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Argument maps can support decisions to declare the presence of alien species: South Africa as a case study

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1 **Title:** Argument maps can support decisions to declare the presence of alien
2 species: South Africa as a case study.

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15 **Abstract**

16 Accurate alien species lists are essential for effective biodiversity policy and
17 regulation. However, the evidence that a species is present at a site can be weak. In
18 South Africa, of the 560 taxa listed under invasive species regulations, at least 11
19 taxa (~2%) are assumed present based on anecdotal or outdated evidence. This
20 study presents a structured argument mapping approach to assess whether an alien
21 species should be considered present at a site based on the credibility, specificity,
22 sensitivity and quantity of the available evidence. This method was applied to three
23 South African case studies. The sea urchin, *Tetrapygus niger*, was assessed as not
24 present with high confidence. A population of the urchin was present at an oyster
25 farm but has died out, notably this site was the likely site of introduction based on the
26 putative pathway (a contaminant of oyster spat). Surveys of the surrounding area did
27 not find any evidence of spread and there have been no reports from other oyster
28 farms in the country. Heather, *Calluna vulgaris*, was classified as present with
29 medium confidence. Heather was originally classified as not present under South
30 African regulations, but there were verified herbarium and citizen science records.

31 During this study an existing plant was extirpated, but it seems likely that plants are
32 still present, albeit in low numbers, in historical ornamental collections. Leafy spurge,
33 *Euphorbia esula*, was assessed as not present with medium confidence. A single
34 unverified report was likely a misidentification of a congeneric alien found within the
35 same region (*E. terracina*). *Euphorbia esula* has not been found in subsequent
36 surveys of the site. In each case regulatory and research recommendations were
37 developed as part of a formal risk analysis process in support of South Africa's
38 regulations. By providing a transparent and systematic methodology that
39 incorporates various data types and multiple lines of evidence, argument maps can
40 support decisions on the present of an alien species when evidence is conflicting,
41 sparse, or questionable. Argument maps thus provide a useful method to support
42 risk analyses.

43 **Keywords:** alien species, presence status, absence evaluation, argument mapping,
44 evidence assessment, species listing, invasive species management, risk analysis

45 1. Introduction

46 Biological invasions are one of the leading threats to biodiversity (Bellard et al. 2022;
47 Roy et al. 2023). In the coming decades, it is anticipated that the international
48 exchange of alien species due to human activities will continue to increase (Seebens
49 et al. 2021). The probability of an introduced alien species becoming invasive,
50 however, is generally low (Smith et al. 1999), most introductions either fail to
51 establish or if they do establish, they struggle to form invasive populations
52 (Blackburn et al. 2011; Simberloff 2013). Moreover, invasive populations can, and
53 do, disappear (Simberloff and Gibbons 2004). This dynamic nature of invasions calls
54 for transparent, up-to-date and evidence-based alien species lists to support
55 appropriate and effective management (Roy et al. 2023).

56 Maintaining alien species lists is challenging as these lists are often outdated,
57 inconsistent or based on incomplete evidence (McGeoch et al. 2012; Pyšek et al.
58 2012). Errors such as misidentifications or false presences, can lead to
59 underestimations or inflated species counts (McGeoch et al. 2012), affecting policy
60 and resource allocation (Pyšek et al. 2012; McGeoch et al. 2016). These issues
61 arise both when listing new species and when evaluating whether previously
62 recorded species are still present. In some cases, species are listed as invasive but

63 are no longer detectable, or were never introduced (Simberloff and Gibbons 2004).
64 Conversely, some alien species not currently listed may be incorrectly assumed to
65 be not present (McGeoch et al. 2012). For instance, a thorough revision of alien
66 species in the Mediterranean resulted in the exclusion of 73 species previously
67 considered established (Zenetos et al. 2017). However, the premature removal of
68 species from lists can result in missed opportunities for eradication and long-term
69 control efforts (Nishimoto et al. 2021). These issues highlight the importance of
70 careful evaluation before changing species' listing status, particularly in cases where
71 presence is uncertain. They also underscore the importance of using a transparent,
72 standardised framework to assess whether an alien species is present, enabling
73 more reliable updates of alien species lists.

