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Predator exclusion cages as visual attractants to coyotes

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Abstract
Coyote (*Canis latrans*) depredation of sea turtle nests is a growing concern along the US East Coast and while several designs for predator exclusion cages (PECs) have been used, no one PEC is 100% effective. We investigated if PECs are a visual stimulus that lure coyotes to sea turtle nests. We used camera traps to evaluate coyote behavior and visitation rates at two PEC designs on Bald Head Island, North Carolina, USA, between 11 and – 28 June 2021. We quantified coyote presence and absence, number of independent coyote observations (behavioral events), and aspects of observed coyote behaviors. Our results indicate that PECs do not act as a visual cue to coyotes which will provide flexibility for sea turtle management in choosing PEC designs. We discuss the prospect of using a variety of PEC designs as a deterrent to coyotes and the possible effects of human activity on coyote behavior near sea turtle nests.

Keywords Behavior · Cue · Depredation · Endangered species · Management · Sea turtle

Introduction

Challenged with coastal development, climate change, nesting obstructions, pollution, inundation by overwash, and poaching (Lovemore et al. 2020; Madden et al. 2020), loggerhead sea turtles (*Caretta caretta*) are listed as vulnerable globally on the IUCN Red List (Casale and Tucker 2017). In the United States, the Fish and Wildlife Service and National Marine Fisheries Service designates loggerhead sea turtles as endangered or threatened, depending upon the distinct population segment (USFWS and NMFS 2011). These turtles also have numerous nest predators including coyotes (*Canis latrans*), feral hogs (*Sus scrofa*), raccoons (*Procyon lotor*), armadillos (*Dasypus novemcinctus*), fire ants (*Solenopsis invicta*), mongeese (*Herpestidae* spp.), feral cats (*Felis catus*), dingoes (*Canis lupus dingo*), red foxes (*Vulpes vulpes*), ghost crabs (*Ocypode quadrata*), and opossums (*Didelphis virginiana*) (Nordeberg et al. 2019; Butler et al. 2020; Lovemore et al. 2020). Of these threats, preventing nest depredation is likely the most attainable management action in sea turtle recovery plans (NMFS and USFWS 2008). Trapping, baiting, and culling of known predators is one method of reducing nest depredation in sea turtle management strategies (Nordeberg et al. 2019), however, these lethal techniques are often negatively perceived by the public (Drake et al. 2019), and not always effective (Spencer et al. 2017). Therefore, many managers deploy predator exclusion cages (PEC) as nonlethal deterrents alone, or in conjunction with, other lethal and nonlethal methods.

While several designs have been used (Lovemore et al. 2020; Nordeberg et al. 2019; Welicky et al. 2012; Madden et al. 2019), no one PEC is 100% effective. Lovemore et al. (2020) used camera traps to assess coyote behavior at sea turtle nests protected by three PEC designs: metal screens, metal cages, and plastic cages. Regardless of design, all nests were depredated, but they reported that plastic cages were the most successful at deterring coyote depredation. Conversely, Butler et al. (2020) stated that plastic cages were ineffective at keeping feral hogs from successfully

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depredating nests. Nordeberg et al. (2019) observed that the use of plastic was not effective against feral pigs but deterred dingoes. Buzuleciu et al. (2015) noticed that plastic mesh was ineffective at excluding raccoons from nests while wooden dowels largely prevented access to terrapin nests. In a study on goanna (*Varanus* spp.) predation of loggerheads, researchers found that aluminum mesh devices were more effective at deterring predators than unmeshed nests (Madden et al. 2019). Welicky et al. (2012) learned that nests are less likely to be depredated in areas with more human activity and late in the season while being protected by screening. O'Connor et al. (2017) found that meshing played an important role in reducing red fox depredation. Given the current literature, each PEC type appears to have predator-specific effectiveness (Nordeberg et al. 2019).

