STEEP

Sources, Transport, Exposure & Effects of PFAS

UNIVERSITY OF RHODE ISLAND SUPERFUND RESEARCH PROGRAM

2022–2024 Progress

STEEP at a glance

STEEP Director
Rainer Lohmann, PhD
Graduate School of Oceanography
University of Rhode Island

STEEP Co-Director
Philippe Grandjean, MD DMSc
University of Rhode Island, College of Pharmacy

Director Lohmann and Co-Director Grandjean combine complementary expertise in environmental and epidemiological sciences. They brought together a team of individuals that function as an effective and integrated interdisciplinary team, including researchers from the University of Rhode Island Graduate School of Oceanography, Coastal Institute, and Colleges of Pharmacy, Engineering, and the Environment and Life Sciences; Harvard School of Engineering and Applied Sciences, and the Silent Spring Institute.

Per- and polyfluorinated alkyl substances (PFAS) are extremely resistant to environmental degradation and are found in humans and the environment around the world.

The most notable PFAS include perfluorooctanoic acid (PFOA) and perfluorooctanoic sulfonate (PFOS). In the US, there are industrial PFAS production and manufacturing sites, and over 600 fire/crash training sites nationwide where PFAS-containing aqueous film-forming foams have most likely contaminated groundwater and sediments. Additional human exposure results from widespread use of PFAS in consumer products, e.g., stain-resistant furnishings and carpets, grease-proof food packaging and wrappers. Production and use of PFOS and PFOA have declined in the U.S. since the early 2000s following a voluntary phase-out by 3M, and subsequent stewardship plans by U.S. EPA and international agreements. Industrial production in the U.S. shifted away from PFOA and PFOS as the public was provided evidence of their adverse human health impacts. As production decreased in the U.S., new fluorinated compounds have been and continue to be developed to meet society's demand. As a result, environmental contamination and human exposure continues.

Despite widespread PFAS use since the 1950s, there are still knowledge deficits about the environmental and public health impacts, thus this contaminant is considered emerging. STEEP (Sources, Transport, Exposure & Effects of PFAS) is committed to researching compelling environmental and human health concerns to inform development of appropriate benchmark dose levels for PFAS. Moreover, STEEP disseminates research results to a variety of stakeholders and train the next generation of scientists essential to the management of these ubiquitous compounds. Within the past few years, a burgeoning awareness of PFAS has exposed its transport through consumer goods and into the food web. From Vermont dairy farms to global applications of thousands of permutations of PFAS, presence of these "forever chemicals" in humans and ecosystems continues to be of concern and under scrutiny.

RESEARCH PROJECTS OVERVIEW: STEEP Research Projects aim to better understand the pathways of PFAS contamination from entry into the environment through groundwater contamination, dispersal through the food web, and distribution to vulnerable human populations during early development, in part through breast milk. In addition, STEEP supports the development and deployment of in situ passive sampling techniques for PFAS and their precursors in water. STEEP addresses limitations in the current understanding of human exposure to PFAS by combining targeted human exposure assessment with chemometric approaches to characterize existing PFAS sources.

CORE OBJECTIVES OVERVIEW: To ensure a legacy of scientific awareness, dissemination of broadly accessible research findings, and practical application by affected communities, STEEP cores serve to prepare the next generation of interdisciplinary emerging contaminant researchers, translate scientific findings generated by STEEP projects for internal and external stakeholders, and engage Cape Cod communities on the front lines of PFAS exposure through contaminated drinking water.

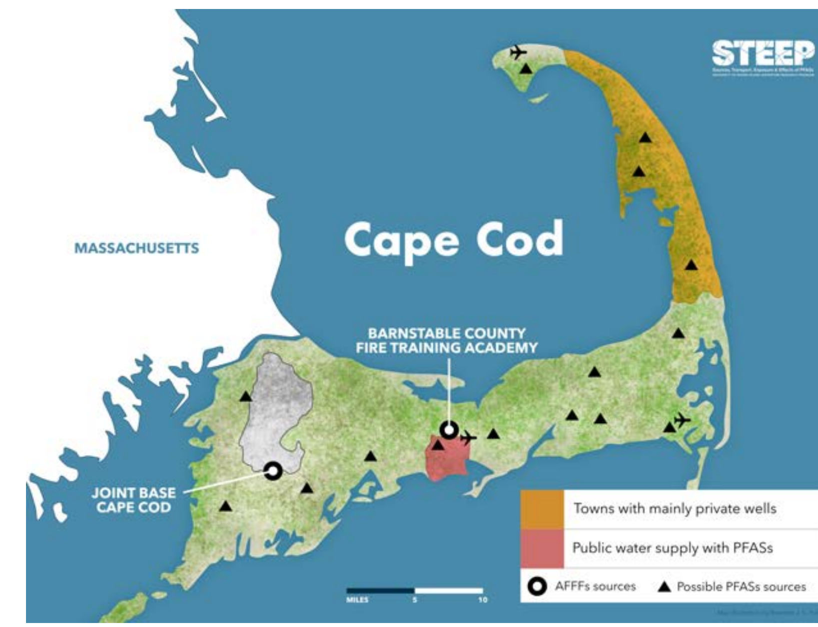
STEEP is focused on two study sites, one on Cape Cod and the other in the Faroe Islands. Barnstable County, MA, is STEEP's primary site for community engagement activities. STEEP partner Silent Spring Institute has conducted community-engaged research and activities focused on water quality and public heath on Cape Cod for more than 20 years.

Faroe Islands is STEEP's epidemiological research site, where for decades Co-Director Grandjean, in partnership with Pál Weihe, MD (Adjunct Professor, University of the Faroe Islands; Head, Department of Occupational Medicine and Public Health), has studied the impact of persistent chemicals on pre-natal and post-natal health which enriches STEEP's understanding of the adverse health impacts of PFASs.

The vast majority of people worldwide are exposed to some level of PFASs due to its presence in a wide range of manufactured products and consumer goods; however, some communities akin to STEEP study sites experience increased exposure from secondary sources. In Cape Cod, the additional exposure to PFASs is linked to contaminated groundwater that finds its way to residents' tap water. Communities in the Faroe Islands may experience additional exposure linked to a cultural tradition of consuming pilot whale meat and blubber.

Barnstable County, MA, is a Cape Cod area beloved for its sweeping coastline, quaint villages, and welcoming community ambiance. Groundwater on Cape Cod has been contaminated by PFAS from multiple sources. To date, these sources have been identified as fire training areas, airports, military bases, landfills, municipal wastewater, and septic systems. The spread of PFAS is exacerbated by Barnstable's location in an outwash plain with permeable soil. The result is that groundwater aquifers are highly susceptible to movement of contaminants from the surface of the ground—the place where surface water both contributes to aquifers and enters the food web. Once PFAS get into groundwater, they eventually can contaminate both public and private drinking water sources. Given multiple inputs of PFAS and the unique geology of the area, there is an ongoing threat to Cape Cod's sole-source aquifer that provides drinking water for 200,000 year-round and 500,000 summer residents.

The Faroe Islands consist of 18 remote, rocky, volcanic islands, which are connected by a network of roads, ferries, subsea tunnels, and bridges. These remote islands are a self-governing archipelago of the Kingdom of Denmark. With a population of slightly more than 50,000, this prosperous fishing community is situated in the heart of the Gulf Stream in the North Atlantic, northwest of Scotland and halfway between Iceland and Norway. Faroese culture emphasizes tradition and the arts. In a generation, with the help of the fishing trade that accounts for approximately 20% GDP, Faroese affluence has promoted widespread use of technology and well-established infrastructure. Beginning in 1985, study cohorts of ~2300 Faroese children focused on the effects of mercury in their diet and later expanded to include PFAS. Consequently, the overall health threats from toxic chemicals to the current and future generations of Faroese are compelling and timely.



Project 1: Environmental Exposure

Assessing the Contribution of Precursors to Diverse PFAS Exposures near Contaminated Sites

OVERVIEW:

Understanding the magnitudes and composition of PFAS exposures from diverse sources and their accumulation in food webs.

