

From training to implementation: building capacity in invasion science

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Abstract

Effective management of biological invasions requires scientifically robust decision-support tools and the capacity to apply them consistently. Risk identification is the first step of invasion risk analysis, yet comparatively little attention has been given to how such tools are transferred into operational use. This paper describes an international training programme based on the Invasiveness Screening Kit (ISK) decision-support tools, originating in 2023 from a commission by the International Trade Centre under the ARISE+ Malaysia project for training in the Aquatic Species Invasiveness Screening Kit (AS-ISK). The original four-day programme comprised four Modules subdivided into Sessions and Topics; this architecture was retained while content was updated to incorporate methodological and software developments and new applications. Between August 2023 and April 2026, ten training activities were delivered across academic, governmental, conservation and industry settings to 170 participants representing 50 institutions and organisations across 15 countries. Formal evaluation of the two ITC/ARISE+ Malaysia workshops documented mean pre- to post-training knowledge-score increases of 17.0 and 24.8 percentage points, with more than 80% of participants improving. Across successive deliveries, the curriculum progressed from risk-analysis concepts and screening protocol to hands-on ISK use, statistical analysis, interpretation and communication, while examples and exercises were adapted to context. Post-training trajectories were heterogeneous, with a multinational regional programme providing the clearest example of training embedded within coordinated implementation through a harmonised transboundary risk-identification exercise. Formal training, systematic updating, contextual adaptation and continuing technical support should be regarded as components of the implementation infrastructure required to translate invasion-risk science into reproducible decision support.

Key words: biosecurity; capacity building; decision support; invasive species; Invasiveness Screening Kit (ISK); risk analysis; risk identification

Introduction

Biological invasions are a major component of global environmental change, with invasive species (*sensu* Soto et al., 2024; Vilizzi et al., 2025b) capable of adversely affecting biodiversity, ecosystem processes, human well-being and economic activities (Early et al., 2016; Haubrock et al., 2026). Prevention, early detection and prioritisation are therefore central to biological invasion management because interventions generally become more difficult, expensive and uncertain once a non-native species has become established and widespread in the recipient environment (Roy et al., 2024; Egawa et al., 2026). The ability to identify potentially invasive species before, or during the early stages of, their introduction consequently represents a crucial component of national and regional biosecurity capacity (e.g. O'Shaughnessy et al., 2023; Vilizzi et al., 2026c).

Within biological invasion risk analysis, risk identification, also referred to as risk screening, constitutes the first analytical step, followed by risk assessment and risk management (Vilizzi et al., 2026c). Its purpose is to identify those non-native species posing an elevated risk of invasion and hence warranting further evaluation through comprehensive risk assessment and subsequent consideration of management options (Britton et al., 2011; Copp et al., 2016). Risk identification should therefore not be conflated with either risk assessment or risk management, as its outputs provide evidence for prioritising these subsequent activities (Vilizzi et al., 2026c).

A range of decision support tools has been developed to assist risk identification of non-native species (Srèbalienè et al., 2019; Canavan et al., 2025). Among these, the Invasiveness Screening Kit (ISK) family of decision support tools derives from the Australian Weed Risk Assessment protocol (Pheloung et al., 1999; Gordon et al., 2008) and uses structured questionnaires, evidence-based responses and semi-quantitative scoring to quantify and rank the invasion risk of non-native species. These toolkits have been applied extensively across a wide range of taxonomic groups and geographical contexts, with 209 applications undertaken across 266 risk assessment areas and encompassing 1,927 taxa over a 21-year period (Vilizzi, 2026). The framework originated with the freshwater Fish Invasiveness Screening Kit (FISK: Copp et al., 2005a, 2005b, 2009; Lawson et al., 2013) and subsequently expanded to other taxon-specific aquatic toolkits (Copp, 2013). These were superseded by the second-generation multilingual Aquatic Species Invasiveness Screening Kit (AS-ISK), which extended screening to all aquatic taxonomic groups and incorporated a climate-change assessment component (Copp et al., 2016, 2021), followed by the siblings Terrestrial Animal Species Invasiveness Screening Kit (TAS-ISK: Vilizzi et al., 2022c) and Terrestrial Plant Species Invasiveness Screening Kit (TPS-ISK: Vilizzi et al., 2024). Following harmonisation of their questionnaires (Vilizzi et al., 2025a), ISK v3 now integrates AS-ISK, TAS-ISK and TPS-ISK within a single platform with enhanced database-management, taxonomic-validation and risk-calibration functions (Vilizzi and Al-Marhoun, 2026).

