Sea Grant Contaminants of Emerging Concern: Initial National Framework

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Infographic: Virge Kask

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Executive summary

Contaminants of emerging concern (CECs), which are not well characterized, are increasingly detected in seafood, drinking water, surface water and groundwater, posing risks to aquatic and terrestrial life. CECs include, but are not limited to: pharmaceuticals, personal care and household cleaning products, industrial chemicals (e.g., per-and polyfluoroalkyl substances (PFASs)), lawn care and agricultural products, and microfibers. While several federal and state entities are addressing some aspects of CECs, no one entity has full jurisdiction, and Congress has directed Sea Grant to invest in CECs. The National Sea Grant Office competed funds to develop this national framework to guide Sea Grant's investments in the field of CECs. The funded project's effort included an extensive literature review, a national survey, and a series of virtual regional workshops, with participation from federal and state agencies, Sea Grant staff, academia, environmental NGOs, the private sector, and interested citizens. The high-level conclusions of the scoping process follow.

Functional and topical priorities included that Sea Grant should continue to engage in the integration of research, extension and education, a strong identity for Sea Grant. Sea Grant should also continue to engage with relevant partners, especially given the diversity of organizations engaged with CECs. Different CECs may be important for different reasons to different parties under various circumstances, and Sea Grant should not limit its efforts to individual CECs or classes of CECs. While it was recognized that monitoring is important, it is a long-term commitment that may be beyond what Sea Grant can support.

On scope and scale, Sea Grant should focus on the concept of One Health/Environmental Health, including species of ecological importance. While humans are important, they should be considered as part of the ecosystem. Prevention and policy interests align with the research, extension, education, communication, and legal functions of Sea Grant, and bridge natural and social science. The spheres of ecosystems, commerce and food are all linked and all important to Sea Grant. Sea Grant should focus on a watershed approach, and consider drinking water, wastewater and effluents as relevant point and nonpoint sources of CECs for humans and the environment.

On partnerships, Sea Grant should recognize and focus on the importance of effective and integrative relationships with federal and state agencies, while building on its relationships with the academic research community, and should continue to leverage resources for regional efficiencies. Sea Grant should consider CEC liaison(s) to facilitate partnerships and programming on CECs across the network. Sea Grant should also focus on early and meaningful communications with communities, including minorities and underserved communities.

Sea Grant research priorities should include focus on broader ecosystem/ecological impacts, including impacts on human, animal, and ecosystem health, focus on aquatic species (fish may be of particular interest for ecological, recreational, subsistence and commercial reasons), and

focus on a watershed approach that considers the physical and chemical changes that occur across the watershed.

Sea Grant extension priorities should include focusing on community needs, supporting connection between CECs ecosystem/taxa impacts and human health, and developing meaningful links with other agencies involved with CECs.

Sea Grant education priorities should include efforts at better defining what CECs are, better communicating the risk associated with exposure to CECs and personal actions to reduce individual and widespread exposure, and focusing on the concept of watershed health.

Finally, Sea Grant should devote considerable attention to the concept of environmental justice (EJ). Specifically, Sea Grant will continue to engage with, be sensitive to and bring awareness to communities with EJ concerns, who may be disproportionally affected by CECs as well as legacy pollutants, compounded by infrastructure and climate change considerations. This is particularly important given all the unknowns about CECs, their exposure pathways, and impacts. There is a clear need for meaningful, ongoing outreach and engagement with communities with EJ concerns that addresses language and technology barriers and education and information gaps, and to listen and integrate their perspectives to shape Sea Grant programs. Fish and shellfish consumption, seafood safety, subsistence fishing, recreational and drinking water quality in coastal and Great Lakes communities, and aging infrastructure, are identified as some of the important chemical exposure pathways to incorporate in EJ considerations.

1. Introduction and Background

1.1. Definition of emerging contaminants

Contaminants of emerging concern (CECs) are increasingly detected in surface water and groundwater, posing risks to the nation's drinking waters and aquatic and terrestrial life. This broad class of chemicals and materials is characterized by the Environmental Protection Agency (EPA) for their perceived, potential, or demonstrated threat to human health and/or the environment, but are often excluded from monitoring programs and are characterized by a lack of published health and/or water quality standards. CECs include, but are not limited to: pharmaceuticals, personal care and household cleaning products, industrial chemicals (e.g., per- and polyfluoroalkyl substances (PFASs)), lawn care and agricultural products, and microfibers.

