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Center for Environmental and Health Effects of PFAS

Per- and polyfluoroalkyl Substances (PFAS)

- Approximately **5,000** known compounds
- Properties have been harnessed to make consumer and industrial products more water, stain, and grease resistant
- Found in products as diverse as cosmetics, cookware and firefighting foams
- Resistant to degradation, move easily through the environment, and some accumulate in living organisms
- Exposure and human health poorly understood

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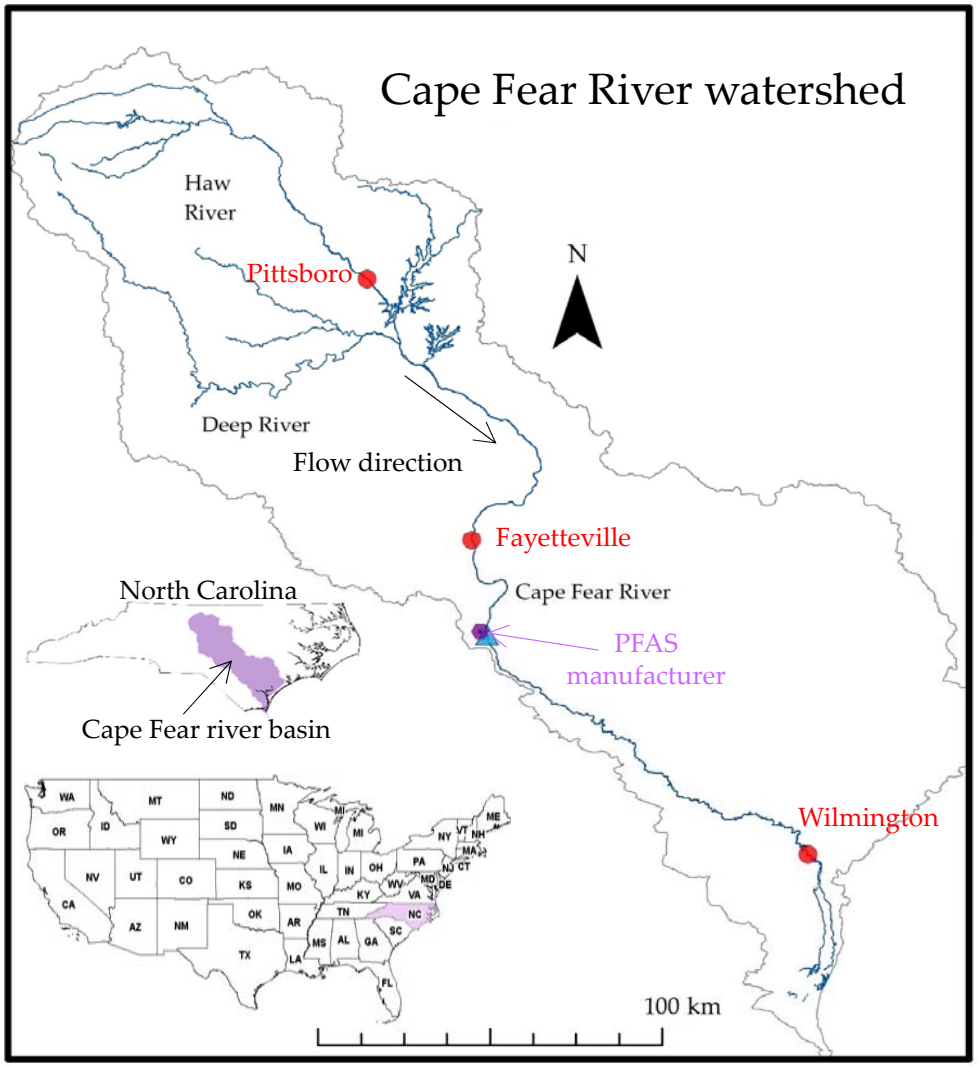

- Largest watershed in NC
- Supplies ~1.5M people with drinking water
- About 1M people affected by wastewater discharges containing high levels of industrial contaminants

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A brief history of PFAS in NC

Fluorochemical production begins at DuPont's Fayetteville Works

1980 2002 2007 2009 2012 2014 2015 2016 2018 2020

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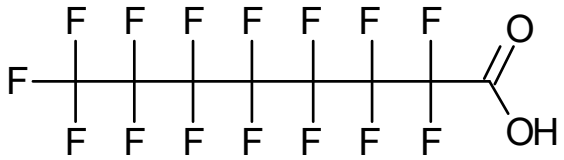
A brief history of PFAS in NC

Fluorochemical production begins at DuPont's Fayetteville Works

1980 | 2002 | 2007 | 2009 | 2012 | 2014 | 2015 | 2016 | 2018 | 2020

PFOA production begins at DuPont's Fayetteville Works



Perfluorooctanoic acid (PFOA = C8)

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A brief history of PFAS in NC

Fluorochemical production begins at DuPont's Fayetteville Works

1st publication of PFAS in the Cape Fear River basin – Nakayama et al. *ES&T*

Perfluorinated Compounds in the Cape Fear Drainage Basin in North Carolina

SHOJI NAKAYAMA, MARK J. STRYNAR, LAURENCE HELFANT, PETER EGEGHY, XIBIAO YE, AND ANDREW B. LINDSTROM*

1980 | 2002 | 2007 | 2009 | 2012 | 2014 | 2015 | 2016 | 2018 | 2020

PFOA production begins at DuPont's Fayetteville Works

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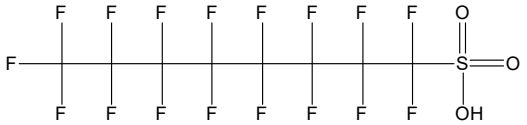
A brief history of PFAS in NC



Perfluorooctane sulfonate (PFOS)

Fluorochemical production begins at DuPont's Fayetteville Works

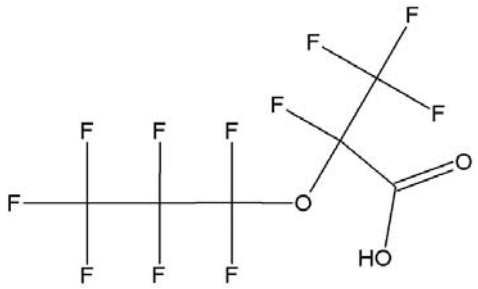
1st publication of PFAS in the Cape Fear River basin – Nakayama et al. *ES&T*

1980 2002 2007 2009 2012 2014 2015 2016 2018 2020

PFOA production begins at DuPont's Fayetteville Works

EPA Consent Order outlines conditions for GenX production. DuPont begins producing GenX as a replacement for PFOA.

EPA issues provisional health advisory levels for PFOA (400 ng/L) and PFOS (200 ng/L).



Hexafluoropropylene oxide dimer acid (HFPO-DA, "GenX")

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A brief history of PFAS in NC

Identification of Novel Perfluoroalkyl Ether Carboxylic Acids (PFECAs) and Sulfonic Acids (PFESAs) in Natural Waters Using Accurate Mass Time-of-Flight Mass Spectrometry (TOFMS)

Mark Strynar,[*,†] Sonia Dagnino,[†,‡] Rebecca McMahen,[†,‡] Shuang Liang,[†,‡] Andrew Lindstrom,[†] Erik Andersen,[†] Larry McMillan,[§] Michael Thurman,[∥] Imma Ferrer,[∥] and Carol Ball[⊥]

1980 – Fluorochemical production begins at DuPont's Fayetteville Works

2002 – PFOA production begins at DuPont's Fayetteville Works

2007 – 1st publication of PFAS in the Cape Fear River basin – Nakayama et al. *ES&T*

2009 – EPA Consent Order outlines conditions for GenX production. DuPont begins producing GenX as a replacement for PFOA.