It is also important to consider if PECs may increase the chance of depredation by acting as a cue that predators later associate with food. Riley and Litzgus (2013) found that red foxes (*Vulpes vulpes*), eastern wolves (*Canis lycaon*), and common ravens (*Corvus corax*) were not attracted to distinctive cage designs (above-ground, below-ground, and wooden-sided). Yet in a study on painted turtles (*Chrysemys picta*), researchers found that popsicle sticks that were used to mark sea turtle nests attracted common ravens and American crows (*Corvus brachyrhynchos*) to the nest (Rollinson and Brooks 2007). Oddie et al. (2015) studied predator cues for snapping turtle (*Chelydra serpentina*) nests and discovered that nests with tactile cues (i.e., live bait or olfactory) were more likely to be depredated than those with visual or chemosensory cues. Similarly, Burke et al. (2005) found no difference in depredation rates on terrapin nests that were flagged and not flagged, but Phillott (2020) reported that red colored flags used to mark nests lured monitor lizards (*Varanus komodoensis*). Mroziak et al. (2000) placed wire cages over real sea turtle nests during their study while they left control "nests" uncovered. Their results indicated that raccoons use PECs as markers when looking for sea turtle nests since many more caged nests were depredated than uncaged nests.

To our knowledge, no study has evaluated coyote visual attraction to PECs, yet coyotes are a novel and dominant nest predator occurring along much of the East Coast of the US (Hody and Kays 2018). Additionally, no study has examined the visual lure of PECs as the only novel stimuli without presence of bait or actual sea turtle nests. Therefore, it is important to distinguish if coyotes use man-made visual cues to find sea turtle nests, and add to the paucity in the literature regarding coyote depredation of sea turtle nests.

In a 2020 pilot study on Bald Head Island, North Carolina, USA, (Fig. 1) we tested the efficacy of four PEC designs at preventing predator nest depredation (Hillbrand et al. 2020). Given that loggerheads are threatened in the Northwest Atlantic Ocean segment (USFWS and NMFS 2011), we conducted this study after the nesting season and defined the term depredation to describe attempts to enter PECs. The two most successful PECs were then used for sea turtle nests during nesting season 2021. The two less successful designs were used in this study. The overarching goal of our study was to determine if coyotes view PECs they potentially have observed used over turtle nests in the past as a visual stimulus they later associate with food. Our specific objectives were to collect behavioral and presence/absence data on coyotes to deduce if PECs act as a visual lure that draws them in without an olfactory cue. This distinction is important for future PEC implementation and design to protect sea turtle species.

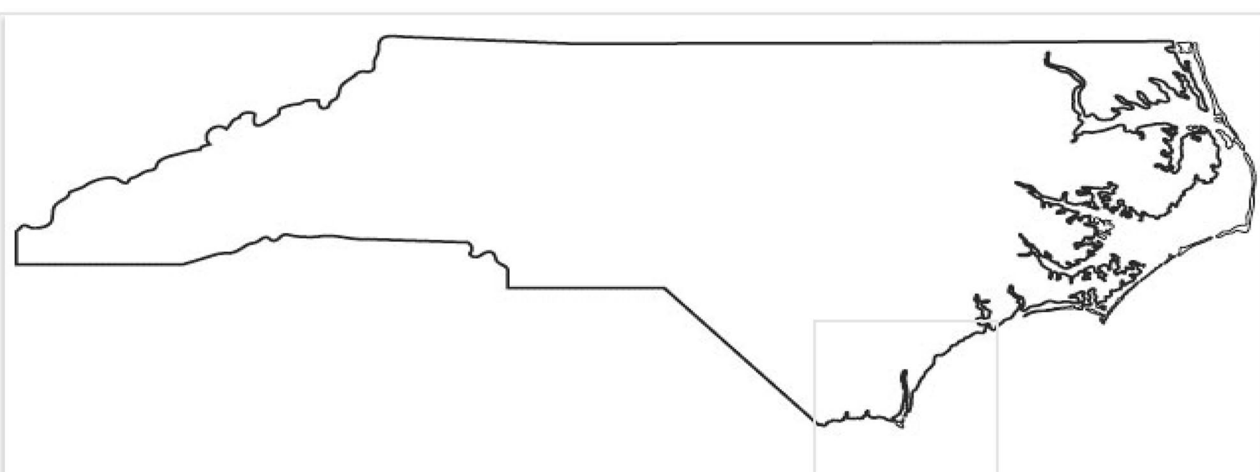

Fig. 1 Bald Head Island is located off the southern tip of the southeastern corner of North Carolina