1.2. Who deals with CECs

Not surprisingly, as CECs are by definition emerging and not well regulated, no single agency is tasked with managing CECs, and several agencies have programs related to CECs. Among federal agencies, the EPA plays an important role in policies to protect public health and the environment, the U.S. Geological Survey (USGS) has strong monitoring programs related to natural resources, the National Institutes of Health (NIH) is focused on human health and relevant models, the National Oceanic and Atmospheric Administration (NOAA) strives to understand and predict changes in climate, weather, ocean, and coasts, and to conserve and manage coastal and marine ecosystems and resources. In addition, the Food and Drug Administration (FDA) is responsible for the safety of human and veterinary drugs and our nation's food supply, the Center for Disease Control (CDC) protects Americans from health threats and fights disease, and Department of Defense (DOD) provides the military forces needed to deter war and ensure our nation's security. Further, a number of state agencies are involved with CECs, differing in form and function but generally related to public health and environmental protection. The present scoping exercise was intended to better understand the national and regional landscape with regard to CECs, and identify a role or niche for Sea Grant that will not duplicate, but rather complement, ongoing efforts.

1.3. Project overview, purpose and approach

Congress has directed Sea Grant to support a research initiative to address this issue. In an important and timely step toward implementing this effort, Sea Grant needs to develop an overarching framework for its work to address CECs. This framework should prioritize research foci, delineate Sea Grant's role within the state, regional, and/or nationwide landscapes, consider integrated strategies across Sea Grant's core functional areas, and identify specific partnerships that are needed to be most impactful. A team from Connecticut Sea Grant, North Carolina Sea Grant, New Hampshire Sea Grant, the University of Connecticut and the Lighthouse Consulting Group received a competitive award to scope an overarching framework and implementation

strategies to address CECs by the Sea Grant Network at national and regional scales. This report was written by the team as a key component of that responsibility.

The approach for the scoping exercise was stepwise. First, an advisory committee was appointed to oversee and guide the project. A detailed literature survey was initiated to help frame the national landscape and guide the content of a national survey to help understand and define Sea Grant interests and aspirations regarding CECs, in view of the national landscape. Specifically, the literature review framed the scope of CECs included in the survey and later discussed in the workshops, including the chemicals/groups of chemicals discussed, their distribution in the watershed and coasts, and their known health effects, as well as the federal and state agencies and initiatives related to CECs. The survey included respondents from both within and outside Sea Grant, and targeted a diversity of sectors including federal, state and local government, academia (including students), non-governmental organizations (NGOs), the private sector, and interested citizens. The highlights of the survey were summarized into outlines for a draft framework, which was discussed in a series of regional workshops to ground-truth and adjust the findings, as well as identify regional differences, if they exist. Workshops were held virtually in each of five broad regions: the Great Lakes; the Northeast; the Mid-Atlantic and Southeast; the Gulf of Mexico; and the West Coast (including Hawaii and Alaska). This scoping report is the result of the integration of the steps above. The overall goal of the scoping exercise was to identify a strategic national role/framework for Sea Grant and guide future program investments on the broad topic of CECs. Consistent with the mission of Sea Grant, this scoping effort focuses on coastal regions, which across this document is explicitly inclusive of the Great Lakes.

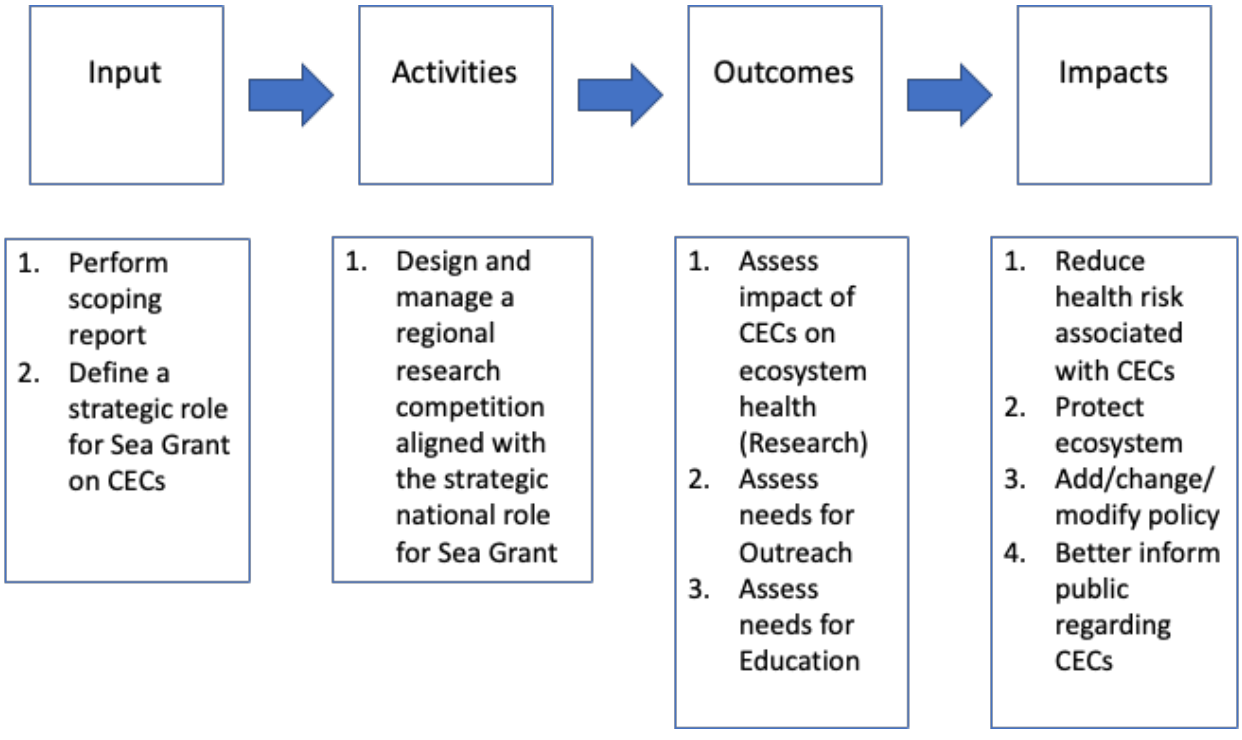
The team was intentional in including all views, and sensitive to the concepts of diversity, equity and inclusion, as well as environmental justice, as underserved communities are often the most affected by and least protected from environmental contaminants including CECs.

