Supporting Information Document:

This document contains two tables (Table S1 and Table S2) and seven figures (Figures S1-S7) associated with the following manuscript:

Title: Tropicalization of temperate ecosystems in North America: The northward range expansion of tropical organisms in response to warming winter temperatures

Authors: Michael J. Osland[1], Philip W. Stevens[2], Margaret M. Lamont[3], Richard C. Brusca[4], Kristen M. Hart[5], J. Hardin Waddle[3], Catherine A. Langtimm[3], Caroline M. Williams[6], Barry D. Keim[7], Adam J. Terando[8], Eric A. Reyier[9], Katie E. Marshall[10], Michael E. Loik[11], Ross E. Boucek[12], Amanda B. Lewis[7], Jeffrey A. Seminoff[13]

[1]U.S. Geological Survey, Lafayette, LA, USA; [2]Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, St. Petersburg, FL, USA; [3]U.S. Geological Survey, Gainesville, FL, USA; [4]University of Arizona, Tucson, AZ, USA; [5]U.S. Geological Survey, Davie, FL, USA; [6]University of California, Berkeley, CA, USA; [7]Louisiana State University, Baton Rouge, LA, USA; [8]U.S. Geological Survey, Raleigh, NC, USA; [9]Herndon Solutions Group, LLC, NASA Environmental and Medical Contract, Kennedy Space Center, FL, USA; [10]University of British Columbia, Vancouver, BC, Canada; [11]University of California, Santa Cruz, CA, USA; [12]Bonefish and Tarpon Trust, Marathon, FL, USA; [13]National Oceanic and Atmospheric Administration, La Jolla, CA, USA

Table S1. Sources for the photos in Figure 1. The numbers correspond to the photo numbers in Figure 1. All but one of the photos are from U.S. Government websites.

Number	Common name	Scientific name(s)	Source	Credit	Website
1	Burmese python	*Python molurus bivittatus*	USGS	Bryan Falk	https://www.usgs.gov/media/images/a-burmese-python-coiled-grass-everglades
2	Joshua tree	*Yucca brevifolia*	NPS	Brad Sutton	https://www.nps.gov/jotr/learn/news/newspaper.htm
3	Saguaro	*Carnegiea giganteus*	USFS	Charlie McDonald	https://www.fs.fed.us/wildflowers/plant-of-the-week/carnegiea_gigantea.shtml
4	Red mangrove	*Rhizophora mangle*	USGS	Michael Osland	Not on a website
5	Melaleuca	*Melaleuca quinquenervia*	USDA	NA	https://www.ars.usda.gov/southeast-area/fort-lauderdale-fl/iprl/docs/melaleuca/
6	Brazilian pepper	*Schinus terebinthifolius*	USDA	NA	https://www.ars.usda.gov/southeast-area/fort-lauderdale-fl/iprl/docs/schinus-terebinthifolius-brazilian-pepper-tree/
7	Cuban treefrog	*Osteopilus septentrionalis*	USGS	Brad M. Glorioso	https://www.usgs.gov/media/images/invasive-cuban-treefrog-new-orleans-la
8	American crocodile	*Crocodylus acutus*	NPS	NA	https://www.nps.gov/ever/learn/news/joe-bay-is-open-to-non-motorized-boating.htm
9	Buffelgrass	*Pennisetum ciliare*	NPS	NA	https://www.nps.gov/orpi/learn/nature/invasive-plant-species.htm
10	Goliath grouper	*Epinephelus itajara*	NOAA	NA	https://www.fisheries.noaa.gov/southeast/endangered-species-conservation/goliath-grouper
11	Sawfish	*Pristis pectinata*	NOAA	NA	https://www.fisheries.noaa.gov/species/smalltooth-sawfish
12	Cobia	*Rachycentron canadum*	NOAA	NA	https://www.fisheries.noaa.gov/species/cobia
13	Bull shark	*Carcharhinus leucas*	NOAA	NA	https://graysreef.noaa.gov/science/research/fish_tagging/visitors.html
14	Manatee	*Trichechus manatus*	USGS	NA	https://www.usgs.gov/centers/wetland-and-aquatic-research-center-warc/science/manatee-health-assessment-and-biomedical?qt-science_center_objects=0#qt-science_center_objects
15	Loggerhead sea turtle	*Caretta caretta*	USGS	NA	https://www.usgs.gov/news/after-hurricane-devastation-sea-turtle-scientists-rebound-help-rebuild
16	Kemp's ridley sea turtle	*Lepidochelys kempii*	USGS	Margaret Lamont	https://archive.usgs.gov/archive/sites/soundwaves.usgs.gov/2018/02/staff.html
17	Greenhouse frog	*Eleutherodactylus planirostris*	USGS	Brad M. Glorioso	https://armi.usgs.gov/gallery/species.php?itis=173568
18	Coqui frog	*Eleutherodactylus coqui*	USGS	Chris Brown	https://armi.usgs.gov/gallery/species.php?itis=173559
19	*Aedes aegypti*	*Aedes aegypti*	CDC	NA	https://www.cdc.gov/features/stopmosquitoes/index.html
20	*Culex quinquefasciatus*	*Culex quinquefasciatus*	CDC	NA	https://www.niaid.nih.gov/diseases-conditions/west-nile-virus
21	Monarch butterfly	*Danaus plexippus*	USDA	Peggy Greb	https://www.ars.usda.gov/oc/images/photos/oct19/d3980-1/
22	Organ pipe cactus	*Stenocereus thurberi*	NPS	NA	https://www.nps.gov/articles/nps-geodiversity-atlas-organ-pipe-cactus-national-monument-arizona.htm
23	Chapparal plants	*Ceanothus megacarpus, Malosma laurina*	NPS	NA	https://www.nps.gov/samo/learn/nature/chaparral.htm