The development and availability of the ISK decision support tools for risk identification, however, represent only one part of the pathway between scientifically robust methodology and effective biological-invasion management. This is because availability of a toolkit does not guarantee that it will be applied correctly. Scientifically defensible risk-screening outcomes depend upon numerous methodological decisions, including identification of suitable assessors, definition of the risk assessment area, appropriate selection of species, compilation and evaluation of evidence, interpretation of questionnaire items, assignment of confidence levels, calibration of thresholds and consistent presentation of results (Vilizzi et al., 2022a, 2022b). Incorrect implementation at any of these stages can reduce comparability among applications and potentially influence subsequent prioritisation decisions (Vilizzi and Piria, 2022).

This implementation problem becomes particularly relevant when risk-identification procedures are transferred among research groups, governmental agencies, countries or regions. Here, implementation refers to the subsequent application of the risk-identification methodology in research, institutional assessment or coordinated screening activities hence it does not imply that training itself constitutes management action or policy adoption. Differences in institutional capacity, technical expertise, access to information, language and previous experience with formal risk analysis can lead to substantial variation in the application of otherwise standardised methods. Recent surveys of practitioners have likewise highlighted the importance of practical constraints and institutional context in invasive-species risk assessment (Canavan et al., 2025). Capacity building is therefore an important component of the transition from methodological development to operational implementation, with structured training providing one mechanism for addressing this gap (Elliott et al., 2018; Verbrugge et al., 2021; Loffeld et al., 2022; Canavan et al., 2025; Lower et al., 2025). Therefore, effective training in risk identification should extend beyond instruction in toolkit operation to include the conceptual basis of risk analysis, study design, evidence compilation and evaluation, treatment of uncertainty, calibration, interpretation and communication of screening outcomes (Johnson et al., 2015; Loffeld et al., 2022). A common training framework may also contribute to methodological consistency where multiple assessors, institutions or jurisdictions are expected to apply the same decision-support procedure (Canavan et al., 2025).

Against this background, the present study describes the development and delivery of an international training programme in biological-invasion risk identification based on the ISK decision support tools between August 2023 and April 2026. The programme encompassed individual researcher mentoring, small-group training, governmental and academic workshops, formal university teaching, industry- and conservation-sector training, and multinational regional capacity building. The objectives were to: (i) document the institutional, geographical and organisational range of the training activities; (ii) describe the common instructional framework maintained across training activities and its adaptation to different participant groups and contexts; (iii) examine how a standardised but continuously updated curriculum can support progression from methodological training towards practical implementation; and (iv) identify broader lessons for capacity building in biological invasion science.

Methodology

Programme development and delivery

The international training programme originated in 2023 from a specific request for capacity building under the EU-funded ARISE+ Malaysia project, which was implemented to support greater economic integration in ASEAN countries through the ASEAN Economic Community Blueprint 2025 (<https://www.intracen.org/our-work/projects/malaysia-trade-related-assistance-arise-malaysia>). The project was coordinated by the International Trade Centre (ITC), a multilateral agency with a joint mandate of the World Trade Organization and the United Nations through the United Nations Conference on Trade and Development, in partnership with the Malaysian authorities. Following a request from Malaysia's Department of Fisheries to ITC for in-depth training in AS-ISK, ITC engaged the author to design and deliver a four-day workshop on "Risk screening of non-native species with AS-ISK" in Putrajaya on 21–24 August 2023 (International Trade Centre, 2023). The assignment required development of the workshop programme and interactive training materials, delivery of the training, provision of methodological guidance and preparation of the associated workshop report. In accordance with the standardised structure specified by ITC, the training programme was organised into thematic sessions within a nested Module–Session–Topic curriculum.