1.4. Summary of survey findings, highlighting regional differences

The survey received 647 individual responses with representation from all regions and sectors targeted. In addition to a series of targeted questions, the survey included ample room for comments, which proved very useful in interpreting the survey results. Overall, 85% of respondents thought CECs were very or extremely important to the mission of Sea Grant, validating the effort. The survey responses were rather consistent across regions and sectors, as well as between Sea Grant and non-Sea Grant respondents. Some minor differences included higher interest in monitoring and drinking water, and more links with state and local education groups in the Great Lakes; more links with local and regional place-based advocacy groups on the West Coast (including Alaska and Hawaii); less interest in septics in the Gulf of Mexico,; and interests related to aquaculture slightly higher in the Northeast and lower in the Great Lakes.

The regional workshops were held remotely to maximize participation and minimize travel costs. The five workshops together engaged 124 participants, for a total of approximately 18 hours of workshop time. Representatives included policymakers/elected officials, advocates/conservationists, regulators, researchers, extension and education professionals from Sea Grant, federal, state and local government, academic institutions, conservation/advocacy organizations, and students. Following a short presentation on the project, participants were asked to provide information on ongoing activities pertaining to CECs in the region to help understand the landscape. Participants were then presented the highlights of the survey in the form of potential elements of a national framework, which were discussed in breakout groups for regionally and nationally relevant feedback.

The combination of the national survey (also analyzed for regional differences) and the input from the regional workshops allowed a somewhat better understanding of the relatively minor regional differences identified in the survey, once we learned more about the regional context/landscape during the workshops. The general findings of the survey, organized as topical and functional principles and as informed by the discussions from the regional workshops, are presented in the sections below as the components of the national framework, and illustrated in the logic model depicted below relative to this stage of relative investment. It should be noted that the timeframe for the impacts is beyond that of this project, and that this logic model should be iterative in nature, and consider further stakeholder input.



2. Proposed role for Sea Grant's engagement in CECs

2.1. Functional and topical areas

Discussions on a potential role of Sea Grant in the field of CECs was inherently centered around the identity of Sea Grant, including its foundational strengths such as the integration of research, extension and education, and it is therefore not surprising that the framework elements align with the identity of Sea Grant. Four key principles, all ranked as important and complementary, emerged from discussions on Sea Grant functional and topical focus:

1. *Sea Grant investments should continue to include the research, extension and education continuum.*

There is strong identity for the Sea Grant model of integrating research, extension and education, and strong support for upcoming Sea Grant investments in CECs to include those complementary aspects. For example, any research competition should require the inclusion of an associated extension or education effort, so that the results from research projects reach the relevant stakeholders. One notable point is that while much research is needed to understand sources, exposure (including levels of concern for CECs that cause deleterious health effects in wildlife and humans, since simple detection does not equate to harm), and extension and education are equally needed to understand true versus perceived risk. This highlights the need for Sea Grant to align its outreach and education efforts. The continuum of research, extension and education may be important in informing regulatory and policy aspects of CECs.

2. *Sea Grant should focus on engaging relevant partners.*

Sea Grant is also well known for engaging partners. This was best exemplified by the diversity of attendees at the regional workshops (convened by Sea Grant programs), including representation from federal, state and local government, academia, NGOs and the private sector. Several noted that the engagement of partners was closely aligned with Sea Grant's integration of research, extension and education. State-based Sea Grant programs may naturally most easily engage with state agencies, whereas national scale partnerships may most effectively emerge with federal agencies. Sea Grant has the opportunity to be strategic in its partnerships. For example, Sea Grant does not regulate, which may facilitate engagement with private sectors that may perceive regulatory agencies as less easy to partner with. Sea Grant may also consider enhancing its efforts with the NGO community to identify the best mechanism for knowledge transfer to communities, and enhance the delivery and reach of its educational materials. Close partnerships with the academic research community, possibly coupled with citizen/community scientists, may represent a relatively affordable alternative to research performed in the private sector. Partnerships in coastal communities may enhance the dissemination of locally relevant

information through trusted sources. Also, partnerships with science agencies/the research community at large may help stay current on what is "emerging" in the field of CECs. Finally, some suggested the need for national coordination to avoid duplication of efforts and help Sea Grant maintain a reasonable scope of focus. More details on partnerships are provided in section 2.3, Partnerships.

