EXECUTIVE SUMMARY

Investigating Potential Risk to Threatened and Endangered Species from Per- and Polyfluoroalkyl Substances (PFAS) on Department of Defense (DoD) Sites

SERDP Project ER18-1626

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ACRONYMS AND ABBREVIATIONS

ADI	Average Daily Intake
AFB	Air Force Base
AFFF	Aqueous Film Forming Foams
BAFB	Barksdale Air Force Base
DoD	Department of Defense
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESTCP	Environmental Security Technology Certification Program
GIS	Geographic Information System
INRMP	Integrated Natural Resource Management Plans
JBMDL	Joint Base McGuire Dix Lakehurst
NAS	Naval Air Station
PFAS	Per- and Polyfluoroalkyl substances
PFOS	Perfluorooctane sulfonate
SERDP	Strategic Environmental Research and Development Program
SIR	Site Investigation Report
T&E	Threatened and Endangered
TRV	Toxicity Reference Value(s)
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

1.0 INTRODUCTION

Per- and Polyfluoroalkyl Substances (PFAS) are emerging contaminants of concern and are found on many military installations that have airborne missions. These chemicals are extremely persistent and somewhat mobile in environmental media and have been measured in nearly all environmental compartments and biota (e.g., Houtz et al. 2013, Long and Porter, 2015, Geisy and Kannnan 2001, Custer et al. 2014). As such, there is growing interest regarding the potential effects of PFAS to public and environmental health, as well as concern from the Department of Defense (DoD) regarding liability under federal statutes such as the Endangered Species Act (ESA). The predominant source of PFAS on DoD sites originates from historical fuel-based fire suppression activities using Aqueous Film Forming Foam (AFFF) which contained a mixture of largely perfluorooctane sulfonate (PFOS) in combination with other PFAS (Houtz et al. 2013). The physicochemical properties that render PFAS compounds effective in fire suppression also translate to resistance to biodegradation, photooxidation, direct photolysis and hydrolysis.

Studies conducted by DoD and researchers at U.S. Air Force installations confirm PFAS detections in environmental compartments, and transportation of PFAS from sites below AFFF training areas to surface water, sediment and groundwater (Lanza et al. 2017, Moody et al. 2002, Gewurtz et al. 2014, Karrman et al. 2011, Oakes et al. 2010). Biota may be exposed via direct and indirect pathways, such as direct contact with soil or drinking water or bioaccumulation. Identifying exposure pathways to ecological receptors can be complex; however, determining risk may prove more challenging based on overall lack of toxicity data on many PFAS.

Given the lack of information concerning the potential risk of PFAS to federal and state listed Threatened & Endangered (T&E) species on DoD lands, the team developed a framework to determine T&E species occurrence and potential overlap with PFAS contamination. This project provides immediate and useful insights into the potential for PFAS exposure to T&E species and points the way toward methods for location and species-specific assessments for PFAS risk.

2.0 OBJECTIVES

The overall objective of this research was to develop a framework for natural resource managers to quickly assess on-site threatened and endangered species likelihood of PFAS exposure and risk. To address this objective, the team developed (1) a methodology for determining spatial overlap of T&E species on DoD sites with areas of AFFF release, (2) prioritization for T&E species with greatest exposure potential and (3) conducted a species-specific probabilistic risk assessment for T&E species to determine risk of PFOS exposure.

3.0 TECHNOLOGY DESCRIPTION

The technical approach followed the schematic below in two main phases with two decision points (as indicated by stars, Figure 1). Phase 1 (silver box) was used to develop the T&E (referred to from this point forward as 'protected') species exposure potential on installations and Phase 2 (blue box) is the determination and/or development of the individual-based probabilistic models. The decision points were used at particular junctures to (1) determine if there are enough data to move forward with generating the spatial exposure potential and (2) determine if there are any protected species that warrant a probabilistic exposure assessment to determine a risk.