The original package included the lecture sequence (agenda), presentation slides, guided and independent practical exercises, worked case studies, software demonstrations, examples of database construction and use, statistical and threshold-calibration exercises, risk-screening templates and supporting documentation. Following the Putrajaya workshop, this package became the master curriculum for all subsequent ISK training activities. Its hierarchical structure was retained, while the content was reviewed and updated before each subsequent delivery to incorporate the latest developments in the ISK tools, including the addition of TAS-ISK and subsequently TPS-ISK methodological advances in screening and calibration, newly published ISK applications and synthesis studies (see Vilizzi, 2026), as well as updated examples and case studies. The master package has consequently expanded since 2023 from approximately 1,000 to more than 1,200 presentation slides, together with associated exercises and supporting material.

This combination of structural continuity and continuous scientific updating allowed the training programme to retain a common methodological framework while remaining responsive to developments in invasion risk identification. Individual examples, practical exercises and case studies were adapted to the geographical, taxonomic and institutional context of each training activity. Variation among successive deliveries therefore reflected deliberate updating and contextual adaptation rather than changes in the underlying analytical principles or instructional framework.

Presentation slides used for delivery were supplied to organisers in Microsoft PowerPoint Show format and branded with the logo of the host or commissioning institution. Participants received the full set of slides as PDF handouts, together with the applicable ISK decision-support tool(s), exercises and supporting documentation. The curriculum, scientific content, teaching materials, practical exercises and successive revisions were continuously updated, whereas host institutions and commissioning organisations supported participant involvement, logistics, institutional branding and programme delivery. All training activities considered in this study were personally delivered by the author.

Training format and participants

The programme was designed principally for academic researchers, environmental managers, policy officers, governmental personnel, consultants and other practitioners involved in biological-invasion research, biodiversity conservation and environmental decision-making, and one delivery was adapted for undergraduate university education. Training activities were delivered over four or five days except for an eight-week online course. These were therefore delivered either in person or through fully interactive live online teaching. Irrespective of delivery mode, the training combined theoretical instruction, guided exercises, practical application of the relevant ISK tools and real-world case studies. Examples and exercises were adapted to the participants' geographical context, organismal groups (i.e. aquatic organisms, terrestrial animals or terrestrial plants) and likely subsequent applications while retaining the same screening protocol and analytical principles. Online training activities included live software demonstrations and supervised practical work rather than lecture-only delivery. The ISK software used during each training activity reflected the version(s) of the relevant second-generation ISK tool(s) available at the time.

Formal post-workshop feedback surveys were administered for the two ARISE Plus Malaysia training activities. Two workshop facilitators were present throughout each activity to support organisation and participant coordination, including administration and collection of the pre-

and post-training knowledge assessments and post-workshop feedback surveys. These surveys evaluated participant satisfaction, perceived gains in knowledge and understanding, perceived professional utility of the training, and aspects of workshop organisation and delivery. For both ITC/ARISE Plus Malaysia workshops, participants completed the same structured 15-item knowledge questionnaire immediately before and after training to assess understanding of the principal concepts and procedures covered by the course. One point was awarded for each correct response and individual scores were expressed as percentages of the maximum possible score. Pre- and post-training responses were matched at participant level for calculation of individual changes in score. Analyses were descriptive and comprised mean percentage scores, percentage-point changes and the proportion of participants achieving higher post-training scores; no inferential statistical tests were undertaken because the assessments formed part of routine workshop monitoring and evaluation rather than a controlled educational study. Notably, the questionnaire forms part of ITC workshop evaluation materials and is not owned by the author; accordingly, the instrument itself is not reproduced here. Only aggregate, non-identifiable evaluation results are reported. Post-training trajectories were described only where subsequent activities were known to the author through continued professional contact, documented project involvement or published outputs; no systematic longitudinal follow-up was undertaken. Certificates of attendance were provided following the training activities.

