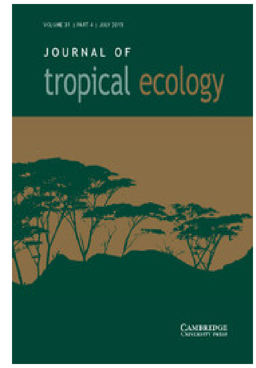

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SHORT COMMUNICATION

Comparison of a native and a non-native insular reptile species

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Abstract: This study compared the life histories of *Hemidactylus frenatus*, a significant invasive gecko, and *Phyllodactylus palmeus*, a Honduran endemic, over 10 wk, June–August 2013 at 12 study sites on the Honduran island of Cayo Menor of the Cayo Cochinos archipelago where *H. frenatus* arrived in 2008. Three different life-history traits related to invasion success were measured: body size, fecundity and population size. During the study 140 natives and 37 non-natives were captured, weighed, measured and marked uniquely. The number of gravid females and number of eggs were also recorded. *Phyllodactylus palmeus* was the significantly larger of the two species (60% larger mass, 25% longer SVL) and had higher population abundance at all 12 study sites with some sites yielding no *H. frenatus* individuals. However, *H. frenatus* had a larger proportion of gravid females. Observations that the native species is more common despite being sympatric with a known aggressive invader suggest two possibilities: the island is at the start of an invasion, or that the two species co-exist in a more stable fashion.

Key Words: Cayos Cochinos, *Hemidactylus*, Honduras, life histories, *Phyllodactylus*

Hemidactylus frenatus is one of the most prolific invasive species ever known – its range is large and ever increasing (Case *et al*. 1994, Hoskin 2011). The range expansion of *H. frenatus* is heavily linked with numerous cases of population decline, extirpation and extinction of the previous native/endemic species (Case *et al*. 1994, Hoskin 2011, McCranie & Hedges 2013). This is particularly evident with cases of insular *H. frenatus* invasion (Case & Bolger 1991). Previous cases of *H. frenatus* dominance are heavily linked to the species' size advantage, reproductive output, population density and resource acquisition rate. A study involving *H. frenatus* and *Lepidodactylus lugubris* revealed that *H. frenatus* exists at far higher densities (approximately double the relative abundance) than *L. lugubris* even in areas where *Lepidodactylus lugubris* does not sympatrically exist with *H. frenatus* (Case *et al.* 1994).

While many studies have investigated the effect of *H. frenatus* on Pacific Islands and Pacific species (Case *et al*. 1994, Hanley *et al*. 1998, Petren & Case 1996) no studies have yet addressed its invasion of the Caribbean and Central America. We therefore undertook a study to compare the life histories of the non-native *H. frenatus* and the native *Phyllodactylus palmeus* off the Caribbean coast of Honduras.

Factors of an individual's life history include body size, population distribution, fecundity, longevity, foraging success, susceptibility to predation and habitat utilization (Boback & Guyer 2003). Many of these factors dictate the survival and reproductive rates of an individual and how an individual exists in, and exploits, an ecosystem (Naganuma & Roughgarden 1990). Investigating the life-history factors of two species could potentially highlight traits where they overlap and therefore compete with one another for the same niche. Sympatric competition in geckos has been proven to negatively influence the fitness and fecundity of the native species when *H. frenatus* is involved (Case *et al*. 1994, Hanley *et al*. 1998, Petren & Case 1996). A life-history comparison between *P. palmeus* and *H. frenatus* offers a perfect model study to identify the potential threat of extinction or population decrease caused by species invasion on Cayo Menor. We used the following hypotheses in this study: (1) There will be an overlap between the morphological traits (particularly body size). (2) *H. frenatus* will have a higher reproductive

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output. (3) There will be similar abundances of the species across the island.

The study took place from 6 June 2013–1 August 2013 on the Cayo Menor (0.62 km^2; 141 m asl) of the Cayos Cochinos archipelago, 17 km off the northern coast of Honduras (Bermingham *et al.* 1998, McCranie *et al.* 2005). Due to the edificarian nature of both gecko species (McCranie *et al.* 2005, Wilson & Cruz Diaz 1993), the sample sites were the 12 different buildings on Cayo Menor.

Phyllodactylus palmeus, the palm gecko, is a medium-sized (maximum male SVL = 82 mm, maximum female SVL = 73 mm), sexual gecko endemic to the Cayos Cochinos archipelago and Roatan, where it mostly inhabits the forested areas (McCranie *et al.* 2005). *Hemidactylus frenatus*, the Asian house gecko, is a medium-sized (maximum male snout-vent length, SVL = 65 mm, maximum female SVL = 60 mm), sexual gecko (McCranie *et al.* 2005). It is native to South-East Asia (Case *et al.* 1994, Hoskin 2011). *Hemidactylus frenatus* is a prolific invader and has been introduced to many other countries, Honduras being one of them (McCranie *et al.* 2005). Both species are edificarian and are found at high densities on human settlements (McCranie *et al.* 2005; DJN pers. obs.).

