ASC EICAT Guidelines for Implementation

1. Purpose of this document

These guidelines serve as a comprehensive roadmap for applying the EICAT (Environmental Impact Classification for Alien Taxa) framework in the context of ASC certified products. The guidelines originate from the EICAT related documents published by the IUCN in 2020 and have been also written to align with the terminology and methods used in aquaculture. They integrate clarifications and guidance on the EICAT framework that have been recently provided by numerous experts within the invasion science community, many of which contributed to the initial development of the EICAT framework (Volery et al. 2020, Vimercati et al. 2022). The document outlines the key features and functionalities of the framework, along with step-by-step instructions on how to use each feature effectively. It will empower users with the knowledge they need to navigate the EICAT assessment process, understand EICAT-related data and how they are to be used for ASC requirements and recommendations by key stakeholders.

2. What is EICAT?

EICAT (Environmental Impact Classification for Alien Taxa) is a unified framework to classify alien taxa based on their impacts on native biodiversity. EICAT responds to the necessity for governments, scientists, conservation organisations, and various stakeholders to transparently evaluate, compare, and predict the magnitudes of the impacts of different alien taxa. This allows for appropriate actions such as eradication, containment, or control measures to be taken wherever necessary. EICAT is a scientific, objective and unified method for classifying alien taxa in terms of the magnitude of their negative environmental impacts in recipient areas. Based on evidence of the impacts they have been causing on native biodiversity in their introduced range, alien taxa are classified into one of five impact categories. Each of these five impact categories represents a different impact magnitude, depending on the level of biological organisation of the native biota impacted (individual, population or community) and the reversibility of this impact. Alien taxa are also classified according to the mechanisms by which these impacts occur: the mechanisms are aligned with those identified in the IUCN Global Invasive Species Database (GISD) http://www.iucngisd.org/gisd/. EICAT is conceptually and structurally related to the IUCN Red List of Threatened Species, where the Red List assesses the risk of extinction for native taxa, while EICAT assesses the negative impact of alien taxa on native taxa.

3. What are EICAT's objectives?

EICAT major objectives are:

(i) identifying most detrimental alien taxa by levels of negative environmental impact,

(ii) the level of impact caused by alien taxa among geographic regions and taxonomic groups,

(iii) predictions of potential future impacts of taxa in different regions,

(iv) the prioritisation and execution of management actions by considering the magnitude of impact and the mechanisms through which impacts are generated.

The last three objectives are shared by other, similarly structured, impact assessment frameworks for alien species such as SEICAT, which evaluates negative socio-economic impacts, and EICAT+, which evaluates positive environmental impacts (Vimercati et al. 2022). Although the use of these frameworks in the context of ASC certified products might be envisioned in the future, only the EICAT methodology is detailed and implemented here. This is because along with habitat loss, pollution, climate change, and overexploitation, invasive alien species are considered today as one of the major threats to native biodiversity, and it is therefore paramount to assess their environmental negative impacts. Since many species farmed in aquaculture are alien (see also glossary) to their surrounding environment, this raises concerns when these animals escape and potentially disturb their recipient ecosystems. The inclusion of the EICAT methodology in the criterion 2.4 (named "alien taxa and native biodiversity") allows for the consideration of scientifically observed impacts caused by alien taxa on native species to inform and facilitate management measures aimed at minimising negative impacts of aquaculture escape on native biodiversity.

4. How has EICAT been developed and used?

From EICAT Categories and Criteria 2020: "The IUCN Species Survival Commission (SSC) Invasive Species Specialist Group (ISSG) were invited by Parties to the Convention on Biological Diversity (CBD) to develop a 'system for classifying invasive alien species based on the nature and magnitude of their impacts' (CBD, 2014). In 2015, the ISSG published a framework and guidelines for implementing the proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT) (Hawkins et al., 2015) developed from the original framework proposed by Blackburn et al. (2014).

Following the publication of Hawkins et al. (2015), Resolution WCC-2016-Res-018-EN Toward an IUCN standard classification of the impact of invasive alien species was adopted at the 2016 IUCN World Conservation Congress. This Resolution requested the SSC to develop EICAT, and to consult with all relevant stakeholders within the

Union to inform this process. It also requested that the SSC integrate the outcomes into the IUCN Global Invasive Species Database and the IUCN Red List of Threatened Species, thus providing an essential background for the achievement of Aichi Target 9 (and subsequent related targets) and SDG Target 15.8. Additionally, the Resolution requested IUCN Council to adopt the framework for the IUCN Environmental Impact Classification for Alien Taxa once the consultation process referred to above had been completed, as the Union's standard for classifying alien species in terms of their environmental impact. In 2017, IUCN undertook a Union-wide consultation on the science underpinning EICAT (Version 1), its processes and governance. The results showed that the Union overwhelmingly supported EICAT becoming an IUCN Standard for classifying alien taxa against the magnitude of their environmental impacts. However, based on feedback received through this consultation process and lessons learnt through its application, significant edits were made to the proposed standard. In 2019, a second Union-wide consultation was undertaken on the EICAT Categories and Criteria (Version 2.3), Guidelines for the application of EICAT (Version 2.3), and the EICAT data reporting template (Version 2.7): the comments received during this consultation resulted in minor edits being made to the documentation. Following this, the IUCN Council (98th Meeting, February 2020), adopted Version 3.3. of the EICAT Categories and Criteria as the Union's Standard for classifying alien species in terms of their environmental impact."