Table S2. Test for trends in winter temperature (Temp) data from four representative locations in North America's tropical-temperate transition zones, reporting Spearman's correlation (r_s) between year and: (1) mean winter temperature (Mean Avg Temp), (2) the absolute coldest annual winter minimum temperature (Lowest Min Temp), and (3) the number of subzero days each winter (# of days ≤ 0°C). See trend depictions in Figure 4.

	Mean Avg Temp		Lowest Min Temp		# of days ≤ 0°C	
	r_s	*p*	r_s	*p*	r_s	*p*
San Francisco (CA)	0.55	0.000	0.62	<0.001	-0.66	<0.001
Tucson (AZ)	0.39	0.000	0.41	<0.001	-0.46	<0.001
New Orleans (LA)	0.19	0.104	0.23	0.047	-0.39	0.001
Tampa (FL)	0.32	0.007	0.22	0.068	-0.30	0.011

Figure S1. Within the tropical-temperate transition zone, extreme cold temperatures control the northern distribution of foundation plant species like the saguaro cactus (*Carnegiea gigantea*; left) and red mangrove (*Rhizophora mangle*; right). Photo credits: NPS (saguaro) and Michael Osland (mangrove).

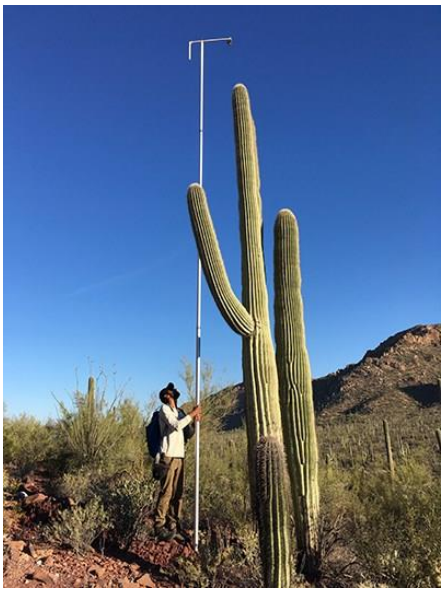
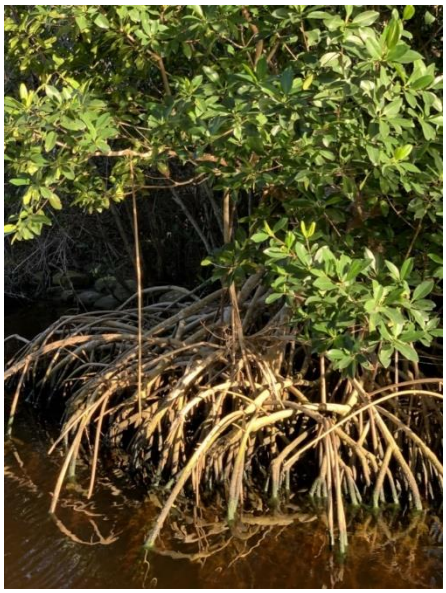

