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RESEARCH ARTICLE

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Activity patterns and reproductive behavior of the Critically Endangered Bermuda skink (*Plestiodon longirostris*)

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Abstract

The study of rare or cryptic species in zoos can provide insights into natural history and behavior that would be difficult to obtain in the field. Such information can then be used to refine population assessment protocols and conservation management. The Bermuda skink (*Plestiodon longirostris*) is an endemic Critically Endangered lizard. Chester Zoo's successful conservation breeding program is working to safeguard, increase and reinforce skink populations in the wild. A key aim of this program is to develop our understanding of the behavior of this species. In this study, using 24 h video recordings, we examined the daily activity patterns, basking behavior and food preferences of four pairs of Bermuda skinks. The skinks displayed a bimodal pattern of activity and basking, which may have evolved to avoid the strength of the midday sun in exposed habitats in Bermuda. Captive Bermuda skinks appear to prefer a fruit-based diet to orthopteran prey. We also documented their reproductive behavior and compared it against two closely related species. Although there were many similarities between the courtship and mating behaviors of the three species, there was a significantly shorter period of cloacal contact in the Bermuda skink. Oophagia was also documented for the first time in this species. This knowledge has enabled the evaluation of the current ex-situ management practices of this species, filled gaps in knowledge that would be challenging to obtain in the field, and enabled the enhancement of both animal husbandry and reproductive success for the conservation breeding program.

KEYWORDS

breeding, captivity, conservation, Scincidae

1 | INTRODUCTION

Due to the ongoing worldwide biodiversity crisis, ex-situ conservation is an increasingly important tool in species preservation. Ex-situ conservation breeding has played a major role in the recovery of at least 25% of species whose threat level has been reduced (Conde et al., 2011). These ex-situ populations are especially valuable for species with small, fragmented in-situ populations that are threatened by disease, pressure from invasive species or destructive events (Jacken et al., 2020). Zoos also contribute more widely to species conservation (Fa et al., 2014) through animal welfare and veterinary research (e.g., Binding et al., 2020), public outreach and education (e.g., Consorte-McCrea et al., 2019) and supporting and running in-situ projects (e.g., Gusset & Dick, 2010). However, an often-overlooked contribution of zoos is filling important gaps in knowledge of species natural history and behavior that would be difficult to obtain in the field, especially for particularly rare or cryptic species.

Skink (Scincidae) species have been highlighted as a Family where zoos can play a key role in their conservation, especially those species that are highly threatened (Wahle et al., 2021). The Bermuda skink (*Plestiodon longirostris*, Cope 1861) is the only extant terrestrial vertebrate endemic to the Islands of Bermuda (Davenport et al., 2001). The species has been listed as Critically Endangered for over 20 years (Cox & Wingate, 2021), with populations becoming increasingly fragmented and isolated (Davenport et al., 1997; Glasspool & Outerbridge, 2004) and restricted to small fragments of rocky coastline, beach and upland coastal habitat (Anderson et al., 2001). It is estimated there are <2500 individuals remaining, with the most viable remaining sub-populations confined to small, offshore islets (Edgar et al., 2010; Turner et al., 2021). There are multiple factors that contribute to their decline including habitat loss, invasive competitors such as *Anolis* species, invasive predators such as the greater kiskadee (*Pitangus sulphuratus*, Linnaeus 1766), yellow-crowned night heron (*Nyctanassa violacea*, Linnaeus, 1758), and cats (*Felis catus*, Linnaeus 1758; both domestic and feral) (Cox & Wingate, 2021). In addition, skinks can become trapped in discarded waste (Davenport et al., 2001).

Very little else is known of the ecology and behavior of this species in the wild, despite research into these areas being recognized by the IUCN as an important conservation action (Cox & Wingate, 2021). This is because of their secretive nature preventing detailed behavioral studies in the field. Skinks are reported to be most active from April to November, but can be found basking throughout the year (Wingate, 1965). They are diurnal, and activity levels in the wild tend to rise throughout the morning before declining sharply at around midday, then rise once more during the afternoon before dropping off just after sunset (Davenport et al., 2001). They are thought to be opportunistic foragers with a diet of invertebrates (Bacon et al., 2006; Wingate, 1965), and unusually, carrion from seabird nests (Davenport et al., 2001; Turner, 2018) and fruit of the prickly pear (*Opuntia stricta*, Haworth 1803) (Edgar et al., 2010).