In 2023 the United Nations' Convention on Biological Diversity (CBD) explicitly recommended the implementation of EICAT for reaching the post-2020 goals to globally prioritise invasive alien species for management (CBD 2023; Annex I 15, II 20, IV 1, V 14). EICAT has also been adopted by national agencies and authorities in several countries. In Switzerland, the Federal Office for the Environment (the Swiss environmental agency) has used EICAT in 2022 to prioritise invasive alien species according to their impacts. In South Africa, the South African National Biodiversity Institute (SANBI) has conducted national- level EICAT assessments of 49 high impact species in 2022 to: i) provide the rationale for management and regulation; ii) improve compliance and implementation of intervention measures; iii) resolve conflicts between stakeholders. Finally, EICAT has been used in the last decade by multiple academics and researchers to address eco-evolutionary questions and assess impacts of species belonging to various taxonomic groups such as: birds (Evans et al., 2016, 2020), ungulates (Volery et al. 2021), amphibians (Measey et al. 2016), marine fishes (Galanidi et al. 2018), gastropods (Kesner & Kumschick 2018), bamboos (Canavan et al. 2019) and bark beetles (Forgione et al. 2022).

5. Glossary of key terms used in these guidelines

Taxa (singular taxon). This term is used here to represent species or lower taxonomic levels (subspecies, strains or breeds), including those that are not yet formally described.

EICAT attributes: In EICAT, the biodiversity attributes used to assess impacts caused by alien taxa on native taxa are performance of individuals, population size, and area of occupancy.

- *Individual performance*: any measurable trait that affects the capacity of an individual organism to survive, gather resources, grow, or reproduce. Examples include body mass or size, number of offspring or seeds, physiological rates (such as rates of growth, respiration, calcification, etc.), and immunocompetence. Note that changes in performance do not necessarily lead to changes in population size.
- *Population size*: the number of mature individuals—i.e. individuals known, estimated or inferred to be capable of reproduction—in a population. Note that changes in population size do not necessarily lead to changes in area of occupancy.
- *Area of occupancy*: the area occupied by a certain taxon within its native range, excluding cases of vagrancy. Area of occupancy can decrease as a consequence of extirpation (negative impact on area of occupancy)

Extirpation: Local disappearance of a certain taxon from an area within the native range. Any extirpation event leads to a decrease in the occupancy area of a taxon.

Alien taxa: Taxa moved and introduced, either intentionally or unintentionally through human activities, beyond the limits of their native geographic range (Blackburn et al. 2011), or resulting from selective breeding, hybridisation or domestication (breeds/strains) that now represent distinct infraspecific taxa or even species genetically or phenotypically distinguishable from their ancestors. In the second case, since these taxa have no native occurrences and their existence is the result of human activities, their entire geographic range is alien (Essl et al. 2018). The definition includes any part, gametes, seeds, eggs, or propagules of such taxa that might survive and subsequently reproduce. Natural dispersal of a taxon either within postglacial habitat expansion or due to climate shift does not qualify to label a taxon as alien. Common synonyms of alien used in the literature include non- native, non-indigenous, foreign, introduced and exotic.

Invasive alien taxa: Alien taxa whose introduction and/or spread threaten biological diversity. This definition follows the CBD (COP 6 Decision VI/23). The requirement that an invasive alien taxon causes threat or harm is common in policy usage (see also Executive Order 13112 – Invasive Species, of the United States Government), but less so in scientific usage, where often, “invasive” simply implies that the taxon has spread widely and rapidly from the point of establishment. Since not all alien taxa cause significant negative impacts, impact assessment frameworks such as EICAT enable transparent and evidence-based approaches to identify high impacts alien taxa that can therefore be considered as invasive, either globally or locally.

Environmental impact: A measurable change to the properties of an ecosystem caused by an alien taxon. This definition applies to all ecosystems, whether largely natural or largely managed by humans, but here explicitly considers only changes on the native biodiversity. As a consequence, changes in abiotic properties of the environment caused by an alien taxon are only considered if they affect native biodiversity. The same alien taxon may also have impacts, positive and negative, on human societies and economies, but these are not considered here.

Negative environmental impact: Any decreasing change caused by an alien taxon to one of the chosen attributes of native biodiversity (individual performance, population size, area of occupancy), so that this comes at the detriment of native taxa (Vimercati et al. 2022). Negative impacts describe quantitative and directional variations that can be objectively and consistently measured, regardless of ethical values and societal judgments from various stakeholders, such as NGOs, aquaculture farmers or academics (value-free classification of impact, Vimercati et al. 2021).

