Department of Defense
Legacy Resource Management Program

Recommended Best Management Practices for the Eastern Diamond-backed Rattlesnake on Department of Defense Installations

Department of Defense Partners in Amphibian and Reptile Conservation

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Introduction

The Eastern Diamond-backed Rattlesnake (*Crotalus adamanteus*; EDB) is a declining species that is currently under review for federal protection by the Endangered Species Act (ESA; USFWS Environmental Conservation Online System). This species is also on the Department of Defense at-risk herpetofaunal species priority list. Through a cooperative effort between the Department of Defense Partners in Amphibian and Reptile Conservation (DoD PARC) network, and the United States Fish and Wildlife Service (USFWS), Best Management Practices (BMPs) were developed for the EDB. The management practices and strategies summarized in this document are specific to DoD installations, but have broad applicability for managing EDB populations throughout their range.

The management practices described in this report are intended as guidelines that DoD natural resource managers can use to help plan, prioritize, and implement conservation and management actions that provide conservation benefits to the EDB, while also providing information to comply with regulatory processes such as the Sikes Act, Environmental Protection Agency's National Environmental Policy Act (NEPA) and associated components (i.e., Environmental Assessments, Environmental Impact Statements), etc. Implementation of these BMPs should not impede military readiness activities, should be documented in installation Integrated Natural Resource Management Plans (INRMPs), and should align with existing efforts among the DoD, federal/state governmental agencies, and non-governmental organizations (NGOs) to prevent this species' continued decline and preclude its listing under the ESA.

Species Profile

Description: The EDB is the largest rattlesnake species, and the second largest snake in the United States, reaching over 8 feet in length and weighing more than 15 pounds. Adults reach sexual maturity at just over three feet, and average sizes for adults range from 40 to 60 inches. Males and females look similar, but males have longer tails and thus more subcaudal scutes, i.e., the ventral scales that run from the cloaca to the end of the tail. Neonates and sexually immature EDBs resemble adults and range from 12-16 inches at birth (Ernst and Ernst 2012; Means 2017).

Like other rattlesnakes, EDBs add a segment to their rattle with every shed cycle (the shed cycle is called ecdysis and rattlesnakes shed multiple times each year). Rattle segments are regularly broken off, and as a result, rattles are an unreliable method for estimating age. Eastern Diamond-backed Rattlesnakes are characterized by yellow-bordered diamond blotches that run down the length of the dorsum, and two light-colored stripes that extend from the rear of the eyes and down to the jawline. The tail is usually banded, but there is a great deal of variation in the tail pattern (Moon et al. 2004). Dorsal patterns can be variable, but no other snakes within the EDB's range exhibit a distinctive overlapping diamond pattern (Fig. 1) that runs down the length of the dorsum.

Range: The historic range of the EDB closely mirrors that of pine savannas and woodlands associated with the Longleaf Pine (*Pinus palustris*) ecosystem on the southeastern Atlantic and Gulf Coastal Plain habitats from eastern Louisiana to southern North Carolina and south

throughout Florida, including the Keys and several other sea and barrier islands (Martin and Means 2000; Timmerman and Martin 2003). The current range of this species is depicted in Figure 2.

Figure 1. Eastern Diamond-backed Rattlesnake (Picture by Martin Korenek –Marine Corps Base Camp Lejeune)

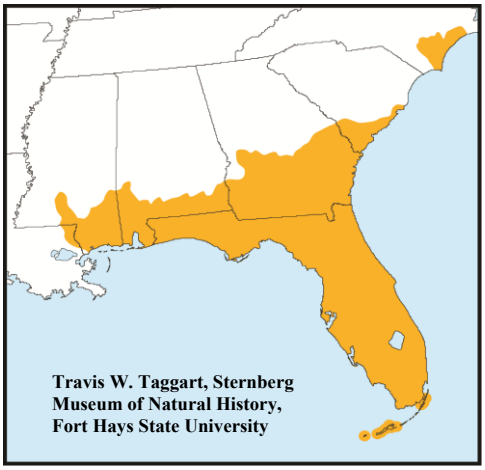

Figure 2. Eastern Diamond-backed Rattlesnake Range.

Distribution on Military Sites: The EDB is *confirmed present* on the following 28 military sites (Petersen et al 2018).