3. *Different classes of CECs may be important for different reasons.*

Participants recognized that the relative importance of different CECs may be location/context dependent, at various scales (regional, sub-regional, state, local), and should be informed by community needs. While public perceptions are important, these may at times be driven, or at least influenced, by what appears in the media, and the identification of priorities should not be a popularity contest. Rather, it should be informed by the current state of the science and a broad diversity of stakeholders, including federal, state and local agencies, NGOs, industry, and what Sea Grant learns from its extension and education efforts. Another condition recognized was that some groups of CECs benefited from better knowledge and understanding than others. Overall, participants broadly agreed that Sea Grant efforts in the field of CECs should not be limited to a single CEC or class of CECs, but allow focus on CECs that are nationally relevant as well as regionally specific.

4. *Monitoring is a long-term commitment that may not be best fit for Sea Grant.*

There was broad recognition of the value of reliable monitoring programs to detect the emergence and distribution of CECs, and identify locally/regionally/nationally relevant research to understand the risks associated with exposure, and inform regulatory/policy actions. However, a consensus understood that Sea Grant does not have the infrastructure, capacity, and means to undertake and sustain meaningful long-term monitoring efforts. Sea Grant should, however, partner with entities involved in monitoring to inform its research, extension and education programs, and extend the reach of those monitoring programs. The potential for Sea Grant research and extension to inform monitoring programs was also highlighted. There was also agreement that targeted and non-targeted analyses to characterize the presence, distribution, and emergence of CECs is an important research contribution. While citizen/community science opportunities have been mentioned as potential partners in monitoring, quality control and logistical considerations would greatly limit involvement in the analytical aspects of CECs monitoring.

2.2. Scope and scale

Five key principles, all ranked as important and complementary, emerged from discussions on Sea Grant scope and scale topical focus, with Priorities One and Two most often cited as most important:

1. *Focus on One Health / Environmental Health, including sources and pathways for exposure, and focus on species of ecological importance.*

The CDC defines One Health as a collaborative approach with the goal of achieving optimal health outcomes, recognizing the interconnection between people, animals, plants, and their shared environment. In other words, it recognizes humans as part of the ecosystem, and human health as part of ecosystem health, rather than separate. Overall, Priority #1 was tied with Priority #2 as most important and should be a focus for Sea Grant. Sources of and pathways of exposure, along with strategies to help remove CECs from source pathways were also considered important. Some species are critical for their contribution to ecosystem integrity, whether because they are key to the food chain, or important to the prey-predator balance; those should be of significant importance to study. Tracking co-occurring CECs, especially along likely/known source pathways for CECs, was considered a useful concept to consider.

2. *Prevention and policy interests align with the research, extension, education, communication, and legal functions of Sea Grant, and bridge natural and social sciences.*

While it is important to understand the effects of CECs, significant efforts should be devoted to preventing exposure, including by using sound science to inform relevant policy. *Priority #2* was tied with *Priority #1* as most important and should be a focus for Sea Grant. Analysis of consumer consumption behavior and demographics of exposure, as well as perception/mental health considerations, are important components of this priority. Individual stakeholders and communities should also be informed about potential chronic, acute and event-based risks in a balanced way. Finally, because several regions directly border other nations, binational agreements and organizations related to CECs can be considered.

3. *Ecosystems (aquatic food chain), commerce (fishing, aquaculture) and food (food security, food safety) are all very important and linked.*

Sea Grant is concerned with both healthy ecosystems and the benefits they can derive, including the provision of safe and sustainable seafood derived from productive coastal and marine areas. Determining chemical thresholds and benchmarks as necessary steps linking health concerns and informing development of regulatory levels of CECs in seafood is important, as are the differences in threshold levels (unacceptable risk levels) for human versus ecosystem processes and non-human species.

4. *Focus on watershed approach.*

Much of the discussion related to this priority focus was related to and thus captured under Priority #1, highlighting the importance of an inclusive approach to CECs. One specific suggestion is to include air as a potentially significant source/transport pathway. More details on the specifics of a watershed approach are provided in section 3.1, Research. There was consensus that significantly changing environmental, climatic and development conditions in coastal ecosystems need to be taken into consideration, which might require significant investments.

