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Reevaluating new and existing challenges early career researchers face across regulatory ecotoxicology

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Abstract

A Society of Environmental Toxicology and Chemistry (SETAC) Pellston Workshop on "Improving the Usability of Ecotoxicology in Regulatory Decision-Making" was held in August 2015. One outcome of the workshop was a publication that highlighted the challenges ecotoxicologists of the future face in applying academic research to regulatory decision-making. The authors proposed that training students on issues of relevance and reliability will lead to improvements in the applicability of academic research for regulatory decision-making while also setting out the importance of cross-sector partnerships in preparing academics for a career in regulatory ecotoxicology. As nearly a decade has passed since the initial workshop, we believe it is important to reevaluate previously identified challenges faced in applying academic research to regulatory decision-making, highlight challenges not previously identified, and assess the uptake of proposed training and skills. A survey was developed and deployed online to gain understanding of the challenges early career researchers (ECRs) face in applying academic research to regulatory decision-making and the training and skills received throughout their career. A total of 52 ECRs responded to the survey. Just over a quarter of respondents (27%) considered themselves to be part of a training network; however, approximately half of all respondents stated that they have received training to understand the regulatory context of their research (52%), ecotoxicology methodologies or guidelines (44%), and principles of quality assurance and good laboratory practice (54%). We explore why ECRs may or may not receive training and assess the extent to which they agree that it has improved the applicability of their research for regulatory decision-making. We conclude that although some areas of training have developed, some remain a challenge (i.e., interdisciplinarity, cross-sector partnership) and set out a series of recommendations for ECRs to overcome new and existing challenges in applying their research to regulatory decision-making.

Keywords risk assessment, ecotoxicology, policy, regulation, chemical

Introduction

Regulatory ecotoxicology plays a crucial role in environmental protection by providing scientific evidence to support policy decisions on chemical risk assessment (Rudén et al., 2017). However, the field operates at the intersection of science, policy, and industry, making it a complex and evolving space (Tapio & Willamo, 2008; Bridle et al., 2013). Moreover, bridging the gap between academic research and regulatory application remains a challenge, particularly for early career researchers (ECRs; Filyushkina et al., 2022; Mitrano et al., 2023). Early career researchers must navigate an increasingly complex landscape that demands not only scientific expertise but also an understanding of regulatory frameworks, interdisciplinary collaboration, and effective communication with stakeholders.

One of the primary obstacles ECRs face is the misalignment between academic research priorities and regulatory needs. Whereas academic studies often prioritize novel discoveries and mechanistic insights, regulatory decision-making requires data that are standardized, reproducible, and directly applicable to policy and risk assessment (USEPA, 2011). Ensuring that academic research aligns with regulatory needs requires a strong foundation in regulatory principles, yet many ECRs receive little formal training in this area (Bernstein et al., 2017; Evans & Cvitanovic, 2018). The transition from academic research to regulatory application is further complicated by the variability in regulatory frameworks across regions, the evolving nature of environmental policies, and the increasing emphasis on alternative testing methods. Beyond scientific challenges, ECRs also struggle with career-related barriers, including limited funding, job insecurity, and unclear career pathways, particularly for those

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seeking roles outside of academia (Johnson & Weivoda, 2021). Early career researchers are often evaluated by their research performance indicated by journal publications and are not evaluated by other contributions leading to lack of time investment in other endeavors (Deng et al., 2022). The transition from academic training to regulatory practice is often hindered by gaps in formal education on regulatory science, data reliability, and interdisciplinary research. These barriers not only affect individual career progression but also limit the field's ability to integrate innovative academic research into regulatory frameworks effectively (John et al., 2023).

Interdisciplinary communication also presents a major obstacle (Pischke et al., 2017). Ecotoxicology draws on expertise from toxicology, ecology, chemistry, and environmental sciences, yet differences in terminology, methodologies, and research priorities across these disciplines can create silos that hinder collaboration. For example, ecologists working at the community level often use broad indicators, such as changes in population dynamics, whereas regulatory toxicologists may require chemical-specific dose-response data. Bridging these gaps requires training that fosters a common language between disciplines, yet such opportunities remain limited for many ECRs (Pischke et al., 2017; Hunka et al., 2013).

Another pressing issue is the availability of funding and career opportunities (Bromham et al., 2016; Deng et al., 2022). Regulatory ecotoxicology exists at the intersection of academia, industry, and government, but ECRs often struggle to navigate these sectors due to unclear career pathways and short-term or temporary contracts. Furthermore, evolving regulatory expectations, such as increased demands for transparency and data accessibility, place additional burdens on researchers without corresponding support structures. These factors contribute to job insecurity, hinder professional development, and may discourage talented researchers from remaining in the field.

Recognizing these challenges, a Society of Environmental Toxicology and Chemistry (SETAC) Pellston Workshop held in 2015 examined ways to improve the usability of ecotoxicological research in regulatory decision-making. One outcome of this workshop was the publication by Harris et al. (2017), which identified key barriers and proposed solutions. However, nearly a decade later, the extent to which these challenges have been addressed and whether new ones have emerged remains unclear. Given the rapid evolution of environmental policies, the increasing emphasis on alternative testing methods, and the growing complexity of chemical risk assessment, it is essential to reassess the state of training and skill development in regulatory ecotoxicology from the perspective of ECRs.

Aims and research questions

The aim of this research was to reevaluate previously identified challenges faced in applying academic research to regulatory decision-making, highlight challenges not previously identified, and assess the uptake of proposed training and skills. Specifically, we sought to assess the extent to which previously identified barriers (Harris et al., 2017) remain relevant, identify new and emerging challenges that have arisen in recent years, and evaluate the uptake and effectiveness of proposed training initiatives designed to improve the applicability of academic research in regulatory decision-making.

We address the following research questions:

1) What are the pathways to proposed training and skills development that exist for ECRs?
2) Which barriers limit the uptake of proposed training and skills development for ECRs?
3) What new and emerging challenges do ECRs face in applying academic research to regulatory decision-making?

By gathering qualitative and quantitative data through an online survey, this study provides a contemporary perspective on the preparedness of ECRs entering regulatory ecotoxicology, offering insights into how training and support structures can be improved to enhance the integration of academic research into regulatory frameworks.