Figure S2. Winter temperature extremes control the distributions of subtropical fishes and drive movements of coastal migrants. The photo on the left is of the common snook (*Centropomus undecimalis*), aggregating at a spring head in northern Florida during winter. The photo on the right shows a biologist tagging a coastal migrant, cobia (*Rachycentron canadum*), with an acoustic transmitter during its run along the Florida panhandle. Photo credits: Florida FWC [Phil Stevens (left) and Jessica Carroll (right)].

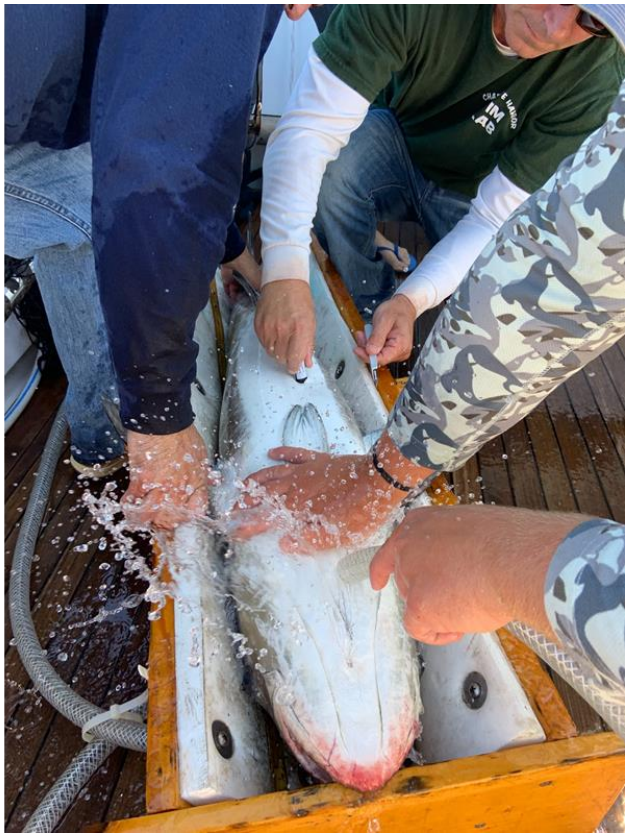

Figure S3. USGS scientists picking up cold-stunned sea turtles floating at the surface of St. Joseph Bay in northwestern Florida (USA) during an extreme cold event in 2018. Note the cold-stunned juvenile sea turtles in the boat. During cold stun events, mortality is often highest for juvenile, smaller sea turtles (Lamont et al. 2018). St. Joseph Bay is located in the northeastern Gulf of Mexico, approximately 50 km southeast of Panama City and 350 km northwest of Tampa Bay. Photo credit: USGS.

