

1 **Applying participatory, integrated, and biodiversity-inclusive spatial planning across**
2 **realms: insights from three European social-ecological systems**

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31

32 **Abstract**

33 Over the past two decades, a large body of knowledge on decision-support frameworks has
34 evolved facilitating decision makers to plan for reaching biodiversity goals articulated in
35 international policy agreements. Here, we adapted a structured decision making framework to
36 operationalize Participatory, Integrated, and Biodiversity-Inclusive Spatial Planning (PI-BISP),
37 providing a practical pathway for implementing Target 1 of the Kunming-Montreal Global
38 Biodiversity Framework while accounting for ecological processes across terrestrial, freshwater,
39 and marine realms. Building on previous efforts, the framework provides guidance for
40 incorporating multiple sectoral objectives, climate change, and other dynamic stressors (e.g.,
41 land- and sea-use change and biological invasions) into the design of conservation areas across
42 realms. We tested the framework in three European case studies representing diverse socio-
43 ecological contexts, geographic scales, and combinations of realms. Across all case studies, the
44 framework consistently identified conservation priorities, critical elements of the problem context,
45 and promising management opportunities that became apparent only when cross-realm
46 interactions, future environmental change, and multiple sectoral objectives were considered
47 simultaneously. The results demonstrate the value of an operational and adaptable framework for
48 PI-BISP in complex social-ecological systems, while highlighting challenges related to data
49 availability, governance complexity, and sustained stakeholder engagement. Beyond providing a
50 transferable methodological foundation for PI-BISP, the implementation of the framework also
51 served as a platform for fostering collaboration and mutual learning among scientists and
52 practitioners. Ultimately, the framework's applicability and effectiveness will depend on sustained
53 political commitment, adequate resources, and the capacity to foster collaboration across sectors,
54 scales, and national borders.

55

56 **Keywords:** environmental decision-making, dynamic stressors, cross-realm, multi-objective
57 planning, spatial prioritization, stakeholder engagement, SWOT analysis

58 1. Introduction

59 Despite substantial conservation and restoration efforts across the globe, biodiversity continues
60 to decline at an unprecedented rate (IPBES 2019; Chase et al. 2020), highlighting the need for
61 more effective and integrated approaches to conservation planning and area-based
62 management. In response, the Kunming-Montreal Global Biodiversity Framework (GBF)
63 established an ambitious roadmap to halt and reverse biodiversity loss by 2030 (CBD, 2022).
64 More specifically, Target 1 of the GBF calls for all areas to be brought under Participatory,
65 Integrated and Biodiversity-Inclusive Spatial Planning (PI-BISP). PI-BISP is a planning approach
66 that allocates and manages land, freshwater, coastal and marine areas through inclusive
67 stakeholder engagement, cross-sectoral coordination, and the systematic integration of
68 biodiversity information into spatial decision-making, with the aim of balancing conservation,
69 sustainable use and development objectives while avoiding biodiversity loss. At the same time,
70 under the GBF Target 3, signatory parties are expected to ensure that at least 30% of their
71 terrestrial, inland water, coastal and marine areas are effectively conserved and managed through
72 ecologically representative, well-connected and equitably governed systems of protected areas
73 and Other Effective area-based Conservation Measures (OECMs). These measures should be
74 integrated into wider landscapes, seascapes and the ocean, while recognizing and respecting the
75 rights of indigenous peoples and local communities and ensuring that any sustainable use
76 remains consistent with conservation outcomes.

77 The limited effectiveness of many conservation initiatives has been partly attributed to
78 shortcomings in how conservation planning is conducted (Maxwell et al. 2020; Hermoso et al.
79 2022), often unable to integrate ecological, economic, social and governance dimensions under
80 global change and across realms (Giakoumi et al. 2019; Rice et al. 2020; Grantham et al. 2024).
81 Historically, conservation planning has focused on representing biodiversity patterns, such as the
82 distribution of species, habitats or ecosystems within individual terrestrial, freshwater, or marine
83 realms. Over the past two decades, a large body of knowledge on systematic conservation
84 planning (Margules and Pressey 2000) and other conservation decision-support frameworks
85 (Bower et al. 2018; Schwartz et al. 2018) have evolved to increasingly incorporate ecological
86 processes, climate considerations, economic costs, and other social aspects into spatial planning
87 (Beher et al. 2024; Giakoumi et al. 2025). Such advances can facilitate the operationalization of
88 PI-BISP by providing analytical tools to tackle complex planning contexts and facilitating
89 communication and participation in informed decision-making.

90 Among the ecological processes central to integrated conservation planning, connectivity across
91 terrestrial, freshwater, and marine realms is particularly important. Connectivity facilitates species
92 movements, including migration and genetic exchange, as well as the transfer of energy and
93 materials across ecosystems, thereby supporting species persistence and enhancing ecosystem
94 resilience (Beger et al. 2010; Hilty et al. 2020; Brodie et al. 2025). Ecological linkages among
95 realms also enable the spread of environmental pressures, such as pollution and invasive species
96 (Abell et al. 2017; Tulloch et al. 2021; Vigo et al. 2026). As a result, conservation actions
97 implemented in one realm can have both positive and negative consequences in others. Recent
98 studies from diverse regions worldwide have demonstrated the substantial benefits of planning

99 across realms (Tulloch et al. 2021; Hermoso et al. 2021; Vigo et al. 2026; Ye et al. 2026). While
100 the need for cross-realm conservation planning was recognized more than a decade ago
101 (Alvarez-Romero et al. 2011, 2015; Adams et al. 2014), conservation practice continues to largely
102 overlook these interdependencies (Giakoumi et al. 2019; Hermoso et al. 2022).