Mature individuals: Mature individuals are the number of individuals known, estimated or inferred to be capable of reproduction. When estimating this quantity, the following points should be considered:

- Mature individuals that will never produce new recruits should not be counted (e.g. densities are too low for fertilisation).
- In the case of populations with biased adult or breeding sex ratios, it is appropriate to use lower estimates for the number of mature individuals, which take this into account.
- Where the population size fluctuates, use a lower estimate. In most cases this will be much less than the mean.
- Reproducing units within a clone should be counted as individuals, except where such units are unable to survive alone.
- In the case of taxa that naturally lose all or a subset of mature breeding individuals at some point in their life cycle, the estimate should be made at the appropriate time, when mature individuals are available for breeding.

6. Main steps of EICAT assessment for ASC

ASC EICAT assessments will be performed by following a series of specific steps necessary to transparently understand and replicate the results. Although these steps derive largely from the IUCN EICAT assessment methodology, some modifications have been made to align with ASC scopes and needs. The steps are:

i. Collection of impact observations

ii. EICAT assessment of impact observations

iii. EICAT Contextualization of assessments outcomes

Collection of impact observations

Prior to the assessment phase, raw impact data from the alien range of the taxon being assessed are gathered using an established search protocol. The search is documented in sufficient detail to enable those reviewing the assessment to replicate the protocol. The search for information considers both published and unpublished sources (grey literature), and extends to the following:

Review of scientific publications

Impact data are gathered through searches of:

- online literature databases and catalogues (as a minimum these databases should include the Web of Science (https://login.webofknowledge.com), Google Scholar (https://scholar.google.co.uk) and Scopus (https://www.scopus.com).
- key texts (for example Leppäkoski, Erkki, Stephan Gollasch, and Sergej Olenin, eds. Invasive aquatic species of Europe. Distribution, impacts and management. Springer Science & Business Media, 2013).

The literature search should be exhaustive. A review of the bibliographies/references listed in the articles/data sources found through the initial search should be undertaken to identify any additional sources of information. This process should be repeated to a point where no new sources of data are identified. A search string should be used for effective database searching. The string should include the alien species' scientific and common name, along with relevant terms to identify the impacts of alien species. The following example is a search string to identify impacts associated with the Nile tilapia (Oreochromis niloticus): ("alien" OR "non-native" OR "invasive" OR "pest" OR "exotic" OR "introduce*" OR "escape" OR "aquaculture") AND ("Nile tilapia" OR "tilapia" OR "Oreochromis niloticus") AND ("impact*" OR "effect*").

Review of published and unpublished grey literature

Searches of the world-wide web (e.g. Google) are performed to source impact related reports, working papers, theses, conference proceedings, technical documentation, policy documents, and other documents that have not been through a rigorous peer-review process as traditional scholarly publications.

Review of ratings by and reports from organisations and repositories

Impact observations are gathered by consulting biodiversity and impact related organisations (as a minimum, including the IUCN Red List of Threatened Species (http://www.iucnredlist.org), Delivering Alien Invasive Species Inventories for Europe (DAISIE) (http://www.europe-aliens.org), the CABI Invasive Species Compendium (http://www.cabi.org/isc/) and the Global Invasive Species Database (GISD) of the Invasive Species Specialist Group (ISSG) (http://www.issg.org/database/welcome/).

Consultation with experts and stakeholders

A set of on-line meetings and email exchanges should be arranged and planned to consult with experts and scholars to source additional impact information that can be relevant for conducting EICAT assessments.

Impact observations are recorded in a format compatible with the EICAT Categories and Criteria and with appropriate supporting documentation (IUCN 2020a,b). Data are generally sourced from primary (i.e. not secondary referencing) scientific literature and grey literature (i.e. unpublished or non-commercially published materials). Literature in other languages is also gathered, for instance by using national and regional databases. When incidentally found, data related to socio-economic and positive environmental impacts are also collected and stored separately for potential future use and assessment through other ICAT frameworks (SEICAT and EICAT +). In addition to impact observations, other types of data — for instance the mechanisms by which the impact occurs, the continent/country of impact, the ecosystem in which impacts have taken place or the species impacted — will be recorded in order to contextualise impacts.

