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Cownose Ray Movement and Behavior in the Intertidal Zone

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Mysteries of the Cownose Ray: Movement and behavior of *Rhinoptera bonasus* in the intertidal zone of Delaware Bay

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Abstract

Variation in cownose ray (*Rhinoptera bonasus*) movements have been attributed to environmental, temporal, and life history factors, but their use of the intertidal zone has not been fully studied. Cownose rays eat ribbed mussels, an obligate intertidal species; thus, their intertidal visitation may be important. We investigated cownose ray movement, from fixed Dual Frequency Identification Sonar (DIDSON) at the Rutgers Cape Shore Laboratory mudflats, relative to water temperature, diel pattern, diurnal conditions, tidal phase, current speed, and heading. Behavioral Observation Research Interactive Software (BORIS) was used to digitally record cownose ray appearance in 170 randomly selected ten-minute sonar videos. Cownose rays enter the intertidal zone at 17 ºC, most likely due to thermoregulation needs which also dictate when cownose rays migrate north. More cownose rays were observed at low current speeds at higher temperatures during ebb tide. Additional behaviors of cownose rays such as feeding, schooling, and remaining stationary require further research to evaluate frequency and potential causes. Understanding cownose ray use of intertidal habitats is important due to its productivity and ecological value. This is especially as coastlines face changes due to sea-level rise, erosion armoring, and development.

Introduction

Atlantic cownose rays are elasmobranchs and batoid rays with 2 genetically distinct stocks, one that lives year-round in the Gulf of Mexico and a second that migrates during the winter to the northern parts of the eastern Atlantic (McDowell & Fisher 2013, Carney et al. 2017). Delaware Bay receives hundreds of cownose rays starting in May when they pup and mate. After mating, males leave the females during July to travel to different habitats before rejoining them in late September to early October to migrate back to the Gulf of Mexico for the winter. Cownose rays are important predators, feeding on bivalves, snails, lobsters, and crabs. When they feed, they beat their wings (pectoral fins) to move sediment out of the way before digging into the sediment to suck up their prey. As the cownose ray suck their prey any sediment they take up is expelled through their gills. They then crush the organism between their tooth plates.

Many marine organisms are influenced by the presence or lack of light since it can provide optimal conditions for feeding (Boeuf and Le Bail, 1999), mating (Fraser et al., 2004), and avoiding predators (Bollens and Frost, 1991; Moreno et al., 1996). Many elasmobranchs are thought to be crepuscular (more active at dusk and dawn during low light conditions). They tend to horizontally migrate and feed more in these conditions, but it is unclear if there is an impact on mating behavior (Hammerschlag et al., 2017). Every year large schools, numbering over a thousand cownose rays migrate between the Gulf of Mexico to waters around New England. Small-scale group movements in elasmobranchs have been attributed to males following females to mate (Hamlett, 2011). Cownose rays have been found in the intertidal zone and ribbed mussels, an obligate intertidal species, have been found in their gut content (Smith and Merriner, 1985*)*. Cownose rays have been seen in the intertidal zone, especially in late spring and early summer, by both scientists and aquaculturists. When cownose rays feed, they dig themselves into the sediment to eat bivalves. These indentations in the sediments are evident after the tide recedes at low tide as large impressions, half a meter to a meter in diameter. After each high tide, new sediment impressions are apparent, implicating cownose feeding in the intertidal zone periodically.

For years, the aquaculture industry has viewed cownose rays as a menace due to their feeding on shellfish stock and perceived lowering of shellfish populations. As a result cownose rays are hunted, despite their near threatened status by the IUCN Red List and shellfish stocks have been declining for years, due to overharvesting, habitat degradation and disease (Grubbs et al., 2016), independent of cownose ray population. Though cownose rays are not responsible for commercial shellfish degradation, they do play an important role in coastal ecosystems as both a predator and as prey for cobia, bull, and sandbar sharks. Shorelines all around the world are changing as sea-level rise changes the shape of coastlines. Seashore armoring, aquaculture, infrastructure, sewage, and nutrient release to coastal waters are changing coastal ecosystems and harming coastal organisms as well. Understanding cownose ray behavior in the intertidal zone can help us understand how their populations will change in the future. It is unclear if they enter the intertidal zone for other reasons, such as mating. The objectives of this study are to understand what cues cownose rays use for entering the intertidal zone by observing cownose ray abundance and unique behavior in relation to diurnal patterns, temperature, tidal phase, diel pattern, current speed, and heading.