Material and methods

Data collection

To address these research questions, we gathered data from ECRs, who considered their work relevant to regulatory ecotoxicology (i.e., chemical research, risk assessment, risk management, and/or chemical policy). We define an ECR to be an individual working at any institution and/or organization at the qualified level of masters, PhD, or postdoctorate or an individual within eight years post-PhD, as defined by United Kingdom Research and Innovation (UKRI, 2020). A survey (see online supplementary material 1) was designed and hosted on the online survey software Qualtrics (www.qualtrics.com) for 10 weeks (July 8, 2024–September 16, 2024). The survey was launched and promoted online using social media (i.e., LinkedIn, X, ResearchGate). Direct promotion (i.e., email; LinkedIn; $N = 151$) was undertaken using the inventory of student and early career membership of SETAC and relevant ECR training networks (e.g., Ecotoxicological Risk Assessment Towards Sustainable Chemical Use Centre of Doctoral Training [ECORISC CDT] etc.) and research groups (e.g., Ecotoxicology and Environmental Monitoring Group at the University of Portsmouth, Chemical Stress Ecology Group at Wageningen University, etc.) in the field of environmental toxicology known to the author team. Reminder emails were sent one month after the survey launch and again during the final week of data collection. Additionally, the SETAC Young Environmental Scientist group disseminated the survey through its own channels. All responses were collected anonymously to ensure participant confidentiality.

Data analysis and processing

The survey consisted of three main sections for participant response and analysis. These included a section on respondents' demographic information, uptake of (question 1) and barriers to (question 2) proposed training and skills development, and new and emerging challenges (question 3). The survey consisted of a series of multiple choice, Likert-scale questions, and free text responses. The survey was designed to collect ECR perspectives

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on the training and skills they may have received (i.e., research reliability, regulatory guidelines) and how this may have contributed to the applicability of their research (i.e., alignment with regulatory standards). Specifically, the survey asked respondents to provide as much detail as possible about the training they received (i.e., the level of research at which it occurred, the location and method of delivery, whether it was part of a network, and whether it was funded or self-funded). This allowed more detailed understanding on the type of training received as well as highlighting opportunities and barriers as perceived by ECRs to engagement with regulatory training programs, interdisciplinary collaboration opportunities, and cross-sector partnerships.

Information gathered in the free text boxes was coded for qualitative analysis with the software tool NVivo (version 14.24.2, www.lumivero.com). A codebook detailing the overall structure, and example codes can be found in the online supplementary material 2. These are used to support thematic analysis of the data and are discussed in more detail throughout the remainder of this article. Codes and subcodes were identified by a single reviewer (L.J.) through the process of grounded theory (Glaser & Strauss, 1967), whereby general concepts (codes) were assigned based on the research questions and data that emerged. Coding was carried out in duplicate (S.M., L.J.) to ensure consistency and enhance the reliability of the analysis through independent validation and comparison of coded data. Inter-coder agreement (97.2%) for all codes and subcodes was calculated using NVivo's built in query tool. Quantitative data from the survey were imported into Excel and analyzed and visualized with R (version 4.5.0, R Core Team, 2024) in R Studio (RStudio Team, 2020). No statistical analysis was undertaken as we do not consider the number of responses and data received sufficiently reliable or powerful for any meaningful analysis.

Results and discussion

Demographic information

A total of 63 individuals responded to the survey. Only those who considered themselves to be an ECR (as defined by UKRI, 2020) and considered their work to be relevant to regulatory ecotoxicology were asked to complete the survey ($N = 52$). More than half of all respondents held a doctoral degree (i.e., PhD; 54%, $N = 28$) and around a third of all respondents held a Master's degree (38%, $N = 20$; Figure 1A). Respondents reported their current level of research to range from Master's level (8%) through to Lecturer (or equivalent; 4%; Figure 1B) with research focused on a range of primary ($N = 8$; Figure 2A) and secondary ($N = 13$; Figure 2B) research disciplines. These included environmental toxicology (48%, $N = 25$); environmental, analytical, or molecular chemistry (17%, $N = 9$); chemical, environmental, or biological modeling (13%, $N = 7$), and ecology (3%, $N = 2$), among

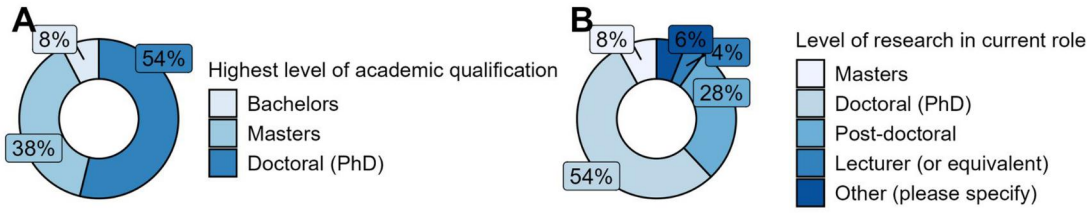

Figure 1. Demographic information of survey respondents including their highest level of academic qualification (A) and the level of research in their current role (B).

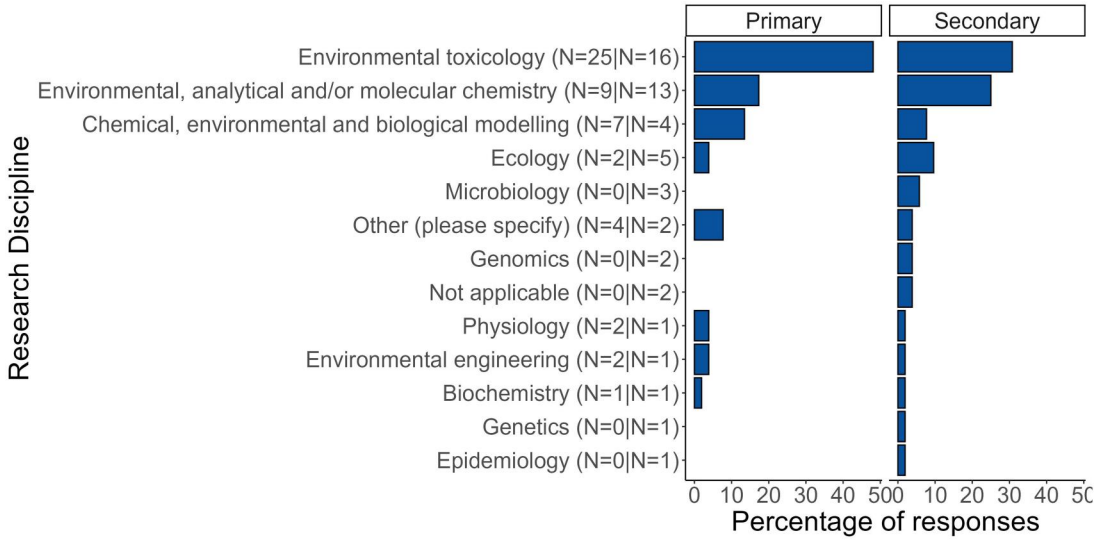

Figure 2. Survey respondents' primary (A) and secondary (B) research discipline.