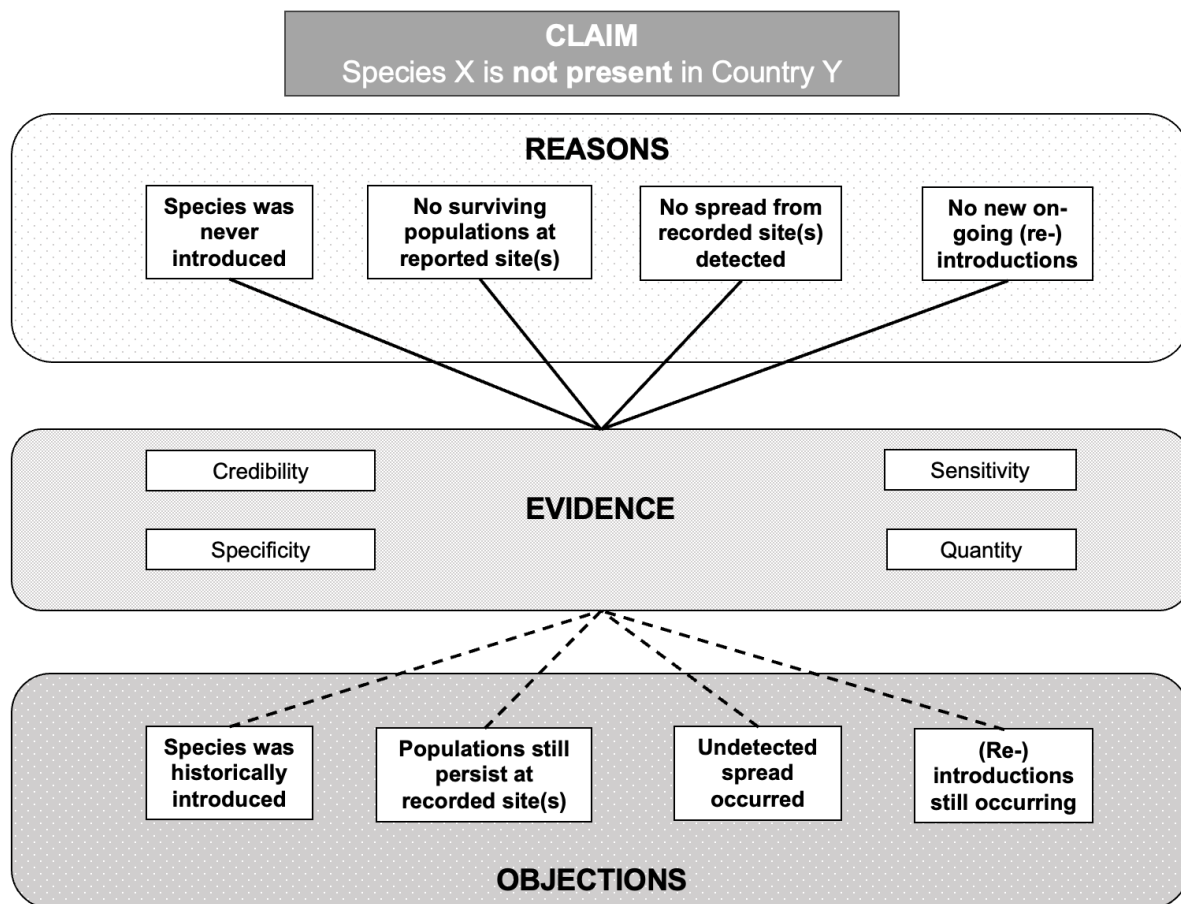
74 Increasing transparency in the listing process and improving detection efforts can
75 help address the uncertainties and enhance the value and reliability of alien species
76 lists for policymakers and managers (Burgman 2001; Butchart et al. 2010). The
77 Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
78 (IPEBS) has identified knowledge gaps in alien species lists, particularly in regions
79 like the Global South where data are often limited or insufficient (Seebens et al.
80 2023). This is often due to limited geographical coverage and insufficient long-term
81 monitoring (Vicente et al. 2022). To address this, well-documented and standardised
82 assessment methods are needed to support reliable listing decisions based on
83 strong evidence and a clear rationale (Burgman 1981; Keller and Springborn 2014;
84 Schmiedel et al. 2016; Karasawa and Nakata 2018).

85 In South Africa, the regulatory framework for managing invasive species was
86 established under the National Environmental Management: Biodiversity Act
87 (NEM:BA) of 2004. The initial lists of regulated alien and invasive species were
88 published in 2014 and updated in 2020, with 560 valid taxa listed as present and
89 invasive in the country [note, 'invasive' is defined here in regulatory terms rather than
90 impact or biogeography, see Wilson and Kumschick (2024) for details of South
91 Africa's regulatory lists]. Concerns have been raised regarding the actual presence
92 of several listed species within South Africa. The issue partly stems from the initial
93 listings being based on expert opinion and perceived threat, without comprehensive,
94 verifiable evidence of presence (McGeoch et al. 2012; Wilson and Kumschick 2024).

95 As a first step to address these concerns, a review of the 560 taxa listed as invasive
96 under NEM:BA (2020) was done to identify cases where presence in South Africa
97 was uncertain (see Supplementary material 1 for full methodology). This assessment
98 found that at least 11 species (~2%) are listed as present, despite weak, ambiguous,
99 or outdated occurrence records (Supplementary Table S1). While this situation may
100 apply to a relatively small proportion of listed taxa, these cases are often the most
101 difficult to resolve and can have significant implications for management. Moreover,
102 additional cases are likely to emerge as analyses are conducted more systematically
103 and in a structured way [e.g., by following the Risk Analysis for Alien Taxa (RAAT)
104 framework (Kumschick et al. 2020, 2025)]. While risk analyses and risk assessment
105 framework typically require some evaluation of the presence of a taxon at a site, as
106 far as we know there is no transparent and standardised process for addressing
107 cases where the evidence is conflicting.

108 **2. Argument maps and their potential application in decisions about alien** 109 **species presence**

110 Argument maps have been used in critical thinking courses and textbooks since the
111 1950s (e.g., Beardsley 1950; Toulmin 1958; Scriven 1976; LeBlanc 1998). It is a
112 graphical way to represent the structure of an argument (Butchart et al. 2009) and
113 provide a logical way to organise uncertainties based on qualitative information and
114 evidence that supports an estimate. It is centred on a claim, which is supported by
115 reasons or challenged by objections each of which must be supported by evidence
116 with sources (Okada 2008; Keith et al. 2017). By mapping out the reasons and
117 objections, experts can estimate the subjective probabilities that the claim is true,
118 which then allows for the calculation of an overall probability (Keith et al. 2017). An
119 argument map presents different lines of evidence that users can evaluate to form an
120 informed judgement about a particular decision.



121
 122 **Figure 1.** Argument map for systematically evaluating an alien species not being
 123 present in a country. Solid lines represent reasons supporting the claim. Dashed lines
 124 indicate evidence that supports counter arguments or objections. Explanations for
 125 each element in the argument map (e.g. claims, reasons, objections and evidence)
 126 are provided in Table 1. Although the reasons are partially hierarchical (if a species
 127 was never introduced there should be no sites to evaluate), given the uncertainties
 128 involved it is prudent to complete the full argument map in all cases.