Curriculum structure

The curriculum was organised hierarchically into Modules, Sessions and Topics, following the nested structure specified by ITC for the 2023 ARISE Plus Malaysia workshop in Putrajaya. Each Module represented a broad component of the risk-identification process, each Session addressed a defined methodological or practical element within that Module, and individual Topics provided the detailed instructional content. The original four-day curriculum comprised four Modules (Table 1):

Module 1 – Risk analysis and decision-support tools covered the foundations of risk analysis, including its definition, history and components; its application in invasion science; Weed Risk Assessment-type approaches; first- and second-generation ISK tools; comparisons with other screening methods; and opportunities for future application.

Module 2 – Risk screening protocol covered identification of assessors, definition of the risk assessment area, species selection and categorisation, and compilation of species information from taxonomic, species-specific, global and regional databases and the scientific literature.

Module 3 – Invasiveness Screening Kits focused on practical operation of the software, including the graphical user interface, data manipulation, screening of sample species, generation of outputs and reports, and multilingual functionality.

Module 4 – Statistical analysis and publication addressed calibration, confidence, threshold computation, risk outcomes and ranking, and preparation and communication of results through text, tables, charts and supplementary material.

This Module-Session-Topic hierarchy has remained the common organisational framework of the training programme. Subsequent training activities retained the same conceptual progression while individual Sessions and Topics were updated, expanded or adapted according to developments in the ISK tools and methodology, the duration of the course, the participants' experience and the geographical and taxonomic context in which the training was delivered.

Results

Programme reach and delivery contexts

Between August 2023 and April 2026, ten training activities in total were delivered across a wide range of institutional and organisational settings (Table 2). The activities involved 170 participants representing 50 institutions and organisations across 15 countries (Supplementary Table S1).

The first delivery took place in Putrajaya, Malaysia, in August 2023 and involved 27 participants representing 12 academic and governmental institutions and organisations. A second four-day ARISE Plus Malaysia workshop was delivered for the Sabah Fisheries Department in Kota Kinabalu in November 2023 for 35 participants representing eight academic and governmental institutions and organisations. Between these two larger workshops, the same curriculum was adapted for a four-day specialist course held in Lodz (Poland) involving three representatives of the Norwegian Institute of Public Health.

In June 2024, a four-day live online workshop was delivered to six participants from six Chinese research institutions, coordinated by Beijing Upcloud Data Technology Co., Ltd (Beijing Upcloud Data Technology Co., Ltd, 2024). From August to November of the same year, the programme was adapted to an eight-week online format for 30 undergraduate students at the University of Santo Tomas in Manila (Philippines), with three-hour sessions distributed across the teaching period.

The programme broadened further in 2025. A five-day regional workshop delivered in Kuwait in January involved 25 experts representing 16 academic, governmental and intergovernmental institutions and organisations across all eight Member States of the Regional Organization for the Protection of the Marine Environment (ROPME): Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. A five-day in-person course at Yerevan State University (Armenia) in March involved 14 participants representing five academic and governmental institutions and organisations (Yerevan State University, 2025). In June, a five-day one-to-one course was delivered in Lodz (Poland) to an academic participant from the Water Research Institute of the Italian National Research Council (IRSA-CNR), Verbania (Italy); and in July a five-day online course was delivered to 24 participants associated with Sarawak Energy and the Bakun Hydroelectric Power Plant in Malaysia. The most recent activity was a four-day online workshop delivered in April 2026 to five participants from the Charles Darwin Foundation in Galápagos, Ecuador.

Formal evaluation was available for both ITC/ARISE Plus Malaysia workshops. In Putrajaya, among the 27 participants with paired assessments, the mean knowledge score increased from 47.2% before training to 64.2% after training, a gain of 17.0 percentage points, with 81.5% achieving a higher post-training score. All respondents reported being satisfied with the training, 93% reported increased knowledge and understanding of aquatic species invasiveness screening, and 96% considered the information and sharing of best practices useful for their professional work. Regarding practical utility, 61% reported that the training would enable them to undertake new activities or techniques, 25% that it would help them perform existing work more effectively, and 14% that they could or would apply the learning in their work. In Kota Kinabalu, the mean score increased from 50.3% to 75.0%, a gain of 24.8 percentage points, with 82.9% of the 35 participants improving. All respondents reported satisfaction with the training, 100% reported increased knowledge and understanding, and 94% considered the information and sharing of best practices useful for their professional work.