Lead: **Elsie Sunderland,** Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS)

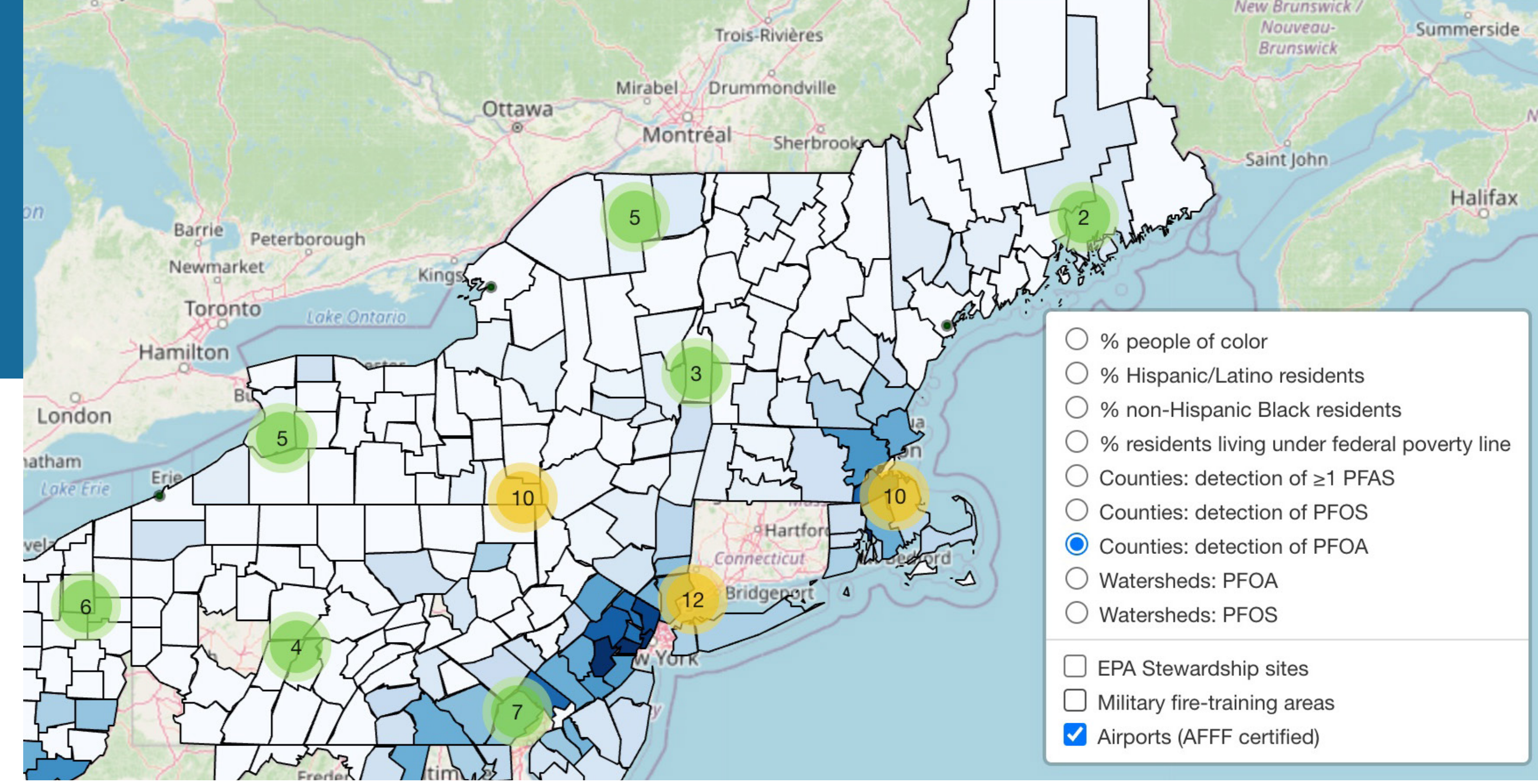
Specific Aims

- Quantify PFAS contributions from an AFFF-contaminated site to fish in downgradient ecosystems using measurements and statistical modeling in paired water and fish samples.
- Develop a mechanistic model for PFAS bioaccumulation in fish based on understanding of PFAS binding to proteins and phospholipids and trophic interactions that can assist in informing fish advisories.
- Use a chemical transport model to characterize the contributions of atmospheric PFAS emissions, including polyfluoroalkyl precursors, to PFAS inputs to ecosystems.
- Develop a screening tool for identifying private wells with PFAS contamination by adapting a hybrid mechanistic-empirical model previously developed for New Hampshire.

Progress

Project 1 (P1) aims to develop methods and resources to detect hazardous PFAS and assess the risks they pose to human health by examining exposures to PFAS from seafood, drinking water and the significance of atmospheric deposition. In 2022-2023, P1 published a new study on paired surface water and freshwater fish species showing many precursors below detection in water have a higher bioaccumulation potential than their terminal perfluoroalkyl acids PFAA (Pickard et al., 2022). Perfluorobutane sulfonamide (FBSA), a short chain precursor produced by electrochemical fluorination was detected in all fish samples analyzed for this compound. At AFFF contaminated sites, P1 showed that biotransformation of abundant C6 perflurosulfonic acid (PFSA) precursors in AFFF is linked to nitrification, showing a link between nutrient cycling and precursor transformation at contaminated sites (Ruyle et al., 2023).

P1 further showed in Liddie et al. (2023) that detection of PFAS in community water systems based on sampling data from 18 states is linked to the abundance of manufacturing sites, military based contaminated by AFFF, airports and waste sector sources. These higher resolution state data with lower detection limits than the UCMR 2013-2015 data confirm earlier analyses and show significant associations with a broader ranges of sources. This means that improved models for lower PFAS concentrations in U.S. drinking water supplies will need to consider a wider range of potential sources that have been suggested in past work but not yet included in important efforts such as the Toxics Substances Control Act (TSCA) record keeping or the Toxics Release Inventory (TRI). Liddie et al. (2023) further showed there are sociodemographic dispartities in drinking water PFAS exposures, particularly among people of color, that likely reflect historical patterns in the siting of pollution sources (see map detail).



In 2023-2024, P1 published recommendations on best analytical protocols for ensuring the reliability and reproducibility of extractable organoflurine (EOF) measurements in water and biological tissues (Ruyle et al., 2023). EOF measurements can provide a useful proxy for total PFAS in many matrices, and developing standardized methods across labs is essential for ensuring the intercomparbility of these measurements. Colleagues at the US EPA responsible for spearheading such standard methods participated in this effort and assisted P1 with drafting the recommendations included in the paper.

P1 has been investigating the abundance of different precursor classes in fish and shellfish and identified that one class of precursors, perfluoroalkyl sulfonamides (FASA), are more bioaccumulative than terminal perfluoroalkyl acids in recreational fish species, emphasizing their importance for fish advisories (Pickard et al., 2024). Most fish advisories presently focus only on perfluorooctane sulfonate (PFOS), but P1 research shows a similar fraction in tissue impacted by legacy contamination from firefighting foams consists of FASA. Perfluoroalkyl acids (PFAA) show a linear increase in field-measured bioaccumulation factors (BAF) with perfluorinated chain-length that likely reflects increased partitioning to proteins and phospholipids with increasing molecular weight.

Similarly, Fischer et al. (2024) showed the unbound fraction of PFAS in blood can be predicted using lab-measured partition coefficients for human serum albumin and globulins, the dominant proteins in blood. The unbound fraction is important for predicting distribution and partitioning to other organs, affects the lifetime of PFAS in the human body, and may provide a useful correction for expsosure metrics used in epidemiological studies. Binding of PFAA showed the same linear relationships as BAF with perfluorinated chain length. However, in both studies FASA did not show chain-length dependent patterns and resolving the dominant factors affecting their accumulation is a task for future research.

PROJECT 1 TRAINEES

Faiz Haque, Research Fellow, Harvard SEAS
Jahred Liddie, Ph.D. Student, Harvard T.H. Chan School of Public Health
Jennifer Sun, Ph.D. Student, Harvard SEAS

PROJECT 1 GRADUATES

Fabian Fischer, Postdoctoral Researcher, Harvard SEAS
Heidi Pickard, Ph.D. Student, Harvard SEAS

Project 2: Childhood Risk

Functional abnormalities and disease risk in children developmentally exposed to PFAS

We have documented some of the negative consequences, and we send the message back to you: ***please learn the lesson.***

Pál Weihe, *The Poison in Us All.* STEEP leads Weihe, Philippe Grandjean, and Laurel Schaider were interviewed by Bloomberg Investigates for the documentary, a powerful look at the impact of PFAS.