129 The argument map is based on a probabilistic statement. Here, argument maps were
 130 used to evaluate the claim that species X is not present in site Y, particular in cases
 131 where the presence of an alien species was uncertain, contested or based on limited
 132 or inconsistent evidence. In the argument map, four sections, made up of reasons
 133 and objections, are considered to support the claim of an alien species not being
 134 present in a given area (Fig. 1; Table 1). Each step provides a logical checkpoint in
 135 the evaluation process. All available evidence is outlined and biological
 136 understanding is used to evaluate the evidence in determining whether the claim is
 137 supported or not. Evidence sources included published data and studies, ecological
 138 measurements, observations, location records, scientific literature, and expert
 139 opinion. These sources are identified and documented, and their reliability is

140 assessed based on criteria such as peer-reviewed status, methodological rigour and
141 source of information. Each piece of evidence is then scored for credibility,
142 specificity, sensitivity and quantity (see Table 2), with informal observations or expert
143 opinions assigned a baseline weight or flagged for verification.

144 **Table 1.** Components of the generic argument map used to evaluate alien species occurrence status under conditions of
 145 uncertainty.

Evaluation	Reason	Objection	Details/considerations
Was the species ever introduced?	Species was never introduced.	Species was historically introduced.	<ul style="list-style-type: none"> • Evaluate historical records, herbarium/ physical specimens, import/ export data bases, and published literature for documented presence. • Review grey literature, expert knowledge, and citizen science observations (e.g., iNaturalist, GBIF, etc.). • Investigate potential for accidental or informal introductions not recorded in formal datasets. • Verify if the data are consistent, recent, and from reliable sources. • Evaluate the geographical precision and temporal relevance of reported records. • Verify species identification accuracy (e.g. morphological ambiguity, genetic confirmation). • Consider whether evidence may be mislabelled or outdated.
Does it still exist at known sites?	No surviving populations at reported site(s).	Populations still persist at recorded site(s).	<ul style="list-style-type: none"> • Examine historical records, population surveys and control measures. • Review outcomes of field surveys, eradication reports, and habitat assessments at previous reported locations. • Assess the frequency, methodology, and spatial extent of surveys. • Investigate whether the habitat at the reported location remained suitable for the species (e.g., considering land use changes, hydrology, fire history). • Consider whether eradication or control efforts were implemented effectively and followed up over sufficient timeframes. • Consider the reproductive capacity and detectability of individuals or propagules, especially for taxa with long-lived seedbanks or dormant life stages.
Has it spread to other locations?	No spread from recorded sites detected.	Undetected spread occurred.	<ul style="list-style-type: none"> • Ensure that any remaining individuals are not viable or reproducing. • Track back from the site to potential sources of introductions based on putative introduction and dispersal pathways • Track forward from known sites to potential sites connected via putative dispersal pathways (e.g., rivers, roads, trade routes). • Consider survey methodology, intensity, spatial coverage, and frequency. • Identify gaps where spread could have occurred unnoticed. • Consider species-specific traits that may influence detectability or dispersal (e.g., spread, dispersal, unnoticed life stages) • Consider observer expertise, sampling limitations and whether monitoring was active or passive.
Are new (re-) introductions occurring?	No new on-going (re-) introductions have been detected.	(Re-) introductions still occurring.	<ul style="list-style-type: none"> • Identify all putative historical, current, and potential future pathways of introduction. • Specifically evaluate whether the putative original introduction pathway remains active (e.g., aquaculture, ornamental or pet trade, contaminated equipment) and survey sites (cf. risk maps above). • Assess management of key pathways.

147 This approach aims to reduce subjective bias, inconsistencies, vagueness, and other
148 uncertainties by requiring clear documentation of the evidence and a structured
149 scoring of the quality of the source . It acknowledges that judgements based solely
150 on personal observations or expert opinions retain inherent bias (Keith et al. 2017).
151 Together, these components allow for a structured and transparent basis for
152 assessment, with each reason supported by a set of considerations and tested
153 against plausible objections. This logical structure underpins the argument map and
154 promotes consistent decision-making under uncertainty. The following components
155 describe how evidence is identified, evaluated and scored to guide the application of
156 the argument map in practice.

157 **Evidence compilation and confidence rating**

158 The first step in the assessment involves collating and organising all available
159 evidence and assigning confidence ratings based on four key criteria: credibility,
160 specificity, sensitivity and quantity (using Supplementary Table S2). These criteria
161 reflect principles drawn from structured evidence evaluation frameworks used in
162 scientific decision-making (Aguayo-Albasini et al. 2014; Dicks et al. 2014; EFSA
163 Scientific Committee et al. 2016, 2017). Each piece of evidence is assessed against
164 all four criteria. For each criterion, the evidence is assigned a confidence level (low,
165 medium, or high) based on how well it meets the relevant standards (guided by
166 Table 2). These individual ratings help determine how much weight to place on each
167 piece of evidence when linked to a reason or objection within an argument map.

168 **Table 2.** Evidence-rating rubric used to assess evidence supporting claims about the
 169 presence of a species at a site.

Criterion	High	Medium	Low
Credibility Reliability of the data, based on expertise, transparency and methodological rigour ^{1,2,4} .	Peer-reviewed research, verified databases, government or academic reports with clear methods.	Grey literature, well-documented expert opinion, standardised field surveys with some uncertainty.	Unpublished observations, anecdotal accounts, or sources lacking methodological transparency.
Specificity How directly the evidence relates to the species and location in question ^{1,2,4} .	Directly addresses the species and specific area under consideration (coordinates, habitat).	Relevant to either the species or the area, but not both.	Generalised or indirect reference with unclear geographic/species relevance.
Sensitivity The capacity of detection methods to identify the species, minimising false negatives ^{1,2,3} .	Uses detection methods known to identify the species effectively, repeated surveys.	Detection methods with limited frequency or coverage.	Detection methods likely to miss key life stages, not conducted during appropriate times, or that are unlikely to distinguish the taxon of interest.
Quantity The volume of independent, corroborative evidence ^{4,5} .	Multiple lines of independent evidence.	Several sources.	Very few or isolated sources.