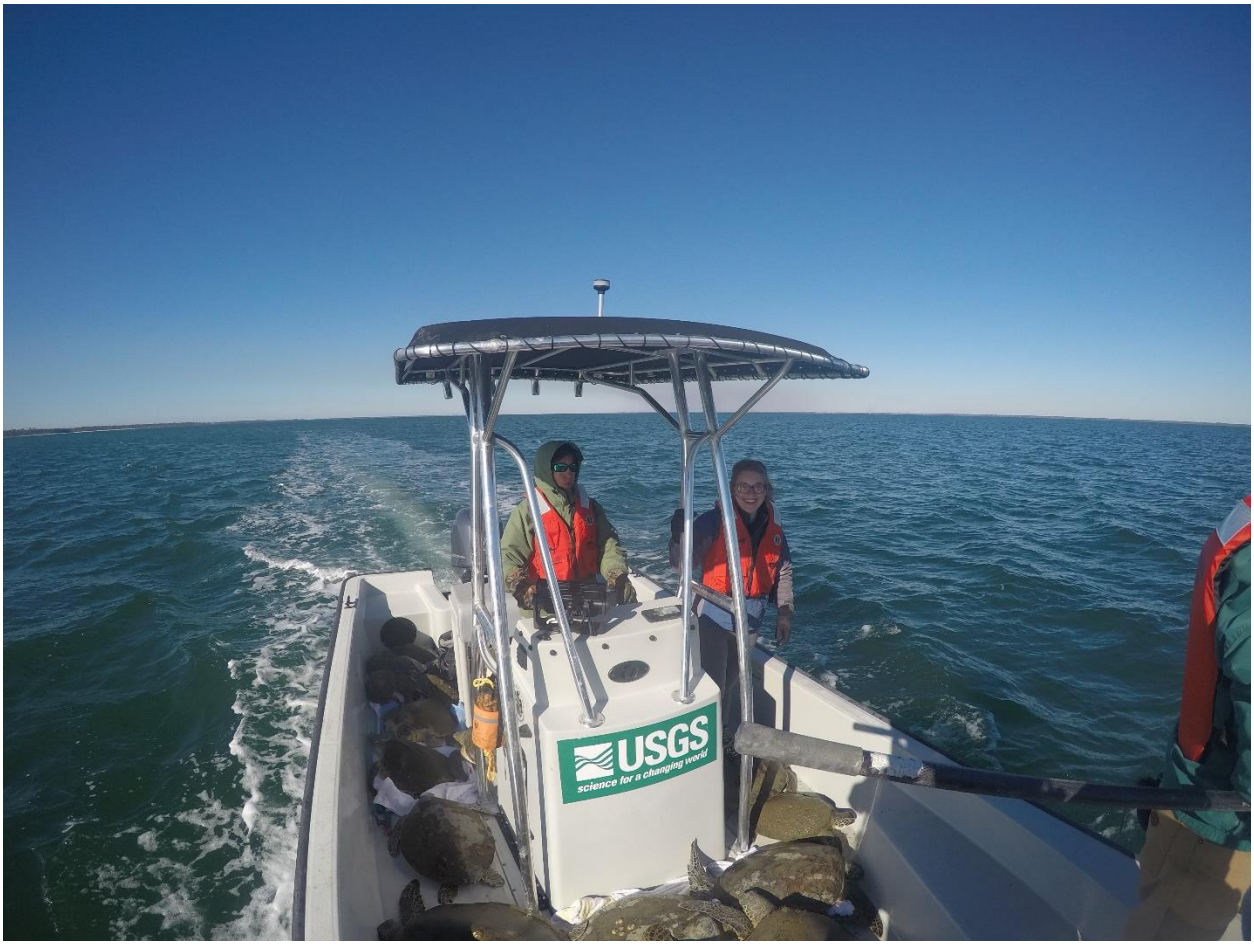

Figure S4. Extreme cold events constrain the distribution of many invasive non-native tropical reptile species. Burmese pythons (*Python bivittatus*) are an especially harmful and well-known example of the negative ecological impacts of pet trade-driven tropical reptile introductions. This large constrictor snake is an opportunistic apex predator, whose expansion within and around Everglades National Park (southwestern Florida, USA) has decimated mammal, bird, and other prey populations. Burmese pythons are also sensitive to cold temperature extremes and expected to expand northward in response to warming winters. Photo credit: USGS.

