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EFFECTIVENESS ASSESSMENT OF PROTECTED AREA MANAGEMENT USING OBJECTIVE INDICATORS: AN APPLICATION TO A COASTAL WETLAND SYSTEM OF THE TYRRHENIAN LITTORAL

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ABSTRACT

One of the fundamental principles of biodiversity conservation is the integration of human development with nature protection, challenging the long-standing notion that these goals are mutually exclusive. Accordingly, conservation strategies must be designed to safeguard biodiversity targets while delivering measurable outcomes. This process should begin with a systematic analysis and prioritization of threats based on objective, transparent criteria.

This need is particularly acute in Protected Areas (PAs), such as Nature Reserves and Natura 2000 sites, where mitigating threats is not only a management priority but also a legal and financial obligation. In these settings, anthropogenic pressures—collectively referred to as “threats”—are widely recognized as major drivers of natural selection, shaping the composition, structure, distribution, and long-term dynamics of biological communities.

This PhD thesis presents the results of a structured evaluation process grounded in the “Project Cycle”, a conceptual framework developed by the International Union for the Conservation of Nature (IUCN) to assess management effectiveness in PAs. The “Project Cycle” consists of six key phases (Context, Planning, Inputs, Process, Outputs and Outcomes) that guide the design, implementation, and evaluation of conservation interventions, integrating both analytical methods and expert judgment.

For the first time in Italy, two methodologies have been systematically applied to assess threats and measure the effectiveness of conservation actions:

- Threat Analysis Threat Analysis (TAN): for the identification, classification, and prioritization of threats to biodiversity targets.
- Threat Reduction Assessment (TRA): for quantifying the degree of threat reduction following conservation interventions.

The research includes a series of case studies primarily focused on two coastal wetland systems along the Tyrrhenian coast of central Italy:

- The Palude di Torre Flavia PA, also designated as the Special Protection Area (SPA) IT6030020 “Torre Flavia” (Rome, Lazio);
- The Diaccia Botrona PA, designated as both a Special Area of Conservation (SAC) and SPA IT51A0011 “Palude Diaccia Botrona” (Grosseto, Tuscany).

In these sites, the TAN and TRA methodologies were applied to evaluate management practices and their ecological outcomes.

Additionally, the research extends to other case studies in different areas, focusing on some

species, such as the birds *Charadrius alexandrinus* and *Charadrius dubius*, and the turtles *Rafetus swinhoei*, *Cyclanorbis elegans* and *Caretta caretta*. In these contexts, the threat assessment framework was applied to biodiversity targets through an expert-based evaluation approach.

This research highlights the importance of adopting rigorous, indicator-based methods for the evaluation of PA management. It also underscores the strategic role of ecologists, conservation professionals, and stakeholders in designing interdisciplinary approaches in line with the goals of the EU Biodiversity Strategy for 2030 and the obligations established by the Birds and Habitats Directives (Directives 2009/147/EC and 92/43/EC).

STRUCTURE OF THE THESIS

This PhD Thesis is structured in twelve chapters.

- Chapter one provides a brief introduction to the main topics addressed in the dissertation.
- Chapter two explores the ecological value of wetlands and the relationships between habitats and species, while also introducing the main study areas.
- Chapter three describes the conceptual and methodological framework adopted in the thesis, particularly the "Project Cycle" and the Threat Analysis (TAN) and Threat Reduction Assessment (TRA) procedures.
- Chapters four to six present the results of case studies published in peer-reviewed journals, in which the candidate is the first author. These chapters evaluate threats, conservation actions, and the achievement of objectives related to target species in protected areas, using the TAN and TRA methodologies.
- Chapters seven to ten consist of previously published manuscripts focused on particularly sensitive conservation targets: the birds *Charadrius alexandrinus* and *Charadrius dubius*, and the reptiles *Rafetus swinhoei* and *Cyclanorbis elegans*. These manuscripts also introduce a simplified conceptual framework to clarify the complex causal relationships in threat analysis by integrating the TAN approach with DPSIR indicators (Driver, Pressure, State, Impact, Response). The field data, whose collection also covered a period prior to the beginning of the PhD research, were the subject of these analyses conducted within the thesis.
- Chapter eleven applies the TAN procedure to the Loggerhead sea turtle (*Caretta caretta*) in the central Mediterranean, presenting the results of a study currently under peer review.
- Chapter twelve offers final considerations, summarizing the main findings of the thesis and suggesting future directions for research and application.

LIST OF ABBREVIATIONS

BD – Birds Directive EU

CBD – Convention on Biological Diversity

DPSIR - Driver, Pressure, State, Impact, Response

HD – Habitat Directive EU

IBA – Important Bird Areas

IUCN - International Union for the Conservation of Nature

PA – Protect Area (includes Natura 2000 network)

SAC - Special Area of Conservation

SPA – Special Protection Area

TAN - Threat Analysis

TRA - Threat Reduction Assessment

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Chapter 1: **BRIEF INTRODUCTION**

The management of environmental, social, and economic issues often reveals critical challenges arising from either natural causes or human-induced pressures (Table 1.1). These approaches must also lead to the achievement of the objectives set, for example, by the Birds and Habitats Directives (Directives 2009/147/EC and 92/43/EC).

In the former case, the term *disturbance* refers to a natural event capable of altering any environmental component or the organizational structure of an ecological system (Pickett et al., 1989). In the latter, the term *threat* denotes any human-driven process that adversely affects specific components of biodiversity within a given context (Salafsky et al., 2008).

TOPIC	CAUSE	TARGET GROUPS	DISCIPLINARY FIELDS	AREA OF INTEREST	BASIC REFERENCES
Disturbance (and related terms)	Natural	Natural components (as well as anthropical)	Ecological disturbance	Ecology	Sousa, 1984; Pickett & White, 1985
Threat (and related terms)	Anthropical	Natural components	Threat analysis	Nature conservation, Environmental management	Salafsky <i>et al.</i> , 2002, 2003, 2008
Calamity, natural disaster	Natural/Anthropical	Mankind (subsequently, natural components)	Disaster Science, Disaster studies, <i>risk analysis</i>	Applied Geology, Environmental Geology, Civil protection	Alexander, 2001

Table 1.1 - Categories of Events in a naturalistic Context (from Battisti et al., 2013 modif.).

Project management is a transdisciplinary discipline grounded in problem-solving approaches aimed at mitigating or eliminating specific anthropogenic threats. It provides a structured framework for evaluating the effectiveness of both routine (ongoing) management and exceptional (project-specific) interventions within PAs (Salafsky et al., 2003; Hockings et al., 2006; Turner, 2009; Leverington et al., 2010; Kerzner, 2013).

In the context of exceptional management, the "Project Cycle" a framework recently developed by the International Union for the Conservation of Nature (IUCN), a non-governmental organization based in Gland, Switzerland offers a sequence of defined steps to guide planning, implementation, and evaluation of conservation initiatives (Hockings et al., 2006) (Fig.1.1).