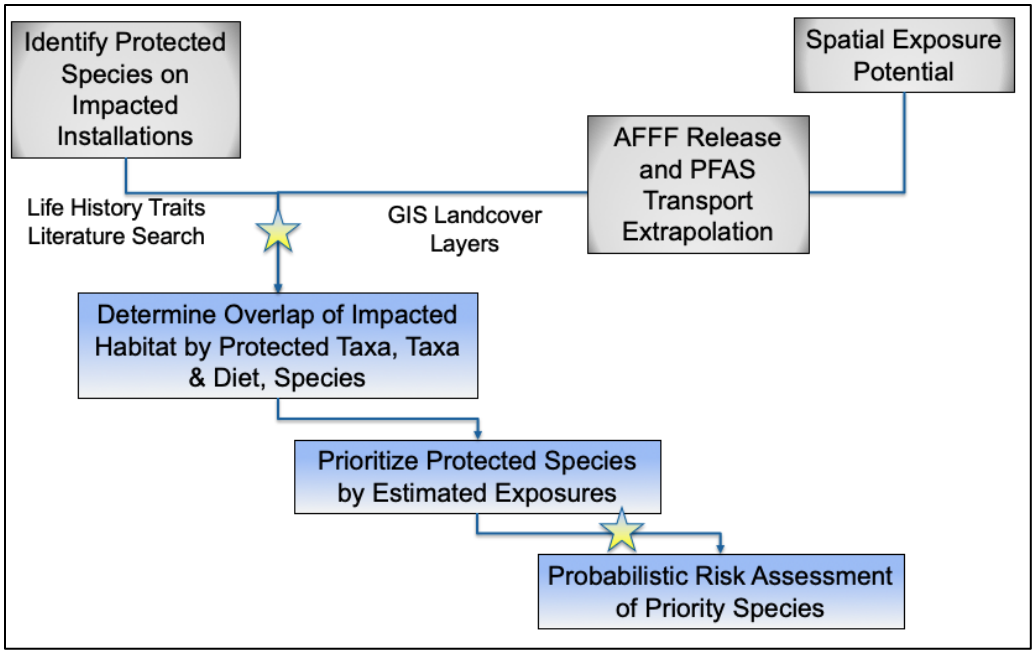

Figure 1. Flow Diagram

Figure 1 - Flow diagram of the technical approach evaluating protected species on installations impacted by PFAS through AFFF release. Stars indicate decision points in moving to the next step within the flow diagram.

3.1 EXPOSURE POTENTIAL MODELING

To develop the spatial exposure potential modeling, installations with known AFFF release locations and environmental PFAS concentrations in the form of a Site Investigation Report (SIR) or published literature were identified. Using Geographic Information System (GIS), landscape layers were obtained from the installation or other publicly available sources, and AFFF release locations from repeated fire training exercises or single use were digitized from the SIR creating a base map of land cover layers (habitat) and AFFF release sites. Transport of PFAS from AFFF release sites is expected, and therefore, using landscape topography, known conveyances and surface water flow direction areas impacted by AFFF and PFAS have been extrapolated out from the release locations terminating at the nearest surface water body. Those extrapolations cross landscape layers that allow for estimation of habitat specific PFAS impacts from AFFF release sites.

Site-specific protected species were identified using the Integrated Natural Resource Management Plans (INRMP) and federal/state/county T&E species lists. Habitat requirements of each species were identified through literature searches and were matched with the available landscape layers on the base map in GIS to determine where those species may be located on the installation. Furthermore, species-specific dietary requirements were also incorporated into the spatial model to capture potential foraging areas.

4.0 PERFORMANCE ASSESSMENT

Results indicate that a screening-level spatial exposure potential assessment will help installations identify protected species that are likely to be exposed to PFAS through historical AFFF release.

Moreover, this analysis provides a ranking of impacted landscapes, and thus those protected species dependent on landscapes ranked higher may have comparably greater exposure potential to those on landscapes ranked lower. Broadly, this tool will aid in identifying habitat that supports non-protected ecological receptors as there is likely overlap in habitat selection by taxa. Using the exposure mapping also provides a spatial component for natural resource managers to visualize areas of potential concern based on habitat type.

Protected species at Joint Base McGuire-Dix-Lakehurst, Naval Air Station Patuxent River and Barksdale Air Force Base (AFB) were prioritized by impacted habitat exposure potential by taxa, taxa and diet, and individual species. Results indicate taxa with large home ranges have the greatest exposure potential, as those that travel further are able to move across the landscape, increasing their habitat range. Whereas the inverse is true for taxa with small home ranges (i.e., invertebrates), should their habitat be limited to an impacted area. In addition to providing a framework for ranking species-specific exposure potential, the aim was to conduct full risk estimates on two species that were identified as having high exposure potential.

The spatial exposure potential assessment is dependent on a few key factors. First, accurate and available landscape layers in GIS is critical at identifying appropriate habitat suitable for protected species on the installation. Secondly, the spatial exposure analysis is limited to reported AFFF release locations. To account for environmental movement of PFAS we extrapolated the area of impact out from the known release site following topography, groundwater and surface water conveyances. Therefore, without environmental sampling of PFAS the true migration is unknown and thus the best estimation of migration has been provided. Furthermore, there may be other sites of AFFF release and measurable PFAS concentrations that are unknown or not available for this effort.