OVERVIEW:

Document the impacts of PFAS during early development on vulnerable body functions that may lead to functional abnormalities or subsequent disease development.

Lead: **Philippe Grandjean**, University of Rhode Island, College of Pharmacy

Clinical Lead: **Pál Weihe, MD**, Adjunct Professor at The University of the Faroe Islands and and Department of Research, the National Hospital of the Faroe Islands

Clinical Lead: **Maria Skaalum Petersen**, professor and head of dept, Department of Research, the National Hospital of the Faroe Islands

Key Personnel: **Flemming Nielsen**, Senior Scientist, University of Southern Denmark

Specific Aims

- To examine the detailed time-dependence of developmental PFAS exposures and their associations with markers of immune system and metabolic functions at age 5 years.
- To determine the time-dependence of developmental PFAS exposure profiles and their associations with markers of immune, endocrine, and metabolic functions at age 15 years, and possible sex dimorphisms and relation to puberty stage.
- To assess the interrelationships between outcomes, especially the possible role of inflammation and endocrine status on exposure-related outcomes, including critical effects in regard to PFAS exposure.

Progress

In 2022-2023, Project 2 (P2) has focused on detailed analysis of the results already obtained from the STEEP-funded examinations of Cohort 5 at age 9 years.

In addition, the IRB application for the new study at age 15 was prepared, and approval obtained from the Faroese IRB and, later on, from the URI committee, and continuation approval from the URI IRB is now anticipated. Further, procedures to be used in the Cohort 5 examinations and blood analyses were fine-tuned and improved, so that examinations could be initiated right away, when the final URI IRB approval was obtained.

In 2023-2024, the examinations were initiated soon after the (delayed) IRB approval. In particular, arrangements were made with the Faroese National Hospital to conduct the DXA scans and agreements were secured in regard to storage of blood samples..

Recruitment and clinical examinations were initiated according to the protocol, including collection of biological material for chemical exposure analyses and clinical chemistry. The latter have not been initiated but are awaiting sampling completion and supplemental funding. At SDU, the PFAS laboratory was moved to new building with upgraded facilities, but quality procedures have resulted in a delay in PFAS analyses. All STEEP-related biological samples are now being moved to new freezer facilities in the Faroes.

The age-15 examinations are proceeding as planned, with more than half of the cohort having completed all clinical procedures (N>200). No incident has occurred, the clinical staff is unchanged, and we have received only positive feed-back. A few families have moved away from the Faroes, but otherwise it seems like the participation rate will be close to what was achieved at age 9, i.e., close to 80%. We expect the examinations to be completed by the end of 2024.

Project 3: Metabolic Effects

PFAS compound effects on metabolic abnormalities in rodents

…they'll basically be completely absorbed into the body…within a couple of days, 100% absorbed…which is not the case for every chemical or drug.

Angela Slitt, as quoted in *Tracing the path of toxic 'forever chemicals' inside the body* with WBUR, Boston's NPR News Station.

OVERVIEW:

Identify molecular and cellular mechanisms that contribute to PFAS tissue uptake, distribution, and elimination in the body.

Lead: **Angela Slitt**, URI College of Pharmacy

Senior Personnel: **Fabian Fischer**, URI College of Pharmacy

Specific Aims

- Organic anion transporting polypeptide 2B1 (OATP2B1) is a critical mechanism for PFAS absorption, distribution, and excretion.
- Serum albumin and fatty acid binding protein (FABP) are critical mechanisms for PFAS absorption, distribution, and excretion.
- Gene ABCG2 is a critical mechanism for PFAS absorption, distribution, and excretion.

Progress

In 2022-2022, Project 3 (P3) made solid progress for all aims. For Aim 1, we completed assessing cellular permeability at pH 6.8 (gut pH) for 16 PFAS to assess apparent permeability at intestinal and blood pH. We completed our cell-based assays with stably human OATP2B1 transfectants to assess transport for 16 PFAS. We were also able to also screen 16 PFAS for hOATP1B1 and OATP1B3 transport and as inhibitors for OATP1B1, 1B3, and 2B1 transporter activity. Lastly, for this aim, we were also evaluate whether known inhibitors of OATP2B1 present in apple juice could decrease OATP2B1-mediated PFAS uptake. 6:2 FTS PFBS, which have low permeability, were considered substrates for OATP1B1, 1B3, and 2B1 with high confidence.

For Aim 2, we completed serum and tissue binding studies for 16 PFAS for human, rat, and mouse. We performed two pharmacokinetic studies and a repeat dosing study with LFABP-null mice. Overall, the studies show that LFABP may be important for the inItial distribution of PFOS to tissue after administration, but then doesn't impact elimination or liver toxicity endpoints. We have completed one pilot study with albumin-null mice and are currently amplifying the mouse colony. The study strongly shows that albumin is important for serum PFOS retention and liver tissue distribution. Lastly, we have screened 16 PFAS for being potential substrates for human ABCG2. We have identified numerous PFAS to be substrates for human ABCG2 with high confidence. We are currently working to attain pathogen free ABCG2-null mice from St. Jude's Research Hospital.

In 2023-2024, we have completed most of Aim 1. Sixteen PFAS have been screened for permeability at pH 6.8 and 7.4 using a MDCK-LE cell line. In general, permeability was closely associated with molecular weight, with permeability increasing as molecular weight increases. We have completed screens for 16 PFAS for human organic anion transporting polypeptide (OATP) and organic anion transporters (OAT) activity and interactions. We identified 6:2 FTS and PFBS as substrates for OATP1B1, 1B3, and 2B1 with high confidence; and X PFAS as OAT3 and 4 substrates. Moreover, administration of an apple juice concentrate, which can inhibit OATP2B1, delayed/decreased PFOS absorption in mice.

For Aim 2, studies so far indicate that LFABP is not critical for PFOS tissue distribution, but is a critical factor for adverse liver outcomes, such as steatosis. Our studies with albumin-null mice indicate that albumin is important for serum PFOS retention and liver tissue distribution, as well as liver outcomes.

For Aim 3, ABCG2-null mice have now been rederived to be pathogen free and the colony is being amplified. We have approval to administer ABCG2 inhibitors as an alternate to using ABCG2-null mice.

PROJECT 3 TRAINEES

Juliana Agudelo, PhD Student, URI Pharmacy
Nick Ferguson, PhD Student, URI Pharmacy
Andrew Kim, PhD Student, URI Pharmacy
Olga Skende, MS Student, URI Pharmacy

PROJECT 3 GRADUATES

Alicia Crisalli, PhD, URI Pharmacy
Emily Kaye, PhD, URI Pharmacy
Sadegh Modaresi, PhD, URI Pharmacy
Sangwoo Ryu, PhD, URI Pharmacy and Pfizer Global Research

Project 4: Detection Tools

Environmental Engineering: Develop passive samplers for the detection and bioaccumulation of PFAS

OVERVIEW

Passive sampling can be used in remediation, detection, and uptake prediction of PFAS and their precursors.