EICAT assessment of impact observations

All assessments are based on information gathered during the data collection step. For each alien taxon, the assessment is carried out by considering individual observations of its impact, specifically any instances where the alien taxon of interest has been observed to negatively affect a native taxon. Assessments are conducted in accordance with the EICAT Categories and Criteria (IUCN 2020a), so that every impact observation is assigned an EICAT Category (see 2.1), a confidence score (see 2.2) and an impact mechanism (see 2.3). The assessed impact observations are externally reviewed by the research group of Dr Sven Bacher at the University of Fribourg. Such a group has significantly contributed to the development of EICAT in 2014 and led to the finalisation of its IUCN standards in 2020 (ref). Once collected, assessed through EICAT and reviewed, assessed impact observations can be, at a later time, used to produce scientific papers and made available to the public via on-line repositories. Assessed impact observations can also be submitted to the IUCN EICAT authority (https://www.iucn.org/resources/conservation-tool/environmental-impact-classification- alien-taxa#overview) so they undergo an official review process and are then published on IUCN's Global Invasive Species Database (http://www.iucngisd.org/gisd/).

EICAT Category

There are five distinct categories into which an impact observation can be classified (Figure 1). These categories follow a progressive series of impact scenarios outlining escalating degrees of impact magnitude. Such scenarios are described such that each transition between categories represents a remarkable rise in the magnitude of impact, signifying an increase in the level of biological organisation affected. Consequently:

Minimal Concern (MC) – denotes no discernible decrease in the individual performance of a native taxon.

Minor (MN) – denotes a decrease in the individual performance of a native taxon, but no decrease in the population size or area of occupancy (as a consequence of extirpation) of the same taxon.

Moderate (MO) – denotes a decrease in the population size of a native taxon but no decrease in the area of occupancy (as a consequence of extirpation) of the same taxon.

Major (MR) – denotes a decrease in area of occupancy of a native taxon (as a consequence of extirpation), which would be reversible whether the alien taxon was no longer present.

Massive (MV) – denotes a decrease in area of occupancy of native taxa (as a consequence of extirpation), which would not be reversible even if the alien taxon was no longer present.

The distinction between Major and Massive impacts is drawn on the basis of the reversibility of an impact after the disappearance/removal of the alien taxon from its recipient ecosystem. However, the (ir-)reversibility of extirpations is not only determined by the action of the alien taxon but depends on the context. For instance, native taxa with very dispersal capabilities that have faced extirpation events because of an alien taxon, are often not be able to recolonise an area after the disappearance of the alien taxon. Similarly, taxa that have faced extirpation events on islands or mountain tops, might not be able to recolonise given the existence of natural geographical barriers. On the contrary, the feasibility of human assisted measures (eradication of the alien population, re-introduction of the native taxon, or habitat restoration after the degradation due to the alien taxon) is not evaluated when assessing the (ir-)reversibility of a local extinction. Finally, a global extinction of a taxon caused by an alien taxon denotes automatically a Massive impact, because such an impact is not reversible.

Impacts that align with the Moderate, Major, or Massive categories are considered particularly severe, and thus termed 'harmful', by IUCN, as they involve effects on native taxa at the population level. The same terminology is therefore adopted here.

According to the EICAT Categories and Criteria (IUCN 2020a), a global level assessment of an alien taxon is based on the highest level of impact recorded anywhere in the alien range of the taxon being assessed and across any impact mechanisms. As a consequence, EICAT Category of impact magnitude can also be directly used to categorise the taxon itself. Nevertheless, it is not always possible to classify taxa using the aforementioned categories.

When assessing impacts and categorising alien taxa, the category data deficient (DD) is used to indicate that current observations are insufficient to assess the level of impact. For instance, the alien taxon might have a negative impact on native taxa but no information is currently available to estimate impact magnitude.

When classifying alien taxa, the category No Alien Population (NA) is used when there is no evidence to suggest the taxon has or had individuals existing in the wild (i.e. outside of captivity), beyond the limit of its native geographic range (IUCN 2020a). Moreover, the category Not Evaluated (NE) applies to taxa that have not yet been evaluated against the EICAT impact categories. Finally, the category Cryptogenic (CG) is applied to taxa for which it is unclear, following evaluation, whether individuals present at a location are native or alien. Following the IUCN EICAT Categories and Criteria “CG is not a category in itself; cryptogenic taxa should be evaluated as if they are aliens, on the basis of the precautionary principle, but their impact classification modified by the CG label”.

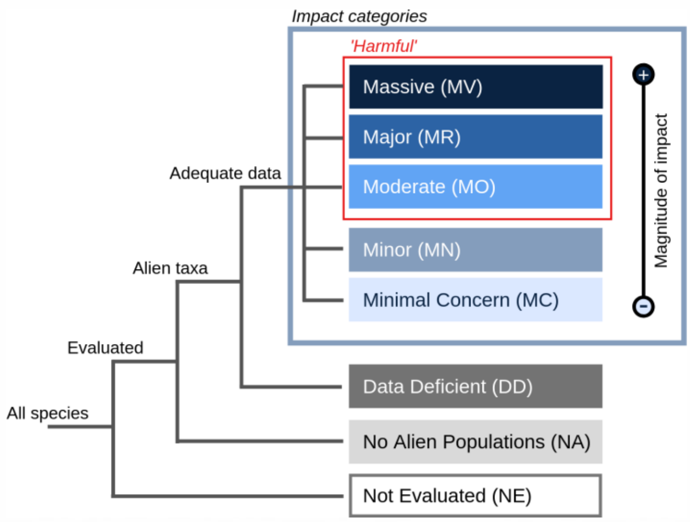

Figure 1 The different EICAT Categories and the relationship between them used by the IUCN.