5. *Focus on drinking water, wastewater and effluents as relevant point and nonpoint sources of CECs for humans and the environment.*

Focus on the fate and transport of CECs as they relate to exposure requires a better understanding of their sources. There was consensus that this priority focus area captures an important dimension of the scope and scale of this issue. Discussions focused on specific contaminants, as well as nonpoint- and point-source analysis capabilities that reflect differences in regional needs and justifies the general nature of this focus area. There was wide discussion that CECs in drinking water, wastewater, effluents, and groundwater are concerns of other governmental agencies and thus possibly a good area for Sea Grant to partner on.

2.3. Partnerships

A Sea Grant foundational principle is the individual state (and national) program's ability to identify, recruit, maintain, and strengthen partnerships that help address challenges, leverage resources for greater impacts than one program working alone can have, and reflect the diversity of Sea Grant program priorities. In order to strongly position Sea Grant for success in the expanding area of interest of CECs, additional federal, state, academic, industry, and local partnerships will be required. Coordination of efforts is always critical, and the Sea Grant role of facilitator will need to continue to expand in this topical area, which can be ably started through investment in a new CECs liaison position with a clearly defined scope of work. Identifying Sea Grant's explicit role(s) in this work, and leveraging other partners' expertise in complementary ways, will be critical to partnering success. Additionally, the focus on partnerships with experience in addressing and engaging in environmental justice considerations will be important.

1. *Sea Grant should continue efforts towards more effective and integrative relationships with federal agencies.*

Sea Grant works closely with many federal partners already, notably NOAA and the EPA. Continuing to leverage these existing relationships will be important to building bridges with additional federal partners that specifically work with CECs in regulatory and non-regulatory

roles. These partners will have greater resources to address CECs and leveraging together will strengthen Sea Grant's complementary efforts. Specifically, increased partnerships with the EPA and the NIH were considered high-priority collaboration opportunities with their existing roles and responsibilities related to CECs environmental and health impacts. Additional federal partners that could be considered include the USGS, DOD, CDC, FDA and U.S. Fish and Wildlife Service. A more comprehensive list of federal partners that include CECs as priority areas of investment would be helpful for the Sea Grant programs to understand as this initiative continues. Sea Grant programs noted some examples of specific federal partners already in place in certain specific geographies, but not across all regions. Clearly, defining Sea Grant's role in working with federal agency partners in this area will be important, supporting complementarity of efforts to achieve greater impacts than any one program can alone.

2. *Sea Grant should maintain effective and integrative relationships with state agencies.*

Similar to Sea Grant's strong connectivity with a variety of federal partners, state Sea Grant programs already work closely with many state agencies. Expanding state-level agency relationships focused on environmental and health impacts of CECs may require states to consider new partners, or expand existing partnerships with state health departments (or equivalents in individual states), environmental departments, and agricultural departments, among other state agencies. Similar to federal partners, state partners may also have additional resources that Sea Grant does not, and leveraging complementary program efforts will further opportunities and impacts. Defining Sea Grant's role in working with state agency partners in this area will be important.

3. *Sea Grant considers the academic research community as important partners.*

Sea Grant already considers the academic research community as a primary partner in delivering the Sea Grant mission. Expanding efforts in CECs may require Sea Grant programs to provide new directed opportunities for academic engagement in funding projects to build and strengthen expertise specifically in the CECs topical area, and regular workshops for engagement with experts on the topics. Interdisciplinary work will be critical, including working with legal and policy expertise. Public outreach and engagement opportunities in partnership with academic community members will expand the reach of Sea Grant impacts as well.

4. *Sea Grant should leverage resources with other partners for regional efficiencies.*

Leveraging resources with partners to develop and deliver regional research competitions, as one example, can make sense. Connecting with other national networks with complementary state-level programs (e.g. National Estuarine Research Reserves) for regional approaches would also be beneficial. There are also opportunities for consideration with bi-national partnerships (e.g. Great Lakes, Northeast) that can also leverage opportunities. However, the balance of regional and local work will need to be flexible, as not all regional research approaches may apply to all regions. Additional leveraging opportunities would also include co-producing and sharing outreach and educational products and curricula.

5. *Sea Grant should consider a new CEC liaison position(s) to effectively facilitate partnerships and programming across the Sea Grant network.*

There will be a critical need for a CEC liaison should the Sea Grant investment continue to expand in this area. A liaison would support increased partnership engagement and facilitation, and maintain strong relationships with partners, among other roles. Potential federal partners could include the EPA, NIH, USGS, FDA, CDC and DOD. A single CEC liaison expert would also need to possess a good amount of freshwater CECs expertise to support Great Lakes needs, as well as support other geographically isolated programs (e.g. Hawaii and Guam) that may have different/additional priorities regarding CECs. Another option, in place of or in addition to a single liaison, would be to support regional liaisons, or sharing/placing Sea Grant team positions (e.g. fellows, staff, technicians, educators, communicators, legal aides) with relevant offices to support partnership opportunities in the CECs area. Potential additional roles: compiling a list of existing relevant federal, state, local, and regional partners in this topical area to share and support states in reaching new partners; establishing a Sea Grant CECs community of practice for internal-facing efforts and related activities.