Materials & Methods

Study Area

Delaware Bay is a large estuary, where the Delaware River empties into the Atlantic Ocean, between New Jersey and Delaware. Sonar videos of the intertidal zone were collected at the intertidal zone of the Rutgers' Cape Shore Laboratory (39° 4'24" N, 74° 54'46" W) (Fig. 1). The area hosts oyster brooding arrays to collect oysters for research purposes. The marine habitat is a mudflat at low tide and extremely turbid at high tide, with no seagrass. The bay's depth is 45m with a tidal range of 1.5m. The temperature ranged from 13°C to 23°C within the course of the study period, which is typical for late May. During the winter Delaware Bay reaches temperatures of 2.11°C and 27°C during the summer. Organisms inhabiting the intertidal zone of Delaware Bay include ribbed mussels, stout razor clam, Atlantic jackknife clam, blue crabs, fiddler crab, diamondback terrapin, Atlantic horseshoe crab, and American eel.

Figure 1: Cape shore laboratory (black star) is on the southern tip of New Jersey, near the outlet of Delaware Bay.

Field Methods

In turbid or dark marine systems dual frequency identification sonar (DIDSON) can collect visuals, unlike other optical systems. The sonar emits either 1.8 MHz or 1.0 MHz to create beams which then bounce back to the camera. The beams that bounce back are used to create visuals. This makes it suitable for use in the waters by Cape Shore, due to the turbidity. The DIDSON collected sonic information from 2 to 7 m from its position, and a 30 degree field of view. The DIDSON was mounted on a pole and placed in the intertidal zone on the Cape Shore beach.

The DIDSON sonar collected data during high tidal events from May 11th to May 23rd, from the time of submergence until it emerged again as the tide ebbed. The DIDSON imagery was viewed and controlled in real time via a cable connection to a shore side laptop. Water temperature, current speed, and current heading were continuously recorded during each high tide event.

Computer Methods

Stratified sampling was applied to take random 10-minute videos from each of the 5 tidal phase conditions: early flood tide, flood tide, high tide, early ebb tide, and ebb tide. The ten-minute videos were numbered from 1 through 27. The actual time of high tide, found on the NOAA website, takes place during video number 14. Early flood tide were videos 1 through 6, flood tide were videos 7 through 12, high tide were videos 13 through 15, early ebb tide were videos 16 through 21, and ebb tide were videos 22 through 27. Seventeen high tide events were recorded for a total of 85 videos selected. This entire process was repeated for a second time. Temperature, current speed, and heading was continuously recorded for each tidal phase event and if light was present during the 10-minute video it was considered to be daytime.

Using the computer software program BORIS, the appearance of animals in each 10-minute video was recorded (Fig. 2). The organisms, along with ray activity, was associated with a certain computer key (Table 1). Whenever an organism appeared on screen, the evaluator would hit the computer key associated with the organism or observed behavior, and its time observed was recorded in the DIDSON program. Additionally, any unusual behavior exhibited by the cownose ray was noted.

Table 1: Specific keys were used to record the appearance of each organism in BORIS, during video recordings. Numbers of occurrences for organisms for each video were then exported and analyzed. Amplexus are mating horseshoe crabs.

Key	Organism
1	Cownose Ray swimming
2	Cownose Ray burrowing
3	Eel
4	Large fish
5	Small school fish
6	Horseshoe crab
7	Amplexus
8	School of fish
9	Turtle
u	Unknown