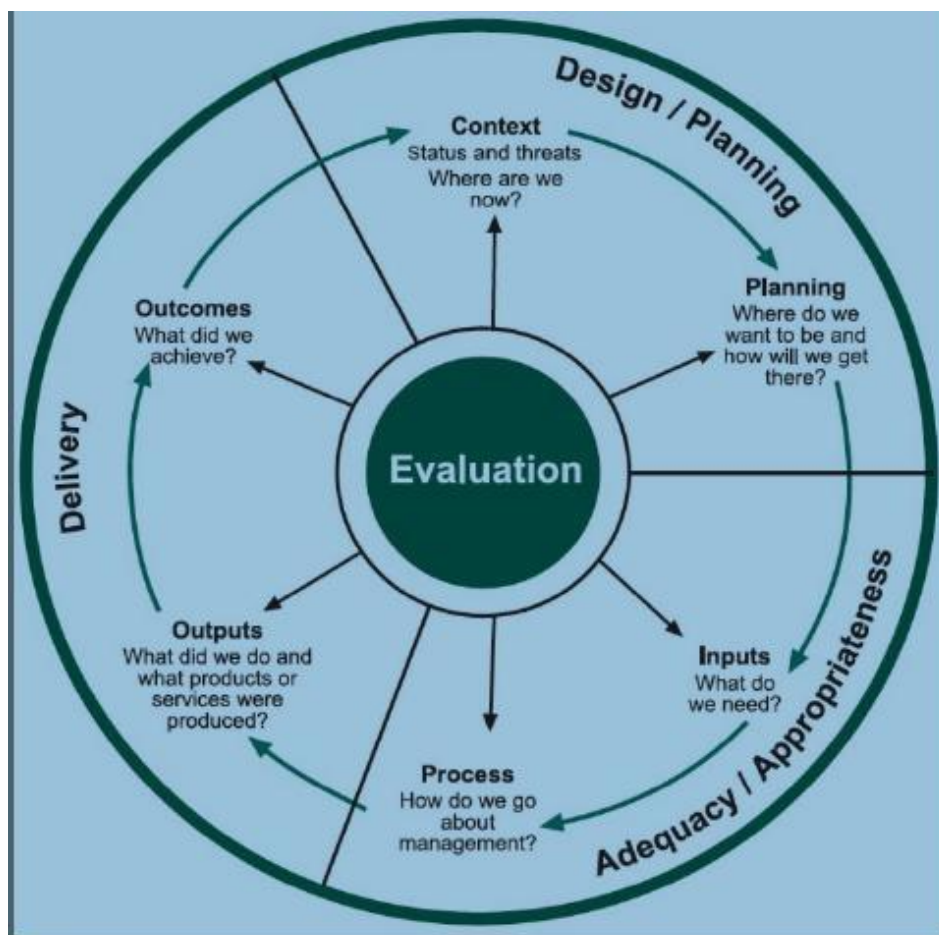


Figure 1.1 - The framework for evaluating the effectiveness of protected area management (from Hockings et al., 2006).

By integrating a wide range of concepts, tools, and methodologies, the “Project Cycle” establishes a coherent conceptual framework that clarifies its underlying logic and facilitates the rapid assessment of management effectiveness in PAs (WWF & The World Bank, 2007).

The problem-solving logic underpinning this framework involves a structured process: first, identifying and quantifying the environmental issue, understanding its underlying causes, and then developing potential solutions. These are subsequently evaluated through a cost-benefit analysis to support informed decision-making. Cost-benefit analysis is a specific analysis of Project Management separate from TAN. In the cost-benefit analysis the costs and benefits of each solution undertaken are compared. Once the most appropriate strategies are selected, project objectives are defined, and corresponding actions are planned and implemented. The outcomes are then assessed for effectiveness using a combination of analytical methods and expert judgment. In the “Project Cycle”, the TAN and TRA methodologies therefore lead, respectively, to the examination of the causal chains that connect indirect threats to direct impacts on conservation objectives, while, through the second methodology, it is the monitoring of threats that then allows to evaluate the effectiveness of the measures undertaken.

Results are typically classified into two levels: first-level results, referring to the actions undertaken, and second-level results, reflecting the impacts on biodiversity and ecosystems. These are measured using appropriate indicators - such as pressure, state, impact, and response - within the DPSIR (Driving forces–Pressures–State–Impact–Response) framework. At this stage, the strategic role of these indicators becomes essential, as they form the basis for evaluating management effectiveness, particularly in the context of project implementation.

The status of the issue is thus a preliminary aspect, which should be explored with data on the context in which a conservation project is to be initiated. The TAN enables the definition of specific objectives aimed at biodiversity conservation. However, this analysis should be conducted considering both natural and anthropogenic disturbances on biological diversity, environmental mosaics, and other ecosystem components (soil, water, air, etc.) (Tab.2.1).

IUCN - CMP Unified Classification of Direct Threats			Direct threats are the proximate human activities or processes that have impacted, are impacting, or may impact the the status of the taxon being assessed (e.g., unsustainable fishing or logging). Direct threats are synonymous with sources of stress and proximate pressures. Threats can be past (historical, unlikely to return or historical, likely to return), ongoing, and/or likely to occur in the future.
Version: 3.2			
Level of Classification		Definition	* See Additional Notes on usage at the end *
1	2	3	Exposition
8. Invasive & Other Problematic Species, Genes & Diseases		Threats from non-native and native plants, animals, pathogens/microbes, or genetic materials that have or are predicted to have harmful effects on biodiversity following their introduction, spread and/or increase in abundance	After much deliberation it was decided to restrict the use of "invasive species" to refer to non-native species to keep things simple for policy makers. The term "problematic native species" is used instead to refer to native species that have become superabundant or otherwise cause problems. If possible, also record the source of the invasive species and/or conditions that exacerbate their effect. This is the class of threats that covers diseases. Where the Kingdom for a fungal disease is unknown, it should be coded under 8.1.1, 8.2.1 or 8.3.1 and the disease name should be noted in the text field.
8.1 Invasive Non-Native/Alien Species/Diseases		Harmful plants, animals, pathogens and other microbes not originally found within the ecosystem(s) in question and directly or indirectly introduced and spread into it by human activities	We are defining non-native/alien/exotic species and diseases as those brought in either intentionally or accidentally by humans in the last 10,000 years. Note that for diseases, it is the infective agent which is considered to be the threat, with the disease being its manifestation in individuals. Domesticated livestock that has gone feral should be coded here, but there is a grey area concerning 'farmed' livestock which are allowed to roam wild; if these are rounded up periodically they could be considered 'farmed' and coded under 2.3 Livestock Farming & Ranching, but if there is little to no management they might be better placed here.
	8.1.1 Unspecified Species		Only to be used if it is known that there is a threat from an invasive, but the species involved have not been named or only named at a very general level - e.g. invasive plants, invasive animals, etc. There is a text box alongside the threat to provide further explanation/detail on this and some of the information might also be relevant for inclusion under the Threats narrative.
	8.1.2 Named Species	List the specific plant, animal, or microbe e.g., <i>feral domesticated cattle, household pets, zebra mussels, Dutch elm disease or chestnut blight, Miconia tree, introduction of species for biocontrol, chytrid fungus affecting amphibians, etc.</i>	A list of named taxa (e.g., species or a group of species like rats if it is unclear which species in particular is involved) is available to select from in the SIS database via the "Quick Add" function (this list has been compiled in collaboration with the IUCN SSC Invasive Species Specialist Group and links to the information held in the Global Invasive Species Database). In addition, any taxon already in the taxonomic hierarchy in the SIS database (at whatever taxonomic-level) can be added as a named invasive via the "Quick Add" function. Note, if the named disease is caused by viruses or prions, option 8.5 should be used instead and there is a separate list of those "organisms".
8.2 Problematic Native Species/Diseases		Harmful plants, animals, or pathogens and other microbes that are originally found within the ecosystem(s) in question, but have become "out-of-balance" or "released" directly or indirectly due to human activities	It is a bit of a judgement call as to when a species becomes "problematic" (also referred to as species being "outside its natural range of variation"). Note that for diseases, it is the infective agent which is considered to be the threat, with the disease being its manifestation in individuals. This category will probably be
	8.2.1 Unspecified Species		Only to be used if it is known that there is a threat from a native taxon but the species involved have not been named or only named at a very general level - e.g. plants, animals, etc. There is a text box alongside the threat to provide further explanation/detail on this and some of the information might also be relevant for inclusion under the Threats narrative.