103 Effective PI-BISP should also consider spatial coexistence of biodiversity with human socio-
104 economic, political and cultural needs. Spatial planning decisions very often entail trade-offs
105 across sectors, stakeholders and policy priorities (Yates et al. 2015; Turkelboom et al. 2018). For
106 example, some biodiversity conservation objectives (e.g., protection of pollinators) align with
107 objectives set by the agricultural sector (food provision) and thus there are opportunities for
108 synergies (Jung et al. 2021; 2025). However, certain objectives, such as energy production and
109 infrastructure development, might conflict with conservation objectives generating trade-offs that
110 need to be recognized and addressed (Fastre et al. 2021). Navigating these trade-offs requires a
111 participatory approach that engages with the views and needs of different stakeholders, while
112 recognizing the emerging tensions from these processes (Raymond et al. 2022). In addition, there
113 is frequently a mismatch between the ecological scales at which ecosystems, species, and
114 ecological processes operate and the administrative or political boundaries within which
115 management decisions are made. Many ecosystems and ecological processes extend across
116 national and jurisdictional borders, making transboundary conservation essential for maintaining
117 ecological integrity and connectivity (Kark et al. 2015).

118 A further challenge for PI-BISP is accommodating the dynamic nature of social-ecological
119 systems. Conservation decisions are often informed by static representations of biodiversity and
120 threats, even though climate change, biological invasions, and land- and sea-use change are
121 among the most significant drivers of biodiversity loss worldwide. These drivers are altering
122 ecosystems, species distributions, and ecological interactions in complex, often non-linear ways
123 (Newbold et al. 2015; Pecl et al. 2017; Pyšek et al. 2020). As a result, conservation priorities and
124 management requirements are likely to shift over time (Lai et al. 2022; Vigo et al. 2024). To remain
125 effective under changing conditions, PI-BISP must incorporate approaches that anticipate future
126 environmental change and evaluate the robustness of conservation strategies across a range of
127 ecological and socio-economic scenarios (Carvalho et al. 2011; Reside et al. 2018; Giakoumi et
128 al. 2025).

129 Several frameworks have advanced integrated and cross-realm conservation planning (e.g.,
130 Alvarez-Romero et al. 2015; Tulloch et al. 2021). Yet, recent developments in conservation
131 science, including climate adaptation, ecosystem services, OECMs, and multi-objective
132 prioritization, have not yet been fully synthesized into an operational framework aligned with the
133 implementation requirements of PI-BISP under the GBF. This limits the translation of high-level
134 biodiversity commitments into spatially explicit conservation actions. The work presented herein
135 draws upon well-established frameworks, in particular Structured Decision Making (Gregory et al.
136 2012) and the cross-realm Systematic Conservation Planning framework developed by Alvarez-
137 Romero et al. (2015), to operationalize the implementation of PI-BISP principles. The proposed
138 framework extends previous cross-realm planning approaches by systematizing the incorporation
139 of stakeholder-defined sectoral objectives, synergies, and trade-offs across the planning process,

140 and by integrating dynamic pressures and future scenarios into spatial prioritization. We move
141 beyond a purely conceptual contribution by applying the framework to three case studies that
142 differ in geographic scale, governance context, and combinations of ecological realms. Drawing
143 on lessons learned across these case studies, we assessed the framework's strengths,
144 weaknesses, opportunities, and threats. The resulting insights extend beyond the Europe and can
145 support the implementation of PI-BISP initiatives in diverse contexts worldwide.

146 **2. A framework operationalizing GBF's Target 1**

147 The framework comprises six main steps (Fig. 1), reflecting the established stages of structured
148 decision making (Gregory et al. 2012), while extending them to address the ecological and socio-
149 political complexities inherent in cross-realm, cross-sectoral, cross-time and cross-border spatial
150 conservation planning. Stakeholder participation is embedded throughout all planning stages, and
151 decision-support outputs are generated and revisited at multiple phases. The framework and its
152 applications were developed as part of a research project and thus scientists drove the initiation
153 and execution of the planning process. In practice, the planning process can be initiated by a
154 governmental or non-governmental agency/organism.

155 **2.1. Step 1: Clarify the decision context**

156 **2.1.1 Scoping the planning process in the ecological and socio-economic context**

157 The first step involves identifying the organizations and/or actors (e.g. agencies, resource users,
158 NGOs, residents, scientists) who will affect or be affected by management actions or have expert
159 knowledge that is relevant to inform the planning process. This typically begins with a stakeholder
160 mapping exercise to ensure that relevant perspectives, knowledge systems, and interests are
161 adequately represented. It also entails considering existing power dynamics and whether and
162 how may be reflected in the process. After identifying stakeholders, they are engaged in co-
163 defining the overarching goal(s) (e.g., halt biodiversity loss and/ or improve the health status of
164 ecosystems) in a specific planning domain. Planners, scientists or trained facilitators will assist
165 stakeholders in developing general goals for the specific planning process, aiming to capture all
166 relevant values (instrumental, intrinsic and relational values of nature) within the socio-ecological
167 context. The overarching goal(s) should align with the broad vision held by stakeholders for the
168 planning region and policy applicable to those objectives. Goals can be revised and refined
169 through feedback loops, based on insights during the following planning steps, including possible
170 (and feasible) actions and their likely consequences. A key component of this step is
171 understanding the broader problem context within which conservation decisions are made, as
172 well as a theory of change that links the relevant pressures and threats to possible pathways of
173 actions capable of addressing the underlying problem. Many aspects of PI-BISP are related to
174 the development of an accurate theory of change, which includes identifying the current and future
175 social, ecological, and economic drivers that influence biodiversity outcomes. These drivers
176 should be identified as well as the implications for achieving the defined goal(s).

177

178 **2.1.2 Identifying cross-realm connections**

179 A key element of a theory of change that is often overlooked in the first step is the consideration
180 of cross-realm interactions (when relevant). This requires the identification and understanding of

181 the dependencies and influences among the terrestrial, freshwater, and marine realms, and
182 therefore need to be considered early in the planning process. This entails understanding how
183 species utilize habitats in more than one realm during their daily activities or life cycle, how species
184 move across realms, and how stressors propagate across realms. For instance, land-based
185 stressors such as pesticides (used in agriculture) propagate to freshwater and subsequently
186 impact downstream coastal and marine ecosystems. Cross-realm planning also calls for
187 integrating conservation action prioritization with established processes for water management,
188 land use, and maritime activities, which are traditionally undertaken independently. It is crucial to
189 comprehend the impact of specific conservation strategies in one realm on the management
190 outcomes in another; e.g., dam removal to restore freshwater ecological connectivity can also
191 benefit marine ecosystems by re-establishing the natural transport of sediments and nutrients
192 from land to the sea.