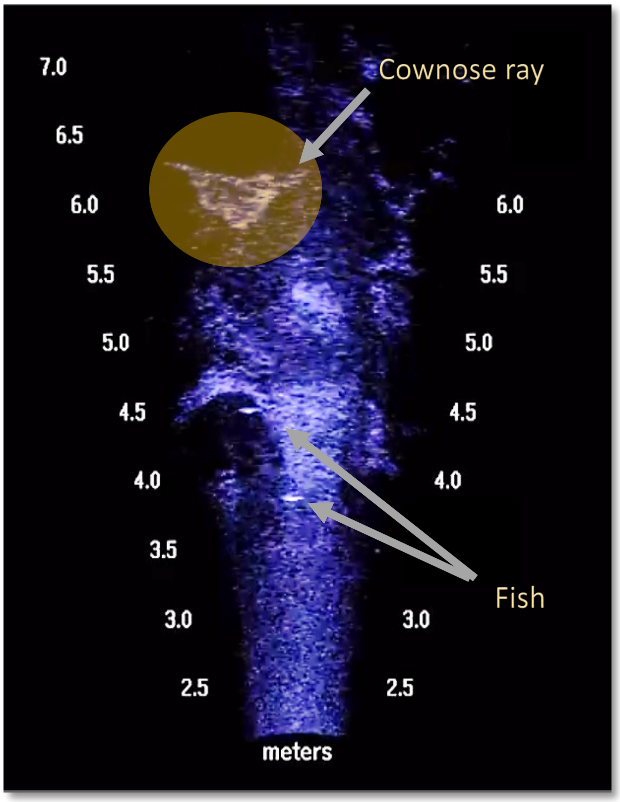

Figure 2: Example of DIDSON video screenshot. Two fish and a cownose ray seen.

Influence of tidal phase on ray abundance was evaluated with a Kruskal-Wallis test. Influence of night and day was evaluated with a Mann Whitney test. Temperature, diel pattern, current heading and current speed were evaluated by use of Kendal's Tau-correlation. Covariance among descriptors was quantified using a principle component analysis.

Results

A total of 76 cownose rays were seen in the sample videos. Of these, 3 were seen feeding, 4 groups were seen, and 1 cownose ray was seen staying in the same position without moving for several minutes. Feeding event had no observable association with the tidal event, temperature, day or night conditions, dial pattern, or current speed and heading. Groups of cownose rays were seen in ebb and early ebb events, during the day (around 10 am to 12 pm), at 18 to 19 °C, at current speeds 15 to 16 cm/s, and on May 18th which was the day of the full moon. One cownose ray was seen staying in one position for a long period in a behavior called "parked". The parked cownose ray was observed during ebb tide, at 18°C, during the day, at a current speeds of 12 cm/s.