Methods

Study area

Bald Head Island (BHI) encompasses 9.43 km^2 and is located off the southeastern coast of North Carolina. The resident population is 268 people (US Census Bureau 2019). Upland habitat (6.20 km^2) land cover predominantly includes a maritime forest (2.75 km^2), dune and strands (1.71 km^2), and suburban development (0.85 km^2) (Walker 2020). Our study focused on two beaches, South Beach and West Beach (Fig. 2). South Beach served as our experimental beach where PECs were deployed, and West Beach was our control without PECs. Each stretch of beach was approximately 500-m of suitable sea turtle nesting habitat, but where nests were frequently relocated to a different beach by managers because of the potential for overwash. During our study, 11 May – 28 June 2021, the temperature averaged 26.7 °C in May and 30.0 °C in June (Environment Climate Observing Network 2021). Precipitation averaged 8.53 cm in May and 12.52 cm in June. A king tide (an exceptionally high tide) also hit the island the night of 20 June 2021.

PEC deployment

We deployed five replicates of two PEC designs (Fig. 3) on South Beach for a total of 10 PECs. The first PEC design was an 85 × 85 cm flat screen of MasterNet® plastic (35 mm x 35 mm) secured by iron rods into the sand. The second design was an 85 × 85 × 45 cm cage with a 32-cm skirt made of plastic mesh fencing material (Terragrid 2.5 cm x 2.5 cm) and PVC pipe. The cage was dug ~ 31 cm into the ground to bury the skirt, while the top of the cage sat ~ 15 cm above the sand surface. The cage PEC could be seen from farther distances while the flat screen PEC could not; this distinction was important to compare the results of visual attraction to either PEC. We installed the PECs in a randomized pattern < 10 m from the dune vegetation and 1-100 m apart to simulate natural distances between sea turtle nests. No edible bait or synthetic olfactory attractants accompanied these PECs.

Sea turtles begin nesting on BHI in May, with an approximately 75% increase in nests in June compared to May numbers, according to 2017 and 2018 data (NCWRC Sea Turtle Project 2020). As such, we deployed PECs in May and June using an incremental pattern consistent with the natural historical pattern. We used Microsoft Excel® and the function Randbetween to choose a random start date in the first two weeks of May for the deployment of the first PEC (11 May 2021); PEC design chosen for each date was also randomized. To mirror the slow increase in nests through time, we then used this function to randomly find a date between 1.5 and 2.5 weeks from the first deployment to choose the second deployment date in May, which again consisted of one PEC (27 May). All subsequent deployment dates had two PECs installed and time periods used in the Randbetween function were incrementally decreased using 1–2 weeks (6 June), 5–10 days (14 June), 3–7 days (19 June), and 1–5 days (24 June). We removed all PECs on 28 June 2021.

Fig. 2 South Beach camera & predator exclusion cage locations (left) and West Beach camera locations (right), Bald Head Island, North Carolina, 3 May – 28 June 2021

Fig. 3 Predator exclusion cage designs: Screen (left) and Plastic cage (right), Bald Head Island, North Carolina, 3 May- 28 June 2021

Sea turtle patrols on both beaches were conducted by BHI Conservancy staff starting 25 May 2021, when the first sea turtle nest arrived, and continued for the duration of the study. These patrols began at 2100 h and ended at 0600 h. Patrols were conducted using UTVs and red flashlights to search for nesting mothers and their nests and check the condition of preexisting nests. These nests had PEC designs which were different than our experimental designs.

Camera deployment

One week prior (3 May 2021) to the first PEC installation, we deployed 10 passive-infrared camera traps (Bushnell Trophy Cam Aggressor HD) on each beach to detect coyote presence and observe their behavior. Camera locations were randomized 1-100 m from dune vegetation. We deployed cameras a week early to obtain a baseline of coyote behavior before the PECs were introduced. Camera traps were removed the same day as PEC removal. On South Beach, one camera trap was constructed approximately 2 m away from the eventual location of each PEC. We identified 10 random locations on West Beach using the same methods and spatial constraints for the PECs, installing camera traps using the same timing as South Beach, but no PECs. Each camera was placed in a lock box and secured to a 4×4 wooden post by a locking cable. We used the following camera settings: 0.6-sec intervals, three images per trigger, night camera mode, high sensor levels, medium LED control, 14 M pixel, and high night vision shutter. We performed maintenance, battery replacements, and SD card swaps at each PEC deployment.