193

194 **2.1.3 Setting the planning timeframe**

195 Another key element of a meaningful theory of change that is often not addressed in sufficient
196 depth is the consideration of an appropriate timeframe to be able to deliver lasting positive
197 outcomes. Conservation planning should span from short term recommendations that address
198 current problems to also foreseeing future conservation needs within a specific timeframe (e.g.,
199 within the next 10 or 20 years). These considerations can include global change effects,
200 projections on the redistribution of biodiversity and ecosystem services, and the integration of
201 strategies for future development of economic activities across realms. This planning timeframe
202 should be defined in collaboration with decision-makers and stakeholders, considering policy
203 agendas (e.g., the GBF Targets) and/or ecological theory and processes (e.g., generational
204 length).

205

206 **2.2. Step 2: Define operational objectives, targets and indicators**

207 **2.2.1 Identifying and mapping social-ecological linkages, cross-sectoral objectives, and** 208 **future pathways**

209 PI-BISP must consider the objectives across multiple sectors, such as agriculture, fisheries, water
210 management, and energy, exploring opportunities and potential conflicts for alignment with
211 conservation objectives. To better understand the interactions among different sectoral objectives
212 and policies it is important to create a conceptual model that depicts these relationships. This
213 model will allow us to identify compatibility and incompatibility between objectives and assess
214 whether co-management of those objectives is possible, or if tradeoffs between them need to be
215 considered when implementing the PI-BISP spatial planning exercise. Integrated planning would
216 also require the identification of management options to address the opportunities and barriers
217 derived from the conceptual map of objective interactions (e.g., opportunity: forestry activities
218 could help maintain open habitat as a way to manage afforestation and the related conservation
219 issues; barrier: avoid impactful forestry activities in areas sensitive/ needed for forest habitat
220 species, old growth forest). As in other structured decision-making approaches, the
221 implementation of this framework requires an assessment of the information available to
222 understand the relationships depicted in the conceptual map, to identify information gaps and
223 priority information needs. Given the uncertainty associated with future environmental and socio-

224 economic conditions, alternative scenarios can be developed to explore different trajectories of
225 change (e.g., business as usual, Nature first scenario, economy first scenario). These scenarios
226 help assess how conservation priorities and management actions may perform under different
227 future conditions, while accounting for uncertainty and different stakeholder perspectives.
228

229 **2.2.2 Setting social-ecological objectives and targets**

230 Based on the ecological and socio-economic context and the formulated theory of change (step
231 1), the next step is to set operational conservation objectives and targets that are SMART
232 (specific, measurable, achievable, realistic, time-bound). This could include identifying key
233 species and ecosystems that require conservation interventions, setting operational conservation
234 targets for biodiversity (e.g., protecting 60% of *Posidonia oceanica* seagrass meadows by 2030),
235 ecosystem functions and/or services, ensuring ecological representativeness, and identifying the
236 spatial and temporal scale at which conservation interventions will be implemented. A key
237 consideration is distinguishing between means objectives and end objectives. Means objectives
238 describe actions or management approaches (e.g., establishing protected areas), whereas end
239 objectives describe the desired outcomes (e.g., improving species persistence or ecosystem
240 condition). Asking several times "why is this important?" allows planners to get from means-
241 end-objectives. Why are PAs important? Because they improve population trends for species, or
242 functions in an ecosystem. Clearly defining end objectives helps ensure that management actions
243 remain linked to the outcomes they are intended to achieve. While area-based targets are popular
244 for their simplicity of communication and tracking progress towards success, they are often not
245 based on ecologically meaningful concepts. Determining whether the most effective conservation
246 action is the establishment of a protected area, captive breeding, assisted migration, pollution
247 reduction, or other intervention requires the systematic evaluation of all available management
248 options for the species of conservation concern (step 3).
249

250 **2.2.3 Defining metrics to measure the target achievement**

251 The next stage involves defining ecological, social, and/or economic metrics/indicators that can
252 be used to measure progress towards the identified objectives and targets. These metrics are
253 used to assess/model the expected consequences of the alternative strategies/actions and
254 compare them during the assessment of trade-offs. Then the same metrics are used to monitor
255 management effectiveness, to understand if the modeled assumptions are realistic and if an
256 implementation does deliver the expected outcomes. When defining metrics, it is essential to
257 consider their specific data requirements, including whether the necessary data already exist or
258 whether sufficient resources are available to support additional data collection.
259

260 **2.3. Step 3: Develop alternative management strategies**

261 This step translates planning objectives into alternative management strategies that can be
262 evaluated and compared in subsequent stages of the framework. The aim is to identify actions
263 that contribute towards the achievement of the agreed objectives set, while accounting for cross-
264 realm interactions, stakeholder priorities, and future environmental change. Building on the
265 objectives, targets that seem likely to achieve the needed change, based on the understanding
266 of contributing cross-realm linkages, the dynamic conditions, and the multi-sectoral objectives

267 identified in previous steps, a range of management strategies can be developed to support
268 desired conservation outcomes. These strategies may include protection of existing habitats,
269 restoration and recovery of declining or lost populations, population reinforcement or other
270 interventions relevant to the planning context. This could include area-based planning for
271 conservation (such as protected areas), spatially targeted management actions (where and how
272 to act to abate threats/ pressures), or identification and recognition of management efforts in non-
273 protected areas, that complement the previous strategies (e.g., potential OECMs).

274 **2.4. Step 4: Estimate consequences of alternative management strategies**

275 This step focuses on evaluating the expected ecological, social, and economic consequences of
276 alternative management strategies. Building on the objectives, targets, and actions identified in
277 previous steps, the aim is to assess how different interventions are likely to perform under current
278 and future conditions. Before the analysis can start, several technical requirements have to be
279 met.