There are some excellent opportunities for future research that have become apparent during this effort. To address uncertainties in extrapolated PFAS migration within the landscape, environmental sampling along a gradient or at the expected surface water termination would be beneficial for proof-of-concept. Protected species are ranked based on the exposure potential which is a critical first step in understanding which species and/or taxa may be receiving the greatest exposure to PFAS. The team acknowledges there are limitations to this based on historical sampling of known AFFF release locations, however, using those limited data, environmental sampling could fill in the gaps of expected PFAS transport.

In addition to environmental sampling, *a critical need* in understanding true ecological receptor PFAS exposure scenarios is the sampling of biota in concert with environmental compartment sampling. This is especially true for the reptilian model as there are very few (if any) data available for PFAS tissue concentrations. The team's model suggests the Northern pine snake may occupy a PFOS impacted site; however, exposures may not elicit an apical response. Sampling blood or tissue of a surrogate reptilian species would be notably informative to this model. Importantly, these data should be collected in conjunction with animal tagging so true PFAS exposure can be ascertained based on a temporal and spatial scale. Other avenues of research to determine exposure would be sampling of shedded reptilian skin, as depuration of contaminants have been previously noted via this route of elimination. These data would then be incorporated into the snake model to refine expected reptile PFAS exposure scenarios.

Finally, and perhaps most important, would be developing a field component to determining PFOS exposures to bald eagle eaglets. As the current probabilistic model suggests there may be risk to eaglets through high dietary exposures. The team assumed that proximity of nest location to PFAS impacted sites plays a role in the eaglet exposure profile and would suggest nest sampling at near and far distances – including nests that are used in consecutive years. One non-lethal approach to determining PFOS exposure to eaglets would be to sample feathers that have been shed; this approach also results in minimum disturbance to the animals. In addition to feather sampling, droppings may also be sampled for PFOS, however the concern with this approach alone is that fecal material may be from parent or the eaglet, whereas feathers can be more easily identified as adult or juvenile.

The abovementioned additional effort could serve as a 'ground truth' to the models developed under this statement of need. Moreover, the risk assessment community frequently requests more information on observed field effects in addition to those modeled and/or inferred by environmental sampling alone.

5.0 IMPLEMENTATION ISSUES

Risk Assessments of two protected species were conducted. The bald eagle (*Haliaeetus leucocephalus*) and the Northern pine snake (*Pituophis melanoleucus*) were selected based on the spatial exposure potential of the three installations evaluated and a broad application to multiple installations. Although the bald eagle is delisted from the Endangered Species Act (ESA), it continues to be a protected species under the Bald and Golden Eagle Protection Act (1940), the Migratory Bird Treaty Act (1918), and the Lacey Act (1900). Given the number of laws in place to protect this species, and the broad distribution of bald eagles on coastal installations, it was prioritized for the risk assessment. The second species, the Northern pine snake, was selected because the exposure potential was relatively high compared to other protected taxa on Joint Base McGuire-Dix-Lakehurst (JBMDL). Many DoD installations have one or more protected reptilian species and there is a significant gap in reptilian risk assessment (Weir et al. 2010), especially pertaining to PFAS (Conder et al. 2019). The Northern pine snake is also a federally protected species at Arnold Air Force Base in Tennessee (Petersen et al. 2017).

A probabilistic exposure and risk model were used to estimate PFAS exposure to the bald eagle and the Northern pine snake. The models were based on allometric equations to predict field metabolic rate (energy needs) in avian and reptilian receptors. For the bald eagle, an exposure model was developed, assuming a realistic diet of mammal and fish with a probability of PFOS contamination using published PFOS concentrations (Chang et al. 2012, Lanza et al., 2017). The study focused on the eaglet (day 0-60, fledgling) as this may be the most vulnerable life stage because of the disproportionally high ingestion rates compared to body weights. Model simulations were comprised of 1000 replicate eaglets and the mean exposure over the developmental period was the average daily intake (ADI). The 1000 replicate estimates of ADI were averaged and compared to the Toxicity Reference Value (TRV) for raptors of 0.021 mg/kg/d (Newsted et al. 2005).

The probabilistic exposure model for the Northern pine snake followed a similar construct to the bald eagle model. A probability of capturing PFOS-contaminated prey items, feeding frequency and PFOS concentration was incorporated into the exposure model. Model results were also comprised of 1000 simulation runs of individual snakes foraging for 90 days; the resulting mean PFOS exposure was the ADI. The overall mean ADI for snakes with varied exposure potential to PFOS was compared to the working PFOS TRV for reptiles of 2 mg/kg/d (Salice et al. *In prep*).

6.0 LITERATURE CITED

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