Table 2.1 - Extract of the threats classification scheme proposed by IUCN (2012).

In management, sampling evaluation based on expert judgment is a less data-driven approach, lacking long timeframes for information collection. However, the method's key strengths include its speed, cost-effectiveness, group analysis, ease of establishing a threat hierarchy, and clarity of

objectives. Subsequent decision-making processes, often strengthened by this methodology, can lead to solutions geared toward adaptive management.

Analytical methods, on the other hand, rely on data collected over long periods of time, selecting indicators that are comparable over time. These methods, however, are more costly, despite providing more precise information on ecological processes (Underwood, 1992; Maxim et al., 2009). These critical issues could lead to the omission of details that are important for accurate subsequent conservation planning and evaluation in heterogeneous socioecosystems. However, it is necessary to start from the implicit assumption that sampling methods can describe a beneficial decision-making process: this is evident when pragmatic approaches come to the rescue because the events to be monitored are extremely complex and not measurable analytically (Stem et al., 2005; Giovacchini et al., 2022).

To address these issues, and therefore to verify the reliability of sampling, managers have a wide array of concepts, tools, and approaches at their disposal. These analytical systems demonstrate robustness but also critical issues (e.g., Haines, 2000; Knight et al., 2006; Battisti, 2018). Considering the important role played by anthropogenic threats and pressures on the environment, it should also be borne in mind that, in general, assessments should also draw on the broader ecological literature available on the subject, as well as a possible hierarchy to be implemented in sampling methods (Stem et al., 2005).

In the context of data collection and sampling, the experimental manipulative method can therefore be described as the subsequent approach in which the researcher deliberately alters or controls one or more variables (independent variables) to observe their effect on another variable (dependent variable), while attempting to minimize or account for the influence of other factors. This typically occurs within an experimental context, with the aim of establishing cause-and-effect relationships, and involves the analysis of environmental data, such as temperature, precipitation and species populations, to understand ecological patterns (e.g. Fox et al., 2003; Smith et al., 2014).

In recent years, through the Convention on Biological Diversity (CBD), a legally binding international treaty opened for signature at the Earth Summit in Rio de Janeiro on June 5, 1992, and entering into force on December 29, 1993, world leaders agreed on a global strategy for the conservation and sustainable use of biodiversity. During those years, the Convention's Secretariat encouraged its member states to conduct assessments of the management effectiveness of at least 30% of each state's PAs by 2010, including the results in their national CBD reports, as well as in adaptive management strategies. However, due to the weak management of these processes, many PAs still fail to meet the conservation objectives for which they were established (Thapa & Lindner, 2023). On the other hand, with clear and defined targets, management strategies must be adaptive, given the large number of factors involved and their unpredictable variation over time and space, while also considering the values represented by areas of particular importance for biodiversity and ecosystem services (Battisti, 2006).

This PhD project involved the use of indicators to conduct a TAN, outlining strategies to mitigate impact phenomena, primarily within a system of wetlands along the Tyrrhenian coastal areas of Lazio and Tuscany: [SAC–SPA IT51A0011 “Palude Diaccia Botrona” - Regional Reserve “Diaccia Botrona” (Province of Grosseto, Tuscany, Italy); SPA IT6030020 “Torre Flavia” - Natural Monument “Torre Flavia” (Province of Rome, Lazio, Italy)], in any case, within conservation projects focused on threatened targets. Furthermore, it is important to note that these areas are complex and dynamic ecosystems where the alteration of natural processes leads to changes at various levels of ecological organization (Amezaga et al., 2002).

The research focused on case studies where the international standard developed by the IUCN (Hockings et al., 2006) was applied, structured around specific extraordinary and routine management projects in order to obtain expert-based data that are then subjected to inferential statistics.

The project involved examining the relationships between threats and targets, primarily through the application of TAN (Salafsky et al., 2008), as well as defining conceptual frameworks of driving forces-indirect threats-direct threats-sensitive targets (Salafsky et al., 2003; Battisti et al., 2023). The TRA procedure (Salafsky & Margoluis, 1999; Anthony, 2008) was also proposed in some cases as a method to quantify conservation success and as a substitute measure for impacts on conservation and threat monitoring (Fig.2.1).

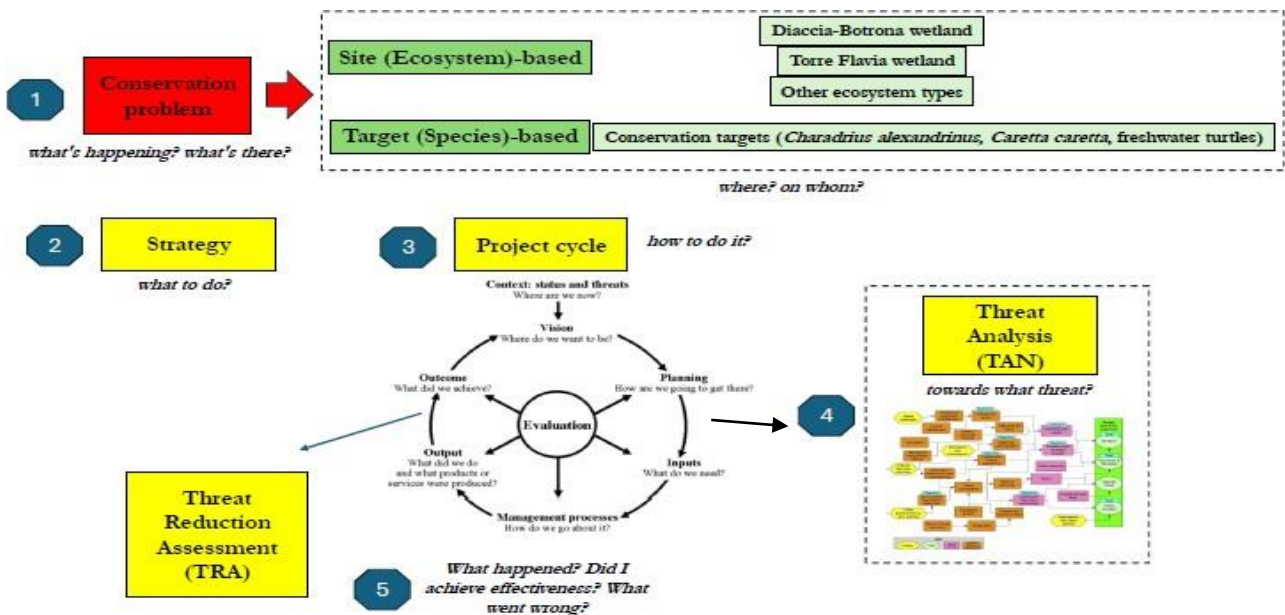


Figure 2.1 – Conceptual framework of this PhD Project.

These analyses, collectively, help to better define their exposure within the context of conflicts related to the human dimension (Decker et al., 2012).

The document represents the first such example in Italy to date.

A synthetical framework has been reported (Fig.3.1).