Air Force: Avon Park Air Force Range (FL); Cape Canaveral Air Force Station (FL); Eglin Air Force Base (FL); Hurlburt Field (FL); Joint Base Charleston (Weapons Station; SC); MacDill Air Force Base (FL); Patrick Air Force Base (Malabar Transmitter Annex; FL)

Army: Camp Blanding Joint Training Center (FL); Camp Shelby Joint Forces Training Center (MS); Fort Benning (AL); Fort Rucker (AL); Fort Stewart (GA)

Marine Corps: Marine Corps Air Station Beaufort (SC); Marine Corps Base Camp Lejeune (NC); Marine Corps Logistic Base Albany (GA); MCRD Parris Island (SC); MCSF Blount Island (FL); Townsend Bombing Range (GA); Marine Corps Reserve Center Jacksonville (FL)

Navy: Naval Air Station Jacksonville (Main Base, Pinecastle Range; FL); Naval Air Station Key West (FL); Naval Air Station Pensacola (Main Base, Naval Outlying Field Bronson Field, Saufley Field Naval Education and Training Professional Development Center; FL); Naval Air Station Whiting Field (OLF Holley; FL); Naval Station Mayport (Naval Fuel Depot; FL); Naval Submarine Base Kings Bay (GA)

The EDB is *unconfirmed, but potentially present* on the following 22 military sites; specimens have been found in the same county as these sites, but not within the boundaries of the installation itself (Petersen et al. 2018).

Air Force: Homestead Air Reserve Base (FL); Jacksonville Air National Guard (FL); Moody

Air Force Base (GA); Seymour-Johnson Air Force Base (Fort Fisher Recreation Area; NC); Tyndall Air Force Base (FL)

Army: Military Ocean Terminal Sunny Point (NC)

Marine Corps: MCAS Cherry Point (NC)

Navy: Naval Air Station Jacksonville (Outlying Landing Field Whitehouse, Rodman Bombing Target Range; FL); Naval Air Station Whiting Field (Main Base (FL), Naval Outlying Field Evergreen (AL), Naval Outlying Field Harold (FL), Naval Outlying Field Pace (FL), Naval Outlying Field Santa Rosa (FL), Naval Outlying Field Site 8-A (FL), Naval Outlying Field Spencer (FL), Naval Outlying Field Wolf (AL); Naval Station Mayport (Main Base, Greenfield Plantation, Ribault Bay Village Housing; FL); Naval Support Activity Orlando (Bugg Spring Facility; FL); Naval Support Activity Panama City (FL)

Habitat: Eastern Diamond-backed Rattlesnakes are indigenous to southeastern pine savannas and woodlands (Fig. 3), a fire-climax system that includes longleaf pine wiregrass sandhills, clayhills, and flatwoods (Martin and Means 2000; Waldron et al. 2006; Hoss et al. 2010; Means 2017). The snakes are selective of pine savanna structure (i.e., open-canopied pine stands maintained by high-frequency fire) at the home range, within home range, and microhabitat scales (Waldron et al. 2006; Waldron et al. 2008; Fill et al. 2015a). Eastern Diamond-backed Rattlesnake foraging is influenced by mast availability, indicating a bottom-up trophic effect on foraging site selection (Heres et al. 2018). Prescribed fire is the primary management tool used for maintaining pine savanna habitats, and military installations that use fire for habitat management or training operations are likely to harbor EDB populations, as well as other plant and animal species that are associated with southeastern pine savannas and woodlands (e.g., red-cockaded woodpecker).

Eastern Diamond-backed Rattlesnakes can reach high densities in Atlantic coastal habitats (Means 2017), particularly along sea and barrier islands where marsh and secondary dune habitats are similar to pine savannas (e.g., open canopy, low groundcover) and support important prey items, such as rabbits (Stohlgren 2013; Waldron et al. 2013a; Fill et al. 2015a; Fig. 4). Data are lacking on predictors of occurrence on sea and barrier island habitats, but it appears that the location and timing of tidal flows within coastal portions of river systems and their corresponding inundation patterns are likely determinants of EDB use of tidal hummocks. Secondary dune habitats are important predictors of EDB occupancy in Georgia sea and barrier islands, but EDB occupancy is not associated with maritime forests in these coastal habitats (Stohlgren 2013).