280 **2.4.1 Collecting social-ecological data**

281 After the metrics for all features of interest have been identified (these could include area of
282 ecosystems and number of species with different conservation significance but also e.g., area of
283 arable land with high suitability for agriculture and sites of cultural or recreational importance),
284 spatially explicit data should be assembled to support the assessment of alternative strategies.
285 These data should cover not only biodiversity or other ecological assets, but also all data that has
286 been found relevant for the theory of change, including the threats, constraints, and costs or
287 technical feasibility that may influence the outcome and feasibility of each management option.
288 Widely accepted scientific modeling techniques, such as ecological niche modeling, or remote
289 sensing data could be used to fill data gaps and extrapolate across areas. Participatory
290 approaches and platforms (e.g., SeaSketch, Marxan Planning Platform) can be employed to host,
291 visualize, and share spatial information among stakeholders, while facilitating the integration of
292 local knowledge into spatial planning and decision-making processes.

293

294 **2.4.2 Assessing current conservation efforts**

295 To define what complementary actions are needed in relation to existing management, it is
296 important to assess current conservation actions and their effectiveness in achieving the SMART
297 targets that have been defined in step 2. The assessment, for example, will identify gaps in the
298 existing protected area networks, guiding the following steps of the framework. It will also include
299 an evaluation of the conservation benefits of OECMs such as community-managed areas,
300 fishing/hunting-restricted areas, archaeological sites, or agricultural land and under which
301 conditions these may contribute to the operational objectives of step 2.

302

303 **2.4.3 Incorporating dynamic conditions into planning**

304 Predictions of the future that are found to be important to include in the analysis come with their
305 own requirements to ensure useful and reliable results. Modelling dynamic ecological processes,
306 future species distributions, socio-economic uses, ecosystem services and other values
307 associated with biodiversity is fundamental for prioritizing actions that will ensure the persistence

308 of biodiversity across space and time. Most importantly, it is essential to report and (whenever
309 possible) estimate the uncertainty associated with future projections of ecological or
310 socioeconomic variables to avoid misplaced conservation efforts and more expensive plans (see
311 Giakoumi et al. 2025).

312

313 **2.4.4 Prioritization analysis**

314 The final stage of this step involves evaluating and prioritizing alternative management strategies
315 in relation to the objectives identified in step 2. Prioritizing actions allows planning to meet
316 objectives for multiple sectors, which accounts for the benefits and costs across stakeholders,
317 sectors, and realms. Integrating information on biodiversity, ecosystem services, costs,
318 stakeholder preferences, and future scenarios decision-support optimization tools e.g., Marxan
319 (Ball et al. 2009), Zonation (Moilanen et al. 2022), and prioritizr (Hanson et al. 2025), can be used
320 to compare alternative strategies and identify efficient allocation of conservation actions across
321 realms. The outputs typically include spatial distribution of actions and uses in a cost-effective
322 manner that balances social and ecological objectives across multiple realms.

323

324 **2.5. Step 5: Evaluate trade-offs and select the most suitable management alternative**

325 Managing ecosystems for biodiversity conservation and securing ecosystem services and
326 sectoral needs most likely include synergies and trade-offs across space and time. Uncertainty
327 about how management actions affect the selection and prioritization of conservation actions in
328 specific places and over time, should be explicitly incorporated in planning and communicated to
329 stakeholders. Estimating trade-offs and co-benefits of management strategies and multiple (often
330 conflicting) environmental and socio-economic objectives should also be part of this process.
331 These trade-offs should be evaluated through adequate scenario planning depicting a realistic
332 planning context. Trade-offs can be evaluated, for example, by running spatial prioritization
333 analyses for a range of different parameterizations relevant to the planning objectives, such as
334 through variations of the input data (e.g., climate scenarios), multiple conflicting objectives,
335 constraints or costs. Decision-makers can then select to implement the conservation strategy and
336 actions based on the co-benefits and negotiation of acceptable trade-offs (Raymond et al. 2022).

337 **2.6. Step 6: Implement, monitor, and review**

338 **2.6.1 Implementing selected management actions**

339 Competent authorities who are responsible for the implementation of the final plan (e.g.,
340 government environmental agencies in collaboration with competent ministries) would and initiate
341 the required processes and funding allocations to start implementation of the selected option. This
342 will also require identifying the most suitable governance option (e.g., whether to designate a
343 priority area as a no-take zone or as an OECM) and refining the spatial outcomes derived from
344 the planning process, to approach the boundaries of management zones closer to the
345 administrative reality (e.g., moving from grid-based planning units to cadastral polygons).

346

347 **2.6.2 Monitoring actions, evaluating outcomes, and adapting management strategies**

348 The development of a defined evaluation process prior to or in conjunction with implementation
349 is essential to assess the efficacy of chosen actions, and allows for adjustment in management
350 or repetition of the planning process using updated knowledge in case the predicted positive
351 changes do not materialize. The selected priority management plan will be associated with
352 indicators that will allow stakeholders and decision makers to evaluate if the solution delivers the
353 predicted benefits (e.g., number of species conserved, improvements in ecosystem services
354 provided). A monitoring program, incorporating the previously defined metrics associated with
355 targets (step 2), should then be implemented to collect and/or collate the data required to
356 undertake the evaluation process. Consideration of not only type of data but also the frequency
357 of collection that is required to ascertain progress on targets is important, especially in dynamic
358 environments. Monitoring is necessary to track progress towards the targets established in step
359 2, evaluate the effectiveness of management actions, and provide the evidence needed for
360 adaptive management and periodic reassessment of conservation objectives.

361

362 **3. Framework applications**

363

364 The framework was applied in three European case studies representing planning contexts
365 relevant to PI-BISP (Fig. 2). Each case study addressed conservation challenges associated with
366 cross-realm environments while targeting issues of high priority to the participating EU Member
367 States, including marine biological invasions in the Greek Aegean Sea and agricultural irrigation
368 in Austria. All case studies were developed through active stakeholder engagement. Together,
369 they span diverse geographical scales, governance arrangements, socio-economic contexts, and
370 combinations of terrestrial, freshwater, and marine realms, providing a proof of concept for the
371 implementation of PI-BISP across a wide range of planning settings. While all case studies
372 adopted a common methodological framework, using statistical and process-based models to
373 develop biophysical and socio-economic spatial layers, and spatial prioritization tools to identify
374 priority conservation areas, their distinct objectives, scales, and local conditions enabled a
375 comparative evaluation of PI-BISP implementation (Table 1; Supplementary Table 1).