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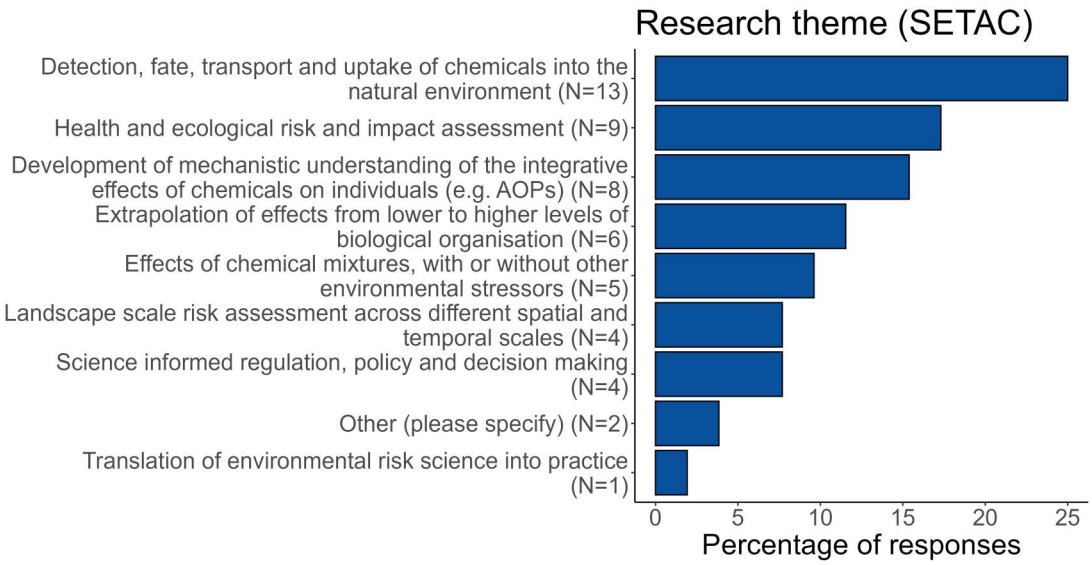

Figure 3. Survey respondents' thematic research area as defined by the Society of Environmental Toxicology and Chemistry (SETAC).

others (Figure 2). Respondents also considered themself to belong to a range of thematic areas of research (as defined by SETAC) including the detection, fate, transport, and uptake of chemicals (25%, $N = 13$); health and ecological risk and impact assessment (17%, $N = 9$), and science informed regulation and policy (7%, $N = 4$; Figure 3).

Pathways to training and skills development

Analysis of the free text responses suggests that respondents received training through a series of routes and pathways. These include formal academic pathways to training (i.e., doctoral training programs, Master's level study); informal (i.e., workshop and discussion) and ad hoc training (i.e., on the job, academia, industry, regulation); opportunities for knowledge exchange (i.e., partnership, internship, placement), and external interaction (i.e., conference attendance, online or in-person seminars).

Respondents reported receiving training through formal academic pathways, such as classes or courses in their Master's degree, PhD programs, or doctoral training networks (i.e., Centre of Doctoral Training [CDT]; Doctoral Training Partnership [DTP], Innovative Training Network [ITN]). They explained that these academic pathways included fundamental training on "statistical validation, data collection, and data filtering" alongside more applied training on practices essential to regulation such as "method development and validation," "training on quality assurance and GLP (Good Laboratory Practice) practices," and learning about "OECD guidelines." Two respondents noted that they had received "regulatory ecotoxicology" specific training including information on "different regulations that apply for pesticides, biocides, drugs and industrial chemicals" at a national and regional (i.e., EU) scale.

Some respondents reported having received informal training as part of discussions with supervisors, colleagues, and partners. For instance, one respondent explained that they had received "informal training through interaction in [their] PhD project, which involves stakeholders from academia, regulatory agencies, and industry." Another respondent highlighted that they had participated in "discussions with members of [their] lab who work on ecotoxicology and utilize guidelines and standardized methods." Our data also suggest that respondents have received "ad hoc" training during their role. This included fundamental laboratory training at academic institutions such as how to "use the FTIR machine." Others note they had received "on-the-job training" such as experiencing a "review of regulatory documents" and "interpretation of regulatory requirements." This kind of training was also largely reported to be "self-taught" or "facilitated by the principal investigators and/or research advisors on projects" highlighting that ECRs would develop skills themselves if they were not receiving formal training.

Opportunities for knowledge exchange, such as collaboration and partnership of academic and nonacademic actors (i.e., involvement of stakeholders in CDT and DTP programs) alongside the completion of placements or internships (both funded and self-funded), are reported in our research as an important route to gain skills and training. For instance, many respondents reported that they had been encouraged to go on secondments at partner institutions or industrial organizations during their PhD projects. One respondent explained that as part of a funded EU Marie Skłodowska-Curie Actions program, they received hands-on training on laboratory methods at the company they were visiting. Another respondent noted that during an internship undertaken at a university as part of their Master's degree, they had used OECD and ISO guidelines for standard toxicity testing. Our data suggest that this kind of training can be useful for ECRs in increasing the regulatory relevance of their research. One respondent explained that completing an internship with the Rivers Trust as part of the ECORISC CDT "has led to a collaborative manuscript being produced, that if published has potential regulatory relevance." This type of experience also provides opportunities to engage in real-life application and use of regulatory standards. These responses highlight the value of structured placements in bridging academic research with regulatory

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practice, providing both practical experience and opportunities for collaboration.