Lead: **Rainer Lohmann**, Graduate School of Oceanography, University of Rhode Island (GSO)

Key Personnel: **Laurel Schaider**, Silent Spring Institute (SSI)

Senior Personnel: **Jitka Becanova**, URI Graduate School of Oceanography

Specific Aims

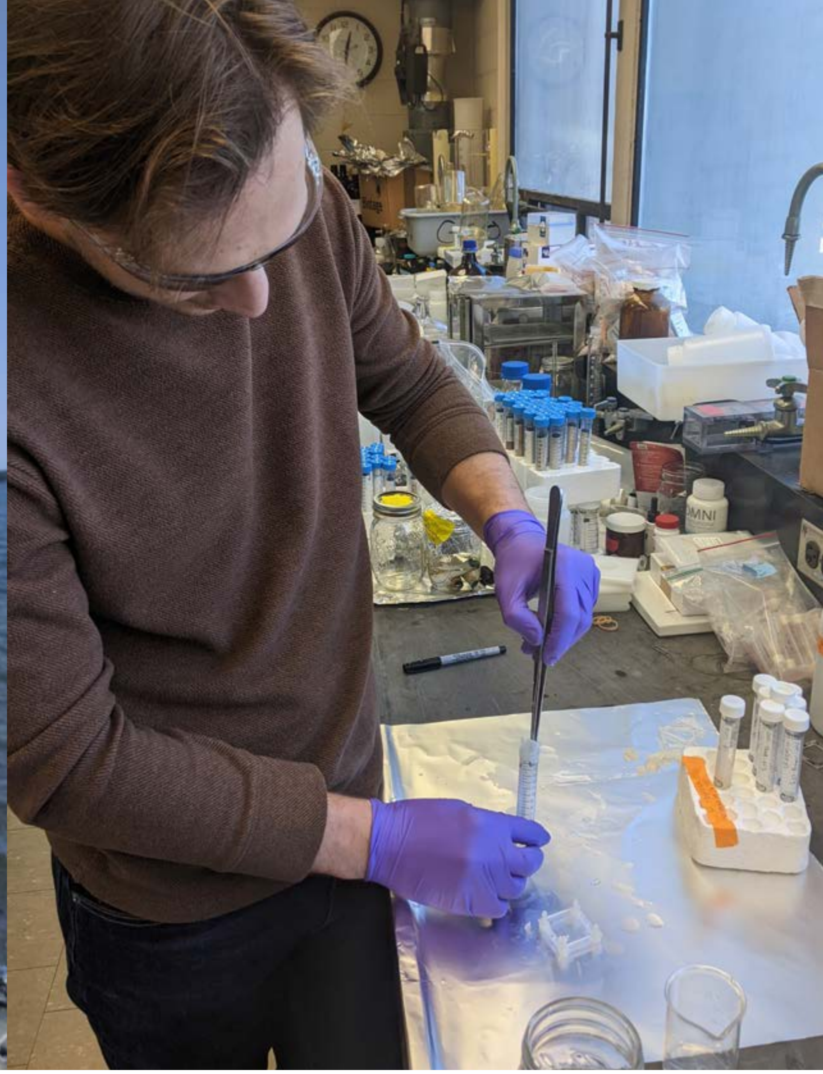
- Develop effective polymer-based remediation filters, and field-test passive samplers to monitor in situ remediation of PFAS-contaminated groundwater on Cape Cod.
- Passive samplers as proxies for PFAS bioaccumulation in laboratory and field studies.
- Validate and use passive air samplers as indoor air samplers for exposure assessment and outdoor atmospheric transport of target, non-target, and total organofluorine.

Progress

In 2022-2023, a passive sampling devise (a porous polyethylene tube filled with a sorbent) was tested as a tool to sample PFAS in the water (Dunn et al., 2023). Two approaches to understand the uptake ot PFAS by the sampler were compared, relying on either partitioning and diffusion, or solely diffusion. PFAS uptake was not different for previously biofouled membranes in the laboratory, suggesting the general applicability of the sampler in environmental conditions.

The potential for PFAS to be taken up by fish and mussels (bioconcentration) and passive samplers was tested in mobile laboratory experiments using groundwater from the AFFF-plume near Joint Base Cape Cod and a nearby reference location (Barber et al., 2023). Overall, passive samplers took up more PFAS than fish or mussels, but passive samplers were useful for assessing PFAS that potentially bioconcentrate in fish but are present at concentrations below minimum quantitation limits in water. Passive samplers also accumulated short-chain PFAS that were not bioconcentrated (Barber et al., 2023).

The sampling of PFAS present in indoor air was performed in 40 homes throughout the Faroe Islands with dust samples collected from the same homes. Several target PFAS, both ionic and volatile, were detected in both indoor matrices. Most notably, volatile PFAS were present in all 40 homes, while both ionic and volatile PFAS were detected in dust. Concentrations found in air and dust were used to calculate estimated daily intake to different PFAS from both direct and indirect exposure.



In 2023-2024, a passive sampling device (a porous polyethylene tube filled with a sorbent) was utilized to assess sources of PFAS in the Pawcatuck, a river in Rhode Island with a history of textile manufacturing, as PFAS were regularly used on textiles. Our results confirmed that both closed and active textile mills were important ongoing sources of legacy and modern PFAS to freshwater and marine regions (Dunn et al., 2024a).

In a related project, the long-range marine transport of PFAS was observed during year-long deployments of passive tube samplers in the Fram Strait across three depth transects (Dunn et al., 2024b). PFAS profiles and concentrations were generally similar to those previously characterized for polycyclic aromatic hydrocarbons (PAHs) at these sites. The detection of several anionic PFAS in "old" water demonstrated that they are not perfect water mass tracers but are also transported to depth via settling particles. These observations suggest that PFAS in the Arctic are governed by a feedback loop with atmospheric transport delivering volatile PFAS to the Arctic, which then get exported as acids via Arctic water masses.

Lastly, in collaboration with P1, we also further assessed the utility of passive samplers to accumulate target and non-target PFAS and extractable organofluorine (EOF) during 1-2 week deployments in groundwater, a river, and an estuary contaminated by aqueous film forming foam (AFFF). Results provide evidence that targeted PFAS, suspect PFAS, and EOF downstream of AFFF contamination are taken up by the tube passive sampler in a predictable manner, greatly expanding passive sampling capabilities.

PROJECT 4 TRAINEES

Taylor Elpers, PhD Student, GSO URI
Asta Zerue Habtemichael, PhD Student, GSO URI
Nicholas Izak Hill, PhD student, GSO URI
Rachel Nelson, PhD Student, GSO URI
Justin Sankey, PhD Student, GSO URI
Jarod Snook, PhD Student, GSO URI
Melissa Woodward, PhD Student, GSO URI

PROJECT 4 GRADUATES

Matthew Dunn, PhD Student, GSO URI
Erasme Uyizeye, Postdoctoral Researcher, GSO URI
Tatyana Yanishevsky, MS Student, GSO URI

Community Engagement Core

> *…at the end of the day, it shouldn't be on all of us as individuals to have toxic chemicals on our mind when we're at the grocery store or buying clothes or furnishings for our homes and our families..*
>
> **Laurel Schaider**, as featured on NPR's Living on Earth.

Co-lead: **Laurel Schaider**,
Silent Spring Institute (SSI)

Co-lead: **Emily Diamond**,
Communication Studies/Marine Affairs,
University of Rhode Island

Specific Aims

- Address community concerns about PFAS exposures from environmental sources by offering a testing program for homegrown produce and locally caught fish and supporting STEEP's extended exposure assessment in Hyannis.
- Collaborate with the Mashpee Wampanoag Tribe (MWT) to collect fish, shellfish, and well water for PFAS analysis, develop identity-based messaging strategies to communicate PFAS risks with tribal members, and evaluate the effectiveness of various messages and delivery channels to reduce PFAS exposures.
- Connect STEEP trainees with high schools on Cape Cod to enhance understanding of PFAS and other water quality issues through supplemental curriculum and Cape-wide high school water quality summits.
- Collaborate with community organizations on Cape Cod and more broadly to educate and empower communities affected by PFAS contamination.

Progress

TThe sand and gravel aquifer of Cape Cod, Massachusetts is the sole source of drinking water and is vulnerable to contamination from septic systems, runoff, landfills, and other pollution sources. PFAS have been found in public and private drinking water wells, in some cases above health guidelines, and in surface water, fish, and shellfish. STEEP's Community Engagement Core (CEC) is addressing community concerns about PFAS contamination and exposure on Cape Cod.

In 2022-2023, we conducted interviews with members of the Mashpee Wampanoag Tribe to understand the importance of local fish and shellfish to their cultural traditions. In 2023, we also launched a community-wide survey to measure baseline knowledge and risk perceptions of PFAS contamination, which was completed by 155 Tribal members. This foundational work will allow us to co-create Tribal messaging strategies in future years and work with the Tribe to minimize PFAS exposure risk while maintaining cultural integrity. Initial findings were presented at the 2022 and 2023 SRP meetings and have been summarized in an in-progress publication. We also completed analysis and developed informational materials to report on fish and shellfish testing in and around popular Tribal fishing areas, in partnership with Project 1.