Figure 3. Longleaf pine savanna-woodland habitat. Eastern Diamond-backed Rattlesnakes are selective of pine savanna structure at multiple spatial scales (photo credit: Shane Welch).

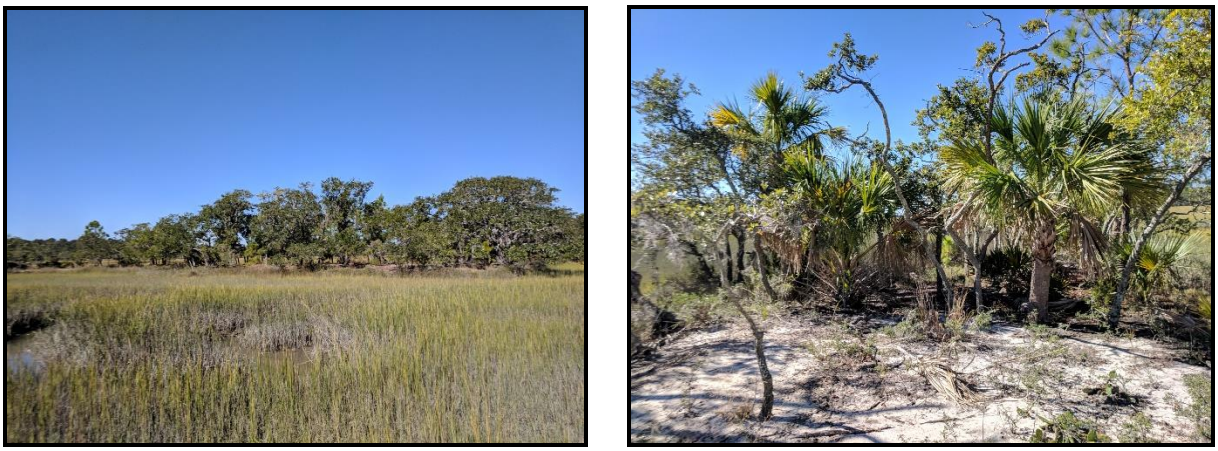

Figure 4. Coastal hummock habitats used by Eastern Diamond-backed Rattlesnakes (Photo credit: Michael Jungen).

Eastern Diamond-backed Rattlesnakes use subterranean habitats for winter refugia, birthing habitat, refuge from heat, and during ecdysis. Specifically, EDBs have been documented to use stumpholes, mammal burrows, hurricane tip-ups, fallen trees, palmetto logs, and gopher tortoise burrows (Martin and Means 2000; Means 2009; Fig. 3). In coastal island habitats, EDBs commonly use the root system of live trees, particularly red cedar (*Juniperus virginiana*), as well as anthropogenic cover along marshes (e.g., tidal rip rap, culverts, and pipes; Fig. 5).

Figure 5. Examples of structures used by Eastern Diamond-backed Rattlesnakes for cover from extreme temperatures, gestation, and ecdysis. From top left to right: stump hole, hollow log (photo credit: Michael Jungen), armadillo burrow, pipe along a tidal marsh (photo credit: Allison Kelley).

Lastly, although its presence may be less noticeable due to either the thickness of understory vegetation or relative difficulty of human access to the habitat, EDBs frequently occupy bottomland hardwood forests that are associated with wetlands and flowing water systems in the summertime, where there is also an abundance of prey items (e.g., squirrels) and cooler temperatures, particularly during droughts (John G. Himes personal communication).

Behavior: Eastern Diamond-backed Rattlesnakes have long active seasons, particularly in southern Florida where winters are mild (Ernst and Ernst 2012), and EDBs have been reported to spend as much as 55% of the winter above ground (Timmerman 1995). Outside of Florida, the EDB winter (inactive) season runs November through March. In northern populations (North Carolina and South Carolina), inland rattlesnake populations have a more pronounced inactive season than coastal island populations because climatic conditions are milder (winters in particular) in coastal habitats (e.g., Andrews and Waldron 2017). Emergence is characterized by a brief (2-3 week) period in which snakes remain in the vicinity of subterranean (winter) habitat. During this time, EDBs bask and shed before moving to foraging areas.