Our data also suggest that external interaction, such as that at a workshop or conference, or through formal talks and presentations (both online and in-person), can be a useful pathway of training. For instance, several respondents mentioned that they had attended in-person training courses such as those organized by SETAC (i.e., on "evaluation of reliability, relevance and regulatory acceptance of research papers" and "DNA sequencing"). Other respondents explained how they had taken part in in-person or online seminars with representatives from industry and governmental agencies on topics of specific regulation (i.e., Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals [REACH], Biocidal Products Regulation [BPR]), guidelines (i.e., OECD), and Good Laboratory Practices (GLP).

Uptake of proposed training and skills for existing challenges

Overall we found that little more than a quarter of respondents (27%, $N = 14$) considered themselves to be part of a training network (i.e., ECORISC, SETAC; Table 1). However, analysis of the multiple choice and free text responses indicates that a high number of participants had received or are receiving training in areas previously identified by Harris et al. (2017). For example, more than half of respondents (52%, $N = 27$) reported that they had received training on the regulatory context of their research; 54% ($N = 28$) had received training to understand the principles of quality assurance (QA) and GLP requirements; and 63% ($N = 33$) had received interdisciplinary training at a university, laboratory, or research institution (Table 1). In contrast, the majority of survey respondents (67%, $N = 35$) had not participated in cooperative training partnerships, internships, or research fellowships, whereas less than half (44%, $N = 23$) had experienced government or industry participation in academic research (i.e., supervision, involvement of government or industry scientists in academic research) (Table 1).

Data from the Likert scale responses suggest that overall, respondents agreed (i.e., strongly or somewhat) that training on regulatory context (96%, $N = 26$) and training on ecotoxicology guidelines and standardized methods (91%, $N = 21$) improved their awareness of the regulatory context of their research (Figure 4A). In particular, instruction on toxicological (i.e., OECD) guidelines and standardized methodologies was viewed as particularly useful. Respondents reported that this training increased their awareness of the wider regulatory and political context of their research, including an understanding of relevant laws and mandates, the importance of QA/QC practices, and GLP requirements for assessing research reliability. More than three-quarters (86%; $N = 24$) of survey respondents who had received training to understand the principles of quality assurance

Table 1. Early career researcher (ECR) survey respondent ($N = 52$) receipt of training identified in Harris et al., 2017.

Survey question	Yes	No	I don't know	Not applicable/ prefer not to say
In your current role, do you consider yourself to be part of a training network?	27%	35%	38%	0%
As an ECR, have you received training to understand the regulatory context of your research?	52%	37%	8%	4%
As an ECR, have you received training to understand ecotoxicology guidelines and available standardized methods (such as those from the OECD)?	44%	46%	8%	2%
As an ECR, have you received training to understand the principles of quality assurance (QA) and Good Laboratory Practice (GLP) requirements?	54%	37%	8%	2%
As an ECR, have you received interdisciplinary training at a university, laboratory, and/or institution?	63%	19%	17%	0%
As an ECR, have you participated in cooperative training partnerships, internships, and/or research fellowships (i.e., EFSA traineeship)?	25%	67%	6%	2%
As an ECR, have you experienced government and industry participation in academic research (i.e., supervision and/or involvement of government or industry scientists in academic research)?	44%	40%	8%	8%
As an ECR, have you been engaged in informal partnerships (i.e., guest speakers, lecturers in classrooms) by government or industry scientists?	48%	37%	8%	8%
Are you in the process of completing, or have completed (since 2015), the SETAC Europe Certified Environmental Risk Assessors program?	2%	63%	35%	N/A

Note. EFSA = European Food Safety Authority; SETAC = Society of Environmental Toxicology and Chemistry.

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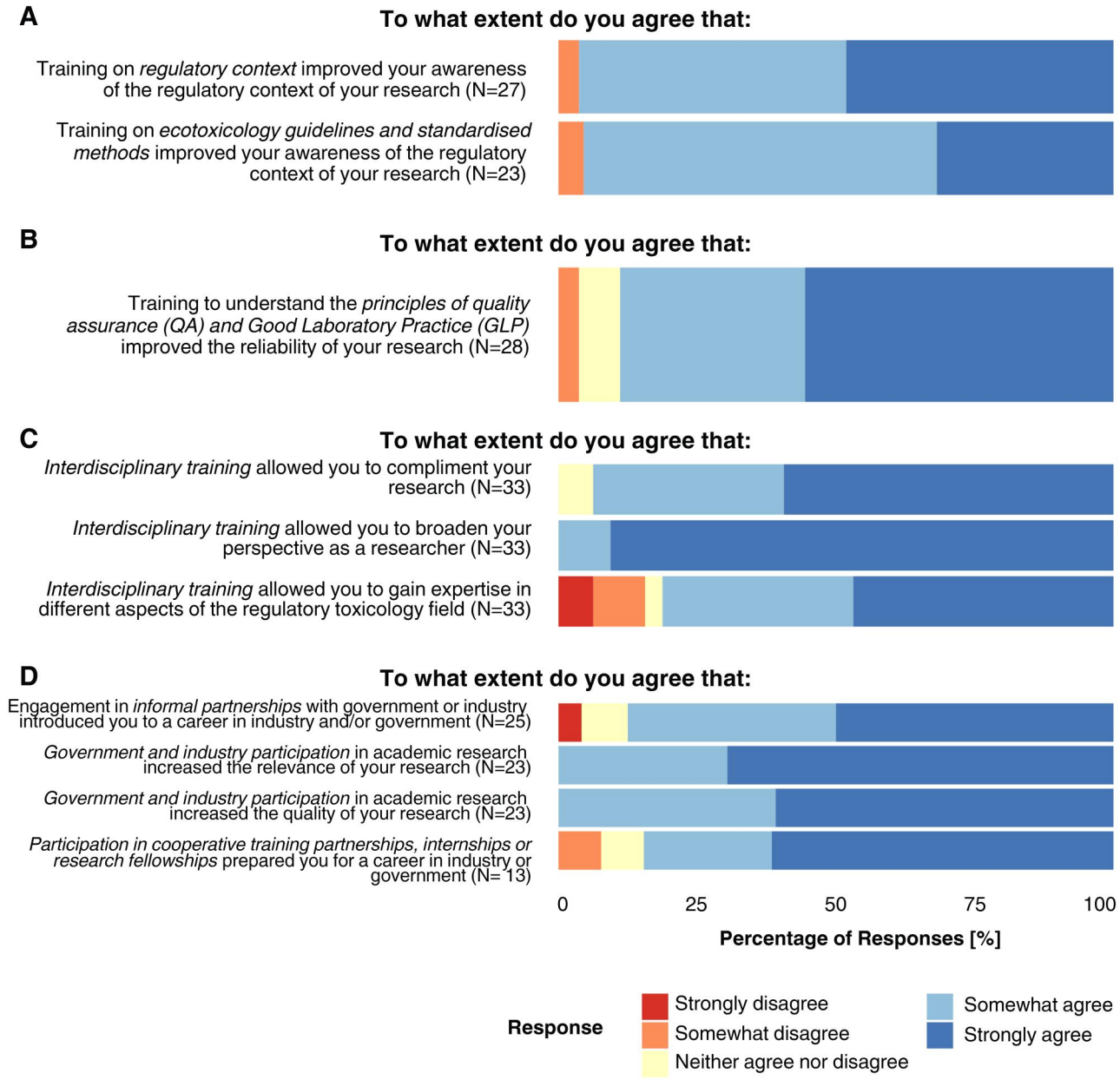