EPA issues provisional health advisory levels for PFOA (400 ng/L) and PFOS (200 ng/L).

2012 – 1st detection of GenX and other fluoroethers in Cape Fear River water

2014 – First detection of GenX and other fluoroethers in Wilmington drinking water

2015 – Fluoroether structures published in ES&T (Strynar et al. 2015)

2016

2018

2020

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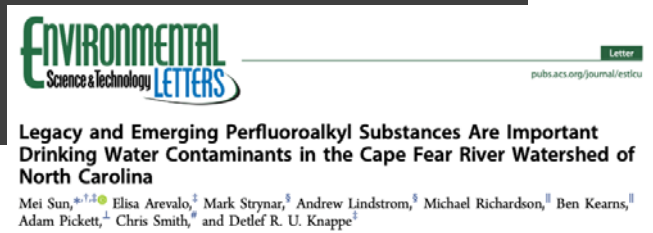
A brief history of PFAS in NC



1980 – Fluorochemical production begins at DuPont's Fayetteville Works

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2015 – Fluoroether structures published in ES&T (Strynar et al. 2015)

2016 – ES&T Letters reports high levels of PFAS, including fluoroethers, in drinking water (Sun et al. 2016)

EPA issues health advisory level of 70 ng/L for PFOA and PFOS

2018

2020

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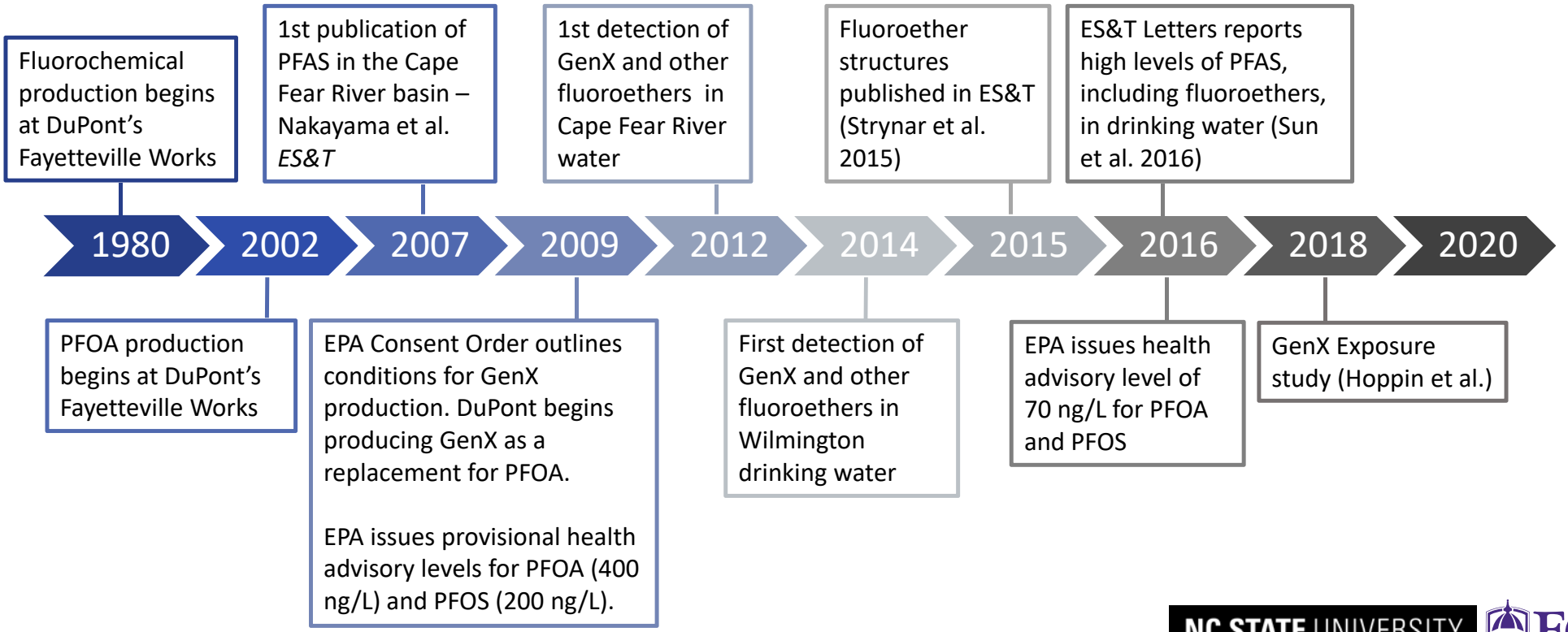
A brief history of PFAS in NC



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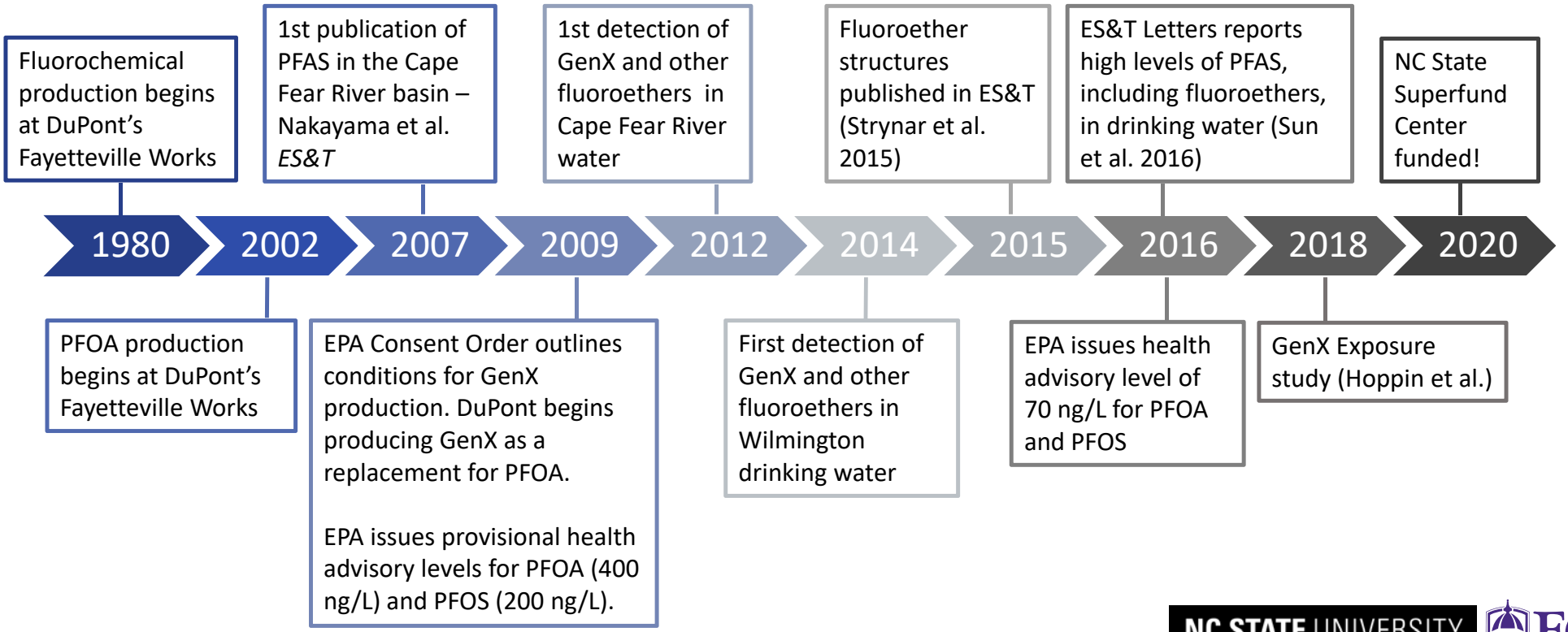
A brief history of PFAS in NC