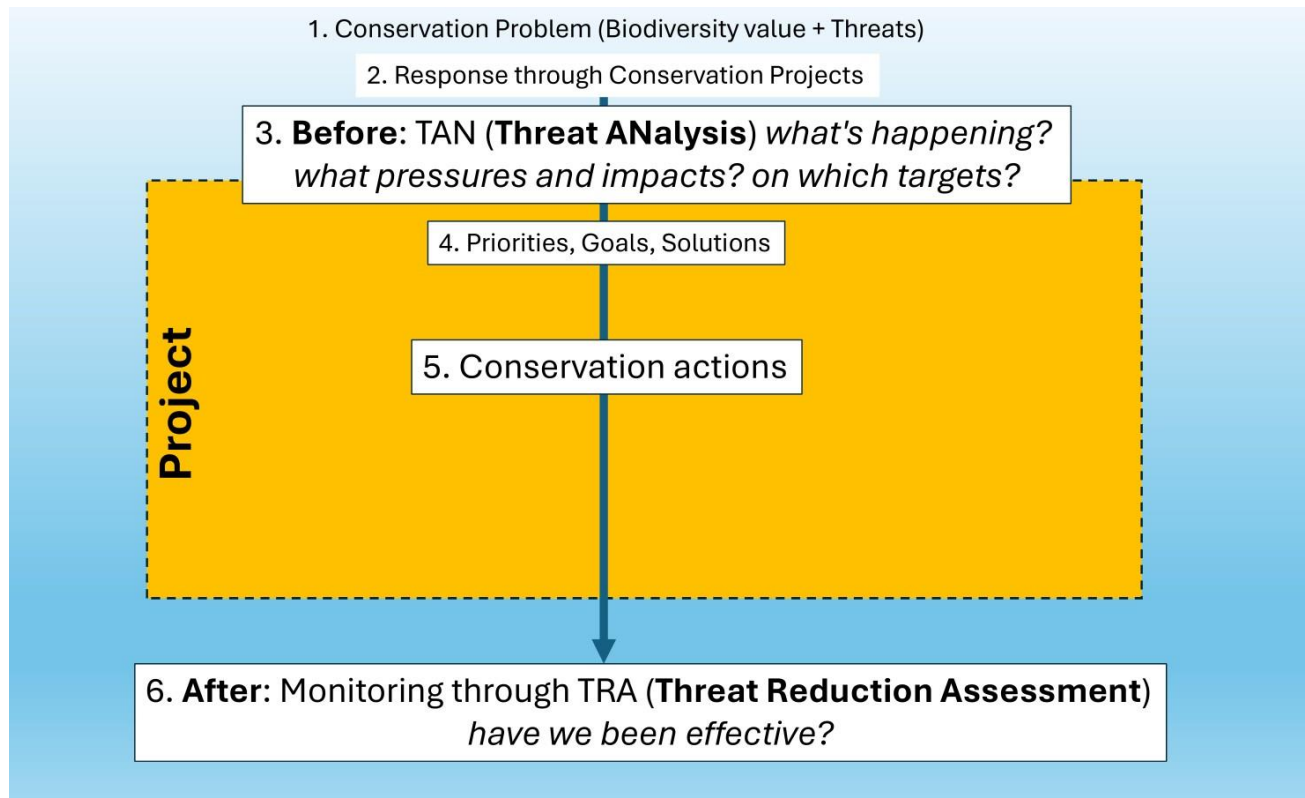


Figure 3.1 - Synthetical conceptual framework of the project steps with location of TAN and TRA approaches.

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Chapter 2: ECOLOGICAL RELATIONSHIP ON HABITATS AND SPECIES IN WETLANDS

Wetlands are transitional environments, primarily characterized by significant fluctuations in physical characteristics, leading to considerable variability and availability of diverse habitats both spatially and temporally.

A historical impetus for the conservation of these fragile ecosystems came in the 1970s with the International Wetlands Conference, held in Ramsar, Iran, in 1971.

These environments primarily:

- Influence and regulate hydrogeological cycles, playing a crucial role in erosion control and coastal zone stabilization, while also regulating groundwater and surface water regimes (Barbier, 2007; Banerjee et al., 2013);
- Are often characterized by high levels of trophic status (Hart & Lovvorn, 2005; Lu et al., 2024);
- The productivity and biological diversity of these ecosystems make them suitable for sustaining a rich and varied network of biological populations, providing essential sites for reproduction and refuge (Johnston et al., 2002; Sanchirico & Mumby, 2009);
- Are recognized for their productive-economic role linked to the enhanced fertility of adjacent agricultural areas (Banerjee et al., 2013; Huryňa et al., 2014);
- Hold significant educational, cultural, and scientific value (Kwak et al., 2007; Giblett, 2024).

Each wetland should be part of a network of PAs, for which one of the most relevant functions is to ensure year-round protection for wildlife, facilitating interchanges of species, especially during winter and migration periods. The disappearance of these areas and the transformation of the surrounding natural habitats result in reduced wetland surface area and increased isolation of remaining wetland fragments, triggering edge effects at various levels with different modes and intensities on the residual fragments (Humphreys et al., 2020; Battisti, 2023).

More generally, among the threats, industrial activities near the wetland cause possible pollution through the percolation of surface water into the underground aquifers as happens with any landfills present or abandoned nearby, while hunting and poaching cause significant impacts over time with the accumulation of lead in soil; equally worrying are the tourist load, the presence of ungulates, stray dogs and exotic species and finally, in the adjacent areas, industrial agriculture that could make use of synthetic fertilizers and pesticides (Wisser et al., 2010; Butt et al., 2021; Barasona et al., 2022; Pegg et al., 2022). A technical-professional approach to addressing ecological and management issues is therefore essential. Only through the objective assessment of factors and processes, utilizing indices and indicators, can appropriate strategies be defined to mitigate these challenges (Noss, 1990; Gregory et al., 2005).

The study areas. Disturbances and threats in ecosystem.

The "Torre Flavia Wetland" (geographical coordinates: 41° 58' N; 12° 03' E) is a PA classified as a "Natural Monument". Located along the Tyrrhenian coastline in the municipalities of Ladispoli and Cerveteri, in the province of Rome, it was established on March 24, 1997, by Regional Government Decree No. 613. The management of the area is under the responsibility of the Province of Rome (now the Metropolitan City of Rome since 2016). According to the BD and Natura 2000 database, the wetland is also designated as SPA IT6030020 "Torre Flavia" (RM) in the official list of the Ministry of the Environment and Energy Security. This area largely coincides with the "Natural Monument" site, which also includes the sandy coastal strip.

Torre Flavia lies within the Mediterranean climate region, characterized by a lower mesomediterranean thermotype and a superior dry-subhumid ombrototype. It is a xerothermic region (thermomediterranean/mesomediterranean subregion), typical of the coastal areas of the province of Rome (Blasi, 1994). Precipitation distribution peaks in November-December and reaches a minimum in July, following a typical Mediterranean pattern. The average minimum temperatures in the coldest month range from 3.7°C to 6.8°C, with precipitation levels between 593 mm and 811 mm (Battisti, 2006a).

As of the 1960s, the vast area of Torre Flavia had not been reclaimed. Today, the wetland represents one of the last sites on the Lazio coastline characterized by reed beds and rush beds, after other, fragmented, and heterogeneous wetlands that once covered several hundred hectares have disappeared, linking with the Macchiatonda and Furbara areas (Mantero & Panzarasa, 1986).

The area covers 40 hectares, extending northwest-southwest for approximately 1000 meters, reaching up to 500 meters inland, with an altitude ranging between 0 and 5 meters above sea level. The water depth typically varies from 20 to 80 cm. The area is situated on clayey-silty soils, rich in organic material of plant origin, with water accumulation in the retro-dune section, where remnants of an ancient sand dune separate the wetland from the sea (Battisti et al., 2020). Despite its marked semi-natural heterogeneity, characterized by rush beds, marshes, reed beds, and channels, Torre Flavia is almost devoid of freshwater from June to October. Its water input is primarily limited to storm surges and rainfall, with a modest contribution from the hydraulic networks that drain into the protected area from a few neighboring regions (Causarano et al., 2006).