Data analyses

We developed a predator ethogram (Table 1) using 4,528 data images from previous PEC field trials on BHI conducted during November and December 2020 (Hillbrand et al. 2020). We focused this study only on coyotes because they were detected and interacted with PECs more than red foxes, the only other wild mammalian predator in the 2020 study. We categorized each image of a coyote, from both beaches, as a single behavior from the ethogram. We defined an event as a series of images that a coyote was detected at a camera for a continued block of time until not seen again (e.g., a coyote was present at a camera for 2 min, and another coyote image did not occur for 10 min, signifying a new event). This sampling methodology parallels instantaneous sampling so that we can quantify each behavioral event independently. For each event, we recorded the number of different behaviors (i.e., changes in behavior for each individual in the event) observed in the image series; number of total behaviors observed (i.e., counted every behavior even if repeated later in the series); total time each behavior was displayed; number of images per behavior; number of images per event; and total event time. At each camera site for each night, we then calculated the average number of events, event time, and behaviors per event. We also recorded the number of nights a coyote was detected during a deployment period and latency to detection (LTD)

Table 1 Ethogram used to analyse coyote (*Canis latrans*) behavior detected by cameras at predator exclusion cages (PEC) and control sites, Bald Head Island, North Carolina, 3 May – 28 June 2021

Behavior	Description
No interest	Travel in foreground or background and NOT in the direction of PEC/Control; No interaction with PEC/Control
Approach	Traveling in the direction of the PEC/Control
Depart	Traveling away from the PEC/Control, in any direction
Investigation	Nose down at base of PEC or Control area and/or nose touching PEC
Investigation_other	Nose down on ground or on other object away from PEC/Control
Swipe	A single paw at the cage
Digging	Multiple swipes in one event
Chewing	Mouth on and/or teeth exposed on PEC
Eating	Eating away from PEC/Control
Marking territory	Urinating or defecating
Marking scent	Marking scent by rubbing body on PEC/Control area
Standing_near	Standing adjacent to PEC/Control
Standing_far	Standing away from PEC/Control, parallel or in foreground/background
Standing_on	Standing physically on the PEC/Control area
Inside PEC	Limb or snout physically inside of the PEC
Unseen	PEC or another animal impedes view
Other	Does not fit in a description above; must be described

during the deployment period. Deployment periods were the periods of time between new PEC setups (e.g., 11–26 May began when PEC 1 was deployed and ended at the setup of PEC 2). To determine if PECs in general acted as a visual stimulus for coyotes, we used the 10 cameras on each beach as our samples. We used the Shapiro-Wilk test to determine if the paired differences between the beaches were normally distributed. We used paired *t*-tests for normally distributed data or Wilcoxon signed-rank tests for paired samples for non-parametric data ($_{\alpha} = 0.05$) for each deployment period (7 total) to compare these metrics. Similarly, we also used paired *t*-tests or Wilcoxon signed-rank tests for paired samples to compare the proportion of cameras on each beach that detected a coyote per night. We conducted all analyses in Microsoft Excel® with RealStats® (Zaiontz 2021). Given the small sample size ($n = 5$) and lack of independence between cameras on South Beach we could only summarize these metrics to compare between PEC designs.

Results

South Beach had 58 total camera nights and 20,716 images. West Beach had 55 total camera nights and 55,860 images; there were fewer camera nights due to a king tide that swept away a camera, and two cameras being left on setup mode during the deployment period 19–23 June. We observed coyotes in 277 images on South Beach, comprising 186 events over the course of the study. We observed coyotes in 204 images on West Beach, comprising 117 events over the course of the study.