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Overall

The NC State Superfund Center is focusing on several key areas to advance understanding about PFAS -

- **Exposure** in NC communities and environment
- Toxicity and underlying mechanisms of **thyroid** and **immune** function
- **Bioaccumulation** potential
- **Remediation**

NC STATE UNIVERSITY ECU

Administrative Core

Carolyn J Mattingly, Director
Detlef Knappe, Deputy Director
Jamie DeWitt, Research Translation Coordinator (ECU)

(BMR) Project 1

PFAS Exposure and Thyroid Related Health Outcomes in Communities along the Cape Fear River, NC
Jane Hoppin, David Collier (ECU)

(BMR) Project 2

Uncovering the mechanisms of PFAS-induced immunotoxicity: An important public health endpoint
Jamie DeWitt, Jeff Yoder, Seth Kullman

(ESE) Project 3

Integrating experimental and field studies to understand PFAS bioaccumulation and impact in aquatic food webs.
David Buchwalter, Tony Planchart, Scott Belcher

(ESE) Project 4

Uncovering Mechanisms of PFAS Adsorption by Granular Activated Carbon to Support PFAS Remediation
Detlef Knappe, Morton Barlaz

Community Engagement Core (CEC)

Katy May, Nicole Wilkerson

RETCC

Ranji Ranjithan, Antonio Planchart

Research Support Core CAPTURE

Erin Baker, David Muddiman, Jeff Enders

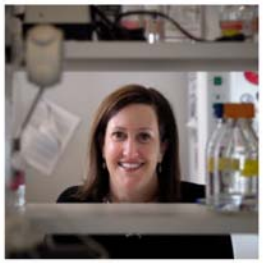
Data Management and Analysis Core (DMAC)

David Reif

NC STATE UNIVERSITY ECU

Administrative Core

- **Aim 1.** Ensure effective administrative and fiscal management
- **Aim 2.** Foster integration across research projects, cores, and community engagement
- **Aim 3.** Facilitate translation of Center discoveries to broad-based stakeholders



Mattingly
BioSci (NC State)
Director

Knappe
Eng. (NC State)
Dep. Director

DeWitt
Pharm/Tox (ECU)
RTC

Administrative Core

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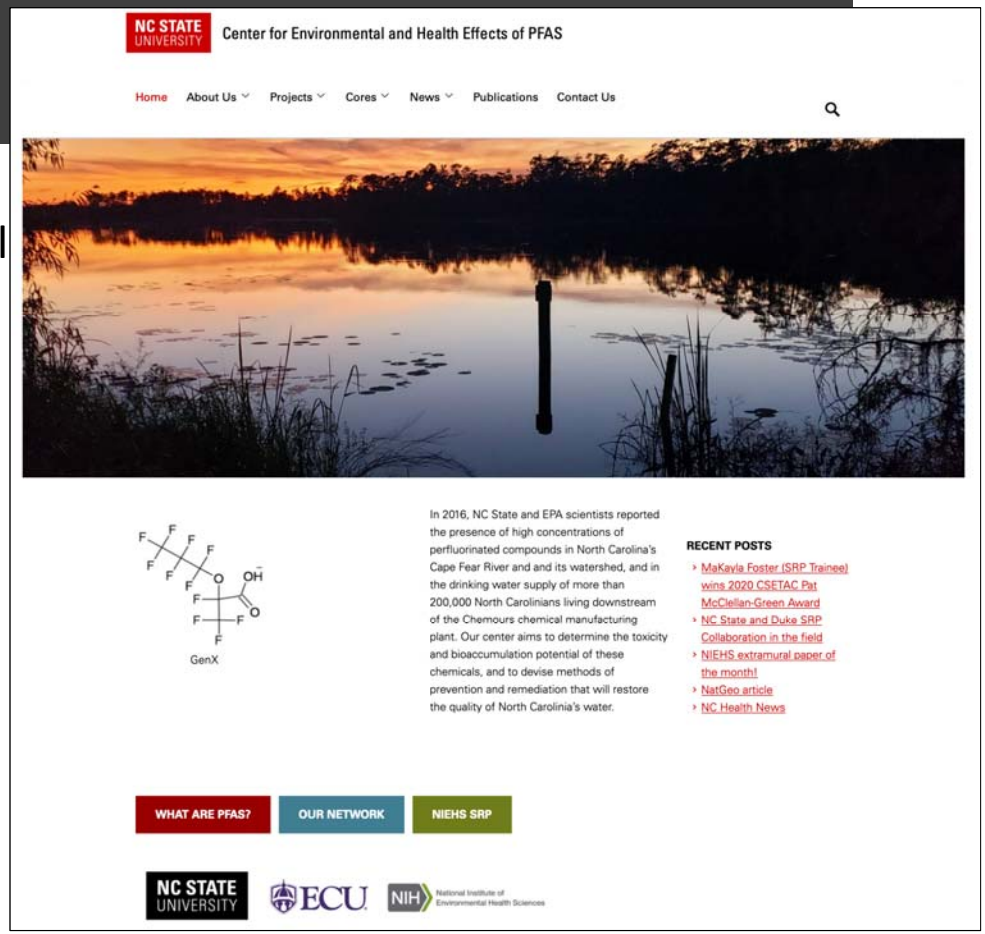


(superfund.ncsu.edu)

Supplement 1

Assess COVID-19 response in an established cohort with documented exposure to PFAS

1. Survey to characterize disease, symptoms, and lingering conditions as well as antibodies to the virus
2. Test to see if levels of PFAS influence disease and antibody positivity.

Supplement 2

Better characterize the diversity of PFAS exposures among impacted communities along the Cape Fear River

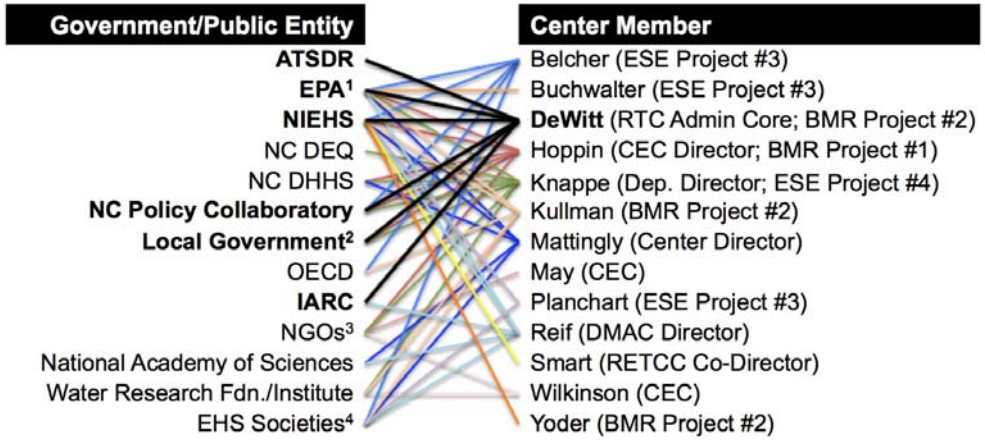
1. Further characterize human exposure in communities **upriver from Fayetteville**
2. Expand analytical capabilities to measure total organic fluorine in biological/environmental samples
3. Demonstrate feasibility for novel blood collection methods that can be employed in the field for PFAS analysis