The Bermuda skink diverged from other *Plestiodon* species at least 11.5 million years ago (Brandley et al., 2010) and this high level of evolutionary distinctiveness increases the importance of this species from the perspective of conserving evolutionary history (a higher than median EDGE score of 12.32, Gumbs et al., 2018). In captivity, Bermuda skinks have been kept mostly for display and educational purposes at the Bermuda Aquarium Museum & Zoo since 1983 (Bacon et al., 2006; Barnes & Eddy, 1986). The only specimens outside of Bermuda were sent to Chester Zoo in 2013 to begin an ex-situ conservation breeding program. An understanding of the behavior and reproduction of the species is critical to maintain and increase the population in captivity and for future reintroductions as well as to help to inform in-situ conservation management. After a first successful breeding at Chester Zoo in 2017, a new specialized breeding facility was built in 2018, complete with 24 h CCTV for each skink enclosure. This enabled continuous monitoring of the skinks in detail. Therefore, the aim of this study was to: (1) quantify a 24 h activity pattern for the Bermuda skink; (2) investigate dietary preference; and (3) to document reproductive behavior and compare this to other closely related species.

2 | METHODS

2.1 | Study subjects

Eight Bermuda skinks were the subject of this study, four males and four females housed in pairs (referred to as pairs three, four, five, and six, which corresponded to their enclosure numbers). Sexual dimorphism is not pronounced in Bermuda skinks (Edgar et al., 2010), but for the purpose of this study, the sex of each skink could be determined using head size, and sexes were confirmed after reviewing courtship and mating behavior. Before any observed mating behavior, each skink in a pair was identifiable using distinguishing features including regenerated tails, distinctive scars, and differences in overall size and body shape between individuals. This study was approved by the Chester Zoo Science and Ethical Review Committees (refs 2018.33 and 2019.44), and obtained Stage 1 Ethical Approval from the School of Anthropology and Conservation, University of Kent.

2.2 | Housing and husbandry

The pairs were housed in four open-topped modular foamex (PVC foam sheet) enclosures, which could be divided by gates into two units if necessary. Each half was 86 × 78 × 60 cm in size, so each skink pair had access to double this space (Figure 1). The enclosures were set up so each pair of skinks was mixed and had access to two modules of the enclosures. Each enclosure module had the same basic features and layout, containing a baby rubberplant (*Peperomia obtusifolia*, A. Dietr), large coral-based rocks and sea grape leaf litter (*Coccoloba uvifera*, Linnaeus) as cover items, a basking spot, a loose clay and gravel-based substrate (deep enough so the skinks were able to burrow), water bowls and shallow food bowls.

Above each enclosure was an Arcadia T5 UVB high output fluorescent tube in a luminaire canopy with reflectors to focus the UV light downwards. One 70w Exo Terra Sunray basking spot lamp (also with UVB), ballast controlled in a shroud to focus the beam, was above a basking rock in each half of the enclosure, the distance from the lamp to the substrate was 40–50 cm. Each basking zone was 15 × 15 cm and provided a high UV exposure within the zone through the halide lamp. The UV range was maintained between 2 and 5 UVi