For the two ITC/ARISE Plus Malaysia workshops, the ROPME workshop and the Yerevan State University course, certificates were issued by the respective organising institutions. For the Sarawak Energy and Charles Darwin Foundation training activities, certificates were prepared and issued directly by the author. Certificates for the China training were arranged through Beijing Upcloud Data Technology Co., Ltd.

Curriculum adaptation and progression to implementation

Across the ten training activities, the Module–Session–Topic architecture established for the first ITC workshop remained the common organisational framework. The content delivered within that structure nevertheless evolved over time as successive versions of the ISK tools became available, methodological procedures were refined, and new ISK applications and synthesis studies were published.

Examples and practical exercises were also adapted to the geographical setting, organismal focus and likely operational needs of each participant group. The University of Santo Tomas undergraduate course was delivered within an academic setting with an established trajectory of AS-ISK research on non-native freshwater fishes in the Philippines (To et al., 2022; Gilles et al., 2023, 2024, 2025). The individual training undertaken for the Water Research Institute–National Research Council (IRSA-CNR) was similarly held within an established research context in which AS-ISK had been applied (Boggero et al., 2025). The Sarawak Energy training associated with the Bakun Hydroelectric Plant was delivered in a management context in which aquatic invasive species were already recognised as a biodiversity concern (Smith et al., 2025). These contrasting settings illustrate how the same methodological framework was adapted to established academic research, individual specialist training and industry-based environmental management.

Training scale and mode affected the way in which the curriculum was delivered rather than the analytical workflow being taught. Larger workshops relied more heavily on collective demonstrations and structured practical exercises, whereas small-group and individual training allowed greater use of participant-specific examples and case studies, direct troubleshooting and iterative discussion. The eight-week University of Santo Tomas course distributed the curriculum across successive teaching sessions, whereas the intensive professional activities were generally completed within four or five days. Online delivery retained live software demonstrations and supervised practical work. Additional facilitation and language support were incorporated where required by the delivery context. During the China training, a Chinese-speaking scientist acted as a facilitator throughout, supporting communication and interaction between the instructor and participants. At the University of Santo Tomas, a member of the host institution acted as a facilitator throughout the course, supporting interaction with the students and coordination of the online training. During the ROPME workshop, interpretation was provided in Arabic and Persian, and two participants served as facilitators, respectively, for attendees from the GCC Member States and Iraq and for Iran.

Subsequent uptake of the training was heterogeneous and could not be inferred simply from workshop attendance or short-term evaluation outcomes. Three activities provide particularly clear examples of training being linked to wider applications. The January 2025 ROPME workshop in Kuwait involved participants from all Member States trained within a common methodological framework. The workshop was subsequently followed by the development of a regional biosecurity baseline for the ROPME Sea Area (Vilizzi et al., 2026a, 2026b) as part of a longer-term project (AlMulla, 2025; Muscat Daily, 2025). The March 2025 Yerevan State University training forms part of an ongoing 2025–2029 national research programme on

invasive animals in Armenia. In Galápagos, the Charles Darwin Foundation team had already begun applying AS-ISK to marine non-indigenous species in Galápagos and the wider Eastern Tropical Pacific before requesting dedicated training for five staff members in April 2026. These examples therefore represent training that respectively preceded, formed part of, or strengthened a wider application of invasion risk-identification methods.

Other activities followed less clearly documented trajectories. Participants associated with the Chinese and Norwegian training activities are known to have remained involved in risk-screening work, although no formal follow-up evaluation was undertaken and the extent to which this reflected the training cannot be determined. In Sabah, interest was expressed in developing a broader case study of non-native species, including terrestrial taxa, although no further implementation support was provided beyond the agreed post-workshop period. For some of the remaining activities, subsequent institutional uptake was either limited or not formally documented. Overall, these varied trajectories indicate that training may provide the technical capacity required for subsequent application, but its translation into sustained institutional implementation also depends on organisational priorities, available resources and opportunities for continued use.