The coastal line exhibits a high degree of ecological interest, including a landscape mosaic with helophytic vegetation, surrounded by dunes and characterized by typical coastal habitats classified in accordance with the HD. Among these, embryonic mobile dunes (Habitat 2110) are commonly represented, notable for the dominance of species such as *Thinopyrum junceum*, *Cakile maritima*,

Anthemis maritima, *Pancratium maritimum*, *Salsola kali*, *Echinophora spinosa* and *Eryngium maritimum* (Ceschin & Cancellieri, 2006). The corresponding Natura 2000 site designation for the SPA "Torre Flavia" also refers to Mediterranean flooded pastures (Habitat 1410) as one of the habitat types present (Petrella et al., 2005) (Fig.1.2).

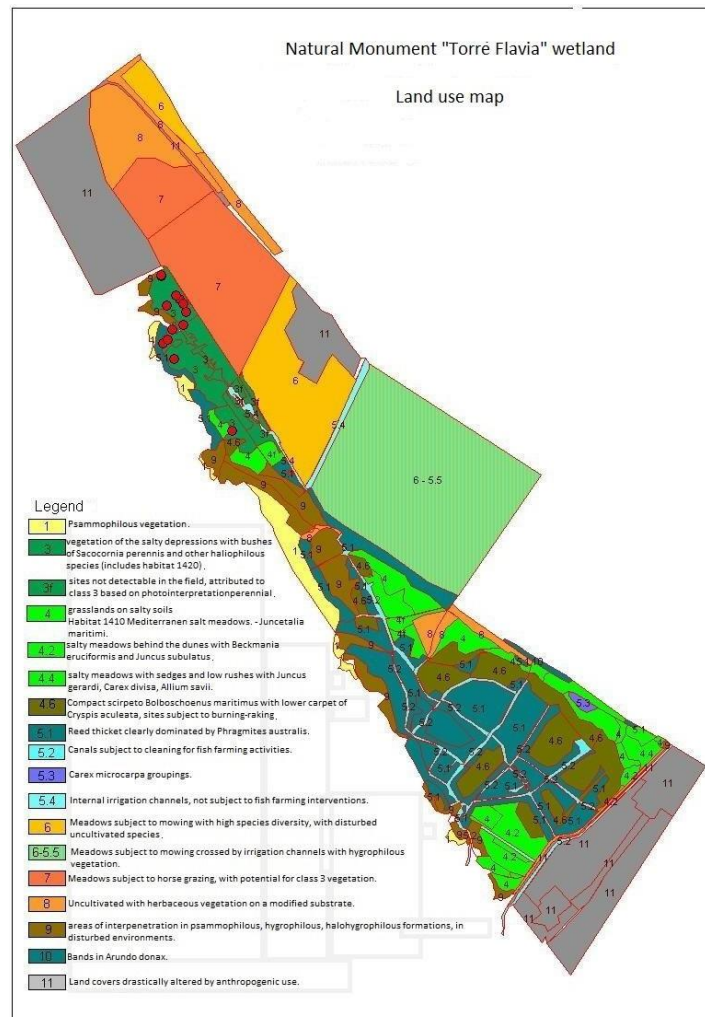


Figure 1.2 – Vegetation covers for the "Palude di Torre Flavia" Natural Monument (from Guidi, 2006 modif.).

The profound alterations and rapid changes in the environmental conditions of the site tend to drastically reduce the area occupied by each plant community, as well as the populations of species of significant naturalistic interest. For example, *Beckmannia eruciformis* and *Allium savii* are located in the part of the PA designated for "faunistic priority", where the management regulation focuses conservation efforts on protecting bird species (Guidi, 2006).

The surrounding areas of the Natural Monument play a crucial role, as the limited extent of the Protected Area necessitates management that focuses on external processes and factors, particularly in relation to the most important environmental matrices (e.g., water) that affect the conservation of

habitats and significant biocenoses. Ensuring broader spatial connectivity is essential for birds. The remaining natural fragments of Torre Flavia are subject to various disturbances that heavily impact population dynamics, particularly for highly sensitive taxa (Battisti, 2006c). Species such as the Kentish Plover (*Charadrius alexandrinus*) and the Little Ringed Plover (*Charadrius dubius*) along this stretch of coast could be negatively affected by critical factors, especially those induced by increased anthropogenic disturbance, particularly linked to the seasonal rise in foot traffic due to recreational activities, which leads to the reduction of natural environments (such as dunes and beaches). Furthermore, the general lack of conservation actions for habitats and species, particularly during the reproductive period, exacerbates the situation (Battisti et al., 2023a).

The accumulation of artificial waste is also a significant disturbance for the "Torre Flavia Wetland". This issue primarily affects the coastal sector, with ecological implications arising from the waste residues, including fishing lines and hooks abandoned by anglers, which pose recurring threats to bird species throughout the year (Battisti, 2006c).

More recently, the presence of alien (or allochthonous) species has introduced new scenarios into the impact assessment metrics for the area. This includes considering the hierarchical level of species, as well as the management perspectives for each species, particularly when interference with the aquatic ecosystem is long-standing and affects taxa that are present year-round (Scalici et al., 2010; Ferri et al., 2019; Battisti et al., 2023b).

Regarding vertebrate fauna, evidence of presence has been recorded for 291 taxa in the Protected Area between 1981 and 2020 (259 native, 26 non-native, and 6 domestic forms). These include 5 species of ray-finned fish (4 native and 1 non-native), 2 amphibians, 20 reptiles (11 native and 9 non-native, the latter all freshwater turtle species available in trade), and 20 mammals (including 2 non-native species) (Battisti et al., 2021).

Particularly, the birds of the "Torre Flavia" SPA exhibit notable temporal dynamics and clear seasonal variations, which are useful for defining optimal management strategies for the area. However, the species richness observed annually is lower than that seen in the nearby Maccarese ponds near Fiumicino, Rome (Biondi et al., 1990). Throughout the year, avian diversity, in relation to trends in species richness, can be attributed to the spatial, structural, and ecological characteristics of the different contexts within the area. The relative abundance of non-passerines is higher in the spring compared to the autumn-winter period, when passerines become more prominent. These patterns provide valuable insights for further studies throughout the year in the entire "Torre Flavia Wetland" Natural Monument (Battisti, 2006b).

The wetland of Torre Flavia is home to 244 native bird species, 36 of which (16%) breed in the study area, with six potentially breeding here. Additionally, there are 14 non-native taxa and 6

domestic forms. Seventy species are included in Annex I of the BD (Battisti et al., 2021). Forty-three species are of conservation concern according to the Italian Red List (Gustin et al., 2019): One species is regionally extinct, five are critically endangered, 15 are endangered, and 22 are vulnerable. Seventy-seven species are of conservation interest according to BirdLife International (BirdLife International, 2017), including 13 with global conservation concern (SPEC 1), 17 with European conservation concern concentrated in Europe (SPEC 2), and 37 with European conservation concern but not concentrated in Europe (SPEC 3). Most of these species are migratory birds. The Torre Flavia Wetland is also recognized as an Important Bird Area (IBA, Code IT147) (Gariboldi et al., 2000).

Torre Flavia Wetland thus stands as a biodiversity hotspot, particularly for birds (86.5% of the total native vertebrates), most of which are migratory, and the area serves as an important stopover site. Some taxonomic groups (e.g., *Actinopterygii*, *Amphibia Salamandridae*, *Carnivora Mustelidae* and *Chiroptera*) require further investigation (Battisti et al., 2021).