FIGURE 1 View of one-half of a Bermuda skink (*Plestiodon longirostris*) enclosure from a CCTV camera. The enclosures consisted of deep loose clay and gravel-based substrate, coral-based rocks, and sea grape leaf litter (*Coccoloba uvifera*) for cover. Each half also contained a baby rubber plant (*Peperomia obtusifolia*), water and food bowls and basking spot heated by a 70w Exo Terra Sunray basking spot lamp. A sliding gate separated the two halves of the enclosure but was open for the duration of the study period allowing the skink pair access to both sides. [Color figure can be viewed at wileyonlinelibrary.com]

in the basking zone (from the outer edge to the central zone) with a temperature of 36–40°C, this is a focused basking zone so the drop off outside is steep, but the ambient temperature of the cool zone was between 25–30°C during the day. Ambient room lighting was provided by natural light, which filtered in through skylights and windows and enclosures were maintained at 70% relative humidity. Ambient air temperature and humidity were measured with a wall-mounted digital thermometer and hygrometer, Blue Maestro data loggers were used for long term monitoring of temperatures within the enclosures and a digital infrared temperature gun was used to monitor basking spot temperatures. Enclosures had a photoperiod of 11 h between 07:00 and 18:00 h.

A CCTV camera attached to a modified adjustable table lamp arm was also present above each enclosure module. The remote cameras recorded continuously, providing footage of behavioral observations for this study without disturbance to the skinks. The enclosures were off-display and only accessible by zoo staff. The skinks were checked once a day between 12:00 and 13:00 h; each enclosure was sprayed with water, and water bowls were cleaned and refreshed. The skinks were fed every 4 days, with the food items rotating between each feed. Live foods offered included juvenile black crickets (*Gryllus bimaculatus*), juvenile brown crickets (*Gryllus assimlis*) and waxworms (larvae of the moth *Galleria mellonella*). Two to three individual live food items were provided in each feed and were dusted with Repashy Calcium Plus. Other food items offered included two Repashy Superfood diets: Grubs'N'fruit (which included 50% dried fruit, 30% dried insect meal, and supplements) and Banana Cream Pie (which included 30% dried banana, other dried fruits, whey protein isolate and supplements), these were mixed with water to form a jelly. The skinks were also offered a plum and kiwi mash. One to two teaspoons of Repashy diet/fruit mash were offered to each skink per feed. Waxworms and nonlive foods were placed in the enclosure in small shallow glass or plastic bowls. Any uneaten food in the bowls was removed the following day.

2.3 | Activity, basking, and food preferences

To investigate activity patterns, basking behavior and food preferences, CCTV footage was analyzed from April 20, 2018 to May 6, 2018. For activity, 24 h recordings for each skink were focal sampled for 5 min between 0 and 5 and 30 and 35 min past the hour for each hour of the day. A binary recording system was used, with "1" denoting if any skink activity was observed within each 5 min period, and "0" if no activity was observed. Activity was defined as any movement seen by the skink when visible on camera. To investigate basking and feeding, footage was analyzed between 07:00 and 20:00 h, the times of highest activity for the skinks as determined following the activity footage analysis. All-occurrences sampling (Altmann, 1974) was used with the start and end time of each basking event recorded along with the individual ID. All-occurrences sampling technique was also used for feeding (defined as ingestion of a prey item or preprepared diet), with the time of feeding, individual ID and food type recorded for each event. All footage was analyzed using Behavioral Observation Research Interactive Software (BORIS); behavioral observation software that enables the recording of behavioral observations from an ethogram in real time while the footage is being observed (Friard & Gamba, 2016).

2.4 | Reproductive behavior

Footage investigating reproductive behavior was analyzed between February and March 2019 (no reproductive behaviors were observed in 2018). All-occurrences sampling was used for recording mating attempts. An ethogram following Pyron and Camp (2007) was developed (Table 1). The courtship and mating behaviors identified in the Bermuda skink were compared to the behavior in the ethogram for coal skinks, *Plestiodon anthracinus* (Briard, 1849), and common five-lined skinks, *Plestiodon fasciatus* (Linnaeus, 1758) (Pyron & Camp, 2007). The behaviors outlined in the ethogram were recorded using continuous focal sampling from which the duration of each behavior was calculated. If visibility was interrupted, but the same behavior was still being performed, the assumption was made that the behavior had continued while the animals were out of sight. If a different behavior was being performed once the animals were visible again the end time of the previous behavior was recorded when the animals went out of sight and the start of the next behavior was recorded when visibility resumed.