376

377 **3.1. Lake Neusiedl and Seewinkel wetlands, and agricultural land in between**

378

379 This case study aimed to identify 'scientifically optimal' areas to expand existing conservation
380 (both strict and 'conventional' protection) and restoration areas for the benefit of biodiversity and
381 productive landscape uses while considering current and future water irrigation constraints.
382 Located in a cross-border area of Austria and Hungary (Fig. 2), the study region is a complex,
383 human-dominated landscape with multiple uses and land-ownerships, and covers both the
384 terrestrial and freshwater realm, the latter including the lake, extensive reed belt and ephemeral
385 soda pans. Key sectoral interactions are the interplay of water availability, both below and above-
386 ground, with the preservation of endangered habitats and species, and agricultural practices, with
387 farmland irrigation. Planning scenarios explored potential restoration areas that maximize
388 biodiversity benefits while maintaining stakeholder accepted agricultural practices. Stakeholders
389 include state-level planning authorities, national park administration and managers, landscape
390 planning offices and NGOs. By applying a BISP framework, the case study focused on filling
391 critical gaps in spatial datasets (e.g., reed extent, regional species habitats) and links between

392 Austrian national biodiversity conservation policies and local stakeholder planning priorities.
393 Special focus was given to incorporating both agriculture and biodiversity demands, the latter of
394 which included structural habitat connectivity and ecosystem services. Stakeholder engagement
395 focused on getting key actors known in the region informed and involved, which given the rather
396 small study extent, could most effectively be conducted through in person workshops and one-to-
397 one interviews. A general difficulty however was continued engagement across borders into
398 Hungary (owing to language differences), data availability, and communicating to stakeholders
399 the benefits of systematic approaches in spatial planning.

400

401 **3.2. Tagus River catchment, estuary and nearby ocean**

402

403 This case study aimed to identify priority areas across the Tagus river catchment spanning
404 Portugal and Spain, the estuary and its nearby marine area that are suitable for the conservation
405 of species with a legal mandate for management (e.g., listed in the regional or National
406 catalogues, and the EU Birds and Habitats Directives). The planning process considered
407 biodiversity conservation alongside ecosystem services and key human activities, such as
408 agriculture, energy production and commercial fishing activities. The spatial planning exercise
409 considered multiple planning horizons and incorporated future distributions of biodiversity
410 features under climate and land-use change scenarios co-developed with stakeholders.
411 Stakeholders included regional and national authorities responsible for environmental planning,
412 biodiversity conservation, water management and regional development, alongside NGOs from
413 Spain and Portugal. This case study was designed to minimize potential trade-off and maximize
414 synergies among biodiversity conservation and other productive sectors, previously identified with
415 stakeholders. The framework facilitated stakeholder engagement throughout the planning
416 process, supporting the contextualization of the PI-BISP exercise, the critical evaluation of the
417 management recommendations, and identification of governance opportunities and barriers to
418 those recommendations. The weak existing transboundary coordination mechanisms and lack of
419 adequate funding were identified as key barriers to the implementation of management
420 recommendations. In contrast, PI-BISP was recognized as an effective tool for promoting actions
421 that address social and ecological problems in rural areas, such as the sustainable development
422 in areas impacted by abandonment.

423

424 **3.3. Aegean Sea and contributing river catchments**

425

426 This case study aimed to identify priority areas for conservation to reach the targets set by the
427 EU Biodiversity Strategy for 2030 across multiple realms, sectors and timeframes in the Greek
428 Aegean Sea and the contributing river catchments (Fig. 2). For this, we integrated information on
429 protected and threatened habitats and species, ecosystem services, climate change and
430 biological invasions under different scenarios and timeframes. We also accounted for the
431 propagation of land-based threats to rivers and the Aegean Sea from all adjacent countries (Vigo
432 et al. 2026), as well as synergies and trade-offs with the main marine industries (aquaculture,
433 fisheries, energy, tourism sectors). The study area encompasses all drainage basins discharging
434 into the Aegean Sea and spans four countries (Greece, North Macedonia, Bulgaria, and Turkey),
435 not all of which are EU Member States, thereby introducing substantial challenges related to

436 transboundary governance, policy coordination, data harmonization, and natural resource
437 management. The stakeholder engagement process involved representatives from terrestrial,
438 freshwater, and marine planning authorities, sectoral governmental bodies and managers,
439 protected area management agencies, and national environmental NGOs. The application of the
440 framework provided a unique opportunity to create new spatial datasets and develop novel
441 methods enabling the simultaneous consideration of cross-realm ecological connectivity,
442 propagation of land-based pressures, biodiversity conservation objectives, ecosystem services,
443 and sectoral interests within a single prioritization framework. This revealed conservation priorities
444 and management opportunities that would not have emerged from marine-only, freshwater-only,
445 or static protected-area planning approaches. However, the scale of implementation (national)
446 was large and encompassed multiple layers of governance, making meaningful and continuous
447 stakeholder engagement difficult. Cross-border collaboration was also constrained by geopolitical
448 complexities in the region.

449

450 **4. Reflection on the framework**

451

452 The application of the framework across three contrasting case studies provided an opportunity
453 to evaluate its practical strengths and limitations for implementing PI-BISP across realms,
454 borders, and policy objectives. Although the framework builds on established conservation
455 planning approaches, the case studies demonstrated both the benefits and challenges of
456 integrating multiple ecological realms, sectoral objectives, future environmental change, and
457 stakeholder perspectives within a single planning process. However, like every theoretical
458 framework, PI-BISP presents several inherent strengths and weaknesses in its implementation,
459 creating broader opportunities but also facing broader external challenges (Fig. 3). Critically
460 reflecting on the framework implementation across the three case studies, we argue that the
461 framework's principal strength lies in its participatory and integrative design. By co-developing the
462 planning process with key stakeholders, the framework promotes ownership, legitimacy, and
463 transparency in decision-making (Reed 2008; Nadin et al. 2021). This collaborative approach to
464 the planning process encourages dialogue across sectors that traditionally operate and decide
465 independently (Hermoso et al. 2022; Grantham et al. 2024). Across all three case studies, the
466 framework consistently revealed conservation priorities, key aspects of the problem context and
467 promising management opportunities that emerged only when cross-realm interactions, future
468 environmental change, and multiple sectoral objectives were considered simultaneously. The
469 inclusion of objectives from multiple sectors, together with explicit consideration of terrestrial,
470 freshwater, and marine realms, allowed planners to identify ecological connectivity, cross-realm
471 pressures, and management interactions that are often overlooked in conventional spatial
472 planning (Alvarez-Romero et al. 2015; Giakoumi et al. 2019; Hermoso et al. 2022). In this way,
473 the framework supports a more holistic understanding of biodiversity conservation and
474 sustainable resource use across multifunctional landscapes and seascapes.