Geckos were collected by hand from the side of buildings individuals were identified to species based on the shape of the toe pads. Specimens were collected between 19h00 and 22h00 during the active period of most geckos (Case *et al.* 1994). Individuals were collected when observed individuals that successfully evaded two capture attempts were allowed to escape to reduce stress. Individuals were returned to the building of capture after no more than 4 h. Observation of the cloacal vent allowed for the individuals to be sexed, as the males of both species have easily visible hemipenes.

To avoid counting individuals multiple times, all geckos were uniquely marked using a Visual Implant Elastomer (VIE), version 10.1; a product of Northwest Marine Technology, Inc. When illuminated with black light the elastomer becomes luminescent allowing for simple observation. This marking method has been proven to be viable and safe in small lizards with no impact on survival rate and a 95% retention rate (Daniel *et al.* 2006, Kondo & Downes 2004, Waudby & Petit 2011). Buildings were surveyed every 3 d to reduce the level of stress on individuals and allow the elastomer injection tags to cure sufficiently and the body to heal.

Individuals were measured for snout to vent length (SVL; from tip of the snout to the cloacal vent), and tail length (cloacal vent to the end of tail). All measurements were taken using digital callipers accurate to 0.01 mm. Individuals were also weighed using digital scales accurate to 0.01 g.

In gravid females, it is possible to observe the ovaries which become swollen during oogenesis. During this period shining a light through the abdomen allows the developing eggs to be counted non-invasively (Ota 1994). Each captured female was observed to ascertain whether they were gravid and the number of eggs counted. *Phyllodactylus palmeus* and *H. frenatus* typically only produce two eggs (Hoskin 2011, King 1977).

Using timed visual searches it was also possible to estimate the population abundance of each species per building. Each building was searched five times and the numbers of each gecko species observed were recorded, as was the total search time. This allowed for gecko abundance to be determined per building for each species.

Mann–Whitney *U*-tests were used for the morphological assessment due to the non-normal distribution of the data regardless of transformation attempts. The number of eggs developing in each female of each species at time of capture was analysed using a chi-squared test on a contingency table with two rows (species) and three columns (zero, one or two eggs). This provides a test of differences in potential fecundity between the two species. A Wilcoxon signed-rank test was used to non-parametrically analyse abundance (gecko min^{-1}) between species amongst each site (all 12 buildings across the island). Data were analysed using SPSS v20.

Analysis of a range of body size measurements (snout to vent length SVL, tail length and mass) using Mann–Whitney U-tests showed that *P. palmeus* was significantly larger than *H. frenatus* in all measurements taken. SVL: Mann–Whitney U: $U = 169$, $P < 0.0001$. Tail length: $U = 711$, $P < 0.0001$. Mass: Mass: $U = 121$, $P < 0.0001$ (Table 1).

A chi-square test was used to analyse the number of eggs produced between the total numbers of females between each species, *H. frenatus* was shown to produce more eggs ($\chi^2 = 19.4$, $df = 2$, $P < 0.0001$). More female individuals of *P. palmeus* were found with no eggs and respectively more *H. frenatus* females were found with one or two eggs (Table 1).

A Wilcoxon signed-ranks test for the mean abundance of each species showed that there was a significant difference between the encounter rate (geckos min^{-1}) of *P. palmeus* and that of *H. frenatus* with *P. palmeus* having a higher encounter rate at all 12 of the study sites (Wilcoxon: $W = 60$, $Z = -6.62$, $P < 0.0001$).

Of the two species, the native (*P. palmeus*) is the larger for all morphological aspects recorded. Body size is closely tied to many factors crucial to an individual's existence (Naganuma & Roughgarden 1990). In the case of this study it could suggest that *P. palmeus* has a significant advantage over *H. frenatus*, if for example intraspecific aggression is an issue within the population. While intraspecific aggression was not observed during the study period it has been shown that *H. frenatus* will physically

Table 1. Species sample size with mean body size (snout to vent length), mean tail length, mean mass (± SD), percentage of gravid females in each sample population and the mean number of eggs per gravid individual for *Phyllodactylus palmeus* and *Hemidactylus frenatus* on Cayo Menor, Honduras in June–July 2013.

Species	No. captured	Mean body length or SVL (cm)	Mean tail length or TL (cm)	Mean mass (g)	% of gravid females	Mean no: of eggs
Phyllodactylus palmeus	140	65.3 ± 5.4	61.3 ± 12.8	7.53 ± 1.7	29	0.45
Hemidactylus frenatus	37	50.2 ± 4.3	41.7 ± 12.4	3.04 ± 0.9	69	1.31

compete with and prey on sympatric heterospecifics (Bolger & Case 1992).