2.5 | Data analysis

The mean activity was calculated using the number of "active" samples per hour across each of the eight enclosure modules. The mean

TABLE 1 Ethogram outlining definitions of mating behaviors observed in captive Bermuda skinks, *Plestiodon longirostris*, based on Pyron and Camp (2007)

Behavior	Description
Investigation and recognition	
Precontact investigation	The male shows interest by orienting his head toward the female, and then moving forward toward the female.
Contact and recognition	The male tongue-flicks the female's tail. This may be at the tail base, or from the end of the tail moving up to the tail base. Male may slightly wag his tail.
Precoital bite	
Bite	The male bites the female on her torso and holds her by a skin fold.
Bite progression	The male shifts the bite-hold up female's torso until he holds her by the nape of her neck.
Head shake	Both lizards walking forward during this behavior. While the male is biting and holding the female by the nape of her neck, the male shakes the female's head regularly and lifts her anterior off the ground.
Cloacal contact	
Vent rub	The male briefly stops shaking the females head, and lifts her anterior to curl his tail under the female's tail. The male rapidly rubs his vent against her until the male's hemipene is inserted.
Coitus	Both lizards lie in position with the male's hemipene inserted in the female's cloaca. The male may pump his hips during coitus. Coitus terminates when the female shifts position and walks forward.

time spent basking was calculated as the number of seconds spent basking in each 1 hour period per skink from 07:00 to 20:00 h. Activity levels and basking are reported as mean ± standard error (SE). A single complete mating attempt was recorded for each pair apart from Pair three, for which two attempts were recorded. Pair five: 3 February 2019, Pair three: February 12, 2019 (twice), Pair four: February 23, 2019, Pair six: March 15, 2019. For analysis, only one mating attempt from Pair three was used to avoid pseudoreplication. The second attempt was used as the skinks were in sight for the full sequence. For Pair four, no "investigation and recognition" behaviors were recorded as the first visible behavior in the sequence was the precoital bite. The duration of behaviors were grouped and analyzed by behavioral stage; "investigation and recognition," "precoital bite," and "cloacal contact" behaviors. The mean times for the behaviors for *P. longirostris* ($n = 4$) were compared against those for *Plestiodon anthracinus* ($n = 15$) and *Plestiodon fasciatus* ($n = 13$) reported in Pyron and Camp (2007). The full data sets of *P. anthracinus* and *P. fasciatus* were not available so independent *t*-tests were conducted for each behavioral stage using the mean and SE reported in the paper. The comparative analysis was conducted in Microsoft Excel. Normality testing for *P. longirostris* data was conducted in R Studio (Shapiro Wilks $W = 0.869$ $p = .296$).

3 | RESULTS

3.1 | Activity and basking

Activity patterns followed a bimodal distribution across a 24 h period. Activity levels were highest in the hour following each basking peak with 08:00 h (activity seen on a mean of 7 ± 2 days) and 16:00 h (activity seen on a mean of 9 ± 2 days) being the hours with highest observed activity levels (Figure 2). Low levels of activity were also observed in hours of darkness (21:00–05:00 h). Basking behavior also followed a bimodal distribution peaking at 07:00 h, with skinks basking for a mean of 410 ± 44 s. A second smaller basking peak was seen at 15:00 h, with each skink basking for a mean of 235 ± 21 s (Figure 2). The mean basking event across two peaks was 194 s, with the shortest and longest recorded durations being 12 and 1029 s respectively.

3.2 | Food preferences

Four feed days occurred within the 17-day observation period and 25 bouts of feeding behavior were recorded; 56% (14) of these were of the skinks eating the preprepared Repashy diets, products originally created to feed fruit-eating species in the pet trade. Of the live food, waxworms were consumed on eight occasions and crickets were only seen to be consumed three times. No skink was seen to consume the plum and kiwi mash.