475

476 By fostering the participation of multi-sectoral stakeholders to map interactions between the
477 objectives pursued (whether synergistic or conflictive), this framework addresses a commonly
478 identified need to strengthen conservation planning and practice: a better integration of
479 conservation and other sectoral policies (Oldekop et al. 2016; Yates et al. 2015). This can help

480 policymakers and practitioners identify synergies between biodiversity conservation, climate
481 adaptation, and sectoral development priorities, while also revealing potential conflicts before
482 implementation (Groves et al. 2012). The creation of spatial datasets from collected ecological
483 and socio-economic information, and their projection toward the future, provide an evidence base
484 that allows the mapping of synergies and trade-offs between objectives (Iglesias et al. 2025; Vigo
485 et al. In review). Recent reviews highlight that trade-off analysis and mapping are often poorly
486 addressed when applying planning frameworks such as systematic conservation planning, which
487 may be limiting the adoption of planning outputs (Beher et al. 2024; Giakoumi et al. 2025;
488 Fabbri et al. 2026). By explicitly recognizing the need for the identification of biodiversity
489 conservation opportunities beyond protected areas, the framework provides guidance on how to
490 account for multiple objectives, identify win-win solutions or the level of acceptable trade-offs.
491 Furthermore, early stages of planning benefit from future-oriented approaches that help
492 practitioners anticipate ecological and social change, explore alternative scenarios, and identify
493 robust strategies under uncertainty (Groves et al. 2012; Cook et al., 2014). In this line, the
494 framework also supports adaptive planning under climate change by accounting for dynamic
495 conditions.

496
497 Alongside these strengths, the framework implementation revealed some weaknesses. The case
498 studies highlighted the challenges of harmonizing ecological and socio-economic datasets across
499 sectors, jurisdictions, and ecological realms. These challenges were particularly evident when
500 integrating terrestrial, freshwater, and marine information, or when considering future climate
501 scenarios derived from different modelling frameworks. Spatial datasets are often incompatible
502 across administrative boundaries and sectors (e.g., using different sampling techniques, data
503 format, reporting systems etc.), while data sharing may be further constrained by institutional,
504 legal, or political barriers (Wetzel et al. 2018; Josset et al. 2019; Lodge et al. 2023). Even though
505 the framework can be implemented at any scale, obtaining high-resolution data for fine-scale
506 planning can be particularly challenging (this was emphasized case in the Lake Neusiedl and
507 Seewinkel wetlands case study; see Table S1). The harmonization of datasets across realms can
508 add an extra layer of difficulty. For example, climate projections are typically produced by multiple
509 models with differing spatial resolutions, structural assumptions, and scenario frameworks across
510 terrestrial and marine systems (Frieler et al., 2017). Overall, this lack of appropriate and
511 harmonized data can compromise cross-realm planning and the adequate cross-sectoral
512 integration of objectives into the spatial process.

513
514 Moreover, the framework requires continuous and meaningful stakeholder engagement, which
515 can be difficult to initiate when enabling governance conditions and participatory mechanisms are
516 lacking, and sustaining over long planning processes that require multiple iterations. Stakeholder
517 fatigue, unequal participation, or limited enabling conditions may reduce the effectiveness of
518 participatory governance or hinder implementation (Reed 2008; Linke and Jentoft 2016). Another
519 challenge concerns the alignment of planning scales with governance and decision-making
520 scales, particularly when ecological boundaries do not correspond to administrative or political
521 jurisdictions, as the case studies exemplify. As a result, implementing the framework may face
522 challenges due to the complexity of hierarchical governance structures and legal frameworks
523 (Adams et al. 2019). These limitations can hinder coordination across scales and jurisdictions,

524 particularly in transboundary contexts (Cittadino et al., 2025). Furthermore, the initiator of the
525 planning process would benefit from a deep understanding of the existing governance
526 mechanisms and flow of decision-making in the planning region (Adams et al. 2019). This should
527 not be limited to the information obtained through stakeholder engagement but should extend to
528 governmental/legislative documentation and advice by experts, such as lawyers specialized in
529 environmental law.

530
531 Despite its limitations, we identified a broader transformative potential of the framework. By
532 fostering collaboration and policy alignment across sectors and borders, the framework can
533 contribute to more coherent and integrated biodiversity governance. The framework aligns with
534 growing international commitments to biodiversity conservation and restoration, including area-
535 based conservation targets, biodiversity restoration initiatives, ecosystem-based management,
536 and the increasing recognition of nature-based solutions. In the EU context of the presented case
537 studies, the framework could also help mobilize and guide existing EU financial mechanisms,
538 such as the Common Agricultural and Fisheries Policies, towards biodiversity-inclusive land- and
539 sea-use practices that create social-ecological incentives for sustainability. The explicit
540 incorporation of OECMs into the planning process can create additional synergies with other
541 sectors, such as the agricultural, fisheries, and energy sectors (Petza et al. 2026). Furthermore,
542 the framework fosters knowledge exchange and collaborative learning among scientists,
543 practitioners, and stakeholders, enhancing capacity building and supporting the integration of
544 future-oriented planning approaches.