The Diaccia Botrona Wetland (coordinates 10° 56' E; 42° 46' N) is both a SAC and SPA IT51A0011 "Palude Diaccia Botrona", listed under the HD and BD, as well as a Ramsar site, according to the International Ramsar Convention. It was established by the Provincial Council of Grosseto on February 27, 1996, and has been managed by the Tuscany Region since January 1, 2016. It is also an IBA (Code IT059) (Gariboldi et al., 2000).

This wetland, a remnant of the historic "Lago Prile", spans over 120 km². The Reserve and Natura 2000 Site cover an area of 1,348 hectares, of which over 800 hectares are wetland, with an average water depth of about 70 cm. The area is situated at altitudes ranging from 1 to 12 meters above sea level. The wetland is separated from the coastline by a 550 hectare sandy tombolo with a pine forest of *Pinus pinea*, which has good natural regeneration and is rich in herbaceous and shrub undergrowth. This area hosts a significant breeding site for herons (Corsi & Giovacchini, 1995).

Until 1989, part of the wetland was subject to hunting activities under a concession granted by the State Property Agency to the Grosseto Hunting Federation, which had managed the area as a "Specific Regulation Area" since 1963. While this area was not yet affected by many of the current environmental issues, it was managed in ways that sometimes conflicted with the protection of wildlife and habitats, such as the practice of draining the wetland in early spring for mowing the grassland in the summer (Corsi, 1991; WWF, 1993). Only recently, with the establishment of the PA, have the impacts of lead contamination from hunting activities been identified (Ancora et al., 2010).

The Diaccia Botrona Wetland is located within the Mediterranean climate zone. Precipitation is typical for the coastal areas of southern Tuscany, with an average annual rainfall of 669 mm. November is the wettest month, receiving an average of 145 mm, while July is the driest, with 24

mm on average. The temperature data also follow a typical pattern, with the highest average monthly temperature in August (24.7°C), and the lowest in January (7.8°C) (Regione Toscana, 2021).

The current layout of the wetland, which was planned for drainage but never executed, consists of two embanked areas, "Diaccia" and "Botrona", separated by the "Canale della Molla". The canal is in direct communication with the sea depending on the degree of silting in the estuary and is influenced by tidal levels (Puglisi et al., 1995).

The "Diaccia" sluice, historically designed as the final floodplain expansion for the reclamation of the Castiglione della Pescaia plain, has undergone a significant transformation from an isolated state in relation to polyaline and marine waters to one where these waters now continuously inundate the area. Seasonal variations in the chemical characteristics of the waters indicate limited circulation, with a modest contribution from meteorological water inputs. Moreover, the presence of an intensive aquaculture facility within the area has sparked an ongoing debate regarding the use of water resources and the environmental impacts it causes (Bencini & Pranzini, 1993).

The freshwater marsh has rapidly transformed into a brackish lagoon, and the reed beds of *Phragmites australis* are now confined to a few small sectors of the Botrona. In contrast, larger areas are dominated by herbaceous hygrophilous-alo-nitrophilous communities, consisting of small-sized graminoids and succulent plants typical of marsh environments, such as *Arthrocnemum perenne*, *Salicornia patula*, and *Halimione portulacoides*. Extensive areas also host subhalophilous hygrophilous vegetation, predominantly *Juncus subulatus*, *Juncus maritimus* and *Bolboschoenus maritimus* (Selvi & Stefanini, 2004). The flora of the area is notably diverse, comprising around 450 species (Selvi & Sforzi, 1999).

The priority habitats of the SAC are associated with the lagoon system of the entire Diaccia Botrona, which include:

- Habitat 1150: Coastal lagoons
- Habitat 1510: Mediterranean salt steppes (*Limonietalia*)
- Habitat 2270: Dunes with *Pinus pinea* and/or *Pinus pinaster* forests
- Habitat 91F0: Riparian mixed forests of large rivers with *Quercus robur*, *Ulmus laevis*, *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*.

These habitats are essential for maintaining biodiversity in the area and for safeguarding the species that depend on them (Fig.2.2).

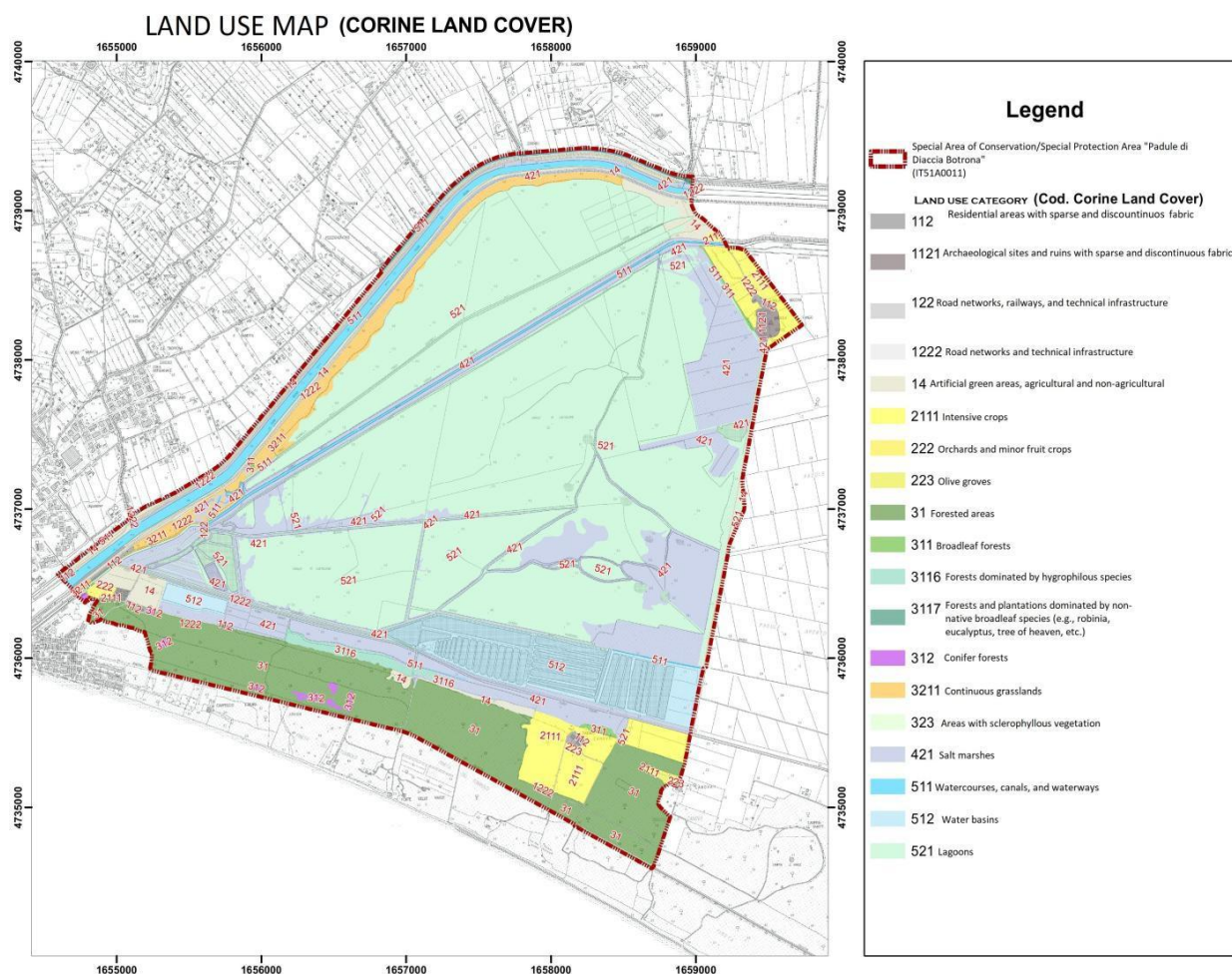


Figure 2.2 – Land use map for the “Diaccia Botrona” Regional Reserve (from Regione Toscana, 2021 modif.).