3.3 | Reproductive behavior

The five mating attempts recorded were all captured in the morning with the earliest at 06:15 h and the latest at 08:36 h. The same behaviors were identified in all *P. longirostris* mating attempts (Table 1). Indeed, the behaviors observed were present in the ethogram for *P. anthracinus* and *P. fasciatus* (Pyron & Camp, 2007), with only some slight additions (Table 1). For instance, the contact and recognition behavior in the *P. longirostris* ethogram noted that male tongue-flicking behavior may be at the female's tail base (as with *P. anthracinus* and *P. fasciatus*) but this tongue-flicking was also observed from the end of the tail moving up to the tail base, and males often slightly wagged their tails during this behavior.

For investigation and recognition behaviors there was no significant difference between *P. longirostris* and *P. fasciatus* ($t = 0.46$, $df = 14$, $p = .65$, Figure 3) or *P. anthracinus* ($t = 1.87$, $df = 16$, $p = .08$, Figure 3). *P. longirostris* exhibited similar durations of precoital bite behaviors as both *P. anthracinus* ($t = 0.61$, $df = 17$, $p = .54$, Figure 3) and *P. fasciatus* ($t = 0.12$, $df = 15$, $p = .91$, Figure 3).

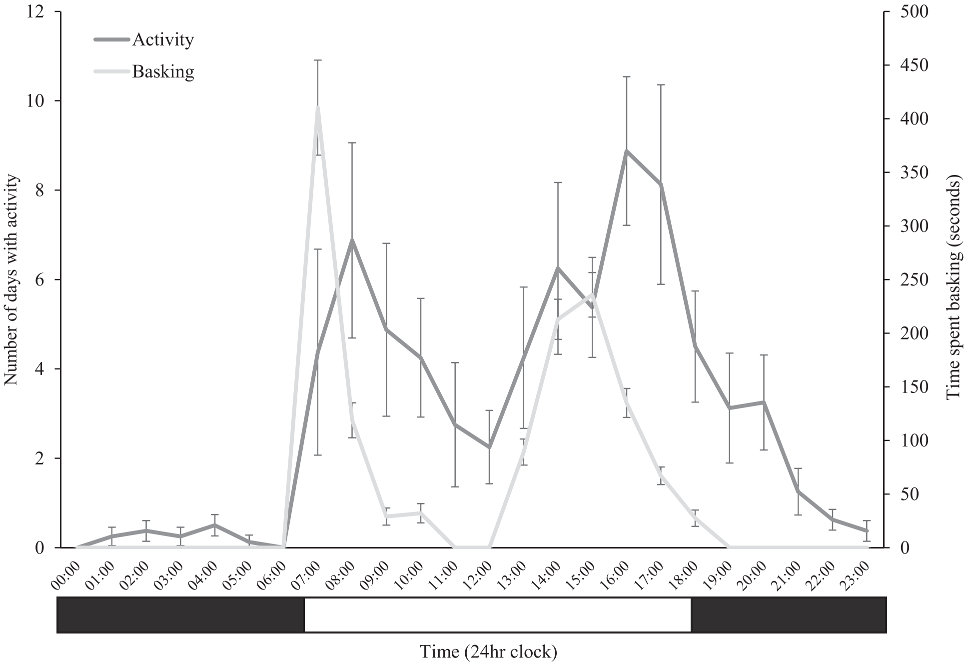

FIGURE 2 Mean (±1 standard error[SE]) number of days activity and mean (±1SE) number of seconds spent basking across a 24 h period of ($n = 8$) Bermuda skinks (*Plestiodon longirostris*) across a 17-day observation period. The box along the *x*-axis represents the photoperiod and thermoperiod, with black signifying periods of darkness, and white signifying when the light and heat lamps were on.