6. *Sea Grant should prioritize partner and stakeholder assessments and communication to integrate communities, including Black, Indigenous, and People of Color (BIPOC), at the beginning of processes, projects and programs and ensure communication throughout the projects, including findings and impacts.*

Consistent communication was identified as an important component of successful partnerships at all scales (federal, state, local and others) and types (agency, academic, community and others) and throughout the length of a project/program. Additionally, partners with strengths in risk analysis and translation of risk impacts to communities will be an important part of communication efforts. Early integration of community and stakeholder input will likely require additional support (for example, funding and logistical) to develop integrated research teams that include this skill, which may or may not be a skill associated with academic researchers focused on CECs.

Additional partner considerations that were identified included policymakers and those in industry, the military, agriculture and water treatment/utilities, along with legal experts, activist organizations including environmental justice organizations, community clinicians, and relevant non-profits. These partners may be important collaborators in Sea Grant programming related to CECs and may require new approaches and considerations if engaged through research and extension efforts (e.g. confidentiality agreements, advocacy training). Regional and local agencies and connections are important for success and should be explicitly incorporated as part of implementing any national framework, acknowledging that regional approaches may make greater sense in some parts of the network than others depending on the topic and other factors. Citizen/community scientists as partners may also be important for on-the-ground CECs research and outreach.

3. Recommendations for Sea Grant programming

3.1. Research

1. *Focus on broader ecosystem/ecological impacts.*

An integrated ecosystem approach to assess the impact of CECs is a particular strength and niche for Sea Grant. However, there is value for conducting basic research (e.g., screening, toxicity, threshold levels, chemical transformation), which could contribute to the ecosystem approach. The ecosystem approach may include CECs input/source, transport/fate, distribution/uptake through food webs, and impacts on exposed animals and humans.

CECs include, but are not limited to, brominated flame retardants (BFR), microplastics (MP), nanomaterials (NM), per- and polyfluoroalkyl substances (PFAS), and pharmaceutical and personal care products (PPCPs). Sea Grant recognizes that different CECs may have different priorities in different regions. Further, non-targeted analytical approaches may identify novel CECs previously unrecognized. Although Sea Grant recognizes the importance of harmful algal bloom (HAB) biotoxins, they are generally not considered CECs, and several other agencies, including NOAA's National Centers for Coastal Ocean Science, already have established research programs related to HAB biotoxins.

The role of climate change (e.g., temperature, hypoxia) may have a direct or indirect role on the impact of CECs on the ecosystem but would require significant investments. Similarly, although forward-looking research on chemical mixtures, cumulative effects and chronic lifetime/sublethal impacts and exposure is important, such studies are expensive, and may be beyond the scope of what Sea Grant can support at this time. However, opportunities to collaborate with other agencies to conduct these types of basic research may prove useful.

2. *Focus on impacts of CECs to health (human, animal, ecosystem health).*

The mere detection of CECs in tissues does not necessarily infer negative health effects, and there would be value in better linking exposure and effects, especially demonstrable health effects. The impact of CECs on the ecosystem is a priority, and assessing relationships between CECs tissue concentrations in animals and health could be included/considered as part of the basic research identified in Research Priority #1. The impact of CECs specific to human health outcomes, such as determining specific thresholds for human health effects, are better left to agencies other than Sea Grant such as the NIH, but may be an important consideration for other Sea Grant efforts such as outreach efforts on fish consumption.

3. *Focus on aquatic species, but fish may be of particular interest.*

There is a need for Sea Grant to focus on the impacts of CECs on a variety of aquatic species, including, but not limited to invertebrates, fish, reptiles, birds, and marine mammals. However, fish may be of particular interest, and may include forage fish (fish that make up the base of the aquatic food chain), recreational fish (those fish caught by recreational fisherman), subsistence fish (those non-commercial fish caught for human consumption), and commercially caught fish. Understanding the impact of CECs on fish could contribute and inform food (seafood) safety concerns.

4. *Focus on watershed approach.*

There is a need for Sea Grant to focus on how CECs move through the watershed, which will link CECs movement through different, but continuous watersheds, such as streams, rivers, estuaries, and coastal systems. This focus can also include CECs uptake by organisms, as well as the fate/final deposition of CECs within and among each ecosystem. Importantly, the source (point and/or nonpoint source) of CECs should also be identified when possible. This focus may also include the impact of chemical transformation (e.g., from parent precursor to metabolites; transformation as some CECs pass through water treatment facilities), ability to absorb other chemicals, and lifespan (i.e., chemical half-lives) as CECs move within and among fresh, brackish, and marine waters. The importance of air transport/distribution of CECs among different ecosystems should also be considered.