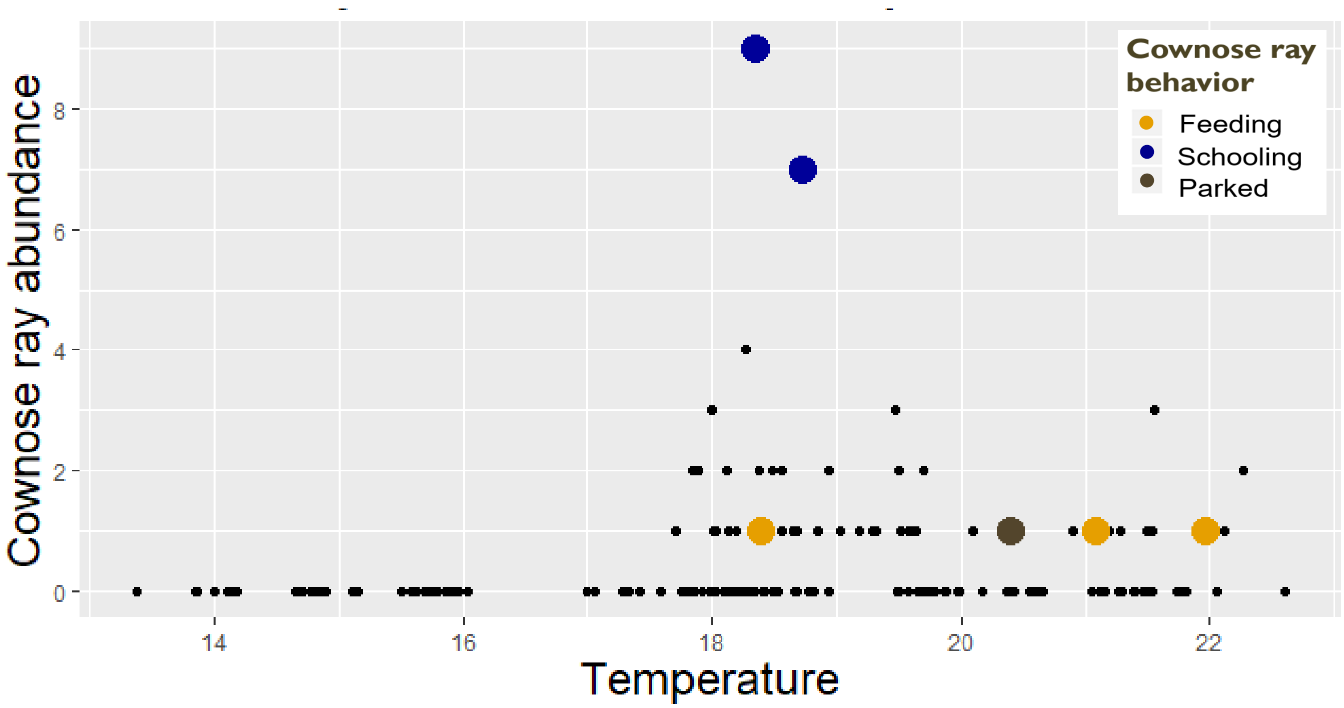

Figure 3: Cownose ray abundance and behavior at different temperatures are shown. Schools of rays were seen during the day of May 18th across tidal events. Feeding occurred during both day and night, and during flood and ebb tide. Non-moving (parked) occurred during the day and ebb tide.

The tidal event, day vs. night vs. lowlight (crepuscular) conditions, diel pattern, current speed, and heading had no apparent influence on cownose ray abundance or behavior on their own. It is very clear that higher temperatures positively correlate with a higher cownose ray abundance ($p=0.0026$). At 17 °C cownose rays started entering the intertidal zone (Fig. 3).

A principal component analysis (PCA) was used to determine which variables most strongly influenced cownose ray abundance. Blue dots are observations with no cownose rays and red circles are observations with cownose rays with circle size radius equaling the number of cownose rays seen per video squared, with a range of 1 to 9 rays per video. Tidal phase, temperature, current heading and speed, and dial pattern (circularized as cosTime and sinTime) are represented in the PCA. All variables were standardized to units of standard deviation. The

PCA suggests that more cownose rays were seen in low current speed, high-temperature waters durring ebb tide (Fig. 4). The x-axis explains 34.71% of the data's variance, and the y-axis explains 21.44% of the data's variance.