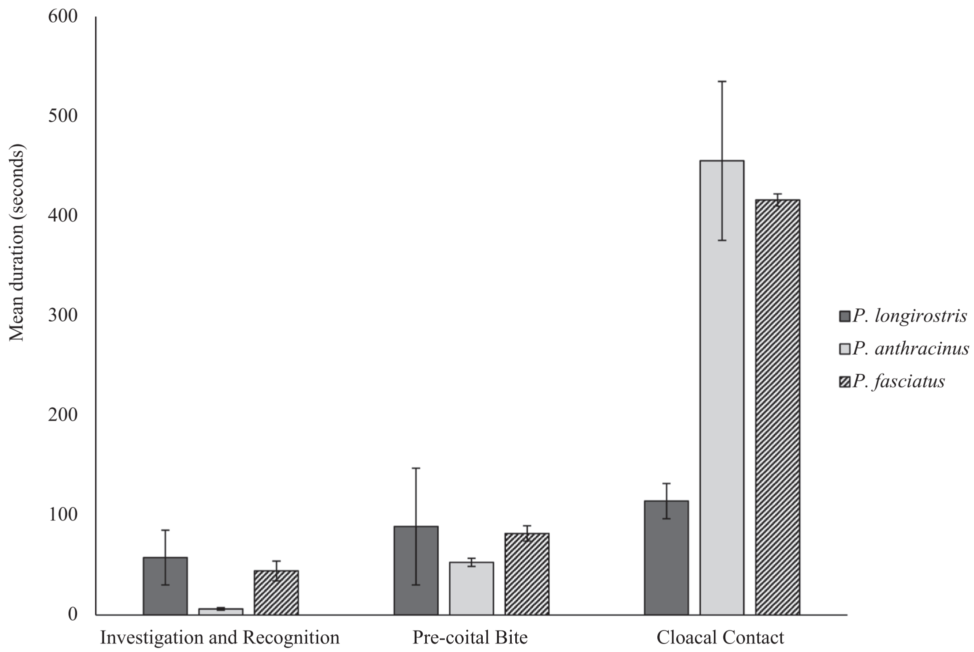

FIGURE 3 Mean (±standard error) duration of mating behaviors of pairs of captive Bermuda skinks *Plestiodon longirostris* ($n = 4$) in comparison to coal skinks *Plestiodon anthracinus* ($n = 15$) and common five-lined skinks *Plestiodon fasciatus* ($n = 13$) during laboratory-based mating trails reported in Pyron and Camp (2007).

The most significant difference in reproductive behavior was seen in the cloacal contact behaviors with *P. longirostris* exhibiting a significantly shorter duration than both *P. anthracinus* ($t = 4.18$, $df = 17$, $p < .001$, Figure 3) and *P. fasciatus* ($t = 16.12$, $df = 15$, $p < .0001$, Figure 3).

A clutch of five eggs from Pair five was first found on May 4, 2019, which were removed and incubated until they later hatched on June 9, 2019. Similarly, a clutch of three eggs from Pair six was found on May 5, 2019. However, after the male was observed consuming an egg on camera, the two remaining eggs were removed and incubated until hatching on June 11. Eggs were incubated within an unvented container on a mixture of 1:1 vermiculite:water by weight at a temperature of 27°C for around 32–35 days.

4 | DISCUSSION

This study documents the activity and basking patterns, food preference and reproductive behavior of the Bermuda skink in captivity for the first time. A bimodal basking pattern was exhibited which was closely followed, approximately one hour later, by a bimodal activity pattern. Bermuda skinks demonstrated a food preference for the fruit-based jelly diet over crickets, but did not eat the plum and kiwi mash. Finally, the courtship and mating behaviors recorded were similar to those seen in the coal skink (*P. anthacinus*) and the common five-lined skink (*P. fasciatus*) (Pyron & Camp, 2007); however the cloacal contact in the Bermuda skink was significantly shorter.