To assess impacts and categorise alien taxa, EICAT relies exclusively on impacts that have actually been observed, or inferred based on evidence, in the alien range of a taxon. Potential impacts, i.e. estimates of the magnitude of impact that would result if an introduction occurred, and that generally incorporate information from the native range, trait analyses and mechanistic models, are not part of EICAT.

Data instrumental in assessing impact magnitude are broadly classified as either observed or inferred:

- **Observed data:** Information directly based on documented impacts of an alien taxon upon native taxa. In this context, the term "observed data" incorporates empirical observations, designed observational studies (natural experiments) and manipulative experiments that measured impacts of an alien taxon on certain native biodiversity attributes. EICAT biodiversity attributes are individual performance (for impact magnitudes MC and MN), population size (for impact magnitudes MO), and area of occupancy (for impact magnitudes MR and MV). Such attributes can be measured, for instance, by comparing: i) sites before and after the introduction of an alien fish species in a basin; ii) reference plots in areas in which an alien fish species has escaped and areas in which it has not; iii) fenced and unfenced plots within the alien range of a mussel species; iv) sites before and after the removal of an alien shrimp species.

- **Inferred data based on evidence:** Information not directly based on documented impacts of an alien taxon on EICAT native biodiversity attributes but that includes assumptions about relationships between an EICAT biodiversity attribute and another variable acting as a proxy. For example, changes population size (criterion for MO) can be inferred from changes in the number of i) all individuals in a population (index of abundance); ii) changes in catch statistics; iii) mathematical models based on real data; iv) decrease in range or an ecosystem function or service provided by the native taxon. Any assumptions have to be stated and justified in the documentation. In all these examples, even though EICAT native biodiversity attributes were not measured, the observed variables are assumed to be related to them. Variables not directly related to the variables of interest should not be used to infer impacts. For example, changes in abiotic ecosystem properties (e.g. pH, water availability, etc.) should not be used to assign an impact magnitude unless they have been explicitly shown how they are affecting an EICAT biodiversity attribute (individual performance, population size, occupancy area).

Moreover, to be classified in EICAT, changes in the biodiversity attributes have to be observed or inferred in the context in which they are reported: extrapolations or projections in time or space are not considered. For instance, claims as: "The substantial predation by introduced trout on native invertebrates is expected to ultimately result in the extirpation of the latter in the future" (extrapolation/projection in time), or "Events of hybridization between introduced trout and native trout in Europe will likely take place in South America as well, thus causing extirpation in South American native trout (extrapolation/projection in space)" are of no use in EICAT.

Confidence score

In many cases, uncertainty exists about the correct classification of an impact. Each impact assessment is therefore accompanied by an assessment of the level of uncertainty. This is achieved by assigning a confidence score, thereby making the confidence level in each classification evident. Only epistemic or reducible uncertainty (i.e. uncertainty due to data quality) matter here. Uncertainty related to variation in impacts in space or time (stochasticity or irreducible uncertainty) is not considered here, because each impact observation is assessed individually. To put it in context, if two distinct studies describe the same impact of an alien shrimp species on native mussels but at two different times, the confidence score will evaluate how certain we are that each of these studies captured a real impact pattern rather than how the studies relate to each other.

A number of factors (see below) affect the confidence in an assessment, including: the reliability and type of data used as evidence of impacts; the spatial and temporal scales over which data were collected; the ease of interpretation of the available data; the chances of including confounding effects in the observation; and whether or not evidence within a single source of information is contradictory (IUCN 2020). These factors are always considered when a confidence score is given to each individual impact observation under assessment.

- **Data quality and type:** In some cases, information about impacts is inferred from observations of variables that are (seemingly) related to the variables of interest in EICAT (individual performance, number of mature individuals, extinction). Inferred data are likely to provide a much lower level of confidence in the assessment. In addition, many studies focus only on one particular level or organisation (individual level), not investigating higher levels (e.g. whether the impact on the individual performance is affecting the population size). For instance, studies might only investigate whether native fish prey species alter their behaviour in response to the introduction of an alien predator species, but without exploring the consequences of predation at the population level. Uncertainty in the assigned Impact Category can exist in these cases, since the impact might be higher than the observed/reported one, but the study design and reporting of results do not allow to detect such impact.
- **Spatial and temporal scales:** For each individual impact observation, assessors must evaluate the suitability of the spatial and temporal scales over which evidence of impacts is recorded, as this affects the confidence rating of the assessment. A full justification for this evaluation should be provided in the

rationale for the confidence rating, along with details of the spatial and temporal scales at which impacts have been measured. When possible, it is important also to justify how these scales relate to spatial- temporal scale over which the local native population can be characterised or to the probability of detecting the taxon across space and time. For example, research conducted within a restricted geographical area or over a single week will yield lower confidence scores compared to studies carried out across multiple locations or spanning several weeks or months.