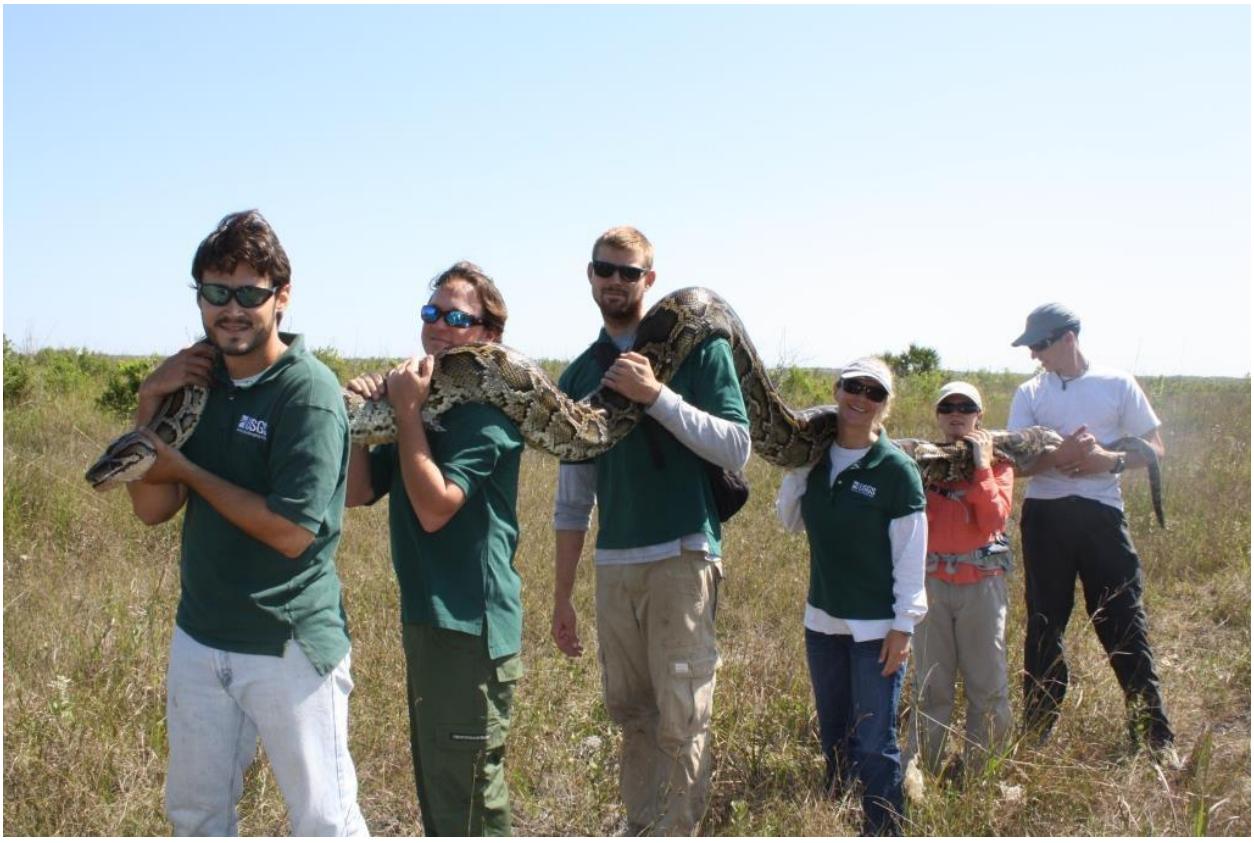

Figure S5. Dispersal constraints may affect the ability of some species to expand their range northward in response to warming winters. However, there are species [e.g., the Cuban treefrog (*Osteopilus septentrionalis*), as shown in this photo] that have successfully established populations in new areas following long-distance transport (>100 km) in ornamental tropical plants. These species have inadvertently traveled on horticultural shipments from Florida and other more tropical locations, which is a long-distance dispersal pathway that may enable more rapid poleward range expansion of certain amphibian species in response to climate change. Photo credit: Brad M. Glorioso.