Eastern Diamond-backed Rattlesnake home ranges are variable, reflecting habitat availability and prey densities. Studies of EDB movement patterns have been largely limited to quail management areas, and little is known about movement patterns in coastal habitats. Inland populations exhibit large home ranges, ranging from 8 to > 300 ha (Timmerman 1995; Timmerman and Martin 2003; Waldron et al. 2006; Hoss et al. 2010; Means 2017). Males have larger home ranges than females on average, reflecting differences in breeding strategies between the sexes, where males search for receptive females during the breeding season. Sea island populations exhibit small home ranges, ranging from 1 to 55 ha (Waldron and Welch 2012; Waldron and Welch 2015; Kelley et al. 2020), inherently due to the small size of the land masses.

Eastern Diamond-backed Rattlesnakes mate in the fall (Aug-Nov), but winter and emergence breeding observations have been observed as far north as South Carolina (Timmerman and Martin 2003; Palis et al. 2012; Fill et al. 2015b; Means 2017), suggesting the species may have a bi-modal breeding season (fall and spring; Fill et al. 2015b). Winter breeding activity might explain why communal hibernation occasionally occurs. Unlike other *Crotalus* species, EDBs tend to hibernate singly. In addition to short-term sperm storage from a previous mating with a male, female EDBs can store sperm for up to five years (Booth and Schuett 2011), which may enable them to reproduce without successive matings, although sperm viability declines over time, and thus females must mate again to maintain high fertility.

Healthy males mate annually, but females have long birthing intervals in response to high energetic costs associated with reproduction. Long-term EDB monitoring projects in South Carolina (inland and coastal populations) have indicated that ~32% of adult females breed per year, reproducing every 2-3 years, on average (Waldron and Welch 2014). After mating takes place, females emerge in the spring, begin foraging, and then seek shelter in early to mid-summer. Birthing habitats include subterranean refugia (e.g., stumpholes, piles of downed pine needles and branches, hollow logs, and gopher tortoise burrows) that provide optimum cover for

concealment, while providing access to solar radiation for basking. Females at inland study sites have longer birthing intervals (i.e., up to 4 years). Clutch sizes ranges from 4 to 32 neonates (Timmerman and Martin 2003; Fill et al. 2015b; Means 2017).

In addition to high adult survival, delayed maturation, and limited dispersal ability, EDBs are long-lived snakes, living over 20 years in the wild (Waldron et al. 2013b). These 'slow' life history traits suggest that populations benefit from savanna woodland management practices that focus on maintaining habitat as a functionally dynamic, yet stable landscape (Waldron et al. 2013b).

Threats: Habitat loss is the primary cause of EDB declines. Because the EDB is dependent on pine savanna structure at multiple scales (Waldron et al. 2006, Waldron et al. 2008, Hoss et al. 2010), it is considered an important component of the historical southeastern woodland-savanna landscape (Martin and Means 2000). Historically, pine savannas and woodlands extended from southeastern Virginia to eastern Texas (Frost 2006), although the EDB is not known to have historically occurred north of southeastern North Carolina or west of extreme eastern Louisiana. Following colonization, southeastern pine savannas experienced extensive fragmentation and habitat alteration due to human activities, and now only 4% remain (Noss et al. 2015). Plants and animals endemic to the imperiled ecosystem face imperilment (e.g., Bachman's sparrows, red-cockaded woodpeckers, gopher tortoises, gopher frogs, frosted and reticulated flatwoods salamanders), and it is estimated that pine savannas provide the primary habitat for 85% of the endemic vascular plants in the southeastern Coastal Plain (Noss et al. 2015). Remaining pine savannas and woodlands are managed with prescribed fire, and prescribed fire protocols that mimic historic, evolutionarily derived fire regimes that are necessary to ensure resilience and maintenance of these habitats (Fill et al. 2015c).

Negative attitudes toward snakes have made snake conservation efforts difficult (Gibbons and Dorcas 2002). Venomous snakes in particular incite fear and elevate risk perceptions among people, increasing the probability that they will unnecessarily kill such snakes (Christoffel 2007). Rattlesnake roundups and wanton killing have had profound effects on EDB populations (Means 2009). Historically, rattlesnake round-ups were implemented to reduce rattlesnake abundance, but economic gains associated with the events became an impetus for perpetuating round-ups, even after rattlesnake numbers were reduced and more difficult to find and collect (Weir 1992; Fitzgerald and Painter 2000; Adams and Thomas 2008; Means 2009). In addition to round-ups, EDBs are collected from wild populations for use in venom labs (i.e., venom extraction), the pet trade, and as stuffed curios. Wanton killing and over-collection pressures are exacerbated by a lack of regulatory policy aimed at curving EDB declines.