170 ¹Aguayo-Albasini et al. 2014; ²Keith et al. 2017; ³Saltelli et al. 2013; ⁴Suter et al. 2017; ⁵Suter et al.
 171 2017a.

172 **Evaluating competing arguments**

173 Once evidence is linked to specific reasons and objections, each line of reasoning is
 174 evaluated by comparing the cumulative confidence ratings of the supporting
 175 evidence. This evaluation follows a weight-of-evidence approach commonly applied
 176 in scientific assessments (EFSA 2017). Confidence is assigned based on
 177 established criteria, ensuring that the credibility, specificity, sensitivity and quantity of
 178 each piece of evidence are considered systematically. Lines of reasoning supported
 179 by direct, high-quality and verifiable evidence, such as peer-reviewed studies,
 180 systematic records, or structured survey data, carry more weight than those based
 181 on low-confidence evidence, absence of evidence or speculative claims (EFSA
 182 2017; Pan et al. 2018; Kumschick et al. 2020). This structured comparison helps
 183 ground conclusions in the quality and consistency of the available information, rather
 184 than the number of sources or persuasive language, aligning with international best
 185 practices in risk evaluation (Mastrandrea et al. 2010; IUCN 2020).

186 **Constructing the argument map from rated evidence**

187 Following the evaluation of evidence, an argument map is constructed for the study
188 species (based on Fig. 1) using the outcomes recorded. Each line of reasoning in the
189 map is based on evidence that has been systematically rated, ensuring transparency
190 and consistency across the assessment. This approach allows for a clear
191 visualisation of how individual pieces of evidence support or challenge the central
192 claim. While expert opinion and informal observations can offer valuable insights,
193 they are more susceptible to bias and uncertainty and are therefore treated with
194 appropriate caution in the argument mapping process (Keith et al., 2017; Table 2).

195 **Determining occurrence status and assigning confidence**

196 Once the argument map is constructed and the quality of evidence evaluated, a
197 conclusion must be drawn whether the species is considered present in the study
198 area. This decision should be based on how the available evidence supports or
199 challenges the central claim, as reflected in the logical structure of the argument
200 map. Each decision must be accompanied by a corresponding confidence rating,
201 which indicates the level of certainty based on the quality and consistency of the
202 evidence (guided by Supplementary Table S3; SANBI and CIB, 2022:
203 occurrenceStatus). The decision on occurrence status must be justified by a clear
204 explanation, referencing supporting evidence and any assumptions involved. If the
205 overall confidence is medium or low, recommendations should be provided for
206 targeted surveys or further data collection to increase the confidence in future
207 assessments (cf. SANBI and CIB, 2022; using Supplementary Table S4).

208 **3. Case studies from South Africa**

209 The argument map method was applied to three case studies from South Africa,
210 namely the Chilean black urchin (*Tetrapygyus niger*) and two plant species, heather
211 (*Calluna vulgaris*), and leafy spurge (*Euphorbia esula*). These three species' have
212 uncertainties surrounding their presence in South Africa (Mabin et al. 2015;
213 Henderson and Wilson 2017) and illustrate different initial assumptions about their
214 presence.

215 A risk analysis was first conducted or consulted (where already completed) for each
216 case study species following the RAAT framework v2.0 (Kumschick et al. 2025). As
217 part of this process, a literature review was conducted to create a historical account
218 of each species occurrence, distribution, and introduction pathways, including any

219 past or ongoing management efforts. Detailed information was gathered from
 220 herbarium records, scientific peer-reviewed and grey literature, and biodiversity
 221 databases such as the Global Biodiversity Information Facility (GBIF)
 222 (www.data.gbif.org), the on-line spotter network iNaturalist (www.iNaturalist.org)
 223 (restricted to research-grade observations), GenBank
 224 (<https://www.ncbi.nlm.nih.gov/genbank/>), SANBI's National Herbarium Database
 225 (NEWPOSA) (www.newposa.sanbi.org), Web of Science, and Google Scholar using
 226 the species name and 'South Africa' as search terms. Searches included the species
 227 names as listed in the Alien and Invasive Species Regulations of 2020, as well as
 228 accepted names and synonyms (cross-checked using global taxonomic backbones
 229 such as GBIF and Plants of the World Online) to ensure taxonomic accuracy and
 230 completeness.

231 Each piece of evidence was organised on the evidence evaluation table (using
 232 Supplementary Table S2). Each piece of evidence was scored as either high,
 233 medium, or low confidence and an argument map was drawn up thereafter using the
 234 gathered and evaluated evidence. Based on this, a conclusion was drawn for each
 235 species on whether it should be considered present or not present, with an
 236 associated confidence rating (low, medium, or high) (using Supplementary Table
 237 S4).

238 **3.1. Case Study 1: *Tetrapygyus niger*: formerly present, the population was**
 239 **extirpated and is now considered not present**

240 The proposed argument map method was applied to *T. niger* with the claim that it is
 241 not present in South Africa (Fig. 2). All evidence was evaluated in Supplementary
 242 Table S5. There was strong evidence (high confidence) that *T. niger* had been
 243 introduced to South Africa in the past (Haupt et al. 2010). A single introduction was
 244 recorded in 2007 at an aquaculture facility in Alexander Bay, and this was supported
 245 by museum specimens and published literature (Haupt et al. 2010; Mabin et al.
 246 2015). However, follow up systematic surveys found no living individuals at the only
 247 known site and surrounding areas (Mabin et al. 2015). Only empty shells were
 248 observed and no evidence of spread was detected.