545
546 At the same time, several external threats may constrain the successful implementation of the
547 framework. Political and sectoral competition sometimes favor short-term, opportunistic, or self-
548 interested approaches that undermine integrated planning efforts (Alvarez-Romero et al. 2015;
549 Giakoumi et al. 2019) and weaken collaborative processes. Existing sectoral policies are often
550 fragmented or insufficiently articulated, making coordination difficult (Hermoso et al. 2022). In
551 addition, mismatches between ecological boundaries and administrative or political jurisdictions
552 may hinder the alignment of planning and decision-making scales. Geopolitical instability,
553 administrative barriers, and incompatible data standards may also hinder cross-border
554 collaboration (Katsanevakis et al. 2020; Mason et al. 2020). Data sharing and harmonization can
555 become even more challenging when language barriers are added to uneven technical capacity
556 across institutions constraining the cross-border implementation of the framework (Negret et al.
557 2022). Furthermore, conflicting interests among sectors, together with short political and funding
558 cycles, may impede long-term implementation and continuity (Wyborn et al. 2018; Adams et al.
559 2019). Decision-makers and stakeholders may also struggle to engage with long-term future
560 scenarios, especially when immediate economic or political pressures shape institutional priorities
561 (Rickards et al. 2014). Changes in political priorities may additionally weaken the existing
562 momentum behind biodiversity and restoration commitments. Consequently, while the framework
563 offers a promising pathway for operationalizing PI-BISP, its practical implementation and
564 effectiveness will ultimately depend on sustained political commitment, adequate funding, strong
565 governance arrangements, and long-term stakeholder engagement.

566

567 In conclusion, the framework offers a practical and adaptable pathway for advancing biodiversity-
568 inclusive spatial planning in complex social-ecological systems. Integrating multiple sectors,
569 governance levels, dynamic conditions, and ecological realms within a participatory planning
570 process helps identify synergies, navigate trade-offs, and support more coherent decision-making
571 across landscapes and seascapes. The experiences from the three case studies demonstrate
572 both the value of this approach and the challenges associated with its implementation, particularly
573 regarding data availability, governance complexity, and sustained stakeholder engagement. The
574 strengths and challenges presented herein are not exclusive to the presented framework but
575 characterize most systematic planning approaches. Nevertheless, as biodiversity loss, climate
576 change, and competing land- and sea-use demands intensify, the need for integrated and
577 forward-looking planning approaches becomes increasingly urgent. The framework, therefore,
578 provides not only a methodological foundation for operationalizing PI-BISP, but also a platform
579 for fostering collaboration, learning, and adaptive governance. Its long-term success, however,
580 will depend on continued political commitment, adequate resources, and the capacity and
581 motivation of institutions and stakeholders to work collectively across sectors, scales, and
582 borders.

583

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597

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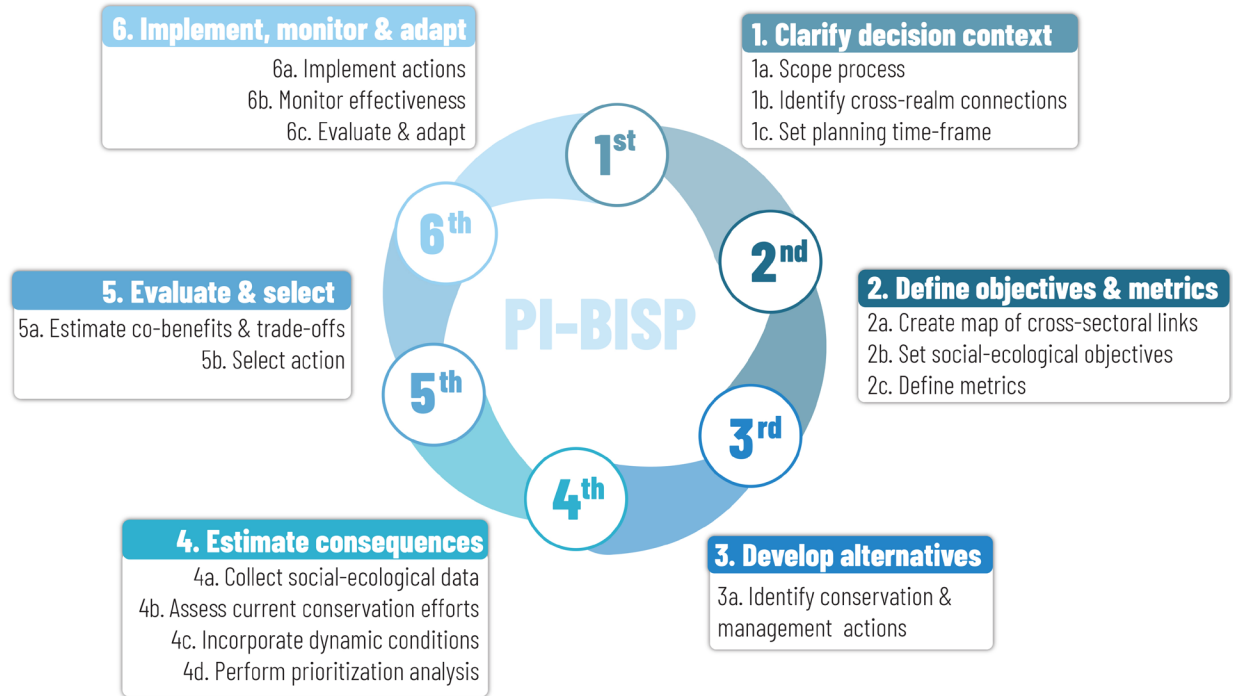
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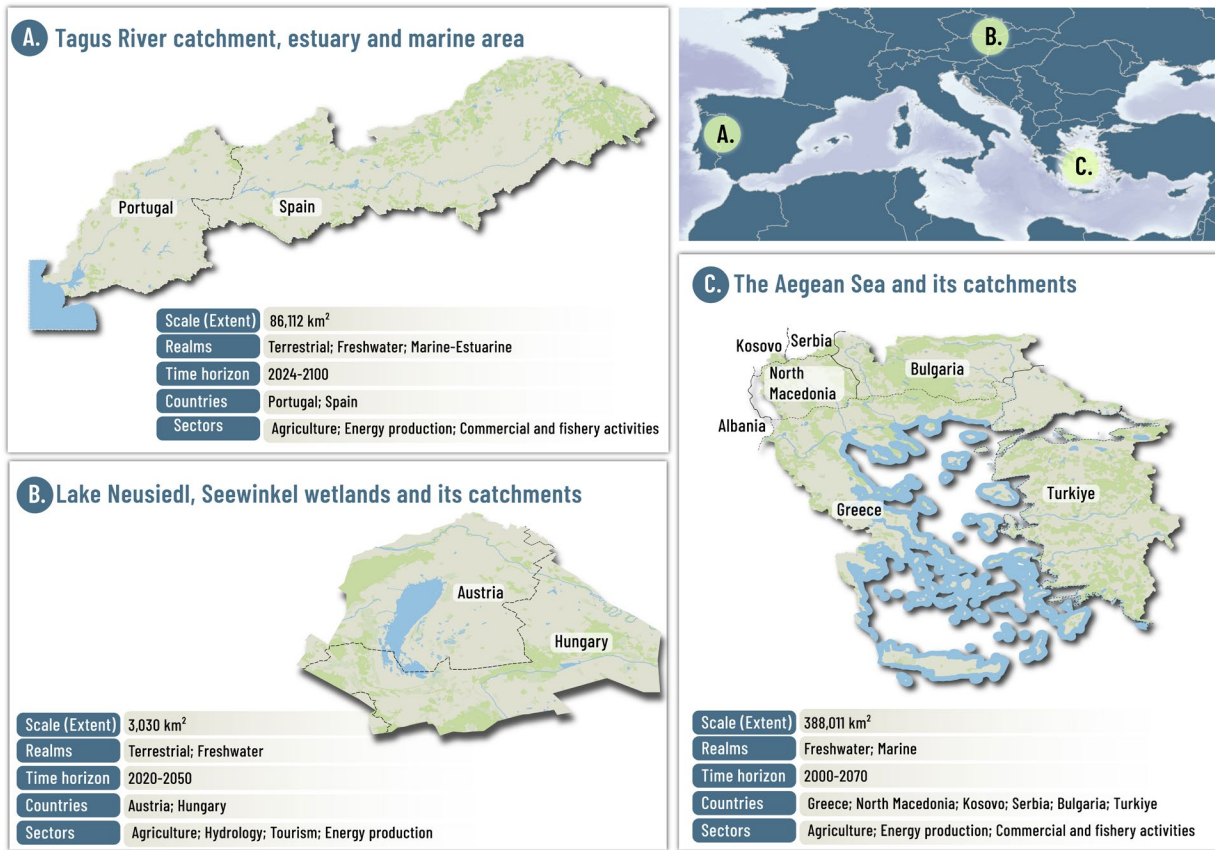
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847 Figure 1. Steps of the framework for operationalizing participatory, integrated, biodiversity-
848 inclusive spatial planning (PI-BISP). The framework is iterative, with feedback loops among all
849 steps allowing objectives, assumptions, and management options to be revisited as new
850 information becomes available.