Conservation Status

Eastern Diamond-backed rattlesnakes are under review for federal protection by the Endangered Species Act (US DOI 2012). The species has a G3 global ranking, meaning EDBs are considered vulnerable. State rankings reflect the status and range of their respective EDB populations, such that at the core of the species range (i.e., Georgia), populations tend to be more secure. The EDB is listed as critically imperiled (S1) in North Carolina and Louisiana, vulnerable (S3) in South

Carolina, Mississippi, Alabama, and Florida, and apparently secure (S4) in Georgia. Eastern Diamond-backed Rattlesnakes are likely extirpated from Louisiana. The species is designated as a species of conservation concern with high management priority in the Alabama, North Carolina, South Carolina, Georgia, and Mississippi State Wildlife Action Plans (SWAP).

Recommended Conservation Implementation Strategies and Best Management Practices for Eastern Diamond-backed Rattlesnakes on Military Sites

The BMPs listed below should not be performed at the expense of existing EDB populations. Natural resource management activities should be carefully pre-planned prior to implementation to minimize negative impacts to EDB activity and habitat. Make sure to document performance of any of the following BMPs, whether current or future, in your installation's INRMP. The USFWS may consider these proactive conservation actions prior to making a listing determination for this species.

1. **Identify, protect, and restore EDB habitats (pine savanna woodland structure, hummocks, and marsh edges) on military properties.** Conduct habitat assessments using aerial imagery, GIS data, and visual surveys to identify suitable pine-savanna woodland habitats, island hummocks, and marsh edges. Visual, on-the-ground habitat assessments should quantify the availability of important micro-habitat structures, including stumpholes (partially decomposed stumps with openings into underlying root systems), Gopher Tortoise burrows, mammal burrows, hollow logs, windthrows, and rip-rap along tidal marsh edges. These important micro-habitats provide subterranean refuge (birthing sites, refuge from extreme heat and cold, and ecdysis) and can be particularly important along woodland and marsh edges that are south-facing. South facing marsh edges should be sampled intensely in coastal habitats during spring emergence to improve the probability that EDBs are detected.

   Pine-savanna woodland habitats are pyrogenic, and high frequency fires (every 2-3 years) during the growing season are likely to support plants and animals endemic to this habitat. Munitions training operations likely benefit EDB populations through habitat maintenance, which outweighs any direct mortality of snakes associated with training activities. Installations that do not conduct munitions training, but occur within the range of the EDB, should identify remnant savannas and woodlands using historical and contemporary aerial imagery. Remnant patches of suitable habitat that have been excluded of fire should be considered a high priority for restoration.

   Pine savanna restoration will benefit populations of EDBs on military installations. Pine savanna restoration protocols include timber thinning, mechanical or chemical spot-treatment of encroaching hardwood shrubs to suppress their growth, and prescribed growing season fire that restores an open canopy (i.e., canopy cover $\leq$ 60%) and ground cover structure (i.e., grass and forb-dominated ground cover). If natural fuels (e.g., dead vegetation) are high, dormant-season fire can be used with the goal of reducing fuel load. However, growing season fire should be implemented as soon as possible to mimic the natural fire regime and prevent hardwood encroachment. Growing season fires are crucial for maintaining resilient

savannas and woodlands, outweighing potential negative effects (e.g., snake mortality) associated with fire prescriptions. Long-term management should include an adaptive 3-7 year growing season burn regime, based on vegetative response to management protocol. Timber operations should be conducted during the dormant season, when feasible, as the snakes are mostly underground during this period. Stump removal should not be included in timber management protocols.