In Fall 2023, we reported back results of private well water testing to 65 well owners on Cape Cod. Water samples had been analyzed for 30 PFAS chemicals, nitrate, and some metals, including lead and copper. We prepared customized, context-rich reports for participants using Silent Spring Institute's Digital Exposure Report-Back Interface (DERBI) and will share findings at an event for the Cape Cod community. In 2024, we partnered with Project 1 to add a new component that involved re-testing wells with the highest levels of PFAS and evaluating PFAS removal using home water treatment systems.

We have also been working with high school educators and STEEP's Training Core to develop PFAS-centered lessons for high school classes and identify opportunities to connect trainees with high school classes on Cape Cod. We hosted several outreach events with the Tribe, various high schools, and the broader Cape Cod community, including a half-day educational event at the Mashpee Wampanoag Preserving Our Homelands summer camp for youth, classroom presentations, a high school visit and lab tours at URI, and a film screening/panel discussion event with the Mashpee Wampanoag Tribe.

Facing page: Mashpee Wampanoag youth participating in a hands-on game to demonstrate PFAS bioaccumulation in ecosystems at the 2023 *Preserving Our Homelands* summer science camp. Left: STEEP trainee demonstrating chromatography to Tribal youth at the *Preserving Our Homelands* summer science camp. Right: CEC co-leads Schaider and Diamond with CEC team member Cheryl Osimo from the Massachusetts Breast Cancer Coalition.

Research Translation

There's a perception out there that science communication is just checking a box. If you come from the mindset that it is a chore, it's a real missed opportunity. The times when I'm at the lowest is when communicating science lifts me; that's my life preserver.

Chris Reddy, a University of Rhode Island Graduate School of Oceanography (URI GSO) alumni and Senior Scientist at the Woods Hole Oceanographic Institution (WHOI), sat down with STEEP to discuss communicating science in a in crisis, featured in two articles and a public lecture held at URI.

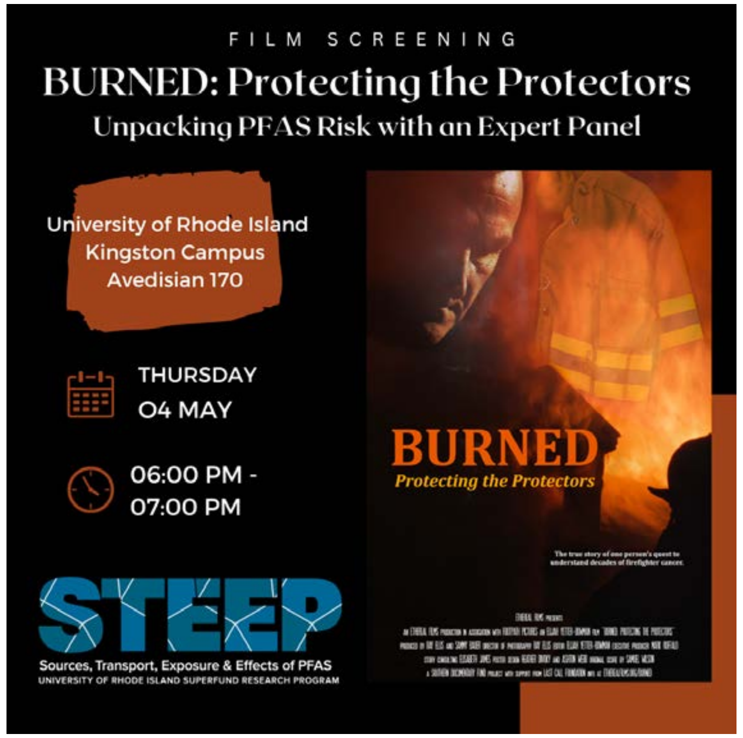
Co-lead: **Amber Neville**, Coastal Institute at URI

Co-lead: **Jaclyn Witterschein**, Coastal Institute at URI

Senior Personnel: **Madison Jones**, URI Harrington School of Communication and Media

Specific Aims

- Ensure that STEEP provides relevant and timely research translation, technology transfer, and tools for stakeholders and communities.
- Identify and work with new stakeholders and collaborators.



Progress

In 2022-2023, the STEEP research translation team (RT) launched *Silent Chemicals, Loud Science*, a podcast series designed for PFAS concerns of people of all backgrounds and educational levels. Intimate conversations with our experts, Rainer Lohmann, Laurel Schaider, and Philippe Grandjean, lead listeners through the world cycling of PFAS, and how these chemicals impact every part of our lives.

In October 2022, RT assisted in the organization of a press conference to announce the STEEP renewal, and RT created and provided project briefing sheets and researcher biographies to those in attendance, including state leaders and RI legislators. In addition to the press conference, RT has also coordinated press releases to announce major STEEP events and the publication of critical research.

RT established a formal partnership with the University of Rhode Island Harrington School of Communication and Media (HSCM), engaging Assistant Professor Madison Jones, member of the HSCM, to assist RT co-leads to create innovative multimedia products. Additionally, RT collaborated with URI Professors Emily Diamond (STEEP CEC) and Jason Jaacks to work with communication students in URI course COM410, Advanced Topics in Communication Studies.

In 2023-2024, RT launched an overhaul of the STEEP newsletter and website to promote a more robust scope of STEEP to a wider audience. The enhanced newsletter and website deliver longer feature articles, expansive research translation, and trainee-developed content and highlights. These efforts are complimented by a dynamic social media presence, engaging a multi-generational audience.

RT worked closely with both CEC and RETCC to promote events and activities, develop public engagement materials, and design summaries of research findings. RT also strengthened its partnership with the URI Harrington School of Communication and Media (HSCM) and collaboratively designed and delivered sci-comm workshops for STEEP trainees and piloted interactive media projects to educate stakeholders.

AC/RT also supported trainees as the future of science communication by providing mentorship; and likewise, trainees have become the character of STEEP in the world beyond the lab as they are increasingly integrated into STEEP engagement and research translation efforts.

Highlights

RT hosted a public film screening of *Burned: Protecting the Protectors*, the true story of how the spouse of a firefighter revealed significant exposure to PFAS affecting the fire community. We hosted an expert panel, including project leads Rainer Lohmann and Angela Slitt, as well as Jason Burns, Executive Director of The Last Call Foundation.

Beginning in 2023, RT recruited the social media prowess of trainee Melissa Woodward, whose witty approach to communication sparkles in her engagement and consistent creation of fresh content for STEEP social platforms.

RT assisted in the creation of research explainers, as well as material to engage at events, including a PFAS explainer, STEEP Research Brief, and Trainee Impact Map, co-created by trainee, Justin Sankey.

RT has provided tools and mentorship to trainees in research simplification, writing style, and graphic design to create research translation of their work, engaging op-eds, and original content around experiments, experiences.

RT engaged Matt Dunn, PhD, former trainee, beginning with the 2024 Newsletter, to create dynamic and varied PFAS content. Dunn catalyzed a public lecture with his interview article, *A Wonderful Jigsaw Puzzle: Science Communication According to Dr. Chris Reddy.*

Training Core: Next Generation

Lead: **Angela Slitt**, URI College of Pharmacy

Senior Personnel: **Jitka Becanova**, URI Graduate School of Oceanography

Specific Aims

- Support cross-disciplinary, experiential training in environmental health sciences by taking advantage of STEEP's diverse and collaborative academic environment.
- Provide professional career development by enhancing leadership, mentoring, oral, and written communication skills, and in Responsible Conduct of Research.
- Engage in bidirectional dialogue with the public and decision makers to advance environmental protection and mitigate human health risks associated with toxicant exposures.
- Create a diverse and inclusive training program that advances women and minorities in STEM and promotes a diverse and inclusive environment.

Progress

RETCC was busy at the start of the STEEP renewal in 2022-2023. Trainees had a day-long retreat in August 2022 to kick off the renewal, which covered leadership and professional development, data management, and team building activities. Throughout the year, trainees participated in monthly virtual meetings, where trainees had an opportunity to present research findings and host guest speakers to discuss PFAS-related research and career paths. Additionally, trainees hosted two joint laboratory meetings with North Carolina State University Superfund Center Trainees, which were used to present research findings.