Research Translation

Facilitate broader impact of our findings to other SRP Centers and national stakeholders with the goal of protecting human health and addressing mandates of the broader Superfund program

3rd Annual National Conference on Per- and Polyfluoroalkyl Substances - Social and Scientific Discovery (June 21-23, 2021)

(URI STEEP, Northeastern U, EPA + many more)



DeWitt
Pharm/Tox (ECU)

Biomedical Project 1

PFAS Exposure and Thyroid Related Health Outcomes in Communities along the Cape Fear River, NC

- **Aim 1.** Partner with local community groups to address community concerns and share results with affected communities in a timely and appropriate manner.
- **Aim 2.** Characterize PFAS exposure among people living along the Cape Fear River.
- **Aim 3.** Assess thyroid outcomes via clinical measurement and questionnaire

Hoppin
BioSci (NC State)

Collier
Brody (ECU)

NC STATE UNIVERSITY ECU

Biomedical Project 1

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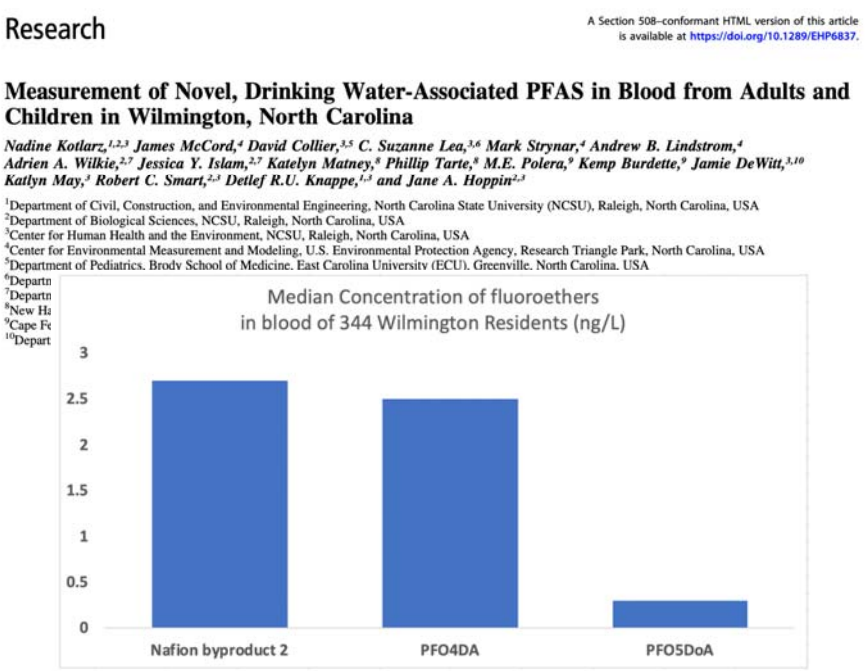
- **Aim 3.** Assess thyroid outcomes via clinical measurement and questionnaire

Status

- Field collection November – January
- Partnering with NAACP, Cape Fear River Watch, UNCW Latino Alliance, New Hanover and Cumberland County Health Departments, Haw River Assembly, Sustainable Sandhills
- Recruiting in English and Spanish
- Initial response is good, many plan to participate again



Research

A Section 508–conformant HTML version of this article is available at https://doi.org/10.1289/EHP6837.

Measurement of Novel, Drinking Water-Associated PFAS in Blood from Adults and Children in Wilmington, North Carolina

Nadine Kotlarz,[1,2,3] James McCord,[4] David Collier,[3,5] C. Suzanne Lea,[3,6] Mark Strynar,[4] Andrew B. Lindstrom,[4] Adrien A. Wilkie,[2,7] Jessica Y. Islam,[2,7] Katelyn Matney,[8] Phillip Tarte,[8] M.E. Polera,[9] Kemp Burdette,[9] Jamie DeWitt,[3,10] Katlyn May,[3] Robert C. Smart,[2,3] Detlef R.U. Knappe,[1,3] and Jane A. Hoppin[2,3]

[1]Department of Civil, Construction, and Environmental Engineering, North Carolina State University (NCSU), Raleigh, North Carolina, USA
[2]Department of Biological Sciences, NCSU, Raleigh, North Carolina, USA
[3]Center for Human Health and the Environment, NCSU, Raleigh, North Carolina, USA
[4]Center for Environmental Measurement and Modeling, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, USA
[5]Department of Pediatrics, Brody School of Medicine, East Carolina University (ECU), Greenville, North Carolina, USA
[6]Departn
[7]Departn
[8]New Ha
[9]Cape Fe
[10]Depart

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Biomedical Project 2

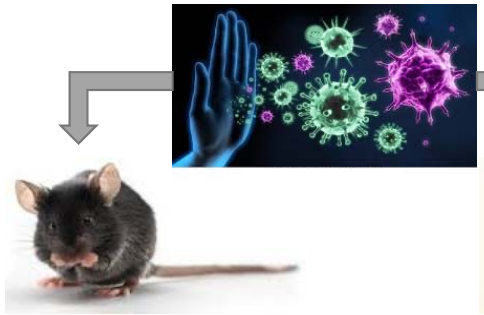
Uncovering the mechanisms of PFAS-induced immunotoxicity

- **Aim 1.** Quantify the impact(s) of PFAS exposure on B cell development and antibody production.
- **Aim 2.** Quantify the impact(s) of PFAS exposure on phagocytotic cell function.

DeWitt
Pharm/Tox (ECU)

Yoder
CVM (NC State)

Kullman
BioSci (NC State)



Aim 1
(Adaptive)

Aim 2
(Innate)

Status

- Standard operating procedures developed/being developed and shared across all laboratories
- Ongoing joint monthly lab meetings to share research progress and products
- IACUC approvals in place for work involving rodent models at ECU

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Environmental Science Engineering Project 3

Integrating experimental and field studies to understand PFAS bioaccumulation and impact in aquatic food webs

- **Aim 1.** Characterize bioaccumulation of individual and environmentally relevant mixtures of PFAS in three (experimental) trophic levels.
- **Aim 2.** Assess biomarkers of aqueous and dietary exposures to individual PFAS and their mixtures in zebrafish.
- **Aim 3.** Determine the presence, persistence, bioaccumulation, and health impacts of PFAS aquatic wildlife species at different trophic levels.

Buchwalter
BioSci (NC State)

Planchart
BioSci (NC State)

Belcher
BioSci (NC State)

NC STATE UNIVERSITY ECU

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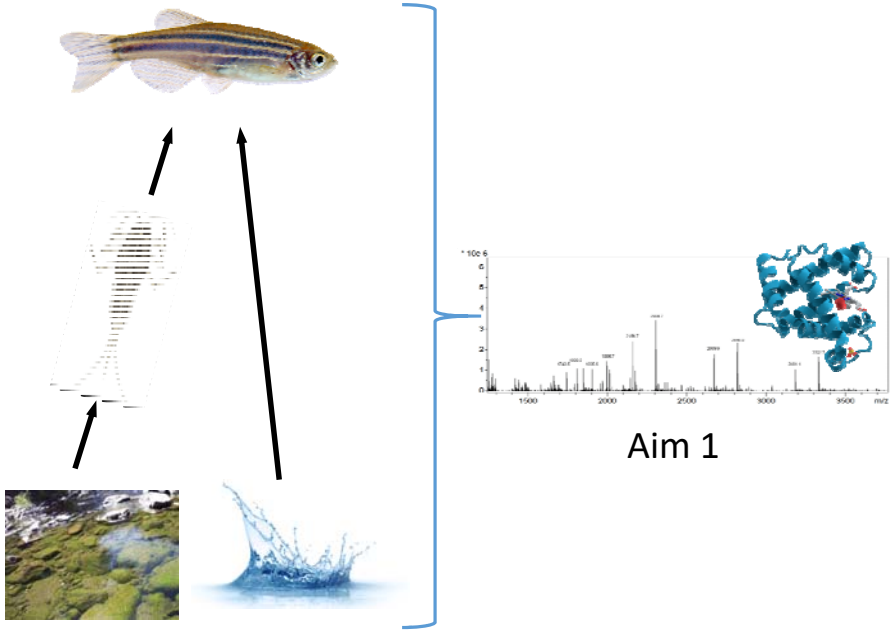