Figure 4. Likert scale agreement of survey respondents who received training on regulatory relevance (A), training on research reliability (B), interdisciplinary training (C), and participation in cross-sector partnerships (D).

and GLP agreed that it improved the reliability of their research (Figure 4B).

Our data also suggest that interdisciplinary training has allowed survey respondents to gain expertise in different aspects of the regulatory toxicology field (79%, $N = 26$), complement their research (91%, $N = 30$), and broaden their perspective as a researcher (97%, $N = 32$; Figure 4C). Respondents agreed that participation in cooperative training partnerships, internships, and/or research fellowships prepared them for a career in industry of government (85%, $N = 11$; Figure 4D). The involvement of government and industry in academic research (i.e., through cross-sector and informal partnerships) is perceived by respondents to increase both the quality (100%, $N = 23$) and relevance of academic research (100%, $N = 23$; Figure 4D).

Barriers to uptake of proposed training and skills

Respondents were asked to provide further information on the training they had (or had not) received in free text boxes. This included details on the level of research, location and method of training, whether the training was part of a network, and whether the training was funded. Respondents were also asked to set out any factors they considered a barrier to receiving training. This allowed for more detailed understanding of the barriers ECRs face in gaining access to skills and training (see Table 2). Thematic analysis of the coded observations collected in the free text boxes identified four main themes. These include the opportunity, availability, and accessibility of training and

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Table 2. Barriers to training, recommendations to overcome them, and the actors responsible for delivery.

Barrier to training	Recommendation	Actor(s) responsible
Opportunity, availability, and accessibility of relevant training (e.g., in regulatory principles)	Increase availability, accessibility, and opportunities for training through the provision of free, equal opportunity, and openly available opportunities for training.	Government ministries (i.e., education), industry employers, educational institutions, universities, and open learning platforms
	Increase the number of available university level ecotoxicology specific courses (whole programs or number of modules). These could be crafted in concert with or with advice from regulatory agencies to maximize their relevance.	Government ministries (i.e., education), higher educational institutions, and university curriculum committees
Regulatory relevance, reliability, and compatibility of research	Increase awareness of ECRs on the importance of regulatory frameworks early in their career to increase the integration of standards and guidelines into project planning and delivery (Rudén et al., 2017; Ågerstrand et al., 2017).	Regulatory agencies, universities, doctoral training programs, professional societies and organizations (i.e., SETAC)
	Develop standardized, easily accessible guidelines for ensuring data from academic research are suitable for use in regulatory decision-making (e.g., as in Harris et al., 2014).	Regulatory agencies, international bodies (i.e., OECD), academic researchers, industry scientists, journal editors
	Provide more opportunities for ECRs to spend time with regulators, such as through short-term internships to improve the regulatory relevance of ECR research.	Regulatory agencies, chemical industries, universities, doctoral training programs, funding bodies (i.e., UKRI)
	Develop and maintain regular, open, and honest exchange between ECRs and regulatory decision-makers on the needs and requirements of regulatory risk assessment.	Risk assessors and risk managers, academic researchers, industry scientists, professional societies and organizations (i.e., SETAC)
	Provide ECRs with training on criteria for reporting and evaluating ecotoxicity, behavioral, and exposure data (CRED, etho-CRED, and CREED) to better support the development and publication of robust, reproducible, and harmonized data that are more transparent (Carnesecchi et al., 2023; Merrington et al., 2024).	Doctoral training programs, academic mentors and supervisors, professional societies and organizations (i.e., SETAC), open learning platforms
	Implement guidance to journal editors to consistently apply data reporting requirements (Ågerstrand et al., 2017; Moermond et al., 2016).	Academic publishers and journal editors
	Increase training on the maintenance and calibration of instruments necessary for GLP to increase the skills and expertise necessary for regulatory use of academic research data.	University and research institution laboratory managers, international bodies (i.e., OECD), professional societies and organizations (i.e., SETAC)
Engagement, collaboration, and awareness	Increase the involvement of nonscientists in academic research through cross-sector partnerships to increase the exchange of regulatory and scientific developments (Jones et al., 2025).	University knowledge exchange, doctoral training programs, funding bodies (i.e., UKRI),
	Provide ECRs with training on how to communicate their research findings effectively to regulatory bodies/institutions.	university knowledge exchange, doctoral training programs, educational institutions, universities, and open learning platforms
Competing goals, demands, and priorities	Reward the publication of regulatory relevant academic research to incentivize ECRs to improve the regulatory relevance and reliability of their research (Jones et al., 2025).	Universities and research institutions (i.e., tenure and awards), funding bodies (i.e., UKRI), policy makers

(continued)

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Table 2. (continued)

Barrier to training	Recommendation	Actor(s) responsible
Limitations of resources and expertise	Build time for placements, internships, and additional external training into higher education programs (such as PhDs) so that they do not detract time from the main body of the program.	Higher educational institutions and universities, doctoral training programs, funding bodies (i.e., UKRI)

Note. ECRs = early career researchers; CRED = Criteria for reporting and evaluating toxicity data; CREED = criteria for reporting and evaluating environmental toxicity data; GLP = Good Laboratory Practices; SETAC = Society of Environmental Toxicology and Chemistry; UKRI = United Kingdom Research and Innovation.

skills development; relevance, reliability, and compatibility of research with training and skills development; engagement, collaboration, and awareness; and competing goals, demands, and priorities (Table 2). These themes are discussed in more detail below.