Trainees presented posters and had oral presentations at Society of Environmental Toxicology and Chemistry, Society of Toxicology, and the Annual Superfund Research Program, as well as regional meetings.

STEEP trainees are also meeting program milestones, with six trainees passing doctoral comprehensive examinations, and one doctoral degree granted. There were 21 publications (first or co-author) from STEEP trainees during the funding period, 17 poster presentations, and four awards.

STEEP graduates continue to be employed in jobs related to PFAS and environmental health, with Emily Marques being recently employed by the EPA and Bridger Ruyle joining the Carnegie Institution for Science.

To start activities in 2023-2024, the trainees had a day-long retreat in August 2023, which covered communicating scientific findings to diverse audiences. This was led by the Community Engagement Core and Research Translation, and was followed by a trainee team-building event.

Throughout the year, trainees participated in monthly virtual meetings, where trainees had an opportunity to present research findings and host guest speakers to discuss PFAS-related research and career paths. Additionally, trainees hosted two joint laboratory meetings with North Carolina State University Superfund Center Trainees, which were used to present research findings.

Trainees presented posters and had oral presentations at Society of Environmental Toxicology and Chemistry, Society of Toxicology, and the Annual Superfund Research Program, as well as regional meetings.

STEEP trainees are also meeting program milestones, with six trainees awarded doctorates. There were eight publications (first or co-author) from STEEP trainees during the funding period, 23 poster presentations, and 20 awards/fellowships.

STEEP graduates continue to be employed in jobs related to PFAS and environmental health, with Matthew Dunn and Emily Kaye being recently employed by private consulting firms in engineering and toxicology, and Sadegh Modaresi accepting a postdoctoral fellowship at the US FDA.

Highlights

STEEP trainee Jahred Liddie gave a number of invited talks this past year, including a keynote talk on environmental disparities in exposures to contaminants at the Emerging Contaminants in the Environment Conference 2024 – ECEC24: https://publish.illinois.edu/emerging-contaminants-conference/2024-keynote-speakers/. He led outreach work with the Federal government on sociodemographic disparities in exposures to PFAS through drinking water during an invited presentation at a Federal-State Risk Toxicology Risk Analysis Committee in September 2023 and a panel convened by the American Association for the Advancement of Science (AAAS) in November 2023. He was also an invited panelist at a Thurgood Marshall Institute panel on Environmental Disparities in October 2023, and presented in August and October at International and National professional society meetings. He updated the interactive tool for visualizing state collected PFAS concentrations in drinking water developed for his 2023 paper (https://sunderlandlab.github.io/pfas_interactive_maps/PFAS_EJ_interactive_map.html) with the most recently available data. He submitted a second first-authored STEEP-paper in collaboration with the DMAC on associations between PFAS detection in US drinking water and Covid-19 severity, which is presently in review.

Melissa Woodward is a 4th year PhD-candidate and STEEP trainee working with Dr. Lohmann at the Graduate School of Oceanography, University of Rhode Island. Melissa is currently a Science Communication Intern, working with STEEP's Research Translation core to manage social media, share STEEP's research, and improve community engagement. In 2022, Melissa received the KC Donnelly Externship Award, for which she collaborated with the Stapleton Lab at Duke University to work on target and non-target analytical methods to measure indoor atmospheric contaminants. This work was later presented at SRP's 2023 annual meeting. She also presented her STEEP research both as posters and oral presentations at various conferences, including FLUOROS 2021, SETAC Europe 2023, and NEWMOA 2024. In 2022, Melissa was invited to present a talk on "Atmospheric Sampling of PFAS" by Michigan EGLE to a multi-state PFAS air group. Melissa also co-wrote a proposal, "Atmospheric transport of PFAS and its impact on surface water contamination", which was funded by USGS in 2023.

Juliana Agudelo is a 4th year PhD-candidate and STEEP trainee working with Dr. Slitt in the College of Pharmacy, University of Rhode Island. Juliana presented her research at regional the Northeast Regional Chapter of the Society of Toxicology meeting in October 2023 and was awarded 3rd place for the poster competition. Her research was presented as a poster at the annual SRP meeting in 2023. She delivered an oral presentation for a symposium at the annual Society of Toxicology meeting in March 2024. She was a 2024 Society of Toxicology Mixtures Specialty Section Jane Ellen Simmons Travel Award Finalist, recipient of the 2024 Society of Toxicology Risk Assessment Specialty Section John Doull Risk Assessment Endowment Award, and recipient of the 2024 Society of Toxicology Mixtures Specialty Section Best Student Abstract Award. Lastly, Juliana is a co-author on several recently accepted publications with other STEEP trainees.

Administrative Core

Director: **Rainer Lohmann**, Graduate School of Oceanography, University of Rhode Island (GSO)

Co-Director: **Philippe Grandjean**, University of Rhode Island, College of Pharmacy

Project Coordinator (outgoing): **Wendy Lucht**, Graduate School of Oceanography, University of Rhode Island (GSO)

Project Coordinator (onboarding): **Cathy Dwyer**, Graduate School of Oceanography, University of Rhode Island (GSO)

Specific Aims

- Ensure the efficient integration of STEEP's projects and centers.
- Provide leadership on STEEP's mission and goals.

Progress

In 2022-2023, the Administrative Core (AC) organized monthly administrative team meetings focused on disseminating NIEHS grant management updates. These meetings focused on budget planning, carryover policy, the importance of forecasts, Human Subject and IRB protocols, and updating each other about noteworthy accomplishments. AC also created a rotation of monthly "deep dive" meetings focused on individual cores and projects. These meetings help team members explore interdisciplinary research and collaborations across projects and cores. STEEP also uses this meeting time to discuss how to work with other SRP Centers, such as Harvard's MEMCARE and NCSU SRP.

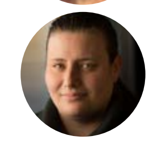
In addition to the AC's efforts within STEEP, the AC is in close contact with US and international agencies in providing new documentation on PFAS dissemination and toxicity. Thus, evidence on PFAS immunotoxicity in children and associated benchmark dose calculations has successfully inspired the U.S. Environmental Protection Agency to substantially lower its reference dose goals for two major PFAS. Likewise, STEEP has communicated with European Commission officers in regard to updated calculations of tolerable PFAS intake levels.

In 2023-2024, AC continues its successful operation of the STEEP SRP Center by integrating advice drawn from a collection of seasoned multidisciplinary professionals in both the Internal Advisory Committee (IAC) and the External Advisory Committee (EAC) through meetings, retreats, and joint video calls with the STEEP team. STEEP AC provides oversight and support to keep STEEP on target with respect to finances, subcontracts, reporting requirements, supplemental funding, data management, mission, and aims. Also, the AC will ensure coordination between STEEP Projects so that new insights are shared and applied across STEEP.

STEEP directors continue to provide leadership and advance the transdisciplinary science of PFAS within the US and internationally. STEEP shares research findings with stakeholders and study site communities through the AC and RT range of activities. The AC also stimulates transmission of new documentation for possible application, including new interventions and regulations at state and federal agencies as well as internationally.

Data Management and Analysis Core

Lead: **Harrison Dekker**, University of Rhode Island Libraries



Senior Personnel: **Jitka Becanova**, Graduate School of Oceanography, University of Rhode Island (GSO)

Senior Personnel: **Marie-Abèle Bind**, Massachusetts General Hospital

Specific Aims

- Address metadata needs across all STEEP research data products.
- Provide integrative statistical support.
- Develop standards for and provide data quality assurance and quality control (QA/QC) across STEEP research projects.

Progress

With respect to data management, year one efforts centered on developing a knowledgebase and workflows for implementing FAIR data management practices across STEEP projects. The data collected from mass spectrometry analysis provided a logical starting point given that it is deployed across STEEP project. Content analysis of both the data and accompanying publications will allow us to develop a STEEP-specific knowledgebase of terminology and ontological concepts which can serve as a reference for our researchers and DMAC staff in our data curation workflows.