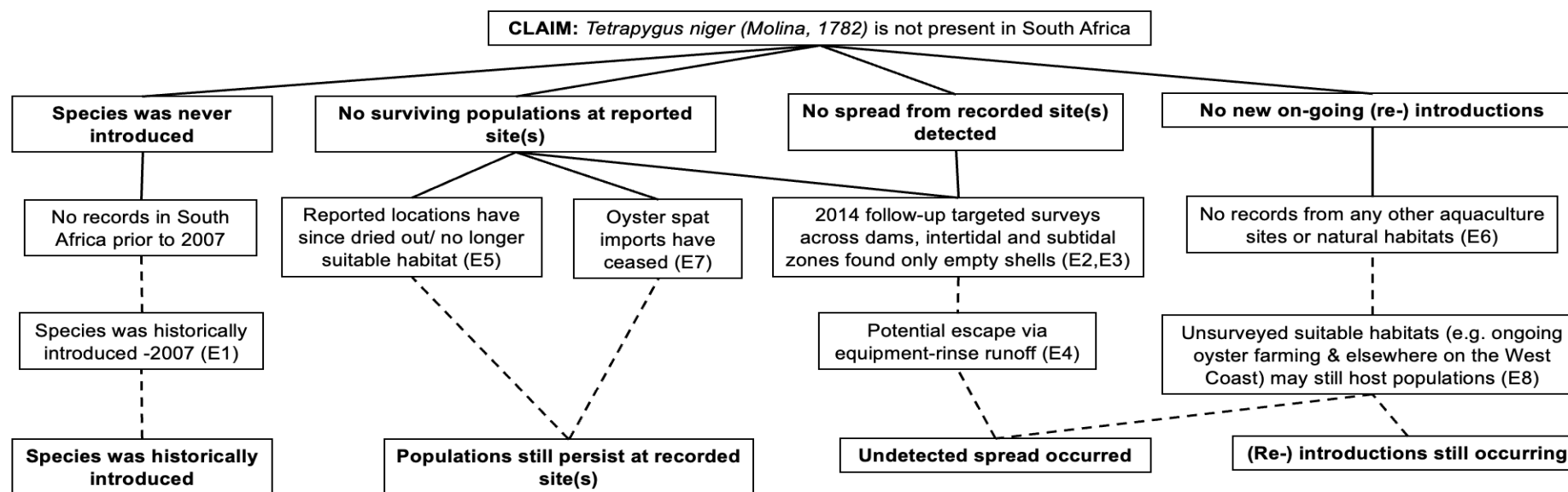
249 The known habitat (a dam used for oyster aquaculture) had dried up and suitable
 250 similar habitats in the region yielded no new detections (Mabin et al. 2015). Given

251 the kelp-dominated ecosystem and visible grazing impacts typical of urchin
252 presence, it was considered likely that the *T. niger* would have been detected if it
253 had persisted or spread. No credible sightings have been recorded since 2007 and
254 the original pathway of introduction via oyster spat imports was confirmed to be
255 inactive in the Alexander Bay facility (Haupt et al. 2010; Mabin et al. 2015). However,
256 since oyster farming continues at other sites in South Africa the broader pathway
257 remains active and poses a risk of new introductions. Nonetheless, given the taxon
258 is highly distinctive, if the urchin is (or had been) present at other aquacultural
259 facilities, it would likely have been detected and reported.

260 In the argument map (Fig. 2), all strong reasons for absence outweighed the few
261 unsupported objections. Based on the weight of evidence and associated confidence
262 ratings, it was concluded that *T. niger* is not present in South Africa, with high
263 confidence. All four reasons supporting this conclusion were underpinned by strong,
264 well-documented sources such as peer-reviewed studies and structured field
265 surveys, and were assigned a high overall confidence (Fig. 2). Additionally, the two
266 objections were speculative, lacked direct evidence and were rated low in
267 confidence.

268 A resurvey of the original introduction site does not seem necessary at present.
269 However, targeted surveys should be reinstated if trade pathways reopen (see
270 recommendations in Fig. 2). Continued monitoring of oyster spat imports is
271 continued and that the other aquaculture sites be evaluated as a precaution. As per
272 a risk analysis conducted previously (SANBI, unpublished), it is recommendation that
273 the listing of the taxon in South Africa is changed from 1a to prohibited, and the
274 taxon is added to a watch list. The taxon should be considered as A1 under the
275 adapted unified framework for biological invasions (Groom et al. 2019).

276



Element	Outcome	Justification	Recommendations
Presence status	Not present	<i>Tetrapygyus niger</i> has not been detected in any recent surveys of the original introduction site and surrounding sites. The only verified record dates to 2007 and was a single introduction event, with no evidence of persistence or spread. Subsequent surveys found only empty shells and no live individuals have been reported since. The original site is now dry and the historical introduction pathway (oyster spat imports) is no longer active. High-confidence evidence support it not being present, while objections were speculative, lacked empirical support, and were rated low in confidence.	Monitoring only if original pathways are still active/resumes. Especially if importation of the spat resumes. Encourage continued public reporting to detect any potential reintroduction. Include <i>T. niger</i> on the prohibited list to prevent future risk.
Confidence in conclusion	High	Recent, peer-reviewed surveys and official reports show no live detections. All evidence rated high in credibility, specificity and sensitivity. While some objections referenced surveyed areas, these were unlikely to support undetected populations given the ecological characteristics of the habitat and species. The weight of reliable evidence strongly supports the outcome.	Given the high confidence, <i>T. niger</i> should be considered not present. Recommend formal listing as prohibited under regulatory frameworks to prevent future introductions. Targeted surveys should be reinstated if trade pathways reopen.

277 **Figure 2.** Argument map and corresponding decision regarding the presence of *Tetrapygyus niger* in South Africa. Boxes represent
 278 individual pieces of evidence. Solid lines indicate reasons supporting the central claim, while dashed lines represent objections that
 279 challenge the claim or its supporting reasons. For details of the underlying evidence, see Table S5. The claim was supported—it is
 280 recommended that *Tetrapygyus niger* be regulated as not present in South Africa.