4.1 | Activity and basking

Activity patterns followed a distinct bimodal distribution with activity levels being the highest at 08:00 and 16:00 h. Basking behavior also followed a bimodal pattern, with the longest durations 1 h before the times of highest activity. Interestingly, although the basking lamps turned off at 18:00 h, the skinks were also found to bask using the residual heat from the warm rock, which has not been recorded in this species before. The morning activity peak was observed one-hour following the light and heat lamps turning on and the afternoon activity peak was seen 2 h before them switching off. A bimodal activity pattern has been documented in wild Bermuda skinks during population monitoring, with Davenport et al. (2001) finding that capture rate was highest late morning at 12:30 h with a large drop by 13:30 h and another slight increase in capture rate at 14:30 h. This bimodal activity pattern is likely to be temperature related, with the skinks retreating during the hottest time of the day, where temperatures can reach up to 47°C in the warmest summer months, a potentially lethal temperature for the skinks (Davenport et al., 2001). The activity peak described here is earlier in the morning than the highest capture rate found in Davenport et al. (2001). This could be due to the differences in the environmental conditions. In the wild the increase in temperature following sunrise takes a number of hours, while the captive environment heats much faster, stabilizes at the optimal temperature earlier in the day, and maintains this temperature throughout the day. This enables the skinks to bask and become active earlier in the morning. However, the skinks still choose to retreat during the midday hours even though they could safely continue to bask and be active. This suggests that these activity patterns are at least partly controlled by an internal biological clock that has persisted in captivity (Slavenko et al., 2022). Although the captive environment has facilitated the Bermuda skinks to exhibit a similar bimodal pattern of activity and basking to those observed in the wild, to more closely replicate the Bermudan environment a gradual thermostatic heating and lighting system could be introduced to better replicate natural conditions.

Interestingly, the Bermuda skinks in this study exhibited low levels of activity during darkness. This is the first recorded instance of night-time activity in this species, with other literature referring to the Bermuda skink as diurnal (Davenport et al., 2001; Wingate, 1965). However, due to their cryptic behavior this may not be observable in the wild, if it occurs. Regardless, nocturnal activities were not recorded frequently, and skinks were only observed moving slowly around the enclosure and did not exhibit any highly active behaviors.

4.2 | Food preferences

Over four feed days the skinks were offered four food types; two fruit-based jelly diets, waxworms, black crickets, and plum and kiwi mash. Although black crickets were the most common food item present, they were only seen to forage on these on three occasions. There may be a number of factors attributing to this; first, there seems to be a lack of temporal overlap between the crickets and the skinks, with the crickets being more active at night, unlike the mostly diurnal skinks, meaning fewer opportunities for the skinks to encounter them. Second, it is possible that the skinks are not adapted to feed on Orthoptera as they are not present in their wild diet (Davenport et al., 2001; Wingate, 1965). This is further supported by evidence from after the main study period, when the skinks were offered katydid nymphs (*Stilpnochlora couloniana*), another Orthopteran, as an alternative livefood, and, like the crickets, these were largely ignored. This could be rectified by offering the skinks different species of feeder insects, such as small beetles, small roaches, isopods, and even ants, all of which the Bermuda skink has been reported to feed on in the wild (Wingate, 1965). The other live food that was more readily taken by the skinks were waxworms. However, captive lizards that feed on waxworms frequently have been found to develop health issues due to their high fat and very low calcium content (Gabor, 2005). The most frequently consumed food item by the skinks during the study was fruit-based jelly diets, a food designed to meet the nutritional requirements of fruit-eating geckos. Although fed out on different days, some crickets remained in the enclosure from previous feeds, so the skinks appear to choose the fruit-based jelly diets over live prey. However, although also fruit based, the skinks did not feed on the plum and kiwi mash offered. Bermuda skinks are known to feed on the fruits of the prickly pear in the wild (Edgar et al., 2010) and as these are readily available they could therefore be a positive addition to their captive diet. Since this study was undertaken, the diet of the skinks has been modified by the addition of defrosted mashed Signal crayfish (*Pacifastacus leniusculus*). Scavenged fish and cephalopods is an important component of the species' diet in the wild, particularly historically, when these would have been scavenged from nests within the large seabird colonies that were formerly more widespread on Bermuda (Davenport et al., 2001).