A major challenge in implementing FAIR practices is the creation of machine-readable metadata. An environmental scan revealed two standards, LinkML and DDI-CDI which appear suitable for our envisioned workflows and infrastructure. Another challenge, particularly with respect to mass spectrometry analysis is conversion of data from vendor proprietary formats into open formats. A tool for doing such conversions on has been identified and is being tested.

Significant progress was made in developing staffing capacity for achieving DMAC's aims. Most importantly, STEEP worked with University of Rhode Island's administration to procure funding for a post-doc position. A job description was created, and a search is currently underway. In addition, a doctoral candidate trainee relevant programming and teaching experience was added to DMAC.

With respect to data analysis, our statisticians worked with project leads and trainees to do needs assessment and provide both individual and workshop training. Experimental design and reproducible research were identified as major areas of needs across project and various modes of training and support are being explored.

In 2023-2024, DMAC has made significant progress under the leadership of Dekker, Becanova, and Bind to advance data curation and research within the STEEP projects. Dekker and trainee Abeysiriwardana have made substantial progress in developing a flexible and user-friendly data curation workflow, crucial for supporting diverse research endeavors within STEEP. Dr. Becanova's leadership ensured the quality of mass spectrometry data across various projects, vital for maintaining data integrity and reliability. Additionally, Dr. Becanova collaborated with Project 1, Project 4, and USGS to update an existing ontology, facilitating data harmonization, particularly in PFAS analysis. Meanwhile, Dr. Bind provided essential statistical training and co-authored a paper currently under review, underscoring the significance of robust statistical methodologies in scientific research. Dr. Bind's presentation on hypothesis testing and guidance to graduate students further exemplify the dissemination of knowledge and mentorship within the STEEP community. Together, the accomplishments of Dekker, Becanova, and Bind have significantly advanced data curation practices and scientific inquiry within the STEEP projects, fostering collaboration and promoting research integrity.

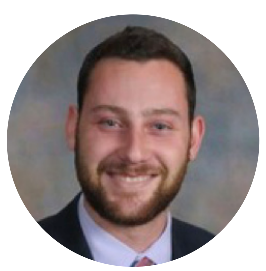
Trainees

Our trainees have become the character of STEEP in the world beyond the lab.

Chamudi Kashmila Abeysiriwardana
PhD Student
URI Computer Science and Statistics
DMAC

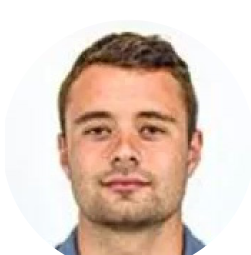
Juliana Agudelo
PhD Student
College of Pharmacy, URI
Slitt Lab

Alicia Crisalli
PhD Student (alum)
College of Pharmacy, URI
Cho Lab/TC Grad Assistant



Matthew Dunn
PhD Student (alum)
Graduate School of Oceanography, URI
Lohmann Lab

Taylor Elpers
PhD Student
Graduate School of Oceanography, URI
Lohmann Lab



Nick Ferguson
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College of Pharmacy, URI
Fischer Lab

Fabian Fischer
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Sunderland Lab

Faiz Haque
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Sadegh Modaresi
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Slitt Lab

Rachel Nelson
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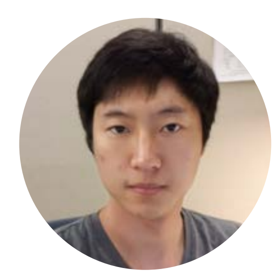

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Lohmann Lab

Olga Skende
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College of Pharmacy, URI
Slitt Lab

Jarod Snook
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Jennifer Sun
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Lohmann Lab

Melissa Woodward
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Lohmann Lab

Tatyana Yanishevsky
Affiliate (alum)
Graduate School of Oceanography, URI
Lohmann Lab/Boving Lab

Select Publications

PROJECT 1 PUBLICATIONS

Pickard, B.J. Ruyle, C. Dassuncao, A. Chovancovaa, C.P. Thackray, J. Becanova, S. Vojta, R. Lohmann, E.M. Sunderland. 2022. Bioaccumulation of PFAS and precursors in freshwater recreational fish and implications for fish advisories. Environmental Science & Technology. 56(22): 15573-15583.

B.J. Ruyle, L. Schultes, D.M. Akob, C.R. Harris, M.M. Lorah, S. Vojta, J. Becanova, S. McCann, H.M. Pickard, A. Pearson, R. Lohmann, C.D. Vecitis, E.M. Sunderland. 2023. Nitrifying bacteria linked to biotransformation of perfluoroalkyl sulfonamido precursors from legacy aqueous film forming foams. Environmental Science & Technology. 57(14), 5592-5602.

Ruyle, C.P. Thackray, C.M. Butt, D.R. LeBlanc, A.K. Tokranov, C.D. Vecitis, E.M. Sunderland. 2023. Centurial persistence of forever chemicals at military fire training sites. Environmental Science & Technology. Accepted.

Liddie, L.A. Schaider, E.M. Sunderland. 2023. Sociodemographic factors are associated with the abundance of PFAS sources and detection in U.S. community water systems. Environmental Science & Technology. Accepted.

Ruyle, H.M. Pickard, L. Schultes, F. Fredriksson, A.L. Heffernan, D.R.U. Knappe, H.L. Lord, P. Meng, M.A Mills, K. Ndung'u, P. Roesch, C. Vogel, D.C. Westerman, L.W.Y. Yeung, E.M. Sunderland. 2023. An Interlaboratory Comparison of Extractable Organofluorine Measurements in Groundwater and Eel (Anguilla rostrata): Recommendations for Methods Standardization. Environmental Science & Technology. 57(48): 20159-20168.

Pickard, F. Haque, E.M. Sunderland. 2024. Bioaccumulation of perfluroalkyl sulfonamides (FASA). Environmental Science & Technology Letters. https://doi.org/10.1021/acs.estlett.4c00143.

Fischer, S. Ludtke, C.P. Thackray, H. Pickard, F. Haque, C. Dassuncao, S. Endo, L. Schaider, E.M. Sunderland. 2024. Binding of per- and polyfluoroalkyl substances (PFAS) to serum proteins: Implications for toxicokinetics in humans. https://doi.org/10.1021/acs.est.3c07415.

Collaborative STEEP papers:

Dunn, N. Noons, S. Vojta, J. Becanova, H.M. Pickard, E. Sunderland, R. Lohmann. 2024. Unregulated active and closed textile mills represent a significant vector of PFAS contamination into coastal rivers. ES&T Water. https://doi.org/10.1021/acsestwater.3c00439.

Nielsen, F.C. Fischer, P.M. Leth, P. Grandjean. 2023. Occurrence of Major Perfluorinated Alkylate Substances in Human Blood and Target Organs. Environmental Science and Technology. 58(1): 143-149.

Petali, E. L. Pulster, C. McCarthy, H.M. Pickard, E.M. Sunderland, J. Bangma, C.C. Carignan, A. Robuck, K.A. Crawford, M.E. Romano, R. Lohmann, K. von Stackelberg. 2024. Considerations and Challenges in Developing Fish Consumption Advisories for Per- and Polyfluoroalkyl Substances (PFAS). Integrated Environmental Assessment and Management. In review.

Hill, J. Becanova, S. Vojta, L.B. Barber, D.R. LeBlanc, A.M. Vajda, H.M. Pickard, R. Lohmann. 2024. Bioconcentration of PFAS and precursors in fathead minnow tissues environmentally exposed to AFFF-contaminated waters. Environmental Toxicology and Chemistry. In review.

Kelly, J. Sun, M. McDougal, E.M. Sunderland, F.A.P.C. Gobas. 2024. Development and Evaluation of Aquatic and Terrestrial Food Web Bioaccumulation Models for Per- and Polyfluoroalkyl Substances. Environmental Science & Technology. In review.

Liddie, M-A Bind, M Karra, E.M. Sunderland. 2024. Associations between drinking water PFAS contamination and Covid-19 mortality in the United States: An ecological study. JESEE. In review.

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Jensen RC, Glintborg D, Timmermann CAG, Nielsen F, Boye H, Madsen JB, Bilenberg N, Grandjean P, Jensen TK, Andersen MS. Higher free thyroxine associated with PFAS exposure in first trimester. The Odense Child Cohort. Environ Res 2022; 212: 113492.