- **Confounding effects:** In some cases, it cannot be excluded that other biotic or abiotic factors might have caused or contributed to the observed impact. Under those circumstances, it is difficult to distinguish whether an alien taxon is the main or only driver of environmental changes, or whether there is a significant influence of confounding effects. The likelihood that the impact level would have been observed if the alien taxon was not introduced must be evaluated by the assessor, based on the context in which the impact is happening (e.g. presence of other stressors which are likely to have led to the observed impact even in the absence of the alien taxon). Confounding effects can lead to an over- or underestimation of the impact caused by an alien taxon and their presence can be considered captured by attributing a lower level of confidence.

Impact mechanisms

Alien taxa can cause negative impacts on native individuals and populations through a specific set of well-described mechanisms. These mechanisms, stemming from those proposed by Nentwig et al. 2010, Kumschick et al. 2012 and Blackburn et al. 2014, and aligning with those identified in the IUCN Global Invasive Species Database (GISD) http://www.iucngisd.org/gisd/ are:

(i) Competition – the alien taxon competes with native taxa for resources (e.g. food, water, space).

(ii) Predation – the alien taxon predates on native taxa.

(iii) Hybridisation – the alien taxon hybridises with native taxa.

(iv) Transmission of disease – the alien taxon transmits diseases to native taxa.

(v) Parasitism – the alien taxon parasitizes native taxa.

(vi) Poisoning/toxicity – the alien taxon is toxic, or allergenic by ingestion, inhalation or contact or allelopathic to plants.

(vii) Bio-fouling or other direct physical disturbance – individuals of the alien taxon accumulate on the surface of a native taxon (i.e. bio-fouling), or cause other direct physical disturbances not involved in a trophic interaction (such as trampling, rubbing, etc.).

(viii) Grazing/herbivory/browsing – the alien taxon grazes, browses or fully consume through herbivory native taxa.

(ix) Chemical impact on ecosystem – the alien taxon negatively impacts native taxa by causing changes to the chemical characteristics of the native environment (e.g. pH; nutrient and/or water cycling).

(x) Physical impact on ecosystem – the alien taxon negatively impacts native taxa by causing changes to the physical characteristics of the native environment (e.g. disturbance or light regimes).

(xi) Structural impact on ecosystem – the alien taxon negatively impacts native taxa by causing changes to the habitat structure (e.g. changes in architecture or complexity).

(xii) Indirect impacts through interactions with other species – the alien taxon negatively impacts native taxa by interacting with other native or alien taxa (e.g. through any mechanism, including pollination, seed dispersal, apparent competition, mesopredator release).

EICAT Contextualisation of assessment outcomes

The main objective of EICAT is to compare alien taxa based on their highest observed negative impact at the global level (IUCN 2020). This precautionary principle assumes that certain alien taxa have traits that make them intrinsically more harmful than others, wherever they are introduced (Kumschick et al. in press). However, alien species impacts are also known to be context dependent (Catford et al., 2022; Sapsford et al., 2020), and comprehensive studies are often hindered by data deficiencies across taxa and continents (Evans et al. 2018, Volery et al. 2021). Considering these factors, it may not always be appropriate to generalise the impact of a species across its entire alien range. Conversely, for specific purposes, it appears necessary to contextualise impacts at a finer spatial scale so that regional and local stakeholders, such as those certified under ASC standards, might be effectively informed. Such contextualisation must, however, consider biogeographic and ecological differences. To contextualise EICAT assessments and scale up the highest impact score of each species to the relevant biogeographic areas, two spatial scales will be employed.

1. The smaller spatial scale, named ecoregion, considers 449 Freshwater Ecoregions (Figure 2) of the World (FEOW) and 232 Marine Ecoregions (Figure 3) of the Word (MEOW), as described by Abell et al. 2008 and Spalding et al. 2007. These ecoregions have been outlined by using the distributions and compositions of freshwater and marine biodiversity and accounting for main ecological and

evolutionary patterns. The use of biogeographic ecoregions, which are instrumental in dividing the entire World into discrete areas where the highest impact of alien species can be generalised at the ecoregional level, follows the approach adopted in Volery et al. 2021. These authors suggested to estimate the highest EICAT score within each region separately, and calculate "the species' frequencies of highest impact, which are the numbers of regions in which the alien species caused their highest impact magnitudes (on their total number of regions with impact observations)." Considering this approach, a species that is known for instance to cause, in a specific region, a Moderate impact (i.e. a decline in population size) on three native species and a Major impact (i.e. decline of species occupancy through extirpation) on another species, must be classified as Major within the region. See below a map of the ecoregions used (brown areas are freshwater ecoregions; blue areas are marine ecoregions).