Opportunity, availability, and accessibility

The lack of opportunity, availability, and accessibility of training is considered by respondents to be a major barrier to training in our data. It was frequently mentioned how respondents had "no opportunity" to receive training both in academic and nonacademic sectors. For instance, one respondent working in the private sector described it as a "prohibitive environment." Another in academia noted that they had not "had the opportunities to collaborate with government or industry scientists" as their research has been "more academically focused" and their institution "hasn't facilitated partnerships with external stakeholders." It was also mentioned that training is not always available to everyone with respondents reporting a "lack of access to opportunities" particularly if they are an international student with respondents reporting "segregation against ECRs from the Global South" with training "only given to the (White) natives." Our data also suggest that there are issues of availability. For instance, it was mentioned that "in the U.S. there are very few environmental toxicology programs left"; therefore, research is being integrated into different departments, with more broad research focus, and the training structure (for understanding regulatory context and application of research) is lost. Another respondent shared the belief that training to understand the principles of quality assurance and GLP requirements "doesn't seem available in [their] academic setting." A second respondent shared how they considered there to be "a lack of conversation and focus on translating research into regulatory development" at their institution. Responses to our survey suggest that this lack of availability or accessibility hampers opportunities for more informal pathways to training (i.e., collaboration, knowledge exchange). For instance, a respondent explained that "there hasn't been a strong focus on inviting external speakers from government or industry in the academic settings" they have been involved in and thus they lack the "networks or connections that could facilitate these types of informal collaborations at this point in [their] career."

The SETAC Europe Certified Environmental Risk Assessor Program was introduced in 2021 "to promote the conduct of scientifically robust and technically advanced assessments of risks from chemical exposure through certification of individuals with demonstrated expertise in Environmental Risk Assessment" (SETAC 2021, https://ibera-certification.org/). The program was designed to ensure that those who successfully completed the course are "fully capable to function as environmental risk assessors for chemical substances." Despite the certification providing and delivering training based on standards of regulatory excellence, only one respondent (2%) had been part of the program. This is not surprising, as most ECRs, if not all, would not have enough experience or training to be involved in the program at this stage of their career (see https://ibera-certification.org/eligibility/). Crucially, the respondent neither agreed nor disagreed that the program had "improved their awareness and understanding of data quality" or "regulatory impact."

Relevance, reliability, and compatibility of research

Our data suggest that the relevance, reliability, and compatibility of ECR academic research with regulatory needs and requirements is considered by respondents to be a significant barrier to training. Some respondents noted that they did not work in a laboratory during their academic studies and that the focus of their research was more "computer based" than those "undertaking empirical research in the lab." This meant that the development of skills and training in GLP and OECD guidelines was not considered relevant or "applicable to all students." One respondent reported receiving training on a specific area of regulation relevant to their own program or research (i.e., pest management); however, other respondents believed that in general, "there is [a] lack of the 'regulatory' aspect in many academic labs" and "that there is a lack of conversation and focus on translating [academic] research into regulatory development" and thus ECRs do not gain the necessary skills or training to align their studies with regulatory needs. They explained how "most academic studies that are reviewed for (for instance) submitting information requirements to ECHA (European Chemicals Agency) do not comply with the guidelines," and that most academic studies are discarded as they cannot be deemed sufficiently reliable or robust due to "missing information."

Engagement, collaboration, and awareness

Lack of communication, collaboration, and engagement is highlighted in our research as a barrier to the uptake of training and skills in ECRs. For instance, it was reported in our research that cross-sector partnerships (i.e., cooperative training partnerships, internships and fellowships, government and industry participation, informal partnerships) had not happened due to

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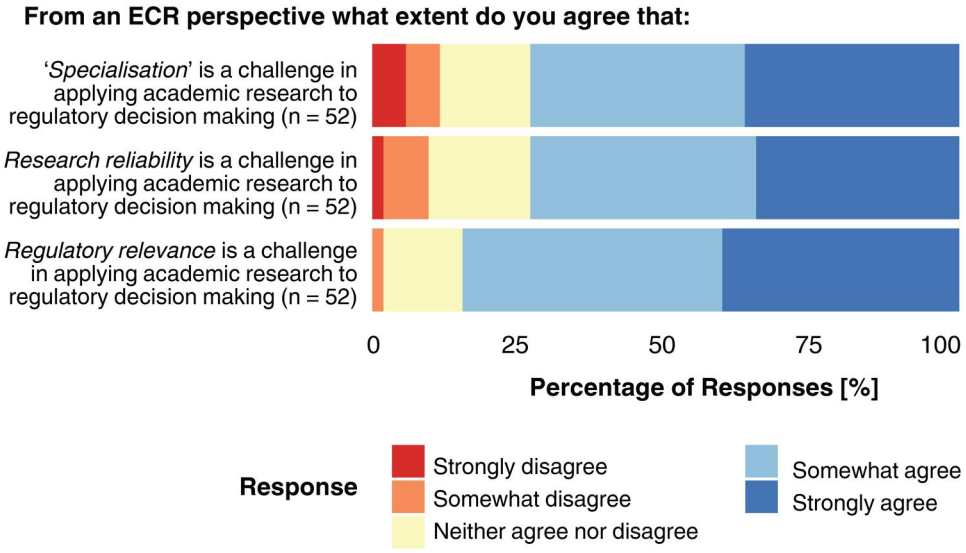

Figure 5. Likert response of survey respondents agreement with challenges previously identified. ECR = early career researcher.

poor collaboration and engagement between actors within the regulatory toxicology system. In particular, two respondents mentioned that they had not "the networks or connections" or "had much exposure to networks that connect academia with government or industry" at this stage of their career, which makes establishing these types of collaborations challenging. Data from the free text responses suggest that a lack of awareness in academics and ECRs of opportunities for training (i.e., collaboration, partnership, internships) have affected their access. For instance, a respondent explained that they had not "participated in cooperative training partnerships or internships because [they weren't] fully aware" and they had "not been actively promoted by my institution or network" whereas another noted that they had "not yet come across any of these [opportunities] and would not know where to look to find one easily." This lack of awareness also affects how academic research is or is not used in regulatory decision-making. Regulatory frameworks play an important role in ensuring that academic research aligns with ethical, environmental, and safety standards, and it is "important for early career researchers to be made aware of these frameworks early on, so they can integrate them into their project planning and execution." One respondent shared the concern that there is a "lack of awareness in academic research laboratories," which results in most tests being "nonstandard" and thus not applicable for regulatory use.