Højsager FD, Andersen M, Juul A, Nielsen F, Moller S, Christensen HT, Grøntved A, Grandjean P, Jensen TK. EFSA, 2020. Prenatal and early postnatal exposure to perfluoroalkyl substances and bone mineral content and density in the Odense Child Cohort. Environ Int 2022; 167: 107417.

Blomberg A, Mortensen J, Weihe P, Grandjean P. Bone mass density following developmental exposures to perfluoroalkyl substances (PFAS): a longitudinal cohort study. Environ Health 2022; 21: 113.

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Ehrlich V, Bil W, Vandebriel R, Granum B, Luijten M, Lindeman B, Grandjean P, Kaiser AM, Hauzenberger I, Hartmann C, Gundacker C, Uhl M. Consideration of pathways for immunotoxicity of per- and polyfluoroalkyl substances (PFAS). Environ Health 2023; 22: 19.

Valvi D, Christiani DC, Coull B, Højlund K, Nielsen F, Audouze K, Su L, Weihe P, Grandjean P. Gene-environment interactions in the associations of PFAS exposure with insulin sensitivity and beta-cell function in a Faroese cohort followed from birth to adulthood. Environ Res 2023; 226: 115600.

Grandjean P, Meddis A, Nielsen F, Sjödin A, Hjorth MF, Astrup A, Budtz-Jørgensen E. Weight loss relapse associated with exposure to perfluoroalkylate substances. Obesity (in press)

Budtz-Jørgensen E, Grandjean P. Benchmark dose calculations for PFAS exposure based on two data sets on immunotoxic effects. Environ Health 2023; 23: (in press).

Sørensen MM, Fisker AB, Dalgård C, Jensen KJ, Nielsen F, Benn CS, Grandjean P, Timmermann A. Predictors of serum- per- and polyfluoroalkyl substance (PFAS) concentrations among infants in Guinea-Bissau, West Africa. Environ Res 2023; 228: 115784.

Grandjean P, Shih Y, Jørgensen LH, Nielsen F, Weihe P, Budtz-Jørgensen E. Estimated exposure to perfluoroalkyl substances during infancy and serum-adipokine concentrations in later childhood (submitted).

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Budtz-Jørgensen E, Grandjean P. Benchmark dose calculations for PFAS exposure based on two data sets on immunotoxic effects. Environ Health 2023; 22: 40.

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Grandjean P, Shih Y, Jørgensen LH, Nielsen F, Weihe P, Budtz-Jørgensen E. Estimated exposure to perfluoroalkyl substances during infancy and serum-adipokine concentrations in later childhood. Pediatr Res 2023; 94(5): 1832-1837.

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Sigvaldsen A, Højsager FD, Paarup HM, Beck IH, Timmermann A, Boye H, Nielsen F, Halldorsson TI, Nielsen C, Möller S, Barington T, Grandjean P, Jensen TK. Early-life exposure to perfluoroalkyl substances and serum antibody concentrations towards common childhood vaccines in 18-month-old children in the Odense Child cohort. Environ Res 2024; 242: 117814.

Nielsen F, Fischer FC, Leth PM, Grandjean P. Occurrence of major perfluorinated alkylate substances in human blood and target organs. Environ Sci Technol 2024; 58: 143-9.

PROJECT 3 PUBLICATIONS

Zhang Y, Mustieles V, Wang YX, Sun Q, Coull B, Sun Y, Slitt A, Messerlian C (2023) Red Blood Cell Folate Modifies the Association Between Serum Per- and Polyfluoroalkyl Substances and Antibody Concentrations in U.S. Adolescents, Lancet Public Health, In Press

Zhang Y, Mustieles V, Wang YX, Sun Q, Coull B, Sun Y, Slitt A, Messerlian C. (2023) Red Blood Cell Folate Modifies the Association between Serum Per- and Polyfluoroalkyl Substances and Antibody Concentrations in U.S. Adolescents. Environ Sci Technol. 57(6):2445-2456. PMID: 36715557.

Marques E, Pfohl M, Wei W, Tarantola G, Ford L, Amaeze O, Alesio J, Ryu S, Jia X, Zhu H, Bothun GD, Slitt A. (2022) Replacement per- and polyfluoroalkyl substances (PFAS) are potent modulators of lipogenic and drug metabolizing gene expression signatures in primary human hepatocytes. Toxicol Appl Pharmacol. 442:115991. PMID: 35337807; PMCID: PMC9036616.

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Ryu, S.; Burchett, W.; Zhang, S.; Modaresi, S.; Agudelo Areiza, J.; Kaye, E.; Fischer, F.; Slitt, A. Species-Specific Unbound Fraction Differences in Highly Bound PFAS: A Comparative Study across Human, Rat, and Mouse Plasma and Albumin. Toxics 2024, 12(4), 253; https://doi.org/10.3390/toxics12040253.

Maurer JA, Kim AM, Oblie N, Hefferan S, Xie H, Slitt A, Jenkins BD, Bertin MJ. Temporal Dynamics of Cyanobacterial Bloom Community Composition and Toxin Production from Urban Lakes. bioRxiv [Preprint]. 2024 Feb 10:2024.02.07.579333. doi: 10.1101/2024.02.07.579333. PMID: 38370816; PMCID: PMC10871351.

Hmila I, Hill J, Shalaby KE, Ouararhni K, Abedsselem H, Modaresi SMS, Bihaqi SW, Marques E, Sondhi A, Slitt AL, Zawia NH. Perinatal exposure to PFOS and sustained high-fat diet promote neurodevelopmental disorders via genomic reprogramming of pathways associated with neuromotor development. Ecotoxicol Environ Saf. 2024, 272:116070. doi: 10.1016/j.ecoenv.2024.116070. Epub 2024 Feb 9. PMID: 38340603.

Zhang Y, Mustieles V, Wang YX, Sun Y, Agudelo J, Bibi Z, Torres N, Oulhote Y, Slitt A, Messerlian C. Folate concentrations and serum perfluoroalkyl and polyfluoroalkyl substance concentrations in adolescents and adults in the USA (National Health and Nutrition Examination Study 2003-16): an observational study. Lancet Planet Health. 2023 Jun;7(6):e449-e458. doi: 10.1016/S2542-5196(23)00088-8. PMID: 37286242; PMCID: PMC10901144.

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Matt Dunn, Jitka Becanova, Jarod Snook, Bridger Ruyle, Rainer Lohmann. Validation of a Novel Tube Passive Sampler for Perfluorinated Alkyl Acids. Environ Sci Technol Water 2023, 3, 2, 332–34, https://doi.org/10.1021/acsestwater.2c00384

Lohmann, R., Letcher, R.J. The universe of fluorinated polymers and polymeric substances and potential environmental impacts and concerns. Current Opinion in Green and Sustainable Chemistry, 2023, accepted. 10.1016/j.cogsc.2023.100795

Larry B. Barber, Heidi M. Pickard, David A. Alverez, Jitka Becanova, David W. Bertolatus, Jeramy R. Jasmann, Aaron Jastrow, Steffanie H. Keefe, Denis R. LeBlanc, Rainer Lohmann, Jeffery Steevens, and Alan M. Vajda. Multimedia Uptake of Per- and Polyfluorinated Alkyl Substances from Contaminated Groundwater at a Historical Fire-Training Area, Cape Cod, Massachusetts, ES&T 2023, accepted.

Snook, J; Becanova, J.; Vojta, S.; Lohmann, R. Avoiding artifacts in the determination of Per- and Polyfluoroalkyl substance sorbent-water distribution. EACS ES and T Water, 2023, 3(8), pp. 2355–2362, https://doi.org/10.1021/acsestwater.3c00084.

Matt Dunn, Nicholas Noons, Simon Vojta, Jitka Becanova, Heidi Pickard, Elsie Sunderland, Rainer Lohmann. Unregulated Active and Closed Textile Mills represent A Significant Vector of PFAS Contamination into Coastal Rivers. EST Water. 2024, 4(1), pp. 114–124, https://doi-org.uri.idm.oclc.org/10.1021/acsestwater.3c00439

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