2. **Incorporate EDB habitat management into timber management operations on military installations.** Timber harvests on military installations are often implemented with the goal of maintaining forest stand health and vigor in support of military training operations. Timber production on military installations should follow guidelines to minimize negative effects to EDB habitats. Timber thinning operations can be used under a restoration scenario to improve stand structure through increased vertical heterogeneity, providing general wildlife benefits. When management goals are to balance wildlife management and timber production, stand thinning during the dormant season can be used to improve habitat structure for wildlife, while increasing remaining crop tree growth. Prescribed fire should be used to reduce fuel loads, improve habitat structure for mast production, and maintain high EDB prey (e.g., eastern cottontails, marsh rabbits, fox squirrels) densities.

3. **Develop brochures, fact sheets, and outreach protocols to prevent negative human-rattlesnake interactions.** Negative human-rattlesnake interactions should be managed using a combination of outreach and brochures/fact sheets that can be distributed to the public with the goal of minimizing fear and reducing exaggerated risk perceptions. Eastern Diamond-backed Rattlesnake management must include protocols that do not enhance snakebite risk for military personnel, civilians, and military installation residents. As such, personnel should be made aware of the presence of EDBs, what to do (or not do) when someone encounters an EDB, and risks associated with initiating contact with EDBs, either out of curiosity, ignorance, or with the misguided intent to harm the snake. The majority of rattlesnake bites result from humans initiating contact with snakes (Morandi and Williams 1997), and outreach materials can be designed to dissuade people from negative interactions with venomous snakes. Military installations should develop protocols for dealing with human-rattlesnake encounters, including how they are reported and what actions are taken to decrease risks to people and snakes, and what to do in the case of a venomous snakebite.

4. **Survey existing EDB populations on military sites.** Eastern Diamond-backed Rattlesnake visual surveys will allow natural resource personnel to know where and in what specific habitats that populations of the snakes are located on the military installation, and potentially provide insight into other aspects of their life history. In addition, mark-recapture and radio telemetry surveys will provide greater insight into population demography (growth, maturation, survival, movement patters, and recruitment) and dynamics that can be used to assess population viability (see Appendix A for inventory and monitoring techniques for this species). Also consider recording the location of opportunistic rattlesnake observations by

installation personnel to identify areas on the base where future human-snake interactions may occur.

5. **Minimize road mortality**. When possible, resource managers should avoid the construction of new, permanent roadways within rattlesnake habitat. Managers should also ensure that threats to EDB attributable to roads and road development activities are adequately addressed during the planning phases of proposed road development projects, as in Environmental Assessments (EAs) and Environmental Impact Statements (EISs). Culverts or low silt fence or similar barriers have the potential to minimize road mortality, particularly on paved roads with high vehicular activity. Reducing speed limits and placement of wildlife-crossing signs in locations where snake mortality is common may reduce mortality in road-crossing hot spots.

6. **Avoid designating recreation areas (play grounds, picnic areas, scenic areas) near established EDB overwintering sites and/or birthing areas.** Do not encourage military personnel and civilians to recreate near known EDB hibernation areas or birthing areas. Seasonal restrictions during active EDB timeframes annually should be considered. Picnic areas have the capacity to attract EDB prey items that feed on food waste, increasing the probability that EDBs will forage near these areas. Discourage fishing along south- and west-facing tidal creeks with an abundance of hibernation and birthing site structures (red cedars, rip rap, stumpholes). Consider installing educational signage where recreation and EDB co-occur.

7. **Retain stumps, logs, and other preferred subterranean EDB habitats**. Natural resource management protocols should not include removal of stumps, logs, and other structures (with the exception of logging debris) that are important winter habitats and birthing sites. EDBs also have a high reliance on "tip-up mounds" (sometimes also called "windthrows") and should not be removed if possible. Windthrows are created when events, such as hurricanes or extreme fires, cause trees to blow over. For EDBs, the size, species, and quality of these trees is very important. For example, longleaf pine has a uniquely large tap root that is not only important for enabling larger subterranean root channels that can be used by snakes, but it also gouges more soil in the case of tip-up mounds to create cavities the snakes use/prefer as refuge. The size and quality of these resulting shelters are very different from those created by smaller less mature trees or by other species of pines. If removal of stumps, logs and windthrows is necessary, it is recommended that management be conducted, when possible, during the growing season to ensure snakes are not killed during ground cover removal.