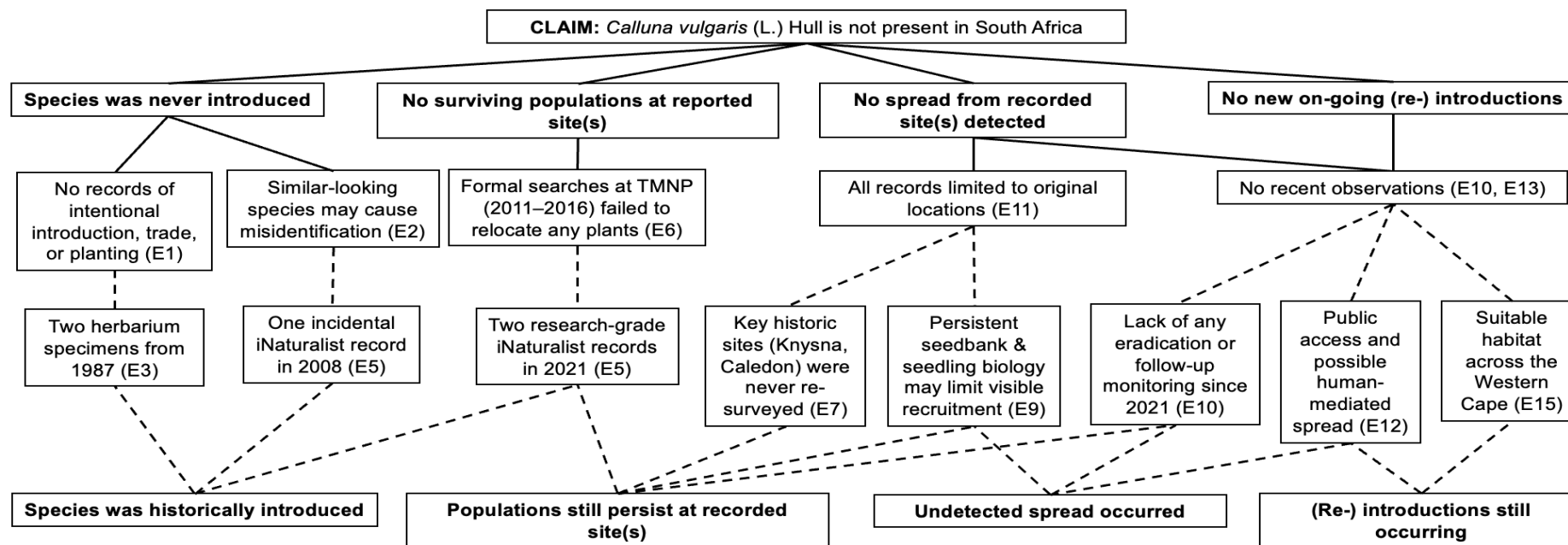
281 **3.2. Case Study 2: *Calluna vulgaris*: regulated as if it were not present,**
 282 **discovered and extirpated, but it is likely still present.**

283 *Calluna vulgaris* was listed as prohibited under the NEM:BA A&IS Lists of 2014 and
 284 2016 implying that it was not present in South Africa but posed a high risk (the 2020
 285 lists did not include a prohibited list). However, *C. vulgaris* is likely present in South
 286 Africa based on historical herbarium specimens (1987), research grade iNaturalist
 287 observations (2008, 2021), and ecological inferences (Fig. 3). These records
 288 suggest past introductions and potential persistence. Although only a single
 289 population had been rediscovered and removed, it was considered likely that other
 290 populations persist undetected.

291 No evidence was found to suggest *C. vulgaris* was formally stocked or traded within
 292 the commercial horticultural industry, and it is not included in a comprehensive
 293 review of cultivated plants of southern Africa (Glen, 2002). However, the species is
 294 presumed to have been cultivated informally in private gardens and possibly shared
 295 as an ornamental plant. The confidence was scored as medium based on the quality
 296 of the evidence and arguments. High credibility sources, such as herbarium records,
 297 supported the claim of presence, while the lack of recent formal surveys and limited
 298 follow-up, reduced overall confidence. Although no widespread establishment or
 299 formal introduction was recorded, multiple verified records and ecological reasoning
 300 pointed to past and potentially ongoing presence. Confidence was medium due to
 301 limited recent detections and scattered survey coverage, but individual sources were
 302 generally high in credibility and specificity. Overall, the weight of evidence justified a
 303 cautious but affirmative classification of presence (see Supplementary Table S6).

304 Based on the risk analysis conducted for *Calluna vulgaris* (Appendix 1), the
 305 recommendation, as for all taxa listed as prohibited that are subsequently found to
 306 be present (Wilson and Kumschick, 2024), is that *C. vulgaris* should be regulated as
 307 a category 1a taxon pending an assessment of the feasibility of nation-wide
 308 eradication. Targeted surveys are recommended in areas where past records
 309 originated, including the Knysna and Caledon districts (see recommendations in Fig.
 310 3). Particular attention is advised for regions with suitable habitat and high human
 311 activity, where unintentional introduction or spread may have occurred. The potential
 312 for undetected dispersal and persistence due to the ability of *C. vulgaris* to form long-

313 lived seedbanks further contributed to uncertainty. These gaps in monitoring and
314 survey coverage supported a classification of medium confidence. In terms of the
315 invasion status, it is suggested the taxon is classified as C1 under the adapted
316 unified framework for biological invasions (Groom et al. 2019).