We detected coyotes between 1700 – 0800 h, however coyote detections were most frequent between 2200 – 0400 h (Fig. 4). On average, coyotes were first detected (paired $t_9 = 2.12$–2.59 $P = 0.10$–0.85; Wilcoxon $P = 0.84$–0.09) on the third day of each deployment period on both beaches, and each camera (paired $t_9 = 1.21$–1.51 $P = 0.14$–0.69; Wilcoxon $P = 0.74$–0.88) detected a coyote 1–2 nights during each period (Table 2). In the week prior to the first PEC deployment, coyotes visited a higher proportion (paired $t_9 = 3.26$ $P = 0.014$) of South Beach cameras (0.26 ± 0.06; mean ± SE throughout) per night than on West Beach (0.10 ± 0.04; Fig. 5). We did not observe any differences in this metric for the remaining deployment periods (paired $t_9 = 0.06$–0.23 $P = 0.26$–1.00; Wilcoxon $P = 0.78$–1.00). We recorded approximately two times more (paired $t_9 = 1.16$ $P = 0.008$) coyote events on South Beach (0.40 ± 0.11) than on West Beach during the first week of PEC deployment (0.19 ± 0.06; Fig. 6). We did not observe any differences in this metric for the remaining deployment periods (paired $t_9 = 0.08$–0.41 $P = 0.07$–1.00; Wilcoxon $P = 0.50$–1.00). The average event time (Table 2) was < 1 min on each beach throughout the study (paired $t_9 = 0.42$–0.56 $P = 0.64$; Wilcoxon $P = 0.87$–1.25). Behaviorally, coyotes appeared equally disinterested in both PEC designs. 64% and 76% of behaviors observed were of No Interest on South Beach and West Beach, respectively. The second behavior that occurred most often on South Beach and West Beach, was Standing Near, 22% and 17%, respectively. The number of different behaviors observed in an event (paired $t_9 = 0.55$–0.69 $P = 0.34$–0.97; Wilcoxon $P = 0.38$–1.25) and the total number of behaviors observed in an event (paired $t_9 = 0.55$–0.70 $P = 0.22$–0.94; Wilcoxon $P = 0.38$–1.25) did not differ between beaches (Table 2). Unexpectedly, real sea turtle nests arrived May 25 and 27; June 4, 22, 24, and 28, and the most common behavior was still No Interest during these deployment periods.

Due to randomizing the PEC deployment, we had 50 camera nights for the cage PECs compared to 23 camera nights for the screen PECs. Correspondingly, we observed twice as many coyote events at the cage PECs (60) than screen PECs (31). Coyotes appeared equally disinterested in