Aim 1

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Environmental Science Engineering Project 3

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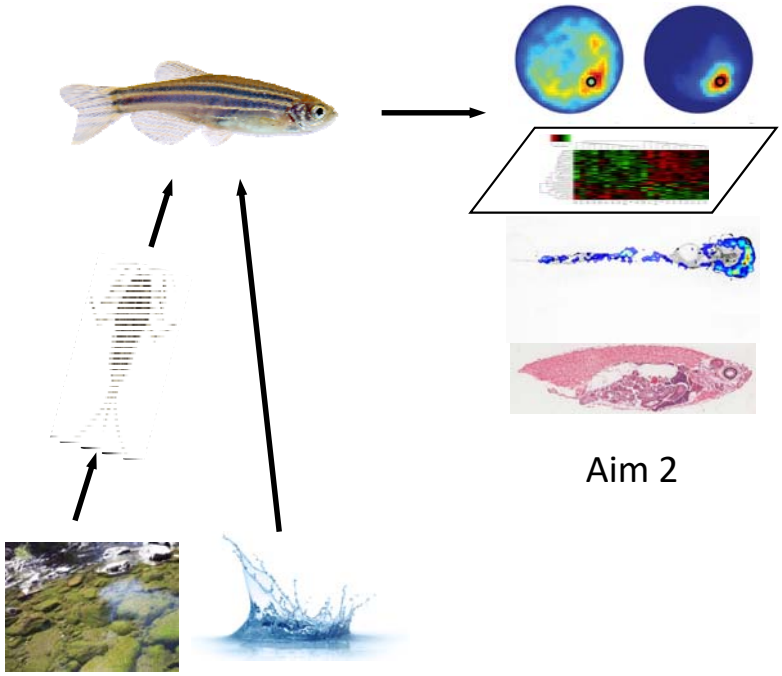

Aim 2

NC STATE UNIVERSITY ECU

Environmental Science Engineering Project 3

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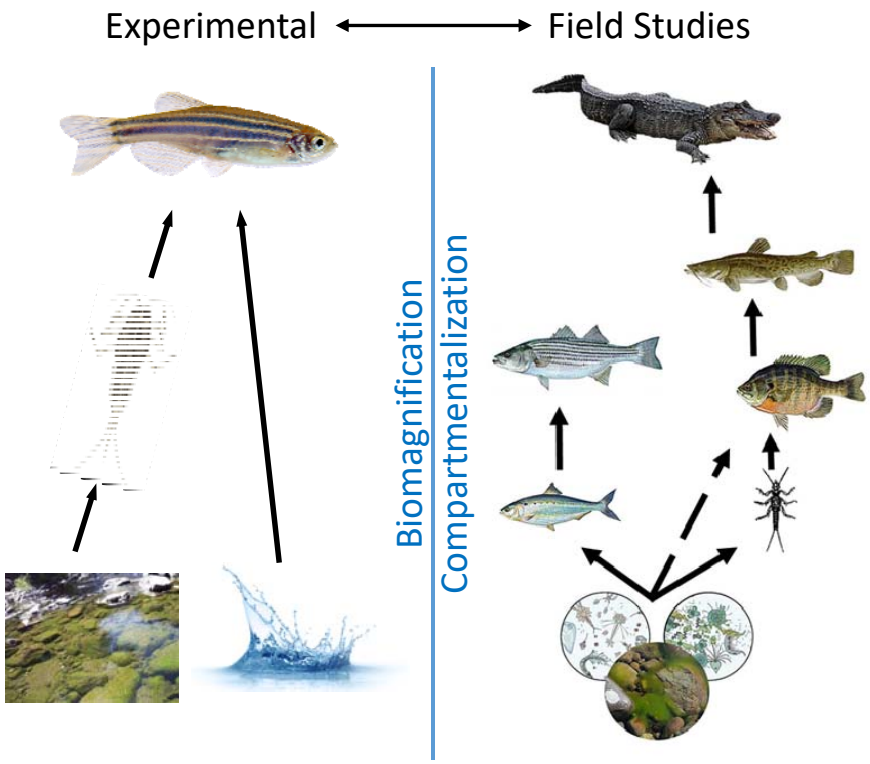

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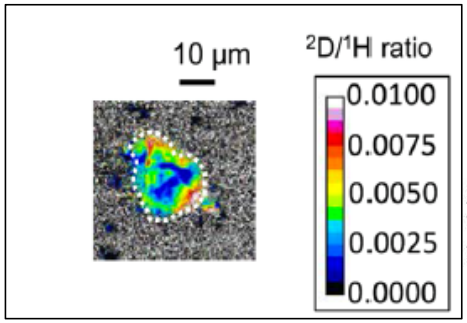
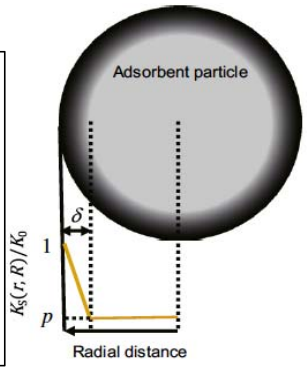
Environmental Science Engineering Project 4

Uncovering Mechanisms of PFAS Adsorption by Granular Activated Carbon to Support PFAS Remediation

- **Aim 1.** Observe and describe intraparticle adsorbate distributions at sorption equilibrium.
- **Aim 2.** Describe PFAS sorption kinetics. Is the apparent size-dependence of the intraparticle diffusion coefficient a result of
  - Shell adsorption
  - Intraparticle heterogeneity?

PFAS-impacted surface/ground water →





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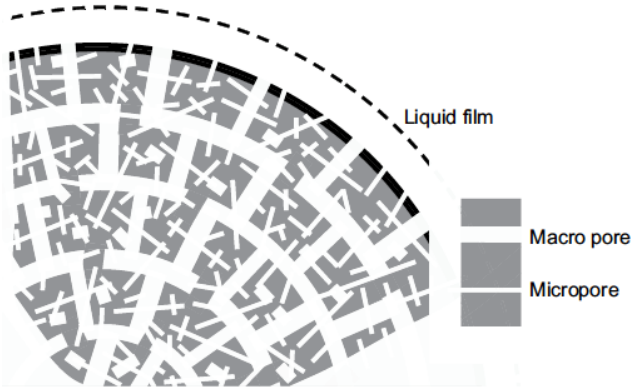