317

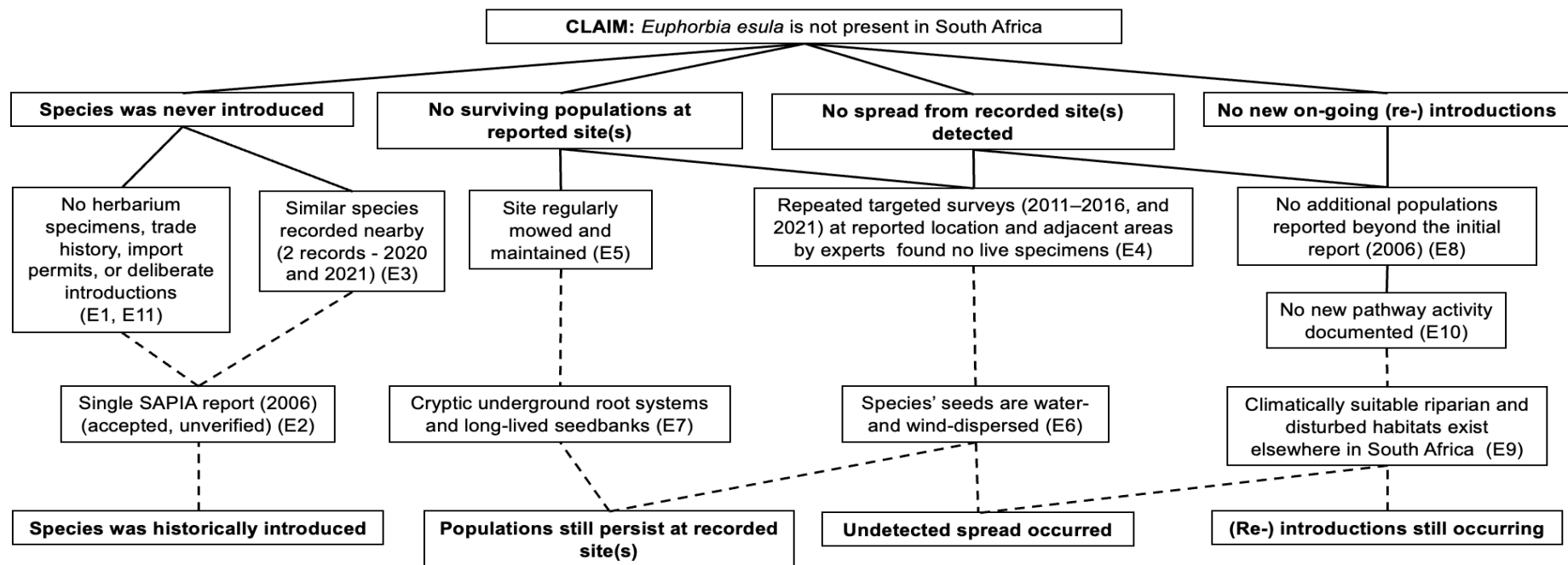
Element	Outcome	Justification	Recommendations
Presence status	Present	The evidence supports that <i>C. vulgaris</i> is present in South Africa, based on herbarium records (1987), iNaturalist observations (2008, 2021), and ecological evidence. These records suggest past introductions and potential persistence.	Periodic surveys and target monitoring efforts should be conducted, particularly in regions where herbarium specimens and observations were recorded and other suitable habitats. Interaction with garden clubs in the Western Cape to establish if any plants in cultivation.
Confidence in conclusion	High	The evidence is a mix of high credibility and medium confidence. Gaps in surveys and the potential for undetected spread result in medium confidence however, the quality of evidence (i.e., herbarium records, observations, and ecological evidence such as seedbank persistence) increases confidence to high.	Evidence gaps should be addressed by prioritising surveys in unsurveyed areas, such as the Knysna and Caledon districts. Given the medium confidence in spread, monitoring for potential dispersal should be considered in susceptible areas, especially where human activity is high.

318 **Figure 3.** Argument map and corresponding decision regarding the presence of *Calluna vulgaris* in South Africa. Boxes represent
 319 individual pieces of evidence. Solid lines indicate reasons supporting the central claim, while dashed lines represent objections that
 320 challenge the claim or its supporting reasons. For details of the underlying evidence, see Table S6. The claim was not supported—
 321 it is recommended that *Calluna vulgaris* be regulated as present in South Africa.

322 **3.3. Case Study 3: *Euphorbia esula*: a case of mistaken identity?**

323 A single, unverified record of *Euphorbia esula* was reported in a reputable database
324 in 2006; however, no supporting physical evidence (e.g., herbarium specimens or
325 photographs) are available to validate the observation (Henderson, 1998; SAPIA,
326 2020). Multiple extensive field surveys have been conducted at and around the
327 original reported location (Cindi et al. 2015; SANBI 2015 and 2016; Cindi 2016;
328 Henderson and Wilson 2017). No individuals of *E. esula* were detected during these
329 surveys. However, a congener, *Euphorbia terracina*, which is also alien to South
330 Africa, was found within the same region as the reported location of *E. esula*
331 (iNaturalist 2025c, d). Given the relative similarity in morphology between *E. esula*
332 and *E. terracina*, and the lack of additional confirmations, it was considered likely
333 that the original sighting involved a misidentification.

334 Based on the available evidence (Table S7), *E. esula* was assessed as not present
335 in South Africa, with medium confidence (Fig. 4). Although the original report was
336 submitted to a reputable data base (SAPIA) by a credible observer, it remained
337 unverified and lacked physical evidence. Furthermore, no herbarium records,
338 introduction pathways or additional reports were identified. The medium confidence
339 rating was assigned due to the high quality and specificity of the negative survey
340 data, despite the ongoing uncertainty stemming from the lack of formal eradication
341 and the potential for overlooked individuals. Additionally, based on the risk analysis
342 (Appendix 2), it is recommended that the listing of *E. esula* be changed from
343 category 1a to prohibited (i.e., it is not present in the country but poses a high risk).
344 No further active surveillance for the species seems warranted.



345

Element	Outcome	Justification	Recommendations
Presence status	Not present	A single unverified record was submitted to a reputable database in 2006; however, it lacked physical evidence such as herbarium specimens or photographs. Multiple structured surveys at the reported location failed to detect <i>E. esula</i> . The original record is likely a misidentification of <i>E. terracina</i> .	No further surveys are currently recommended unless new evidence emerges. Removal from national lists is advised.
Confidence in conclusion	Medium	The confidence rating is due to high quality, specificity and sensitivity of the negative survey data. Although the original record remains unverified and no corroborating evidence exists, the conclusion is supported by repeated surveys over time and the lack of introduction pathways.	No additional surveys are necessary at this stage. Monitoring for future reports is advised.