The analysis of the vegetation reveals the degradation the PA has undergone, including a significant drop in the groundwater table due to widespread water extraction. Although environmental restoration interventions have been carried out in recent decades (Giovacchini & Stefanini, 2008), the rise in average temperatures, particularly during the spring and summer months, driven by ongoing climate change scenarios, has contributed to the further natural proliferation of *Ruppia* spp. beds and floating green algae. This process is aggravated by the shallow depth of the water, which often experiences oxygen depletion and sedimentation phenomena affecting the entire wetland area. More recently, the presence of wild boar (*Sus scrofa*) has had a clear impact on the aquatic ecosystem, posing a threat to bird reproduction (Barasona et al., 2021).

When considering the environmental context of the "Diaccia Botrona", shaped by changes to the ecosystem and the associated animal and plant biocenoses from 1980 to 2019, the data gathered on vertebrate fauna richness reveals the presence of 9–17 fish species, 3–6 amphibians, 9–16 reptiles,

and 16–17 terrestrial mammal species (WWF, 1993; DISCAU, 1994; Regione Toscana, 2021). For birds, a survey conducted in 1992 recorded 169 taxa throughout the year (Puglisi et al., 1995). Updated data on breeding species show that 70 species have been confirmed to breed at least once between 2006 and 2015; of these, 45 are exclusively linked to the wetland, while 22 species from the total are listed in Annex I of the BD (Giovacchini & Stefanini, 2015). The "Maremma Grossetana" macrozone, as classified by the Italian Institute for Environmental Protection and Research (ISPRA), which includes the "Diaccia Botrona", is recognized as an internationally important site for the wintering of *Mareca penelope* and *Anser anser* (Zenatello et al., 2014).

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Chapter 3: APPROACHES TO CONSERVATION STRATEGIES: THE "PROJECT CYCLE", THREAT ANALYSIS AND THREAT REDUCTION ASSESSMENT

The Project Cycle

Anthropogenic threats are activities or processes that can lead to the degradation and destruction of biodiversity, even within sites of conservation interest such as PAs.

The management of these areas and the conservation of specific biodiversity targets require a careful analysis of existing threats and the identification of those that are truly priority, on which to focus potential intervention strategies. Management and conservation projects are often characterized by limited resources in terms of time, financial capacity, and availability of personnel, equipment, and materials (Battisti et al., 2013).

Comparing threat regimes and evaluating their effects on objectives can allow professionals to understand anthropogenic events occurring at a site, optimizing available resources in an approach that properly addresses these threats (Battisti et al., 2016).

Few PAs are immune to any type of threat; on the other hand, many are vulnerable to a variety of pressures: global threats related to climate change, regional issues such as habitat fragmentation, and localized problems such as poaching, excessive visitor impact, and waste disposal (Hockings et al., 2006; Nicol et al., 2019). Most PAs are managed to conserve a wide range of natural values, including ecosystem services and functionality, biodiversity at all levels from landscape scale to ecosystems, species, populations, and genetic variability and the human-nature relationship (Marini, 2013).

Moreover, evaluations should also consider threats that come from outside a PA, such as air pollution, as these also influence the achievement of management and conservation objectives for specific biodiversity targets.

As mentioned in Chapter 1, through a detailed process called the "Project Cycle" a coherent foundation is provided for designing assessment systems, without attempting to impose a standardized methodology. Battisti et al. (2013) and Battisti (2018) also propose a similar approach for effective PA management, explicitly introducing the phase of adaptive management (Fig.1.3). Often, conservation projects focused on species that are significantly declining not only involve monitoring the effectiveness of actions aimed at reducing anthropogenic threats but also play an indispensable role in gathering information necessary to achieve the objectives of adaptive management (Rist et al., 2013).

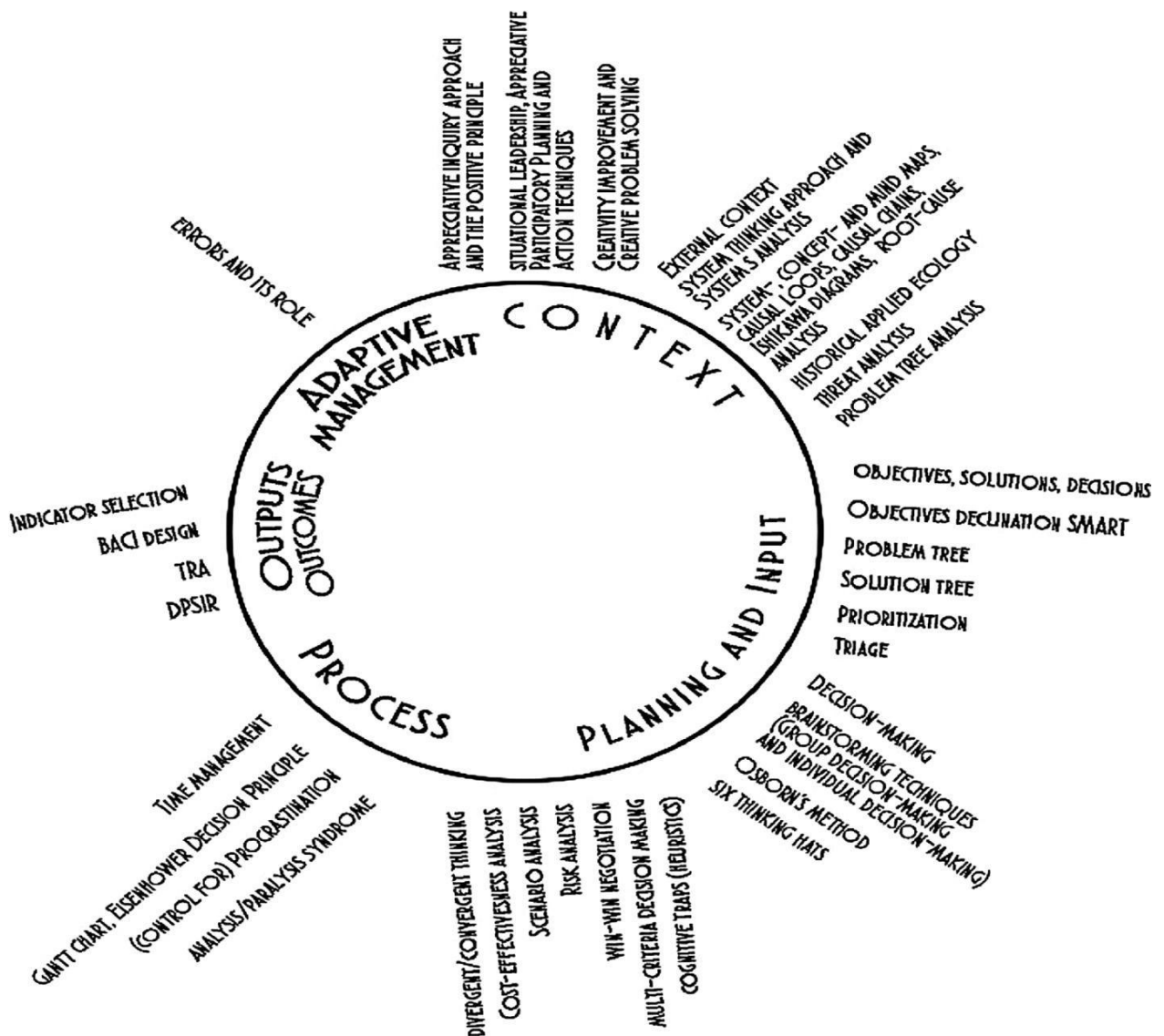


Figure 1.3 - Integrated IUCN star-shaped project cycle (from Battisti, 2018) as a new unified framework, including tools and conceptual approaches (outside the cycle). The main phases of the IUCN project cycle (sensu Hockings et al., 2006) are reported within the cycle.

