Mammal decline, linked to invasive Burmese python, shifts host use of vector mosquito towards reservoir hosts of a zoonotic disease

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Invasive apex predators have profound impacts on natural communities, yet the consequences of these impacts on the transmission of zoonotic pathogens are unexplored. Collapse of large- and medium-sized mammal populations in the Florida Everglades has been linked to the invasive Burmese python, Python bivittatus Kuhl. We used historic and current data to investigate potential impacts of these community effects on contact between the reservoir hosts (certain rodents) and vectors of Everglades virus, a zoonotic mosquito-borne pathogen that circulates in southern Florida. The percentage of blood meals taken from the primary reservoir host, the hispid cotton rat, Sigmodon hispidus Say and Ord, increased dramatically (422.2%) from 1979 (14.7%) to 2016 (76.8%), while blood meals from deer, raccoons and opossums decreased by 98.2%, reflecting precipitous declines in relative abundance of these larger mammals, attributed to python predation. Overall species diversity of hosts detected in Culex cedecei blood meals from the Everglades declined by 40.2% over the same period ($H(1979) = 1.68$, $H(2016) = 1.01$). Predictions based upon the dilution effect theory suggest that increased relative feedings upon reservoir hosts translate into increased abundance of infectious vectors, and a corresponding upsurge of Everglades virus occurrence and risk of human exposure, although this was not tested in the current study. This work constitutes the first indication that an invasive predator can increase contact between vectors and reservoirs of a human pathogen and highlights unrecognized indirect impacts of invasive predators.

1. Introduction

Natural ecosystems and their vertebrate communities are impacted by large-scale anthropogenic stressors such as habitat destruction, climate change and invasive species [1]. Such human-mediated environmental changes have been implicated as factors that may alter the prevalence of zoonotic disease and their spillover to humans [2]. For example, forest fragmentation in eastern North America has been correlated with increased prevalence of Lyme disease by reducing mammalian diversity and increasing densities of a highly competent host, the white-footed mouse, Peromyscus leucopus (Rafinesque) [3], leading to increased contact between the hosts and vectors. Climate change is predicted to shift geographical distributions of some infectious diseases, including many vector-borne pathogens [4]. Invasive species are important drivers of environmental change, threatening the stability of ecosystems and their associated...
hispidus Say and Ord, and the cotton mouse, endemic to Florida that causes occasional nonfatal neurological disease in humans [13,14]. The hispid cotton rat, Sigmodon hispidus Say and Ord, and the cotton mouse, Peromyscus gossypinus (Le Conte), are reservoir hosts of EVEV [15–17] and the mosquito Culex cedecei Stone and Hair is the sole enzootic vector [16,18]. Field studies from southern Florida during the late 1970s demonstrated that Cx. cedecei feeds predominantly (88–90%) upon mammals, acquiring about half of blood meals from rodents in the Everglades [18], the remainder (46%) being derived from medium-sized (northern raccoon, Procyon lotor (Linnaeus), Virginia opossum, Didelphis virginiana Kerr) and large-sized mammals (white-tailed deer, Odocoileus virginianus (Zimmermann)). During the 1970s and thereafter, these medium- and large-sized mammals were common in the Everglades National Park [12]. However, by the early 2000s, raccoon, opossum and deer experienced massive declines (87.5–99.3% reductions) in the Everglades afterward, these medium- and large-sized mammals have remained stable or even slightly increased [11,12]. These changes in host abundance may have profound effects on host use, given dramatic differences in size (deer versus rat) and circadian patterns of activity of the hosts as well as vectors, resulting in unequal exposure to bites. Other than host abundance these factors are not likely to have changed between past [18] and present studies. Comparing host use of the EVEV vector Cx. cedecei prior to python invasion [18] with current host use patterns provides the opportunity to investigate how an invasive apex predator may alter host–vector contact, a key interaction driving pathogen transmission.

2. Methods

We measured host use of Cx. cedecei inside and outside the introduced range of the Burmese python in Florida using PCR-based blood meal analysis and compared our results with analogous data obtained prior to the introduction and proliferation of the Burmese python in the Everglades [18]. Blood-fed Cx. cedecei were sampled in Everglades National Park and Vero Beach, FL using resting shelters (range 14–27 per sampling day) [19], a method targeting Cx. cedecei and other species that exhibit specialized resting behaviours [18]. Everglades sampling was
conducted at eight locations, all occurring on hardwood hammocks of the sawgrass prairie, the same habitat as Mahogany Hammock, site of Edman, and on average 6.3 km distant from that site (range 0.4–14.1 km). Sampling was conducted on 20 days, spread across five non-consecutive months (Dec 2015–Aug 2016) (permit no. EVER-2015-SCI-0054). In Vero Beach, FL, sampling was conducted weekly from December 2015 to November 2016. Blood meal analysis of 2015–2016 samples followed previously published PCR-based protocols [19], whereas Edman [18] used antibody-based methods for identifying vertebrate source of mosquito bloodmeals. We used the chi-squared test of independence to compare historical [18] and current studies (figure 2) and a significant shift in host use between 1979 and 2016, while those on the right increased over the same period.

3. Results

Analysis of Cx. cedecei blood meals (n = 125) from the Everglades revealed a significant shift in taxa-specific host use between the historic [18] and current blood meal data (X^2 = 136.4, d.f. = 11, p < 0.001) (figure 2) and a significant shift towards feeding upon aggregated reservoir hosts (X^2 = 35.0, d.f. = 1, p < 0.001), i.e. cotton mouse and hispid cotton rat (figure 2), that was not related to season (X^2 = 2.2, d.f. = 3, p = 0.533). Feedings on hispid cotton rats, perhaps the most important EVEV reservoir host [17], increased from 14.7% [18] to 76.4% of overall blood meals (increase of 419.7%; figure 2). In contrast, feedings upon deer, raccoon and opossum in the Everglades (figure 1) including rabbits (eastern cottontail, Sylvilagus floridanus (Bachman), and marsh rabbit, Sylvi...
risk. Future studies should quantify pathogen prevalence to determine whether cascading impacts of invasive predators result in measurable increases in risk of human exposure and identify invasive predators with high probability for indirectly increasing incidence of human disease.

Ethics. Everglades National Park granted ethical approval with the permit number EVER-2015-SCI-0054.

Data accessibility. Data deposited in Dryad: http://dx.doi.org/10.5061/dryad.mt3gr [24].

References