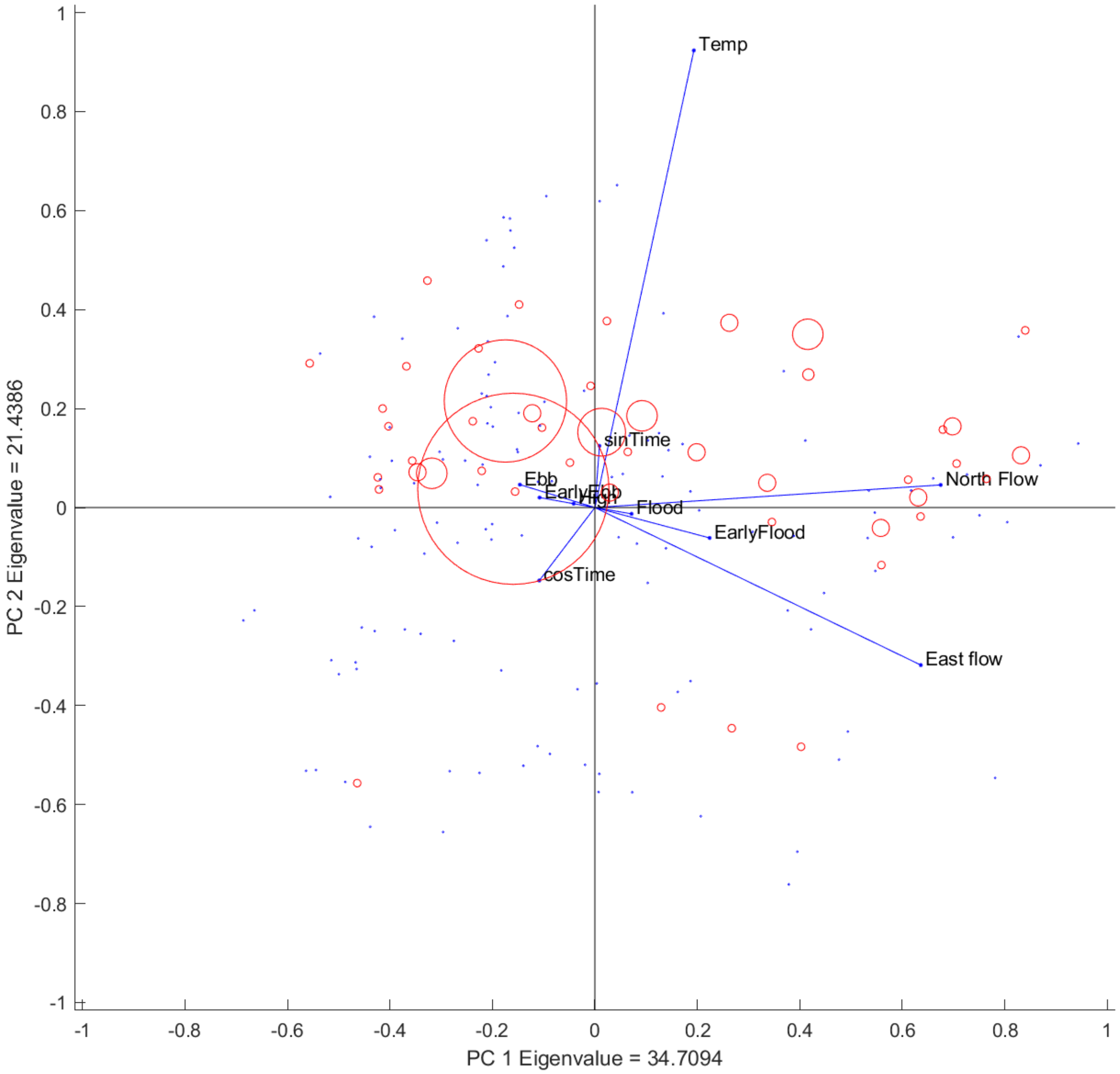

Figure 4: Cownose ray presence (red circles) and absence (blue circles) were evaluated through a PCA plot to determine what variables had the most effect on ray presence. Red circle radius is the number of rays seen in that video squared, with the largest circle being 9 rays and the smallest circles being 1 ray per video. Low current, higher temperatures and ebb tide are associated with higher ray presence. Red circle size radius is the squared number of rays seen.

Discussion

Behavior

The groups of cownose rays were seen on the same day around the same time of day in warm temperatures and slow current conditions. Records of other rays (*Rhinoptera javanica* and *Dasyatis americana*) in small groups have been associated with mating, with multiple males following a single female (Hamlett, William C., 2011). There currently is no data on cownose ray mating behaviors. It is possible what was observed were cownose rays utilizing the intertidal zone to mate. Further investigation of group behavior and frequency of groups of cownose rays will help establish if this is mating behavior. Certain elasmobranchs populate warm intertidal habitats to hasten embryonic development (Hamlett, William C., 2011), which would be consistent with relatively warm intertidal habitats as areas for reproduction. Temperature can play an important role in elasmobranch reproduction and should be investigated in cownose rays.

At one point a cownose ray was seen in one location for an extended period of time. The cownose ray possibly was sleeping or resting. Ray sleeping behavior is not well documented, due to elasmobranchs tending to sleep in hard to reach environments (Heithaus et al., 2002; Papastamatiou et al., 2010). The only ray with known sleeping behavior is the common stingray which reduces their motor activity at night (Karmanova et al., 1976). Though this is different from the cownose ray seen staying in one place during the day, many different records of sharks show different species sleep at different light levels (daytime, nighttime or crepuscular) (Kelly et al., 2019). Since there was only one sighting and no other evidence to support the ray was sleeping, no conclusion can be drawn. However, if the cownose ray was sleeping, investigations into cownose ray sleeping behavior may be observable in the intertidal zone and should be explored.

Feeding behavior occurred too briefly to be analyzed, thus the importance of intertidal habitats for feeding is inconclusive. This does not mean that cownose rays do not frequently enter the intertidal zone to feed. It is difficult to obtain observations of feeding in cownose rays using sonar since the area surveyed was too small. One strategy for evaluating feeding patterns would be to survey the sampling site at low tide to locate and count feeding indentations in the sediment

Abundance

Cownose rays migrate north when the waters become higher than 17 ºC due to thermoregulatory needs (Collins et al., 2007). Cownose rays entering the intertidal zone at 17 ºC and above is consistent with cownose rays having a threshold temperature requirement. The PCA suggested a positive relationship between ray presence, warm temperature, low current speed, and ebbing tide. Though the PCA shows there were more rays in higher temperature, low current speed, ebbing tide conditions (shown by red circles on the left side of the plot) there were also many observations of no cownose rays in these conditions (blue dots on the left side of the plot) (Fig. 2). Due to the video collection occurring over just a two week period, there was a little variation in environmental conditions, with a fair number of videos occurring in warm waters with low current speeds during ebb tide. A longer investigation period with a larger variety of conditions will be necessary to corroborate these results.

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