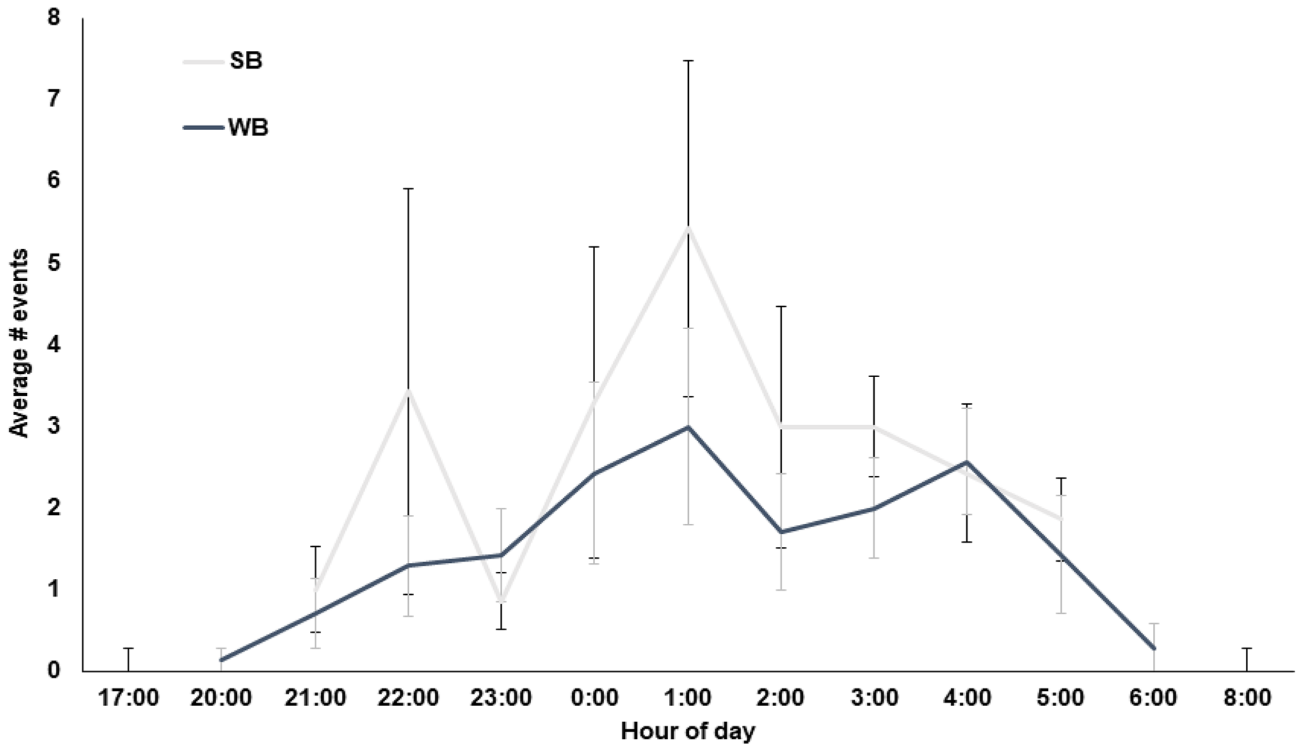

Fig. 4 Average (± SE) number of coyote (*Canis latrans*) events per hour across deployment periods, Bald Head Island, North Carolina, 3 May- 28 June 2021

both PEC designs. The average number of coyote events per night, average number of behaviors per events, and average LTD was similar between the cage PEC design (0.24; 1.3; 5.4, respectively) and screen PEC (0.26; 1.1; 5.9, respectively). The most frequent behavior at each design was of "No Interest." However, it appeared coyotes spent 2.66 times more seconds per event at the cage PECs (1.33 s per event) than at the screen PEC (0.5 s per event).

Discussion

As coyotes are a relatively novel species on the landscape on the Eastern US coast (Hody and Kays 2018), the understanding of their behaviors related to the depredation of loggerhead sea turtle nests is necessary for proper management, especially given their threatened status along the Northwest Atlantic Ocean (USFWS and NMFS 2011). Specifically, understanding if PECs are a potential visual cue to coyotes is crucial to continued protection of sea turtle nests. We had little evidence that PECs act as a visual stimulus that coyotes later associate with food.

Previous studies have examined visual cues to draw predators to nests but have either used bait or had their experimental nests paired with live nests (Mroziak et al. 2000; Burke et al. 2005; Rollinson and Brooks 2007; Riley and Litzgus 2013; Oddie et al. 2015; Lovemore et al. 2020). Our study was designed to only have the experimental PECs as the potential novel stimuli to lure predators. However, six actual sea turtle nests were laid among our experimental PECs on South Beach (May 25 and 27; June 4, 22, 24, and 28) and one sea turtle nest was laid on West Beach (June 14) approximately 60 m from our control cameras. These nests were unexpected since relatively few nests are usually laid on these beach stretches annually, and the nests are commonly relocated from these areas due to overwash. Recent beach renourishment on BHI immediately prior to our study allowed for these nests to safely remain in our experimental areas and given their protected status in the US, were left undisturbed. Despite these nests, there were no depredation attempts on live sea turtle nests during our study. We also did not see a difference in coyote behavior between beaches while these nests were present; we analyzed events and behaviors at experimental cameras near sea turtle nest sites and no changes in behaviors or increase/decrease in events was observed. Our results indicate that PECs may act as a deterrent to coyotes, as detection was highest when the PECs and live turtle nests were not present. Additionally, it is important to note that the live sea turtle nests were protected by two PEC designs different from those used in this field study. Therefore, it is possible that the use of a variety

