonefish follow. Further studies could research other potential spawning cues, like the sex ratio in the spawning aggregation, or a combination of studied cues.

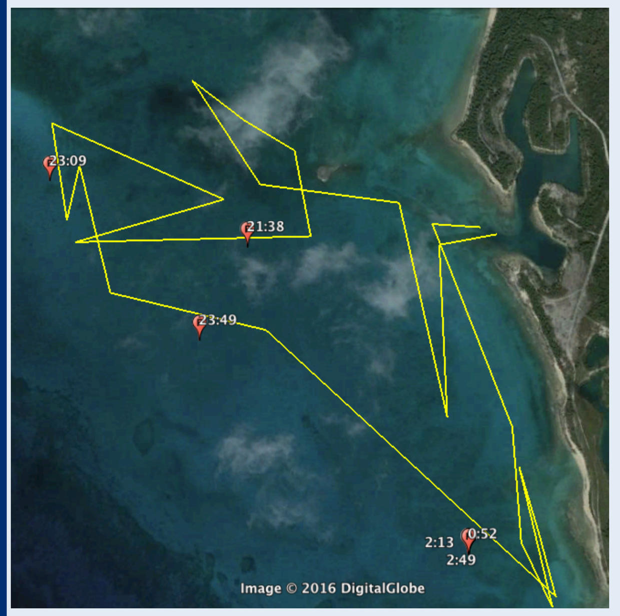

Figure 12. The yellow line signifies the movement of the spawning aggregation at night. The data points show where the barracuda was detected.

Further, predators, such as grouper, barracuda, and sharks, were observed interacting with the aggregation, providing evidence that these interactions need to be further studied. The receiver placed in NNH only picks up data from the harbor whereas the aggregation moves offshore at night. Therefore, predators, including the seven undetected barracuda caught in the far range, could be interacting with the aggregation at night, offshore. It has been noted, via night tracking, that one of the tagged barracuda was following the bonefish aggregation at night for over six hours (Figure 12) (Burruss, G., unpublished data).

Therefore, it is important to collect data from the offshore where the bonefish are spawning in order to study the predator interaction with the aggregation at night, and to look at predator abundance throughout the year. This would reveal more about the dependence and influence of coastal predators on spawning aggregations.

Further studies can use fine-scale acoustic telemetry to individually track bonefish to observe individual and aggregation behaviors during the spawning season and to better understand how and why the aggregation remains throughout the spawning season in NNH. This study and future research about bonefish spawning is important because being able to predict the timing of spawning is critical to the management and success of these species which has huge implications on the success of their spawning. Despite the fact that bonefish are a catch and release species, it is important to protect the aggregations from being fished because it has been observed that bonefish experience an increased post mortality rate as well as predation rate. As there is such a high abundance of large, highly mobile predators in aggregation sites like NNH, a potential marine protected area could have major conservational implications. Protecting bonefish is critical to the success of this recreational fishery and ecosystem stability.


Figure 13. Angler casting on a bonefish school on a Bahamian flat.

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