346 **Figure 4.** Argument map supporting the absence of *Euphorbia esula* in South Africa. Boxes represent individual pieces of
 347 evidence. Solid lines indicate reasons supporting the central claim, while dashed lines represent objections that challenge the claim
 348 or its supporting reasons. For details of the underlying evidence, see Table S7.

349



350 **Figure 5.** Evidence from surveys conducted in 2021 by author. **A.** Verified flowering
351 *Calluna vulgaris* individual (within image, with small, pale purple/pink flower spikes)
352 found on Table Mountain; **B.** *Euphorbia terracina* in flower in South Africa (foreground,
353 with narrow leaves and yellow-green floral structures); note that the prominent purple
354 flowers in the background belong to a different species **C.** Location along the Hennops
355 River in Pretoria, Gauteng, where *Euphorbia esula* was reported being mowed as part
356 of land maintenance (photos by Chelsey Matthys, 2021). The images illustrate the
357 types of field observations used to support or question species occurrence status.

358 4. Discussion and conclusion

359 The use of argument maps provide a structured way to organise uncertainties and
 360 synthesise evidence in cases where doubts exist about the presence of an alien
 361 species within a country. In all three case studies presented here, argument maps
 362 visually represented the reasons and objections alongside supporting evidence and
 363 the logical flow of the argument lead to a clearly justified conclusion which was
 364 supported by an associated confidence rating.

365 The reliability of outcomes derived from argument maps was strongly dependent on
 366 the availability and quality of evidence. Constraints such as inadequate long-term
 367 monitoring, poor geographic coverage, and limited data availability were found to
 368 hinder the assessment process. For example, although the presence of *C. vulgaris*
 369 was supported by five verified records and reliable evidence for the most recent
 370 record (Fig. 5A), the lack of recent targeted surveys in all known locations and
 371 absence of post-2021 monitoring lowered the confidence rating in the conclusion.
 372 These limitations, however, were made visible through the structured argument
 373 mapping process, which helped identify priorities for future research and monitoring.
 374 Evaluating and weighing evidence from sources with varying levels of credibility
 375 (e.g., expert opinion, physical samples, and citizen science identification platforms)
 376 remained complex and somewhat subjective. The argument map approach allowed
 377 these differences to be addressed systematically and transparently by assessing
 378 each source in terms of credibility, specificity, sensitivity, and quantity.

379 Species that persist in low densities, exhibit cryptic life stages, or closely resemble
 380 native or other alien species, pose additional challenges to detection and
 381 identification. These traits can lower confidence scores and risk the inclusion of false
 382 positives in alien species lists (McGeoch et al. 2012). This was particularly evident
 383 for *E. esula* and *C. vulgaris*. In the case of *E. esula*, a single unverified record was
 384 likely a misidentification of *Euphorbia terracina* (Fig. 5B), a morphologically similar
 385 species. Similarly, some records of *C. vulgaris* from citizen science platforms may
 386 have reflected confusion with native species (*Erica* spp. in particular). These cases
 387 highlighted the importance of verifying records through multiple, independent lines of
 388 evidence wherever possible.

389 The argument mapping approach also enabled structured reasoning around absence
 390 claims by distinguishing between different occurrence statuses (present or not
 391 present) and assigning an associated confidence level. In the case of *C. vulgaris*, the
 392 final status was classified as present with medium confidence, reflecting the weight
 393 of historical evidence alongside gaps in recent data. In contrast, *E. esula* was
 394 assessed as not present, also with medium confidence, due to repeated expert-led
 395 surveys, a lack of introduction pathways and the unverified nature of the original
 396 record. Regular mowing and land maintenance at the reported site likely further
 397 contributed to the absence of detectable individuals, potentially eliminating any
 398 above-ground presence if the species had ever been introduced (Fig. 5C). Although
 399 based on personal communication, this context-specific information supported the
 400 conclusion and highlighted how local land use practices can influence detection
 401 outcomes. These assessments helped clarify where confidence was lacking and
 402 where further evidence would be most useful.

403 Demonstrating that an alien species is not present across an entire region remains
 404 inherently difficult. This approach attempted to address the issue by explicitly
 405 presenting the reasons and objections informed by ecological or detection-related
 406 uncertainties. Nonetheless, the possibility of undetected populations in unsurveyed,
 407 suitable habitats remains a persistent limitation. This concern was particularly
 408 relevant for *T. niger*, where strong evidence supported its extirpation but the risk of
 409 reintroduction via aquaculture activities remained.

410 Beyond evaluating individual pieces of evidence, consistency across the evidence
 411 base played an important role in reaching final conclusions. For instance, in the case
 412 for *E. esula*, the absence of herbarium specimens, trade history, or confirmed
 413 sightings was consistent with the repeated failure to detect the species during
 414 targeted surveys. This coherence across multiple independent lines of evidence
 415 strengthened confidence in the assessment, even though the confidence in each line
 416 of evidence alone might be limited. In contrast, for *C. vulgaris*, inconsistent
 417 information, such as recent citizen science records alongside a lack of survey
 418 coverage, resulted in a more cautious, medium-confidence scoring. Recognising and
 419 explicitly considering these consistencies and inconsistencies across the evidence
 420 set adds another valuable dimension to the argument map approach.

421 The main value of this argument mapping approach lies in its transparency,
422 traceability, and adaptability. It provides a way to structure and weigh individual
423 pieces of evidence. The intention is that this method is incorporated into the RAAT
424 framework (Kumschick et al. 2025) to address situations where the evidence of
425 presence is weak or contested (i.e., medium or low confidence). As such, the
426 approach can support evidence-based decision-making for regulatory listings and
427 contribute meaningfully to progress reporting under Target 6 of the Global
428 Biodiversity Framework (Convention on Biological Diversity 2022).

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