3.2. Extension

1. *Connecting community needs*

Both of Sea Grant's existing enterprises in extension and education can augment CECs research and other activities such as legal/policy support. Extension and education have direct connections with communities and specific audiences and can work in multiple modes to provide information, including connections to formal education. That direct connection to communities afforded by Sea Grant's extension will shape the CECs program by infusing local challenges and helping to formulate research questions by leading two-way dialogue. Extension audiences will vary by region and state, but can be selected by the programs based on their direct or indirect connections to CECs and potential for positive outcomes. Every extension program is unique because the states have different actors and environments. To give an example, regulation discussions are likely to be more politically challenging in several regions and may shape policy discussions about how communities can self-regulate.

Specific extension niches are place-based and are driven by local and regional needs. Extension agents/specialists can be neutral and credible brokers by separating opinions from science. Extension can be effective in serving as a synthesis of the state of science and leading or collaborating in inclusive processes that provide a balanced discussion on sensitive issues that include all parties that have a voice.

2. *Supporting connection between CECs ecosystem/taxa impacts and human health*

To maximize the reach of Sea Grant CECs research investments, extension support should be melded into study designs. Extension programs can be an appropriate bridge between other actors including researchers, academia, regulators, policymakers, and the public. In effect, extension can serve as a convener in the diffuse CECs environment. Right-sizing discussions about risk (e.g., seafood consumption) will be challenging as there are unknowns. A critical point is that Sea Grant extension and education professionals must honestly acknowledge these unknowns.

3. *Linking with other agencies*

There is much growth potential for the system in building partnerships to address CECs issues. Support was strong for creating collaborations that span the spectrum of regulatory and non-regulatory aspects of CECs while recognizing non-regulatory approaches are more palatable, now and likely in the future in many regions. There are a myriad of federal, state, and local agencies that can inform research agendas and be collaborators in community extension processes. As a natural coalition builder, Sea Grant extension can help establish and strengthen these connections.

Through this visioning process, several ideas emerged that could be additional considerations for Sea Grant's future focus in CECs. The system could be a purveyor of CECs information (e.g., a resource library, perhaps using the ocean acidification information network or Interstate Technology and Regulatory Council as a model). In assessing regional differences, the Great Lakes region considers public health topics such as food security for wild-caught food as important. The Northeast would like to explore collaborations with business and industry. Finally, environmental justice concerns and ensuring that underrepresented voices, including traditional, non-Western approaches to ecosystems, must be part of a Sea Grant extension program.

3.3. Education

There are several potential audiences, at least at the start of Sea Grant's deeper involvement in CECs education. Students are certainly an important audience, but in addition to formal education, industry partners and other groups should be considered. There will also be a need to produce accessible educational materials (e.g., in different languages) to accommodate audiences.

1. *Focus on CECs definitions*

Sea Grant educational programming can bring CECs knowledge to discrete audiences, and be inclusive of formal and informal education. A guiding element for education is to be strategic in the identification of audiences. Education should be connected to action, beyond identifying community CECs challenges, otherwise the problems persist. As with the Sea Grant extension

program, adapting education to communities, especially for those with environmental justice concerns, is an opportunity for the Sea Grant education network.

Beyond defining CECs for audiences, educational efforts should have learning objectives about sources, impacts, remediation, risk, and mitigation. Regionally, other objectives can include CECs prevention (i.e., a broader focus than remediation and mitigation), proper handling, disposal, and best practices.

2. Risk communication

Communicating risks effectively depends on a framework of robust science that is delivered by trustworthy sources. Sea Grant has a respected role in science communication and the system has built this reputation by placing coastal issues in their proper context of what is known. Sea Grant educators should communicate about realistic levels (i.e., zero risk may not be feasible) and address public concerns by focusing on what communities and individuals can do. There must be transparency where there are data gaps. Education audiences should learn the proper context of CECs and in appropriate detail and understand the actionable implications of research, e.g., relaying actions people can take individually and as part of communities to reduce exposure.

3. Watershed health

Watershed health is an appropriate educational focus, with the caution that these efforts don't duplicate existing programs. There are many existing educational products and curricula that are based on watershed health. Creating resources to assess and understand watershed health, perhaps using existing tools, can be a starting point. Education in watersheds affords an opportunity to expand audiences to land-use actors (planning departments, developers) to understand risks and to better manage waste. Smaller communities may not have adequate data, so considerations should be given about how best to provide outreach to rural audiences.

4. Environmental justice

Sea Grant strives for continual program improvement in addressing diversity, equity, inclusion, justice and accessibility (DEIJA), both internal to program functions, as well as externally in developing and delivering research, extension and education efforts. National Sea Grant's 10-year DEIJ Vision[1], updated in 2021, provides a call and a roadmap for the Sea Grant programs to improve. Chemicals of emerging concern (CECs), individual chemicals as well as mixtures, and associated exposures and risks are just one example in coastal and Great Lakes communities in which environmental justice (EJ) impacts must be incorporated into any expanding Sea Grant

[1] National Sea Grant's 10-year Diversity, Equity, Inclusion, and Justice (DEIJ) Vision, Version 2. (2021). [Strategic Plan]. The National Sea Grant College Program.