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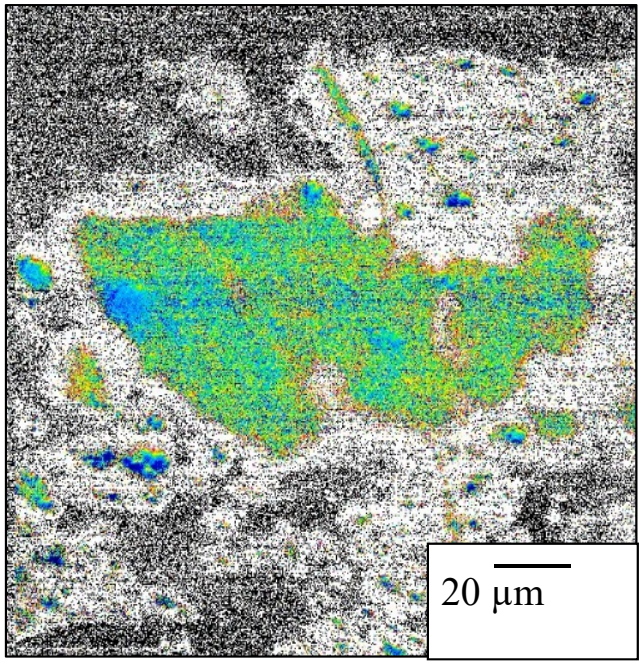
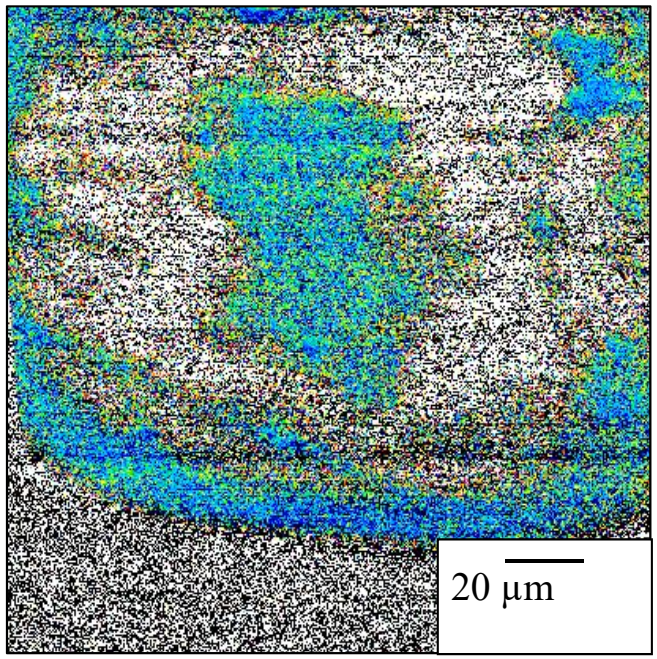
Environmental Science Engineering Project 4

Proof of Concept: visualize intraparticle distribution of PFHxS-18O2 using isotope microscopy

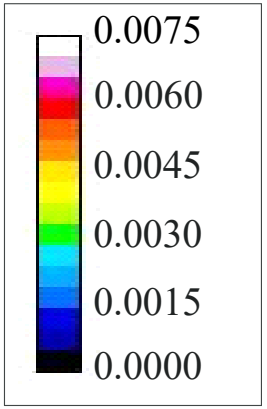
GAC loaded with PFHxS-^{18}O



Control GAC



$^{18}O/^{16}O$ ratio



Natural $^{18}O/^{16}O$ ratio: 0.002

Collaboration with Prof.
Yoshihiko Matsui at Hokkaido University

NC STATE UNIVERSITY ECU

Community Engagement Core (CEC)

- **Aim 1.** Leverage existing partnerships in the Cape Fear River basin (**Haw River Assembly, Sustainable Sandhills, and Cape Fear River Watch**) to support community engagement and education focusing on PFAS.
- **Aim 2.** Provide support for community-based efforts that build environmental health literacy to address and prevent PFAS exposure (Fellow program, mini grants, etc.)
- **Aim 3.** Foster opportunities for Center researchers and trainees to engage with impacted communities
- **Aim 4.** Develop programming and provide resources and enhance environmental health literacy throughout the Cape Fear Watershed.

May
ORI (NCSU)

NC STATE UNIVERSITY ECU

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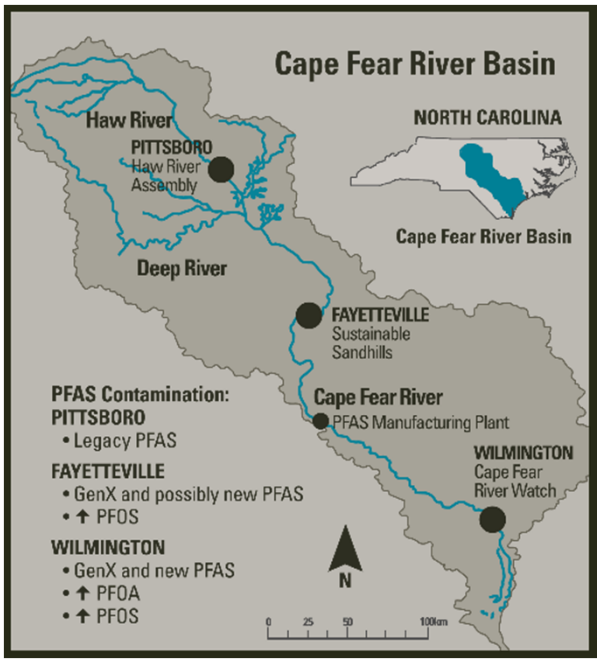
Status

- Implement resource sharing with partners
- Initiate Stakeholder Advisory Board
- Coordinate and create programming with Training Core



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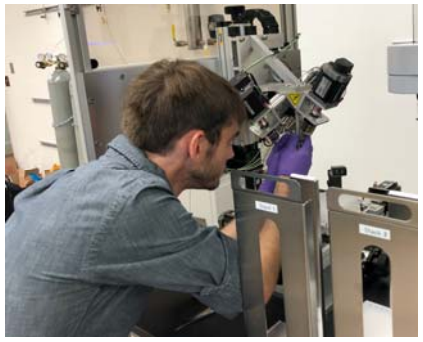
Research Experience and Training Coordination Core (RETTC)

- **Aim 1** - Cultivate cross-training and fluency across disciplines, technologies and communities
  - Diverse research experiences (e.g., rotations)
  - Nanocourses
  - Cross-disciplinary seminars and journal club
  - Engagement with communities affected by PFAS
    (in partnership with CEC).
- **Aim 2** - Provide professional development opportunities (e.g., communication, proposal writing, mentoring) using an Individual Development Plan to track and evaluate cross-disciplinary training