Discussion

Training design as implementation infrastructure

The international ISK training programme illustrates a practical but often underemphasised component of biological invasion risk analysis: decision support methods require implementation capacity. A well-developed and scientifically validated screening toolkit such as the ISK is not ‘self-executing’. Its reliability in practice depends on how assessors define the problem, select the risk assessment area and species, assemble and evaluate evidence, interpret questionnaire items, assign confidence, calibrate thresholds and communicate the resulting prioritisation. For this reason, training should be regarded as part of the infrastructure through which a risk-identification method is transferred into operational use, rather than as an ancillary dissemination activity.

A source of continuity in the training activities is that the same person developed the current ISK software platform and associated screening workflows, created the original training package, maintained and updated it, and personally delivered every training activity included in this study. This provided continuity in instructor interpretation, particularly for concepts at the core of the appropriate use and implementation of the ISK tools (Vilizzi and Piria, 2022; Vilizzi et al., 2022a). At the same time, the course content extended well beyond software operation. Participants were trained to understand and defend the analytical choices underlying a screening, because technically correct use of a software interface cannot compensate for an inappropriate study design, poor evidence or incorrect interpretation of calibrated thresholds.

The formal evaluations of the two ITC/ARISE Plus Malaysia workshops documented measurable short-term gains in participant knowledge. Mean pre- to post-training scores increased in both workshops, while most participants achieved higher scores following training and reported increased understanding and professional relevance of the material. These outcomes should nevertheless be interpreted as evidence of immediate learning rather than of subsequent institutional implementation (Sawrey et al., 2019; Loffeld et al., 2022). The contrasting post-training trajectories observed across the programme reinforce this distinction: acquisition of methodological knowledge and competence is a necessary component of implementation, but sustained application also depends on institutional priorities, resources and opportunities to use the methodology in practice (Sawrey et al., 2019; Loffeld et al., 2022).

Methodological consistency did not imply geographical uniformity. ISK screenings are explicitly conditional on a defined risk assessment area, and the evidence relevant to entry, establishment, spread, impacts and climate change necessarily varies among regions. The programme therefore retained the same analytical workflow while adapting examples, exercises and case studies to the participants' taxonomic and geographical context. This distinction between standardising the method and adapting the application is particularly important where assessments are intended to be comparable across institutions or jurisdictions (Vilizzi et al., 2022a).

Scaling training across institutional and geographical contexts

The ten activities demonstrate that the training programme can be deployed at very different institutional and participant scales without changing the underlying methodological approach. The IRSA-CNR course involved a single researcher, the Norwegian course three participants and the Galápagos course five, whereas larger institutional courses involved 14–35 participants and the ROPME workshop brought together experts from all eight Member States. These formats should not be ranked simply by participant number. Individual or very small-group training permits intensive methodological discussion and troubleshooting; larger institutional workshops can establish a shared baseline of competence; and multinational programmes can additionally promote consistency across political boundaries.

Delivery mode was similarly flexible. The programme was implemented through both in-person and fully interactive online courses, while the University of Santo Tomas course distributed the curriculum over eight weeks rather than concentrating it into four or five consecutive days. Online delivery widened access to geographically dispersed groups in China, the Philippines, Malaysia and Galápagos, but its value depended on retaining live software demonstrations, supervised exercises and opportunities for discussion. Conversely, in-person and small-group formats provided greater scope for immediate troubleshooting and participant-specific work. The relevant issue is therefore not simply online versus in-person delivery, but whether the format preserves sufficient interaction, practical application and continuity of support (Loffeld et al., 2022).

The multilingual architecture of the ISK tools adds a further implementation dimension. Training was generally delivered in English, particularly for multinational audiences, but language support was provided where necessary through interpretation or facilitation, as in the Chinese and ROPME workshops. Participants were also able to work with the software in the language most appropriate to their national context. Methodological harmonisation therefore does not require linguistic homogenisation: a common analytical structure can be maintained while facilitating local use, participant interaction and communication of results to managers and stakeholders who may not routinely work in English (Copp et al., 2021).