8. **Implement prescribed fire protocols in upland habitats to encourage pine-savanna structure**. When possible, incorporate prescribed fire into habitat management and training protocols. Growing season prescribed fire provides the best means of controlling encroachment of hardwood vegetation and maintaining open woodlands that benefit wildlife

and military training operations. Further, endemic plants respond favorably to growing season fire, improving foraging opportunities through mast production for EDB prey items.

9. **Discourage unnecessary attempts to collect, harm, or kill EDBs.** Prohibit EDB collection on military sites. Collection in this context is defined as capturing and permanently removing a snake from its environment by untrained personnel. This will reduce snakebite risks and will protect adult females, which are the most important demographic for maintaining healthy EDB populations. Discourage the intentional harming or killing of EDB by installation personnel in situations where human safety is not jeopardized (such as when snakes are encountered on roads).

10. **Do not remove in-place rip-rap along tidewater creeks that border marshes and woodlands.** Rip rap along tidal creeks provides important cover and winter/spring basking opportunities for EDBs. This habitat is often used for hibernation, foraging, and birthing sites.

Benefits of Eastern Diamond-backed Rattlesnake BMPs to Military Training Operations

1. Identification of important habitats for EDB foraging, hibernation, and reproduction enables military planners to know of and account for these important habitats when developing training operations and natural resource management protocols.
2. Munitions training operations create and maintain EDB habitats and thus should not be excluded from areas containing EDB populations. However, construction of new ranges on military installations should occur in areas of sub-optimal habitat and avoid older, well managed longleaf pine forest, especially those with high quality refugia.
3. The open structure of EDB habitats are ideal for military training operations. Thus, the maintenance of EDB habitats will assist with military training and readiness.
4. Protocols that address how human-rattlesnake encounters are reported will minimize interruptions to training activities.
5. Management of EDB habitat align with those of several candidate and ESA-listed species of the southeastern region including the Red-cockaded Woodpecker, Eastern Indigo Snake, and Gopher Tortoise. An ecosystem approach to the habitat management of these species is supported in INRMP implementation.

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High Priority Research Questions

Confirmation of Eastern Diamond-backed Rattlesnake occurrence at unconfirmed military sites: There are 22 military sites that do not have confirmed EDB sightings that occur within the range of this species. Surveys should be implemented to confirm EDB presence or absence on these sites if one has not been performed within the last 5-10 years. If dead EDBs are detected on roads, specimens should be photographed and their location recorded. Similarly, if live individuals are detected, they should be safely photographed and the location recorded so that this information can be incorporated in the installations' respective INRMPs. Low detection probabilities hamper EDB studies. Efforts to locate EDBs should incorporate sufficient temporal replication to ensure rattlesnakes are detected if they are present at a military site.

Gene flow between coastal populations and inland populations along tidal rivers-implications for critical habitat designation: Eastern Diamond-backed Rattlesnakes have a patchy distribution across the southeastern Coastal Plain as a result of wide-scale habitat loss and degradation. These snakes are excellent swimmers, and are often observed in ambush along tidewater and swimming in tidal creeks. Studies that quantify gene flow among populations will provide insight into the impacts of long-term isolation, as well as offer insight into whether populations inhabiting up-stream habitats (inland pine savannas and woodlands) are source populations for EDBs dispersing passively downstream to sea and barrier islands. This research has potential to aid critical habitat designation, particularly if coastal populations are sink populations.

Population structure and dynamics: Information about EDB population structure and dynamics on military installations will provide much-needed insight into how EDB demography

varies range-wide. The EDB is a long-lived species, and its occurrence on a military site does not equate to population viability. Thus, EDB populations should be monitored to examine abundance and demography (survival, growth, recruitment), ensuring populations remain viable on DoD sites.

Provide outreach to assess risk perceptions among stakeholders: Military readiness relies on consistent, uninterrupted access to training areas. Negative human-rattlesnake interactions have the potential to impact training operations and can be minimized by outreach materials (brochures and fact sheets) and studies that examine stakeholder risk perceptions.

Biosecurity: *Ophidiomyces* (snake fungal disease) is prevalent on North American military installations (Allender et al. 2018, 2020). This disease has been detected in EDBs on military installations, and studies are needed to assess the effect that snake fungal disease has on EDB populations. Studies that repeatedly sample individuals throughout the course of 1-2 years may offer insight into seasonal effects on *Ophidiomyces* occurrence and mortality events associated with the disease. Such sampling could easily be incorporated into EDB monitoring efforts that use radio telemetry to monitor free-ranging snakes on military sites.