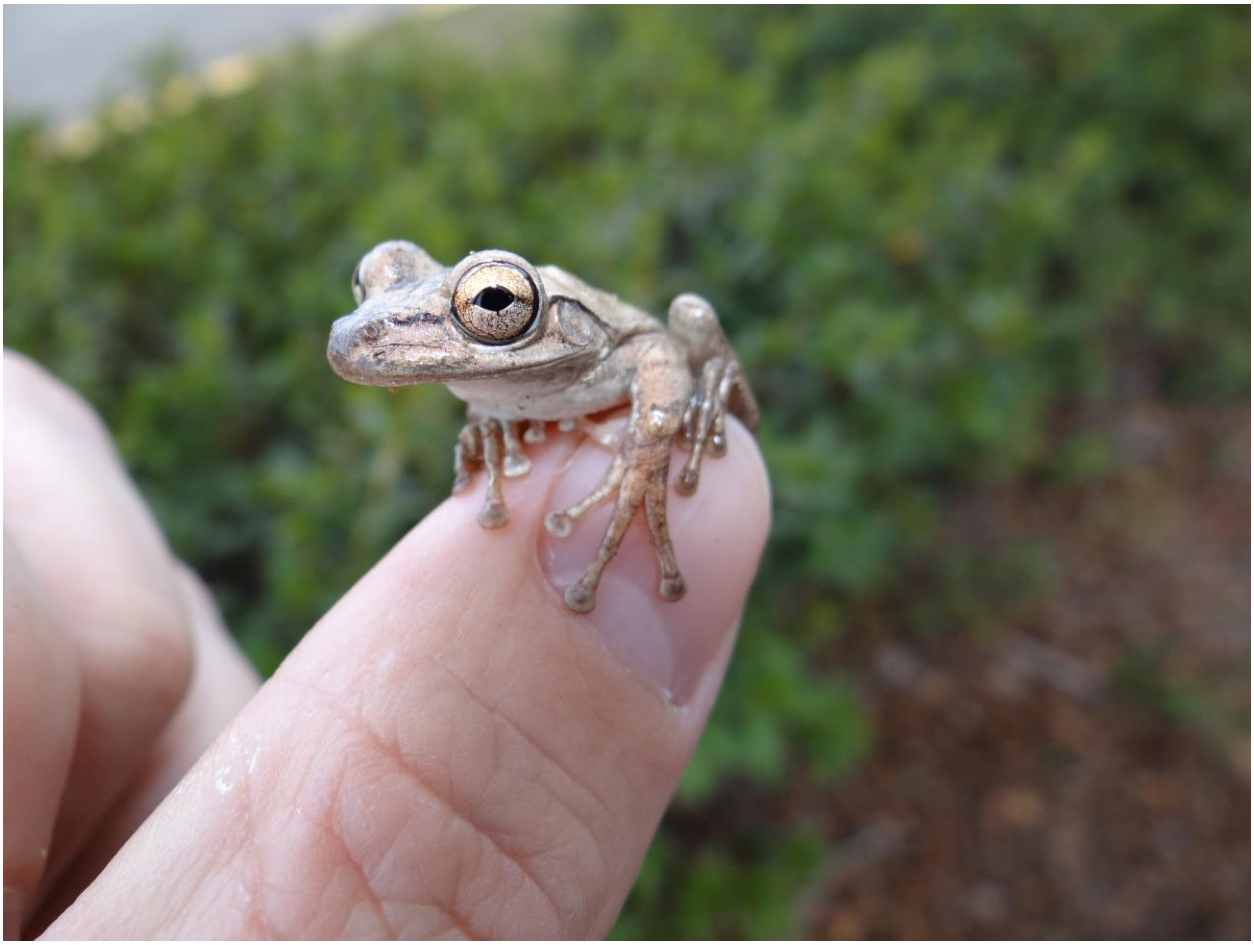

Figure S6. Near the northern limits of the distribution of the West Indian manatee (*Trichechus manatus*), individuals of the southeastern United States forage on seagrass and submerged aquatic vegetation. With advancing cold the population contracts toward Florida warm-water refugia where they often form large aggregations. This photo shows an aggregation at an artificial warm-water discharge produced by a thermoelectric power plant. Photo credit: USGS.

Figure S7. The northern range limits of most tropical insect species are governed by cold temperature extremes, which can lead to mortality of eggs, larvae, pupae, or adults.This photo is of *Aedes aegypti*, which is a cold-sensitive mosquito species. This species is expected to increasingly move northward due to warming winters and become more established in other parts of the southern United States. Photo credit: CDC.