The strongest example of training embedded in a real implementation pathway is the ROPME programme. This resulted from a broader ROPME project (Al-Dimashki and Al-Ahmad, 2025) rather than from the workshop alone, but the training provided a common methodological foundation before the coordinated assessment was undertaken. This distinction is important when considering the relationship between capacity building and management. Training does not itself constitute biological-invasion management, nor does successful completion of a course demonstrate improved management outcomes. Its role is intermediate: it can strengthen the competence required to generate reproducible risk-identification evidence, which may then support subsequent comprehensive risk assessment and management prioritisation. In practical

terms, the pathway is from decision-support methodology to structured training, assessor competence, reproducible screening, an institutional evidence base and, ultimately, better-informed prioritisation.

Limitations and future directions

The programme's single-developer, single-instructor structure represents both a strength and a limitation. It ensured continuity between toolkit development, curriculum design, successive updates and teaching, but it also means that this synthesis is authored by the person who developed and delivered the programme being described. The present paper therefore documents programme structure, evolution, reach and examples of implementation rather than providing an independent evaluation of teaching effectiveness – but see the formal post-workshop evaluation described above.

The workshops were initially organised to build practical capacity, not as a controlled educational study. The ITC knowledge questionnaire was developed for operational workshop evaluation rather than as a psychometrically validated educational instrument, and the post-workshop feedback was self-reported. These measures should therefore be interpreted as descriptive indicators of short-term learning and participant perceptions rather than as causal estimates of training effectiveness. Standardised pre- and post-course assessments were not administered across the complete series, and quantitative changes in participant knowledge therefore cannot be estimated retrospectively in a comparable manner. Subsequent institutional use also cannot automatically be attributed to training simply because it occurred afterwards. The strongest evidence is available where training was an explicit component of a wider implementation programme, as in the ROPME case. Heterogeneity among undergraduate students, researchers, governmental practitioners, conservation professionals and industry personnel further limits direct comparison among activities, although it also demonstrates the breadth of settings in which the curriculum has been used. Moreover, the ten training activities arose from specific institutional requests and do not constitute a representative sample of global capacity-building needs or institutional uptake.

Future evaluation should therefore be prospective. A common standardised assessment administered before and immediately after training could quantify changes in conceptual and technical competence, while follow-up after six or twelve months could determine whether participants subsequently completed screenings, contributed to institutional assessments, trained colleagues, produced reports or publications, or used outputs in decision-support processes (Gerrie et al., 2022; Loffeld et al., 2022).

Conclusion

The international training programme described in this study indicates that effective capacity building in invasion risk identification depends on more than access to, or routine use of, a decision-support tool. A stable methodological core, continuously updated to reflect current software, evidence and analytical practice, can provide consistency while still allowing training to be adapted to different institutional, geographical and taxonomic contexts. The varied post-training trajectories observed here further indicate that acquisition of technical competence represents only one stage in implementation, with subsequent application also shaped by organisational priorities, available resources and opportunities for continued use and support. The modular and adaptable structure of the programme also provides a basis for its extension to additional institutional, geographical and taxonomic settings in which capacity for invasion-risk identification is required. Treating training, curriculum maintenance and post-training support as components of the implementation infrastructure of invasion risk analysis may

therefore strengthen the translation of screening methodology into reproducible scientific and decision-support practice. Although developed around the ISK family, the design principles identified here (i.e. a stable methodological core, continuous scientific updating, contextual adaptation, practical application and post-training support) are not toolkit-specific and may be transferable to other structured decision-support approaches in invasion science.

Supplementary material

The following supplementary material is available for this article:

Table S1. Institutions and organisations represented in the international ISK risk-identification training activities delivered between August 2023 and April 2026.

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Author's contribution

Conceptualization: LV. Formal Analysis: LV. Investigation: LV. Methodology: LV. Writing—Original Draft: LV. Review & Editing: LV.