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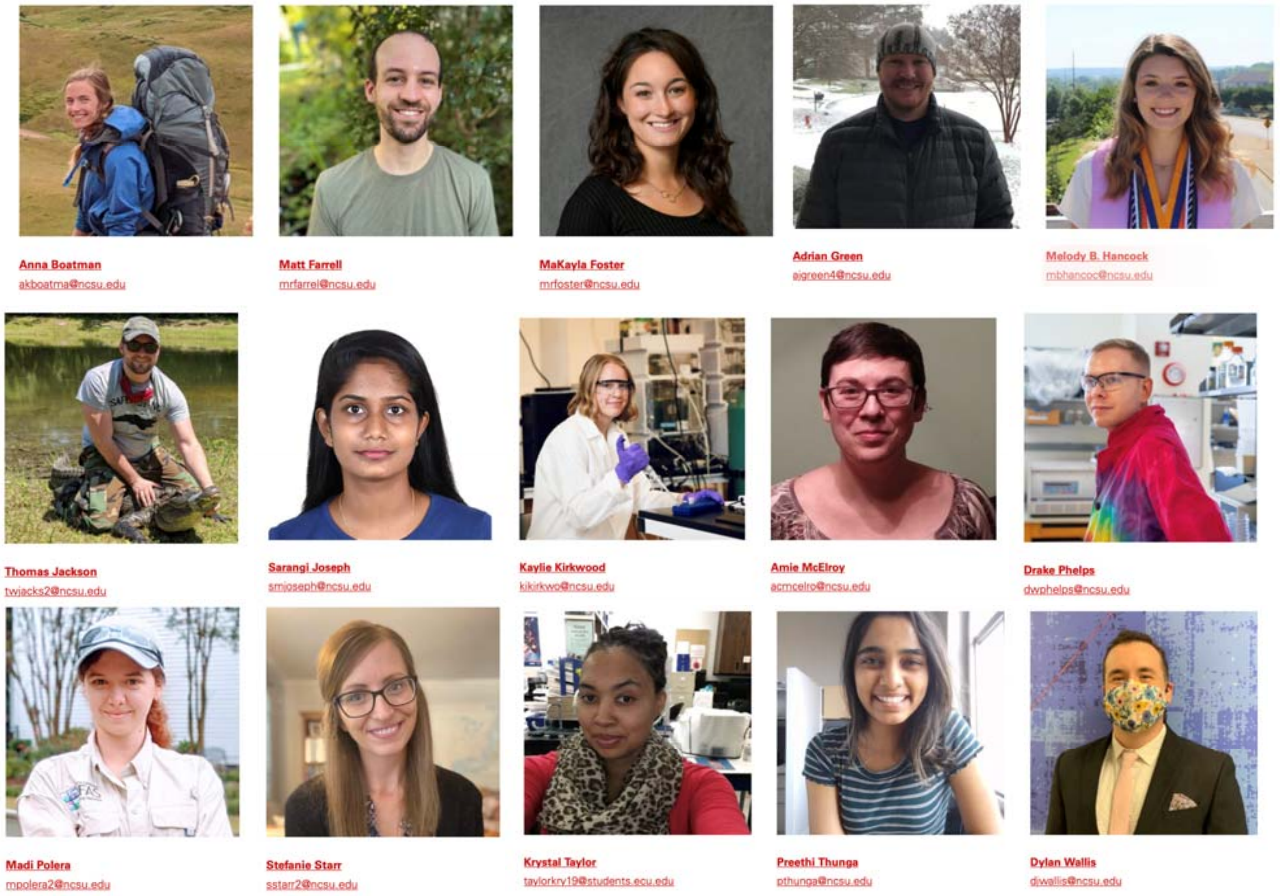
RETTC Trainees



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Adrian Green
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Amie McElroy
acmcelro@ncsu.edu

Drake Phelps
dwphelps@ncsu.edu

Madi Polera
mpolera2@ncsu.edu

Stefanie Starr
sstarr2@ncsu.edu

Krystal Taylor
taylorkry19@students.ecu.edu

Preethi Thunga
pthunga@ncsu.edu

Dylan Wallis
dlwallis@ncsu.edu

- Graduate students and postdocs
- Funded through SRP, other NIH funds and significant institutional support

NC STATE UNIVERSITY ECU

Research Support Core: CAPTURE

Core of Advanced Platform Technologies Used for Remediation and Exploration

Goal: *To develop, apply, and translate a comprehensive set of tools to address human health consequences in response to PFAS exposure.*

- **Aim 1.** Utilize state-of-the-art mass spectrometry (MS) instrumentation to advance identification and quantification of PFAS in human populations, environmental samples, and model systems.
- **Aim 2.** Employ combinatorial, untargeted -omics technologies to increase the understanding of PFAS mechanisms of action.
- **Aim 3.** Implement advanced electron microscopy and spectroscopy techniques to directly observe adsorbate penetration into activated carbon.

Baker
Chem. (NCSU)

Muddiman
Chem. (NCSU)

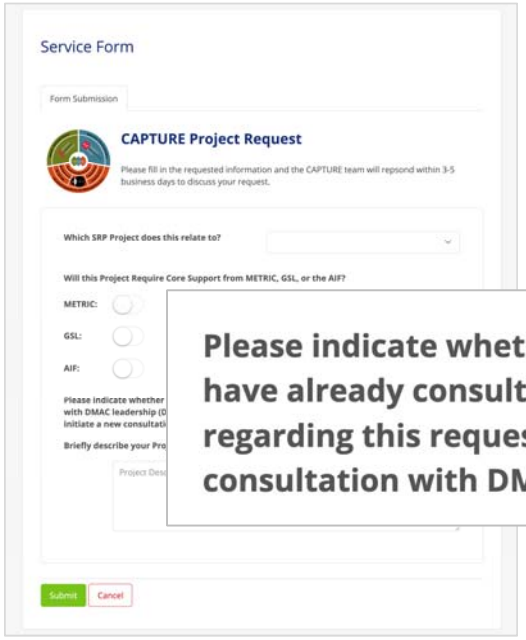
Enders
BioSci (NCSU)

NC STATE UNIVERSITY ECU

Research Support Core: CAPTURE

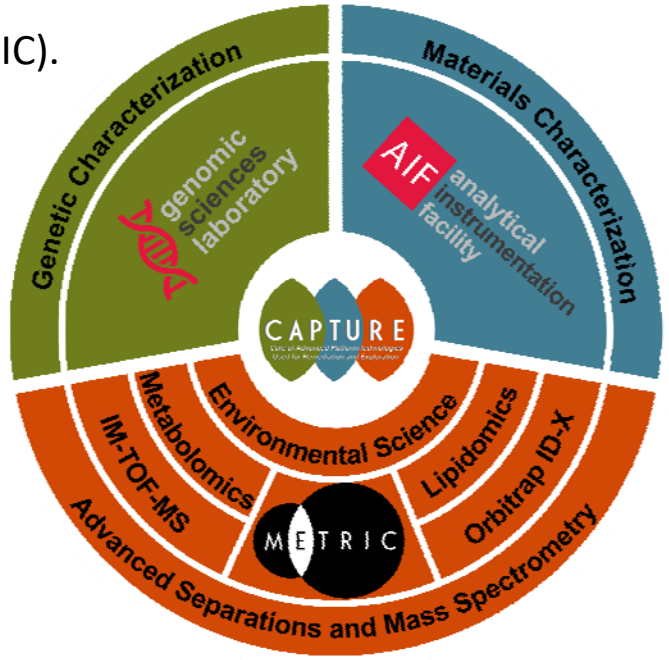
Core of Advanced Platform Technologies Used for Remediation and Exploration

The three Core Facilities that comprise CAPTURE are the Genomic Sciences Laboratory (GSL), the Analytical Instrumentation Facility (AIF), and the Molecular Education, Technology, and Research Innovation Center (METRIC).



Please indicate whether this is a new request (Yes = "I have already consulted with DMAC leadership (David Reif) regarding this request"; No = "I would like to initiate a new consultation with DMAC".

The project request form (screencap at left) helps connect CAPTURE with DMAC to embed informatics and experimental design before data generation.