4.3 | Reproductive behaviors

In the wild, the Bermuda skink breeding season begins in early April and ends in September, with mating and courting occurring in April–May, eggs being laid in June and hatching occurring in late July to early August, which is similar to closely related *Plestiodon* species (Bacon et al., 2006; Jameson et al., 2019). However, all the mating attempts recorded in this study occurred between early February and mid-March 2019, two months earlier than expected. This is probably due to the environmental conditions and food availability being more stable and regular in captivity after winter in comparison to the variable natural conditions. All mating events took place between 06:15 and 08:36 h which coincided with the peak times for morning basking and activity. It is likely mating attempts are linked to basking behavior as the females are out in the open. Indeed, all observed mating took place on or near the basking spot. However, we cannot rule out the potential that mating behavior also took place undercover or in burrows. Some unsuccessful mating attempts were also observed ad hoc, which included male chasing behavior, the female snapping at the male during the investigation and recognition phase, and the female walking forward trying to dislodge the male during the bite progression.

This is the first study and description of courtship and mating behaviors of the Bermuda skink. The best comparison is that of two other *Plestiodon* species by Pyron and Camp (2007). The ethogram and definitions of courtship and mating behaviors produced in this study support the hypothesis that the life history traits and mating behavior of *P. longirostris* are similar to other North American species within the genus (Edgar et al., 2010). All the same behaviors were present in the ethogram for the Bermuda skink as in the ethogram for *P. anthracinus* and *P. fasciatus* (Pyron & Camp, 2007), with only some slight additions to the descriptions of these behaviors. There were no significant differences in the duration of the "investigation and recognition" and "precoital bite" behavioral sequences across species. Interestingly, the cloacal contact phase of *P. longirostris* was found to be significantly shorter than the other two species. It is not clear why the cloacal contact phase would be shorter in the Bermuda skink. It is unlikely that this difference has evolved to prevent interspecific hybridization as the Bermuda skink diverged from its closest relative ~16 million years ago (Brandley et al., 2010), unless this is a relic of past character displacement (Pyron & Camp, 2007). One explanation could be differences in ecological factors, for instance it is possible the shorter coitus behavior in the Bermuda skink could be a defense strategy against predation pressure, especially if mating is associated with basking or when they are out in the open. Historically, the Bermuda skinks' main predator was likely the Bermuda hawk, and today avian predation persists through the great kiskadee and yellow-crowned night heron (snakes are absent from Bermuda). However, both *P. anthracinus* and *P. fasciatus* as species on mainland North America, have also likely evolved to live alongside a range of bird and snake predators. Due to the differences in current predator species composition on Bermuda, it is difficult to compare the predation pressures of the different species. Therefore, the differences in the temporal aspects of reproductive behavior across these three species cannot currently be fully explained.

Oophagia (egg eating behavior) was also documented for the first time in this species by a male skink. Egg eating behavior is known to occur in other species of reptile, including skinks, as addled eggs are thought to be a source of food (Groves, 1982). The remaining eggs from these clutches were artificially incubated successfully, which is important for the conservation breeding program. However, documenting temperature, humidity and temporal data from parental nests, in addition to parental care behavior, would be an important step to fill this knowledge gap.

5 | CONCLUSION

The Bermuda skinks were found to display a bimodal pattern of activity and basking. This has persisted in captivity, and may have evolved to avoid the strength of the midday sun in exposed habitats in Bermuda. Comparisons of the behavior with casual observations on wild skinks and detailed behavioral studies on North American skinks of the same genus revealed some novel aspects. These include some limited nocturnal behavior, shorter periods of cloacal contact than in congeneric species, and oophagia. Likewise, captive Bermuda skinks appear to prefer a fruit-based diet to orthopterans. This knowledge has enabled the evaluation of the current ex-situ management practices of this critically endangered species, resulting in the enhancement of both animal husbandry and reproductive success for the conservation breeding program. This ex-situ research has also complemented in-situ research on the same species and filled gaps in knowledge that would be challenging to obtain in the field. Although we must be cautious with some conclusions, as skinks in captivity may not behave in exactly the same way as wild skinks. Further research on mating behaviors and parental care in these captive Bermuda skinks could identify potential breeding triggers and environmental preferences to further encourage reproduction.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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