Declaration of Interests

None

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Tables

Table 1. Common hierarchical structure of the Invasiveness Screening Kit (ISK) training curriculum developed for the 2023 ITC/ARISE Plus Malaysia workshop according to the Module–Session–Topic structure specified by ITC (see Table 2). Modules contain Sessions, which in turn contain Topics.

Module	Session	Topic
1 – Risk analysis and decision-support tools	1.a – Background on risk analysis	1.a.1 – Definition
		1.a.2 – History
	1.b – Risk analysis in invasion science	1.a.3 – Components
		1.b.1 – Invasion science
2 – Risk screening protocol	1.c – Weed Risk Assessment-type decision–support tools	1.b.2 – Non-native species risk analysis
		1.c.1 – WRA
		1.c.2 – ISK I tools
	1.d – Comparison and opportunities	1.c.3 – ISK II tools
		1.d.1 – Comparison with other screening toolkits
	2.a – Assessors and risk assessment area	1.d.2 – Future applications and development
		2.a.1 – Identification of assessor(s)
	2.b – Species selection and categorisation	2.a.2 – Definition of the risk assessment area
		2.b.1 – Selection of species for screening
	2.c – Compilation of species database I	2.b.2 – Categorisation of species
		2.c.1 – Species categorisation template taxonomy
	2.d – Compilation of species database II	2.c.2 – species-specific databases global databases
2.d.1 – Regional databases literature		
3 – Invasiveness Screening Kits	3.a – Graphical User Interface	2.d.2 – Outcomes
	3.b – ISK usage I	3.a.1 – Description and features
	3.c – ISK usage II	3.b.1 – Data manipulation
		3.b.2 – Screening of sample species I
4 – Statistical analysis and publication	3.d – Multilingual capabilities and opportunities	3.c.1 – Screening of sample species II
		3.c.2 – Data output and report
	4.a – Calibration and confidence	3.d.1 – Multilingual interface
		3.d.2 – Potential for inclusion of other languages
	4.b – Species risk outcomes and ranking	4.a.1 – Calibration
		4.a.2 – Confidence
		4.b.1 – Threshold computation and confidence
	4.c – Write–up and communication	4.b.2 – Risk outcomes
		4.b.3 – Risk ranking
		4.c.1 – Text
4.c.2 – Tables		
		4.c.3 – Charts
		4.c.4 – Supplementary material

825 **Table 2.** International ISK risk-identification training activities delivered between August 2023 and April 2026.
826 *n* = number of participants.
827

Date	Institution	Country / region	Format	<i>n</i>	Principal context
21–24 Aug 2023	Department of Fisheries, Putrajaya; ARISE+ Malaysia, International Trade Centre	Malaysia	4-day in-person	27	Government and academic capacity building
9–12 Oct 2023	Norwegian Institute of Public Health	Norway	4-day in-person (delivered in Poland)	3	Small-group specialist training
27–30 Nov 2023	Sabah Fisheries Department, Kota Kinabalu; ARISE+ Malaysia, International Trade Centre	Malaysia	4-day in-person	35	Government and academic capacity building
13–16 Jun 2024	Six research institutions coordinated by Beijing Upcloud Data Technology Co., Ltd	China	4-day online	6	Multi-institution research training
Aug–Nov 2024	University of Santo Tomas, Manila	Philippines	8-week online (3 h/session)	30	Undergraduate education
5–9 Jan 2025	Regional Organization for the Protection of the Marine Environment (ROPME)	Kuwait; participants from Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates	5-day in-person	25	Multinational governmental and academic programme
17–21 Mar 2025	Yerevan State University	Armenia	5-day in-person	14	Academic and governmental capacity building
2–6 Jun 2025	Water Research Institute-National Research Council (IRSA-CNR), Verbania	Italy	5-day in-person (delivered in Poland)	1	Individual specialist training
14–18 Jul 2025	Sarawak Energy - Bakun Hydroelectric Power Plant, Bintulu	Malaysia	5-day online	24	Industry/environmental-management capacity building
27–30 Apr 2026	Charles Darwin Foundation	Galápagos, Ecuador	4-day online	5	Conservation-oriented specialist training