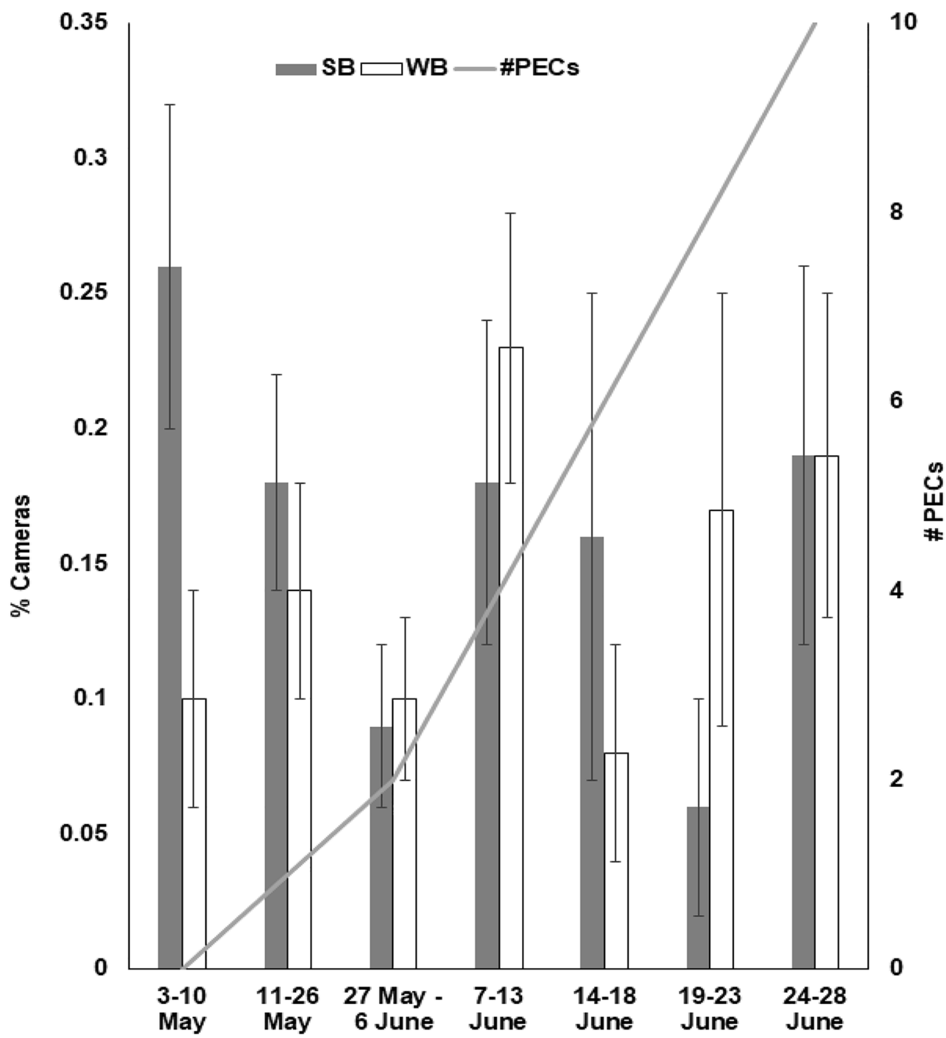

Fig. 5 Average (± SE) proportion of cameras that detected a coyote (*Canis latrans*) on South Beach (SB) and West Beach (WB), Bald Head Island, North Carolina, 3 May- 28 June 2021. Gray line indicates the cumulative # of predator exclusion cages (PEC) deployed over the study

Table 2 Average number of (± SE) coyote (*Canis latrans*) activities and behaviors near PECs per deployment period, Bald Head Island, North Carolina, 3 May- 28 June 2021. There were no statistical differences for these metrics between the beaches

Test	South Beach	West Beach
Event time (sec)	0.56 ± 0.09	0.42 ± 0.10
# Different behaviors	0.69 ± 0.07	0.55 ± 0.07
# Total behaviors	0.70 ± 0.07	0.55 ± 0.08
Latency to detection (days)	2.59 ± 0.62	2.12 ± 0.38
# nights detected	1.51 ± 0.46	1.21 ± 0.24

of cage designs deters coyotes from nest locations and more research on this hypothesis is warranted.

Human activity may also play a role in decreasing coyote predation attempts. Welicky et al. (2012) determined that increased human activity on beaches deterred predation attempts on nests. Our study saw more coyotes present on South Beach than West Beach before Memorial Day weekend, the traditional start to summer (May 29–31, Fig. 4) and later, more coyotes were detected on West Beach, apart from deployment period 14–18 June. South Beach is a more human populated beach than West Beach, and after a busy holiday weekend, it could be that coyotes migrated to the quieter beach since they were deterred by human presence.

Scant literature exists in determining if PECs are visual cues to predators. Riley and Litzgus (2013) investigated raccoon attraction to above-ground and below-ground PEC designs, and similar to our study, they did not observe a difference in predator attraction among designs. Lovemore et al. (2020) recorded coyote behavior using 3 PEC designs (metal screen, metal cage, and plastic cage), but did not examine behavior systematically to determine potential attraction to the PECs. To our knowledge, our study is the first to examine coyote attraction to PECs as the only novel stimuli. It would be beneficial to have further research to replicate our work and assess potential coyote attraction to other PEC designs as well as possible learned behaviors towards PECs.