Competing goals, demands, and priorities

Our research suggests that there are many competing goals, demands, and priorities on ECRs in the regulatory toxicology system that may affect the uptake of training and skills. For instance, it was mentioned frequently by respondents that there is a "large gap between what is required and considered useful by regulatory agencies" and what is required for academic research. Respondents explained that in the field of ecotoxicology, the focus of academic research is often on encouraging the development of "new and novel approaches" and "to elucidate effects that are not captured in, e.g., OECD ecotoxicity testing" (e.g., effects on community structure). A respondent also noted that academia is "less focused on regulatory issues and more focused on things that will bring in grants and publications," and thus "working within existing regulatory mechanisms is often not viewed as 'flashy'." It was suggested that "there is not enough incentive [for academics] to follow and enforce stricter rules that would make data generated useful" and thus, opportunities for training and the development of skills is lacking. In general, our data suggest that respondents believe that there is a lack of conversation and focus within ECRs on translating academic research into regulatory development, and other demands (i.e., publication, geographical location, funding) affect an individual's ability to prioritize training and skill development.

Limitations of resource and expertise

Limitation in resources was highlighted in our research to be a challenge for ECRs when accessing opportunities for training and skill development. In particular, constraints of both time and funding were frequently mentioned by respondents to be a crucial factor. For instance, one respondent mentioned that whereas they were very early in their PhD, something that would stop them from seeking out partnerships and accessing training would be "how much time it would take from [their] project." Another noted that they had been provided opportunities through their CDT network; however, they had "chosen not to partake due to their commitments." Regulatory training can also take a significant amount of time and work to accomplish. As one respondent explained, it "may not always work with the timelines set out for graduate students." A lack of funding available to ECRs coupled with the high costs of training (e.g., SETAC training courses) was also reported in our research as a significant barrier to accessing training. One respondent noted that "some of the training on guidelines and standardized methodologies require funds that are not usually available to students," whereas another commented that "there is little money for science [in South America], so unfortunately this is not a priority." Responses to our survey suggest that there are also challenges related to resources, particularly laboratory equipment and

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methodological expertise. For instance, one respondent explained that "many universities are poorly equipped because there is not enough money to provide state-of-the-art equipment," and thus do not work according to GLP. Another reported that "very few [academic] advisors will want to spend funds on analytical verification of exposure concentrations" (i.e., for GLP studies), and therefore research is not applicable for regulatory use.

ECR perspective on the challenges in applying academic research to regulatory decision-making

Although the majority of ECRs who responded to our survey have demonstrated an uptake of training and skill development in line with the needs and challenges previously identified (Harris et al., 2017), our data suggest that almost a decade later, many challenges remain. For instance, 85% of respondents ($N = 44$) agreed (somewhat or strongly) that regulatory relevance of academic research remains a challenge, and more than two-thirds of respondents (73%, $N = 38$) agreed that research reliability and specialization (i.e., a lack of interdisciplinarity) are challenges in applying academic research to regulatory decision-making (see Figure 5).

Section 3 of the survey (see online supplementary material 1) asked respondents to identify any new or emerging challenges that they consider to affect the application of academic research in regulatory processes. Specifically, we asked respondents to identify these challenges based on their experience as an ECR in the field of regulatory ecotoxicology. Three main themes emerged.

The first is that academics, and in particular ECRs, are stuck in a research cycle that does not sufficiently allow the time, funding, or ability to produce and publish academic research in line with regulatory needs while establishing a scientific career. For instance, one respondent explained that as an ECR they "constantly need to have new results and publications to get grants, have employment, and stay in science." This means that they have to produce a lot of data in a short space of time that is often "detached from reality" with "no connection to EU regulations" (i.e., laboratory-based research on nonspecific scenarios regarding pesticide toxicity). Another respondent noted that "there is a discrepancy sometimes between what researchers are able to get funding for, and what the research needs are." It is suggested that whereas academia is "trying to address many of the existing issues" (i.e., publish or perish, low-quality research), ecotoxicological research in academia is often "driven by funding for topical pollutants at a given time." There is also sometimes a discrepancy "between what researchers are able to get funding for, and what the research needs are to better develop and implement regulations."

A theme that also emerged from ECR responses is that there is a "large gap" between what is required by regulatory agencies and when it is considered useful, and what research is being undertaken and produced in academic institutions. In particular, our research suggests that from an ECR perspective, there is an emerging conflict between traditional toxicological testing (i.e., in vivo models, regulatory endpoints) and what research is being undertaken at academic institutions (i.e., nonanimal testing and in-vitro models). We also noted frustration from ECRs at the lack of uptake and implementation of new scientific methods and approaches (i.e., new approach methodologies) for the regulation of novel and emerging substances (i.e., endocrine disruptors). For instance, one respondent explained that "traditional toxicology has focused on the assumption that 'the dose makes the poison' but recent research on endocrine disruptors has shown that low-dose exposures can have significant health impacts," thus challenging the dose-response models traditionally used in risk assessment. Although it is understood in our research that the implementation of such approaches in regulation face general challenges (i.e., in validation and ensuring appropriate levels of protection), it is argued that the gap between "outdated" regulatory testing and emerging scientific development and technologies is a challenge for ECRs in applying their research to regulatory decision-making.