These morphological results appear to run counter to what is observed in other cases where *H. frenatus* has been proven to be invasive. It is common for an invasive species to be larger than the native species and this can contribute to the competitive advantage for the invasive species (Morin 2011). This has been shown in all previous studies where *H. frenatus* has the size advantage over the native species (Petren & Case 1996, 1998). The study on Cayo Menor however shows that it is the native species which is the larger of the two, a unique finding in relation to other cases of *H. frenatus* (Case *et al*. 1994). In theory Cayo Menor shows, at least where morphology is concerned, an opposing trend to the numerous cases of introduction of *H. frenatus*.

Abundance surveys of the 12 sites revealed that *P. palmeus* exists in far higher numbers than *H. frenatus*, at least double at all sites. While all of the study locations showed established populations of *P. palmeus*, many of the sites yielded no non-native individuals which could suggest that the population of *H. frenatus* is not yet established at these locations. This finding also runs counter to what has been observed in previous studies (Case *et al*. 1994, Petren & Case 1998). This study was proposed under the premise that the non-native population was well established, so it is reasonable to suppose that the population of *H. frenatus* is having no competitive or negative effects. However when looking at past case studies where *H. frenatus* has been proven to be invasive (Case *et al*. 1994, Hanley *et al*. 1998, Hoskin 2011), it may be reasonable to suggest that the population of *H. frenatus* could in time overtake *P. palmeus*. It is possible that *H. frenatus* is currently in the establishment phase or the early expansion phase (Shigesada & Kawasaki 1997). Depending on the expansion pattern, the findings in Honduras suggest that there is the possibility for the population expansion of *H. frenatus* on Cayo Menor.

Phyllodactylus palmeus was formerly found on the neighbouring island of Utila, but has now been extirpated (McCranie & Hedges 2013). *Hemidactylus frenatus* was first discovered on Utila in 2005 (McCranie *et al*. 2005); the native population of *P. palmeus* on Utila was found to be extinct on the island in 2013, 8 y later (McCranie & Hedges 2013). Whether the cause of extinction of *P. palmeus* was entirely the result of the introduction of *H. frenatus* is not yet fully established, but previous studies of the impacts of *H. frenatus* and the coincidental extirpation of *P. palmeus* after the arrival of *H. frenatus* suggests that *H. frenatus* played some role in the extirpation event. *Hemidactylus frenatus* was first officially documented on Cayo Menor in 2008 (Muelleman *et al*. 2009). However, it seems unlikely that the entire population of *P. palmeus* will go extinct in 3 y to match the time frame of Utila. Based on the relative population sizes of the two species, it appears that there is some factor on the Cayos Cochinos which is preventing *H. frenatus* domination. This factor however could not be determined in this study.

Hemidactylus frenatus females produced more eggs in comparison to *P. palmeus*. This becomes more evident when the sample size difference between species is observed. Between the two test populations there is a great amount of variance – there were 97 female *P. palmeus* collected, while only 16 female *H. frenatus* were collected during the study. Yet the analysis still shows that there is a strong statistical difference in the number of eggs produced by each species, *H. frenatus* having the highest production.

These findings suggest that the reproductive output for *H. frenatus* is higher than that of *P. palmeus*. This higher level of reproductive output in theory suggests that *H. frenatus* has the ability to increase its population size more quickly and to a greater extent compared with *P. palmeus*. Looking at past studies and literature it is clear that with many examples of *H. frenatus* invasion, this rapid population expansion is highly possible (Case *et al*. 1994, Petren & Case 1996, 1998). It seems evident that the higher reproductive output of *H. frenatus* gives the species more potential for population growth and expansion. This result follows the general trends observed elsewhere during biological invasions, i.e. that invasive species have a far higher reproductive output than native sympatric species, allowing them to become such successful invaders (Pullin 2004). This could prove to be a factor favouring the non-native in the future. However due to the limited scale of this study and the relatively low sample size any real conclusions would be conjecture.

This snapshot of the ecological interactions between the two species suggests several differences to analogous studies in the Pacific, although the scale of this project is limited and any conclusions should be considered provisional. We cannot yet determine whether *H. frenatus* is truly invasive on the island of Cayo Menor (i.e. having a negative impact on local ecosystems) or whether the non-native species might co-exist with the local communities. However due to its invasive status on the nearby island of Utila and the vastly limited range of the endemic *P. palmeus* it is important to state that this project should be expanded and repeated. Further work should take into account other times of year, long-term population monitoring and a greater consideration of the reproductive ecology of *P. palmeus.* All of these factors are likely to play a vital role in the fate of this narrowly dispersed and little known species.

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