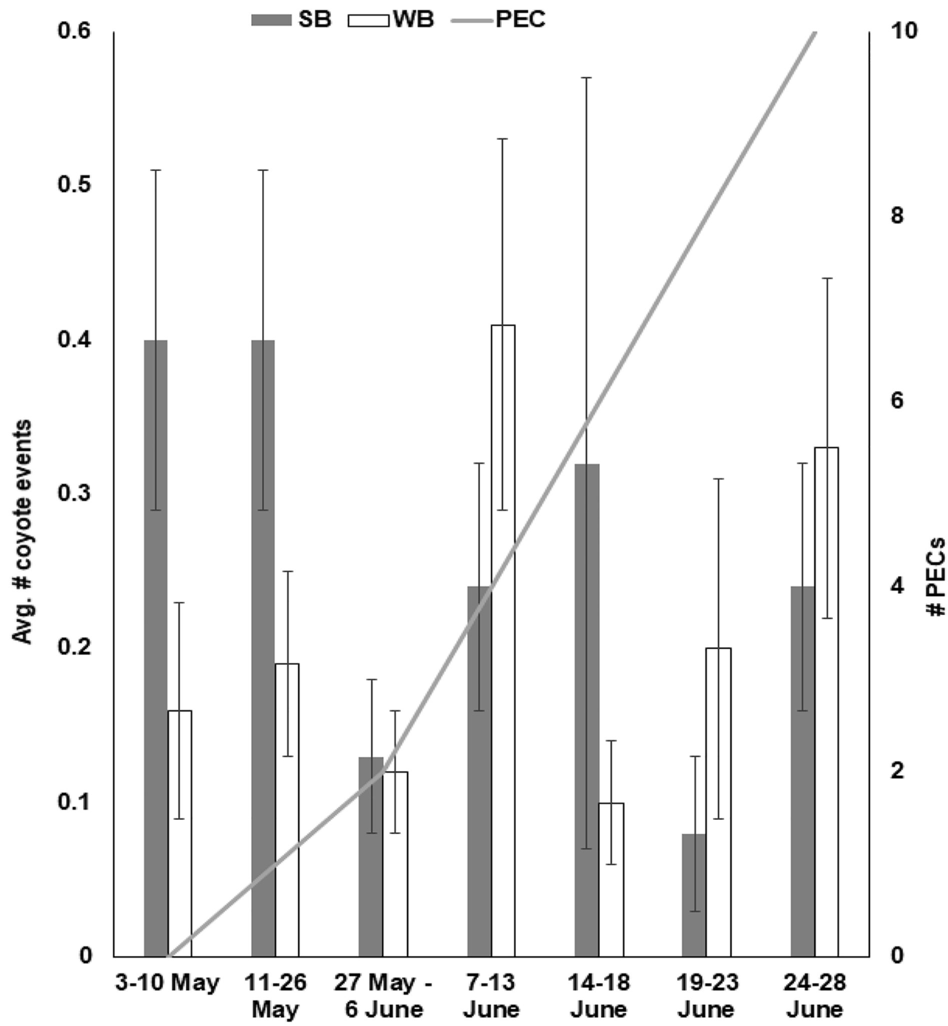

Fig. 6 Average (± SE) number of coyote (*Canis latrans*) events on South Beach (SB) and West Beach (WB), Bald Head Island, North Carolina, 3 May- 28 June 2021. Gray line indicates the cumulative # of predator exclusion cages (PEC) deployed over the study

Management implications

Efficacy of different cage designs is predator specific (Buzuleciu et al. 2015; Nordeberg et al. 2019; Butler et al. 2020; Lovemore et al. 2020). Our study indicates that PECs without an olfactory lure do not act as a visual attractant to coyotes. Further, it appears that PEC design (above ground vs. ground level) does not influence coyote behavior. Coyotes may need multiple cues, not just visual, to develop a learned behavior of associating a PEC with food. These results suggest that managers have more flexibility in picking cage designs in areas where coyotes are the main nest predator. Managers should also consider the amount of human presence on their beaches and how that may impact predator presence. Given that most coyote detections occurred between 2200 – 0400 h, managers can focus frequent beach patrols at these times to disturb and distract coyotes from sea turtle nests.

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Data Availability The data can be made available upon request to the corresponding author.

Declarations

Competing interests The authors have no relevant financial or non-financial interests to disclose.

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