851

852 Figure 2. Case studies where the PI-BISP framework was implemented. Cross-border
 853 prioritization was applied only in case study A; in case studies B and C, priority conservation
 854 areas were only identified in Austria and Greece, respectively.



855

856 Figure 3. SWOT analysis of the framework operationalizing PI-BISP. The analysis synthesizes
 857 the lessons learned from the three case studies.

858

Table 1: Short description of the framework implementation in the three European case studies.

Framework Steps	The Aegean Sea and its catchments	Tagus River catchment, estuary and marine area	Neusiedl Lake and its catchments
1. Clarify the decision context	Stakeholder interviews identified conservation priorities, pressures and threats, challenges, and a 2030 timeframe. Researchers identified cross-realm ecological connections and threat propagation.	A stakeholder-researcher workshop identified objectives pressures, threat propagation, ecological connections across realms, and a 2050 timeframe.	Key stakeholders were interviewed individually on regional cross-realm challenges and priorities. Researchers identified timeframe up to 2050 based on policy context and local decision-making processes.
2. Define operational objectives, targets and indicators	Stakeholders ranked ecosystem services, identified priority species, and interactions between objectives. Targets included biodiversity, ecosystem services, sustainable energy, and protected-area coverage.	Stakeholders identified synergies/ conflicts between objectives, selected targets for biodiversity based on legal responsibility, agriculture, ecosystem services, and energy. Three future pathways were identified: business-as-usual, nature-focused and intermediate.	Stakeholders identified cross-sectoral constraints and interlinkages. Targets included biodiversity, ecosystem services and energy, and were based on local policy. Three pathways were identified: business-as-usual, nature-focused and integrated viewpoints.
3. Develop alternative management strategies	Planning scenarios explored the identification of priority areas for strict and conventional protection, food provision, and the development of offshore wind farms.	Co-creating planning scenarios included nine management zones for allocating areas for strict and conventional protection, intense agricultural use, photovoltaic, and commercial fishing.	Planning scenarios explored for allocating areas for strict protection, conventional protection, restoration, and irrigated and non-irrigated production.
4. Estimate consequences of alternative management strategies	Marxan and prioritizr applied for multi-objective biodiversity planning considering dynamic global threats and minimizing cross-realm threats.	Marxan with zones used in conjunction with stakeholder engagement to prioritize the allocation of nine management zones.	Prioritizr applied for a multi-zonal problem with 35 management zones separated by ecosystem type.
5. Evaluate trade-offs and select the most suitable management alternative	Outcomes of scenarios were compared in terms of spatial configuration, area coverage, biodiversity and ecosystem representation, and exposure to threats.	Outcomes of scenarios were evaluated with stakeholders exploring trade-offs between different objectives. Feasibility of solutions was incorporated into the analysis.	Outcomes of scenarios were evaluated using different penalties and constraints related to landscape use. Feasibility of solutions was incorporated into the analysis.
6. Implement, monitor, and review	Stakeholders showed interest in the approach but implementation is not a consideration at present.	Stakeholders were interested in the approach but currently implementation is unfeasible in terms of governance.	Stakeholders are potentially interested in implementing part of the suggested management actions.