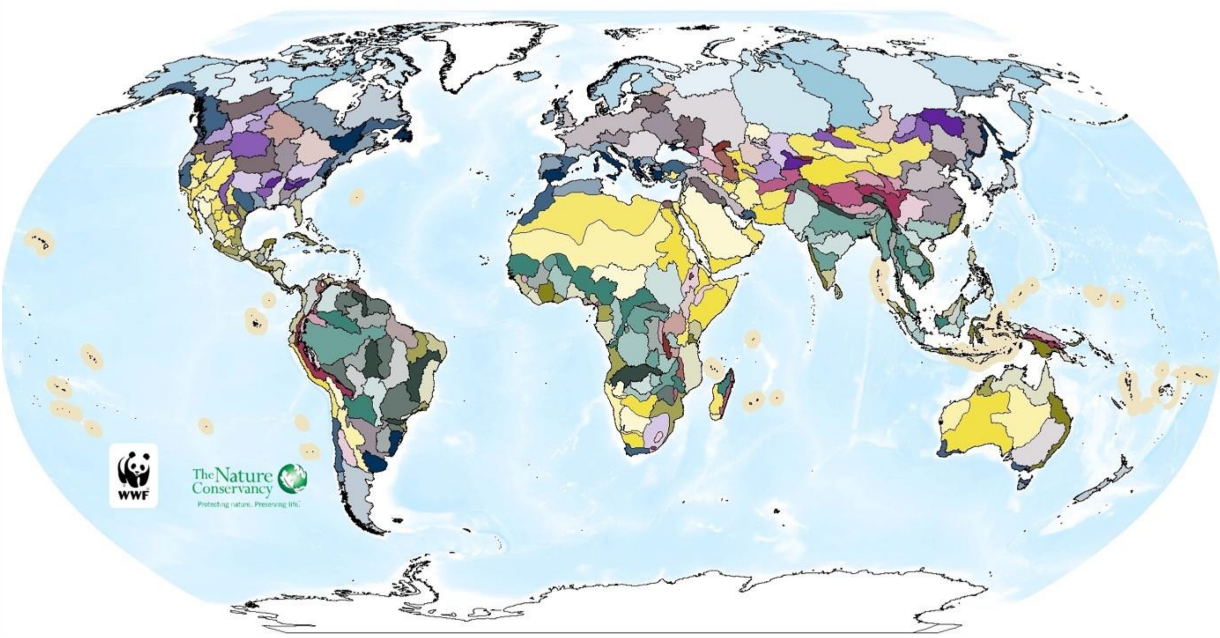

Figure 2 Freshwater Ecoregions

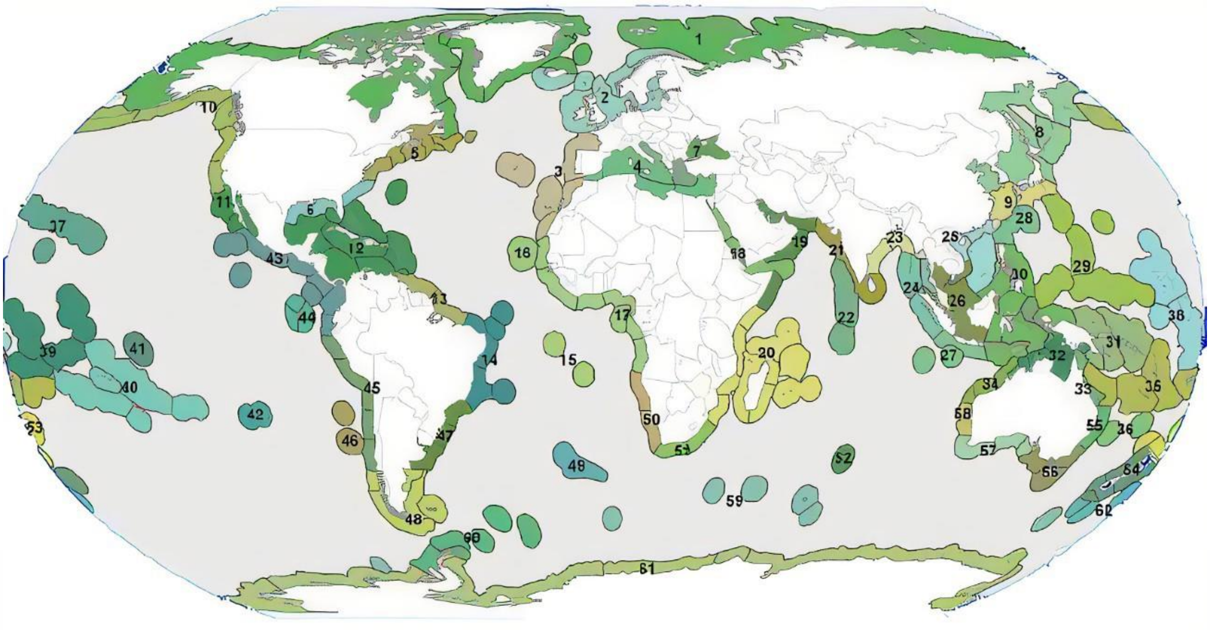

Figure 3 Marine Ecoregions.