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Data Management and Analysis Core (DMAC)

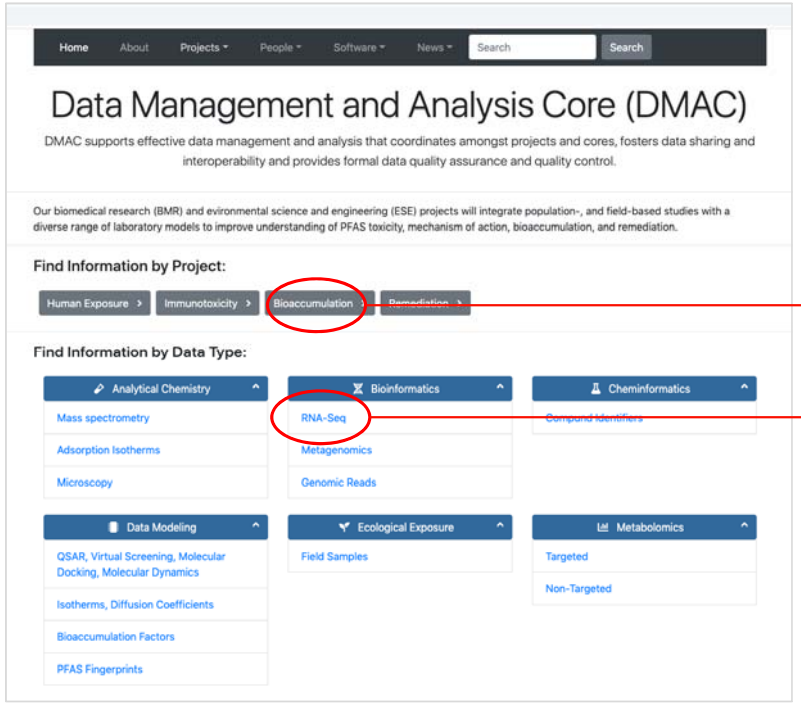
- **Specific Aim 1.** Embed principles of Data Science into every aspect of the Center through coordinated development of project/core Data Management Plans
- **Specific Aim 2.** Implement a software pipeline that standardizes the transfer of data between projects and CAPTURE.
- **Specific Aim 3.** Visualize results in a manner that fosters communication across projects and cores and facilitates research translation.
- **Specific Aim 4.** Advance training of the next generation of Data Scientists.

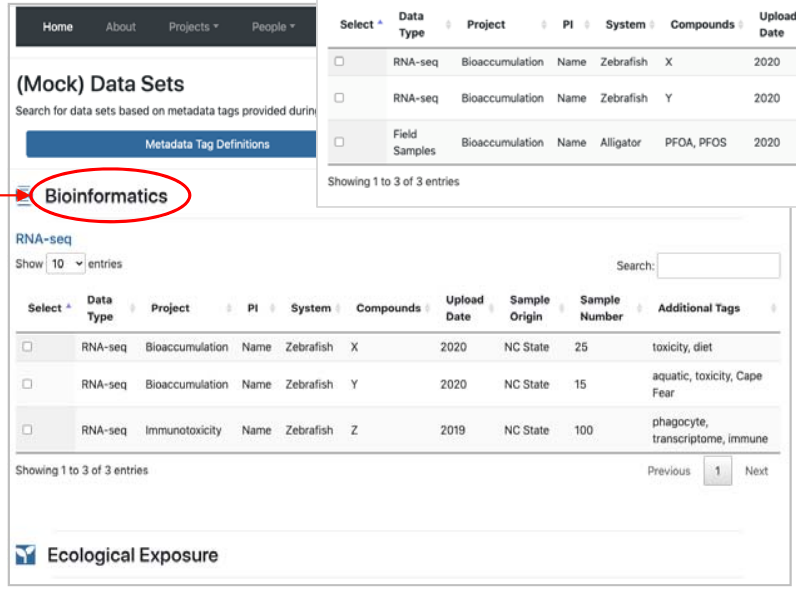
Reif
BioSci (NCSU)

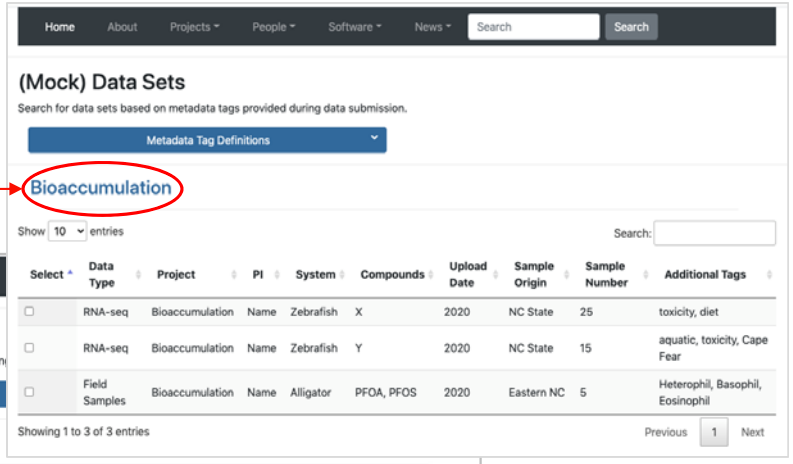
NC STATE UNIVERSITY ECU

DMAC
Coordination that fosters data sharing and interoperability

Data are tagged by our DMP taxonomy upon upload into a web browser application. Modular data structures will let users create integrative analyses from recombinations of Center-wide data.

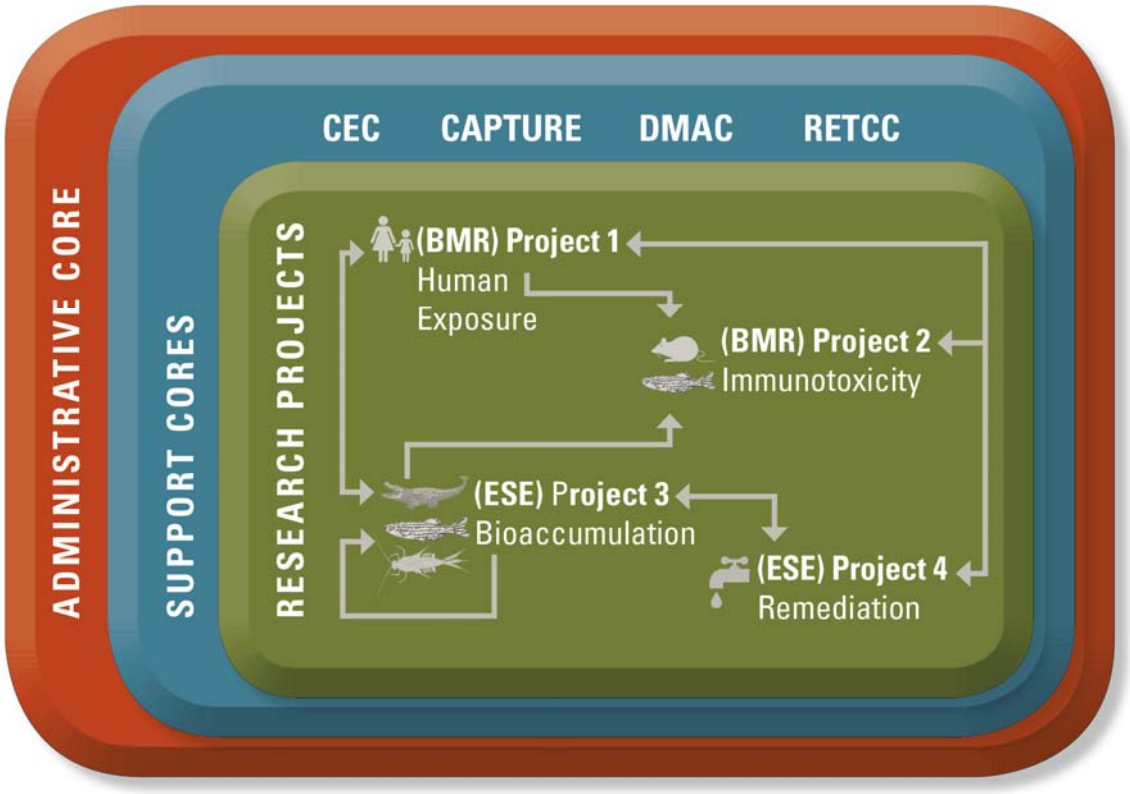






Betsy Scholl,
Allison Dickey,
Skylar Marvel

Project/Core Integration



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Thank you!


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NIH
National Institute of
Environmental Health Sciences