CECs portfolio. The EPA[2] defines EJ as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." There is a need to better identify and understand the many aspects of individuals and communities that Sea Grant desires to support with CECs investments to better align resources and partners as effectively as possible. Communities prefer to identify themselves, rather than have external groups label them. Sea Grant can embrace this community-centered approach by re-framing perspectives and aligning discussions as communities that have EJ considerations (versus EJ communities). Authentic EJ emphasis should be included in calls for proposals, through early engagement and input, as well as include relevant EJ criteria for reviewing proposals. EJ considerations are noted throughout this document. There are many EJ aspects for Sea Grant state and national programming to learn about and consider. The information summarized from regional workgroup discussions is not intended to be a prioritized list and the writers acknowledge it is not inclusive of the other important EJ considerations.

Sea Grant will continue to engage with, be sensitive to and bring awareness to communities with EJ concerns. Sea Grant recognizes the fact that both higher concentrations, and lower (nonlethal) cumulative exposures pose risks in coastal urban and rural communities including those of Black, Indigenous, People of Color (BIPOC) and underserved and underrepresented (UU) individuals and communities. Exposures are a result of current and legacy policy decisions, industrial pollution, aging wastewater and stormwater infrastructure, fewer resources, the cumulative effects of exposure to other contaminants/mixtures (i.e., lead, PFAS), and climate change, along with other considerations.

The known and unknown contaminants, and their known and unknown impacts, and known and unknown exposure pathways in coastal communities present an enormous challenge to address. Contaminants must be considered not just as individual chemicals, but as complex mixtures of chemistry and exposure pathways. These complexities translate directly to supporting education, awareness of exposure and risk. Pre-existing health conditions (e.g. diabetes, obesity, nutritional deficiencies) also pose significant challenges in connecting cause and effect with exposures within communities. One challenge noted was whether Sea Grant resources for CECs efforts may be focused in communities/areas of higher (exposure) risks than others. Additionally, there may be the potential for communities that have EJ concerns to become active participants involved with Sea Grant in monitoring programs and activities.

The identified need for meaningful, ongoing outreach and engagement that addresses language and technology barriers and education and information gaps will help inform research, extension, policy and prevention activities. Integrating perspectives of underserved communities and communities with EJ concerns in the development of programming and in the decision-making process will be critical to success. Sea Grant will continue to play a significant role in connecting results to community action, including prevention, education and policy engagement.

[2] EPA. (2022). Environmental Justice. Available at https://www.epa.gov/environmentaljustice

Sea Grant will need to strengthen program knowledge and skills to fully address EJ challenges related to CECs. Scientific knowledge as well as professional skills focused on addressing DEIJA challenges in coastal urban and rural communities will heavily rely on partnerships. Meaningful engagement and ongoing dialogs with communities to listen and integrate their perspectives must occur at the very beginning. This should occur even before developing any future call for proposals so that community input informs the content and problem identification and potentially the approach for future work proposed. Ongoing engagement with communities and building trust over time is critical to addressing challenges and improving EJ outcomes. Communities with EJ concerns are important partners, just as academic and agency partners.

Fish and shellfish consumption, seafood safety, subsistence fishing, recreational and drinking water quality in coastal and Great Lakes communities, and aging infrastructure, are identified as some of the important chemical exposure pathways to incorporate in EJ considerations. Fish and shellfish consumption, although a potential pathway for individual exposure, are not the only animal species that may be considered for food consumption exposure pathways. Sources for fish and shellfish include recreational, commercial and aquaculture activities. With a reduction in accessibility to safe fish/shellfish resources, Sea Grant and partners need to recognize and work to avoid the potential of losing traditional culture (e.g. indigenous communities). Seafood handling and safety continues to be a Sea Grant extension and research program strength, and is an important aspect to maintaining and expanding support for reduced food contamination and negative human health impacts. There continues to be a need to support educational efforts that find a path to support communities' understanding of potential health risks while balancing subsistence fishing as a critical source of beneficial nutrition for some communities. Food security is also an EJ challenge and Sea Grant can expand programming related to consumption to include this topic as well. Recreation (e.g. fishing, swimming) in poor water quality conditions is an important pathway for exposure (both in water and aerosolized) as is poor drinking water quality. Some of these exposures are voluntary (e.g. the result of individual choices) while other exposures are involuntary (e.g. no other options available for drinking water). An important consideration is how proposed actions or potential solutions to exposures (e.g. installing reverse osmosis systems, changing food sources) may not be possible for some individuals or communities and/or equitably supported or implemented.