2. The larger spatial scale, named realm, considers 8 freshwater realms and 12 marine realms of the world. These realms are used to estimate, for each of them, the frequency of highest impact, which is the number of ecoregions where the species has the highest impacts on the number of ecoregions where the species has been found to have an impact (Volery et al. 2021). This makes it possible to account for the sampling efforts (i.e. which is a measure of how often impacts have been observed) and inform all stakeholders from a specific realm regarding the risk that a species can cause a certain impact. In accordance with Spalding et al. 2012, marine realms used are:

    - Arctic
    - Temperate Northern Atlantic
    - Temperate Northern Pacific
    - Tropical Atlantic
    - Western Indo-Pacific
    - Central Indo-Pacific
    - Eastern Indo-Pacific
    - Tropical Eastern Pacific
    - Temperate South America
    - Temperate Southern Africa

- Temperate Australasia
- Southern Ocean

Freshwater realms, on the other hand, broadly coincide with realms identified for terrestrial ecoregions, as terrestrial and freshwater biodiversity patterns are shaped by similar geographical, climatic, and phylogeographic dynamics (Olson and Dinerestein 2002). Thus, in accordance with Olson et al. 2001 and Abell et al. 2008, freshwater realms used are:

- Paleartic
- Neartic
- Afrotropic
- Neotropic
- Australasia
- Indomalaya
- Oceania
- Antarctic

See Figure 4 of the realms (brown shades outline freshwater realms; blue shades outline marine realms):

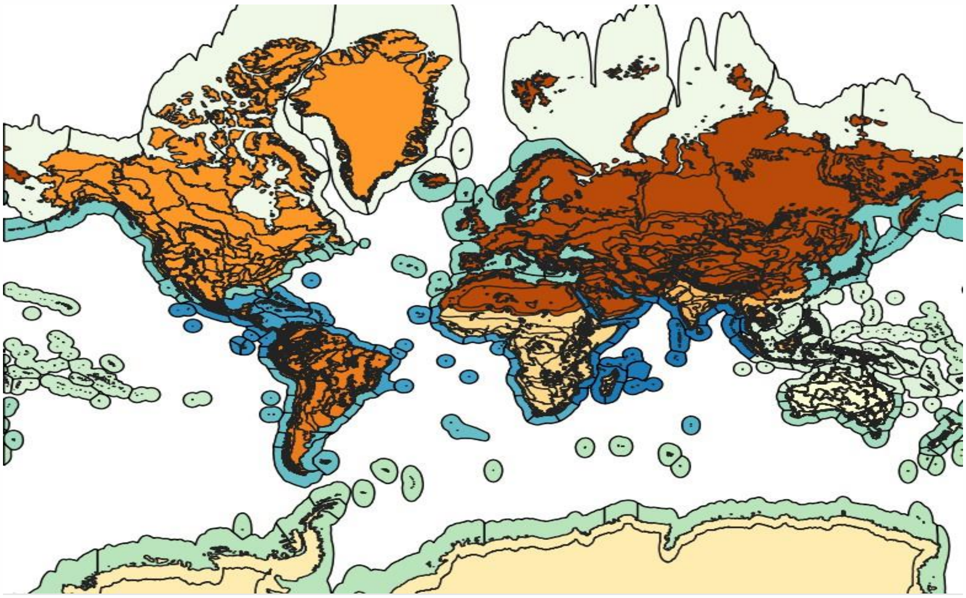

Figure 4 Global realms

For instance, if within the Paleartic realm a species has been classified as Major (as the highest impact score) in three ecoregions out of 15 ecoregions in which impacts have been detected, the frequency of impact (or impact risk, see Volery et al. 2021) is 0.2 (20%). Conversely, if within the Neartic realm, a species has been classified as Moderate (as the highest impact score) in 9 ecoregions out of 10 ecoregions with impacts, the frequency of impacts is 0.9 (90). This approach enables the communication of impact risks posed by an escape event within a specific realm.

Native range: Impacts caused by a species in ecoregions belonging to its native range are not considered. As a result, stakeholders farming in a realm in which the species is known to cause impacts but within ecoregions in which the species is native, do not have to adhere the specified requirements. Data regarding the native range of a species can be found at https://www.iucnredlist.org/. However, this aspect emphasises the importance of clearly defining when a taxon is considered native. All domesticated forms are considered as alien, and they can therefore not be considered as native in any ecoregion of the world. A list of species and domesticated form will be compiled for each certified species.

Impact mechanism: In case the highest impact in a realm is only caused through hybridisation, stakeholders can be subject to lesser strict regulations regarding escapes but that involve the use of sterile individuals to minimise the impact in the wild.