Finally, our data suggest that ECRs consider academia and regulation to be operating in "two different dimensions," which makes communication, integration, and translation of academic research for regulatory decision-making a challenge. In particular, it was mentioned that "the mindset of regulation and academic ecotoxicology is very different," which can lead to poor or broken communication. This disconnect in communication is perceived to be a challenge in applying academic research to regulation in that "specific research needs of the regulatory sector are not being communicated well to the academic research sector," whereas there is often a "lack of translation of research to regulation," as much of the evidence is not "in line with accepted standards" or is communicated in a way that is not understood. For instance, a respondent explained that there is "difficulty in translating scientific data into understandable information to nonexperts" (i.e., decision-makers) and that it can be a challenge "to inform [decision makers of their results] without over-simplifying" or exaggerating the data. It is suggested that without formal training "it is easy for academics to make policy recommendations that are naive in the broader context." With the public's interest in health and environmental safety increasing along with a rise in misinformation, it is important that regulatory agencies and academics are able to communicate complex scientific concepts and decisions to the public in a way that is clear and transparent.

Summary and recommendations

In answering question 1, we found that ECRs receive training and skills development through diverse pathways. Formal routes, such as Master's courses, PhD programs, and doctoral training partnerships or networks, are complemented by informal pathways such as on-the-job mentorship, peer discussion, and self-directed study. In addition, collaborative partnerships (placements, internships, secondments) and sectoral workshops (e.g., SETAC courses) further supply essential competencies in statistics, method validation, GLP/QC, and OECD/ISO guidelines.

In question 2, we identified five main barriers to training and skill development that ECRs consider to affect the applicability of their research to regulatory decision-making. These include limited opportunity, availability, and accessibility (institutional

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inertia, geographic inequities, high costs); lack of relevance, reliability, and compatibility of research (misalignment of theoretical research with hands-on regulatory standards); lack of awareness, engagement, and collaboration (weak cross-sector networks, poor dissemination of opportunities); competing goals, demands, and priorities; and limitations of resource and expertise.

We found that although previously identified challenges, such as gaps in interdisciplinary collaboration, QA/GLP uptake, and government–industry involvement, persist, we identified a series of new and emerging challenges that ECRs face in applying academic research to regulatory decision-making (question 3). These include the tension between traditional toxicology and new approach methodologies, a lack of alignment in academic incentives and regulatory demand, and obstacles in translating complex findings into policy-ready outputs.

We set out a series of initial recommendations (Table 2), specific to ECRs, that build on those previously identified in the literature (Rudén et al., 2017; Ågerstrand et al., 2017; Jones et al., 2025). Previous studies such as Rudén et al. (2017) recommended that scientists can increase the use of peer-reviewed literature in regulation by explicitly assessing and addressing the relevance of their work to regulatory requirements (Table 2). Ågerstrand et al. (2017) listed 10 actions for academics to enhance the regulatory relevance of their chemical research. These include increasing the regulatory usefulness of peer-reviewed data by reporting studies in a way that enables regulatory use and placing academic studies in a regulatory context (Ågerstrand et al., 2017; Table 2). Efforts have been made to increase the reliability, reproducibility, and reporting of academic literature. These include peer-reviewed reporting criteria for reporting and evaluating ecotoxicity data (Moermond et al., 2016), evaluating behavioral toxicity data (Bertram et al., 2025), and evaluating exposure datasets in environmental assessments (Merrington et al., 2024). In addition, OECD harmonized templates (OECD, 2025) for standard data formats have been developed to avoid insufficient reporting detail by academics trying to better contextualize their work into meeting regulatory requirements (Carnesecchi et al., 2023). However, Ågerstrand et al. (2017) and Moermond et al. (2016) suggest that many researchers are unfamiliar with these guidelines and journal editors do not apply the regulatory guidelines consistently, hindering the uptake and inclusion of academic work in regulatory applications.

In a recent study, Jones et al. (2025) found that technical or scientific factors limiting the uptake and use of academic research in regulatory decision-making (i.e., the relevance, reliability, and reporting of academic data) are often reliant or interdependent on social factors such as a misalignment in the goals and demands of academic and regulatory knowledge production or lack structures for knowledge exchange and effective communication (Table 2). They identified a series of system-level factors that limit the uptake and use of academic research in regulatory decision-making and policy and set out a series of recommendations, actions, and opportunities to overcome these factors. These recommendations included elements of codesign, implementation of open access principles, sustained and cross-sector participation, and development of inclusive multisector knowledge exchange platforms (Table 2, Jones et al., 2025).

Although the new and emerging challenges set out in this research are not exhaustive, we consider them to be a useful addition to those previously identified. Although we purposefully did not collect detailed geographic data, the study is constrained by its focus on the European regulatory toxicology system. Although international perspectives were collated, as evidenced by several respondents who provided examples beyond the European sphere, the participant pool is predominantly situated within a European context, and thus we cannot assume that the insights gained through this research represent the global ECR community. We suggest that further studies could extend this research to more comprehensively capture and compare diverse insights and perspectives from ECRs across the globe.

Future efforts should seek to strengthen pathways through which ECRs (and others) acquire and apply regulatory-relevant skills to overcome barriers to training and support the application of academic research to regulatory decision-making. Although the focus of this research is on the perspectives of ECRs, we believe that the requirement for training and skills development will likely be applicable to other career stages, especially in areas of emerging challenge and methodological development, and consider the recommendations set out here to be of relevance or interest to the wider research community.

Supplementary material

Supplementary material is available online at *Integrated Environmental Assessment and Management*.

Data availability

The survey data underlying this article cannot be shared publicly due to the absence of ethical approval for public dissemination or use and informed participant consent for data sharing.

Author contributions

Lowenna Jones (Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing—original draft, Writing—review & editing), Susanna Mölkänen (Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Software, Validation, Visualization, Writing—review & editing), Grzegorz Sowa (Conceptualization, Investigation, Methodology, Writing—original draft, Writing—review & editing), Niamh O'Connor (Conceptualization, Visualization, Writing—review & editing), Dylan Asbury (Conceptualization, Methodology, Writing—review & editing), Rana Al-jaibachi (Conceptualization, Methodology, Writing—review & editing), Thomas Malpas (Conceptualization, Writing—review & editing), Hana Mayall (Conceptualization, Writing—review & editing), and Harry Bond-Taylor (Conceptualization, Writing—review & editing)

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Conflicts of interest

The authors declare no conflicts of interest.

Disclaimer

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