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Appendix A

Inventory and Monitoring Techniques for Eastern Diamond-backed Rattlesnakes

Eastern Diamond-backed Rattlesnake monitoring suffers from the species' low detection probability; even when EDBs are present at a site, detection probability is less than 20% (Waldron et al. 2013a). Surveys are more successful in the spring during relatively cooler parts of the day, increasing the probability that snakes are basking in the vicinity of a hibernaculum and thus easier to detect. Visual surveys should be conducted in appropriate habitats to maximize detection probability. Eastern Diamond-backed Rattlesnakes can be captured in snake traps positioned along drift fences, but visual surveys in appropriate habitats are more likely to be productive. Road surveys and cover board surveys are not reliable methods for detecting EDBs. Unfortunately, no study has been conducted to compare EDB sampling strategies. In coastal areas, where rattlesnake densities are can be higher as compared to inland populations, visual (area-constrained) surveys are suitable for sampling EDB populations. Inland populations are likely to require more intensive surveys that require more surveyors.

If individuals do not need to be captured, camera trap surveys (Hobbs and Brehme 2017), which incorporate drift fences that are equipped with cameras (animals can move freely along the fence and do not get trapped) are an ideal method for detecting EDBs. Because it is a form of passive sampling, camera traps only require little maintenance after installation (battery replacement and image downloads) and sample habitats continuously.

Capture. Venomous snake capture and handling requires proper training and experience before it can be implemented as part of a sampling protocol. Natural resources personnel should be properly trained (and have the appropriate permits) by experienced handlers (e.g., zoo keepers, wildlife biologists) and use proper safety gear and techniques. Venomous snake surveys should only be conducted while surveyors are wearing snake chaps and sturdy field boots. Snake hooks should be used to capture venomous snakes, and then the snakes should be placed in a bag and then a box that can be locked and stored (immediately after capture). Following capture, snakes can be marked in the field (see mark-recapture techniques, below) or moved to a safe facility for mark-recapture processing. Never store snakes in cars or on direct sun. Because they are ectotherms, snakes overheat easily, resulting in death. For more information on snake safety and handling techniques, see the following DoD PARC video: https://www.youtube.com/watch?v=YMAN0HxHGCU&feature=youtu.be

Mark-recapture. Mark recapture surveys can be conducted seasonally and annually, but require that snakes are captured and safely restrained upon each capture. Surveyors must use a snake hook and clear, plastic snake-restraining tube to safely handle EDBs of all size classes. Low detection probability necessitates that mark recapture surveys have sufficient temporal replication to ensure recaptures are sufficient to estimate important population parameters, such as survival, abundance, and growth.

Given their large body size, EDBs are well suited for passive integrative transponder (PIT) tag marking (see Andrews and Gibbons 2004). These tags offer certainty that individuals are identified correctly. After sterilizing the injection site, PIT tags should be injected beneath ventral scales directly adjacent to dorsal scales, approximately 12 ventral scale rows above (cephalad) the cloaca. Ventral scale cauterization (Winne et al. 2006) is also well suited for EDB mark-recapture surveys. Over time, scars from cauterization become more difficult to see, increasing the probability that individuals are not identified correctly. Follow methods outlined in Winne et al. (2006) to implement scale cauterization into EDB monitoring programs.

Radio Telemetry. Radio telemetry surveys should be implemented when questions about habitat use, survival, and movement patterns are required for insight into EDB management options. Eastern Diamond-backed Rattlesnakes can be monitored telemetrically using internal transmitters or externally-attached transmitters. Internal transmitters require at least two surgeries (i.e., one for implantation and one for removal). More surgeries are required for long-term telemetry goals (i.e., multiple years) to replace transmitters with expired batteries (Reinert and Cundall 1982). Follow methods outlined in Jungen et al. (2019) to attach transmitters to the rattle. As compared to internal transmitters, external attachment caries increased risk of losing study animals that drop the transmitter when the rattle breaks off. If populations are small, and capture difficult, then internal transmitters should be used to monitor EDBs. If populations are robust, and capture is not difficult, then external transmitters may work to address questions about habitat use and movement patterns.