As shown in Figure 1.3, following Hockings et al. (2006), the six phases of the cycle are based on a thorough understanding of the individual conditions of a PA, whose effective management should be carefully planned and implemented, including regular monitoring and leading to adjustments as necessary. Moreover, the evaluation process often involves collaborative teams, encouraging the sharing of knowledge and reflections. The management cycle identifies elements that ideally should all be assessed if one wishes to fully understand the effectiveness of the PA management or the project (Hockings et al., 2006; Battisti, 2023):

Context: Defining a vision for managing the site (in the context of its current state and existing pressures), understanding the PAs context, including its values, the threats it faces, its stakeholders, and the management and political context. This phase distinguishes between an internal context, characterized by the group structure and its behavioral dynamics, and an external context, which includes: a) environmental components with the environmental targets of value upon which the project primarily focuses; b) social components related to human processes. This initial phase provides the necessary information for planning and implementing management, focusing on the key aspects of the management process, including threat analysis.

Planning: Establishing a strategy for the project with specific goals and objectives to conserve values and reduce threats. Planning also involves evaluating the characteristics of a PA through physical, legal, and institutional factors, determining whether its management will be straightforward or complex. After defining the objectives, solutions are sought, the most effective options are selected, and actions are defined.

Inputs: Identifying and assigning resources (personnel, money, equipment) to work towards the goals.

Processes: Implementing management actions according to the "work in progress" processes.

Outputs: Producing goods and services that should typically be outlined in the management plans and work plans. The outputs indicate whether the intended goals have been achieved.

Outcomes: Impacts or results, ideally achieving the established goals and objectives. Outcome evaluation is crucial because it measures the actual effects of management actions, assessing whether the management is maintaining the core values for which the PA was established.

It is important to understand the difference between outputs and outcomes: Outcomes are the results on biodiversity while Outputs are the results on the actions taken. Outcomes are expressed through the attainment of objectives (e.g., for *Charadrius alexandrinus*, the populations can reproduce the real effect if the ecological systems function properly because they are protected by actions, projects, and services, leading to a reduction in the most severe threats to the species). This distinction is significant because it is possible to have a PA that meets all objectives but continues to deteriorate (indicating that management strategies or activities need to be modified, necessitating adaptive management), or to have a poorly managed PA that still maintains its broader values (see also Battisti et al., 2020; Battisti et al., 2023).

In the context of strategies aimed at conserving natural resources, especially for threatened species, detectable failures confirm that errors of various kinds can occur during procedures or entire projects, partially undermining objectives. New scenarios and interpretations can thus pave the way for the adaptive management phase to recalibrate the project (Runge, 2011).

By utilizing adaptive management, managers and decision-makers view unexpected outcomes as

learning opportunities, embracing this learning as an integral and valued part of the management process (Hockings et al., 2006). Many decisions, however, are made in the face of uncertainty, exacerbated by global climate change, which is pushing many ecosystems toward irreversible transformations. This presents a complex task for managers to conserve these important resources under unprecedented conditions (Malhi et al., 2020; Lynch et al., 2022).

Threat Analysis

In the “Project Cycle”, the context phase (external) corresponds to the investigation of the existing situation, considering both ecological components (the targets) and the direct and indirect threats acting upon them.

Direct threats are activities, events, factors, or processes that cause, have caused, or are likely to cause, with a certain level of probability, an impact or stress on the ecological targets. These threats directly alter, destroy, or degrade the integrity of the targets in the short, medium, or long term. Indirect threats, or driving factors (drivers), refer to the anthropogenic conditions of a site (historical, social, economic, etc.) that enable or sustain one or more direct threats. In practice, the relationships between the ecological value being considered (e.g., a population, a community, etc.) and the threatening factor or process are investigated (Salafsky et al., 2003). To analyze the relationships between targets and threats, it may be necessary to use a systems approach, which allows for the simplification, schematization, and synthesis of this complexity, helping to address and resolve the problem (Battisti, 2023).

The TAN investigates the origin, role, and relationships between root causes and proximate causes that threaten our targets (Salafsky et al., 2008; Margoluis et al., 2009; Malhi et al., 2020; Bauer et al., 2022). Positioned within the specific field of Conservation Biology, TAN lays the groundwork for standardizing concepts and operational procedures, initiating effective actions where multiple events are present and where priorities must be defined (Salafsky et al., 2008). This process is a critical step in programs implemented by international organizations (TNC, 2000). In the subsequent planning phase, TAN identifies appropriate intervention measures to reduce threats, and in the evaluation phase, it assesses whether the actions taken have effectively reduced the threats and conserved the targets.

This approach builds a conceptual framework that places the causes of threats within the socio-ecological system through the construction of a causal chain (or network) (Fig.2.3).

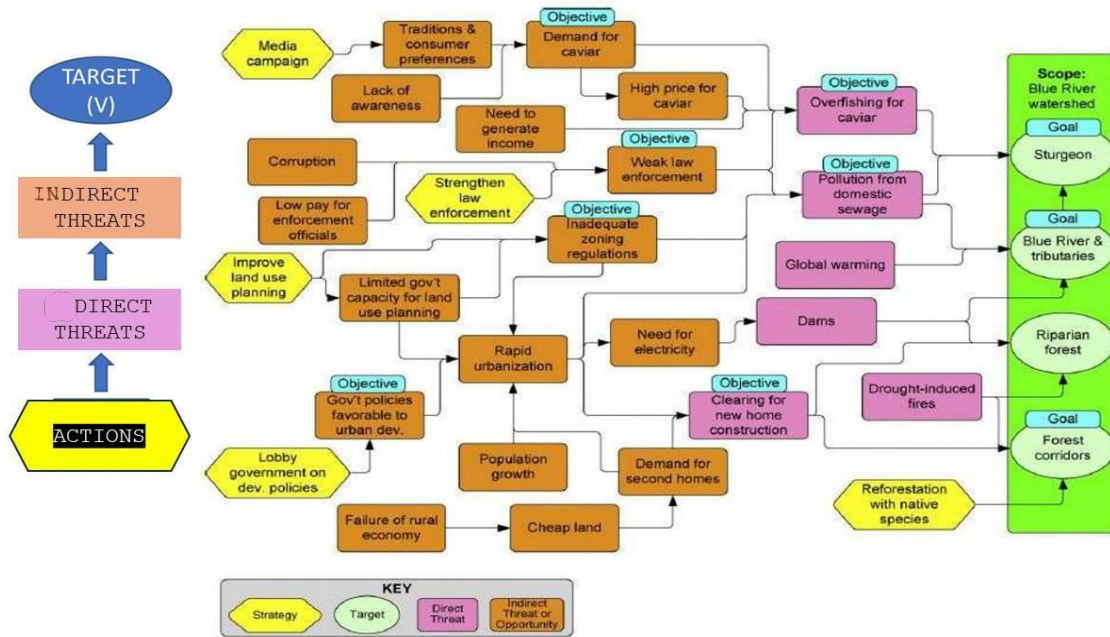


Figure 2.3 - Conceptual scheme with causal chains between Value Targets, Direct Threats, Indirect Threats. The hexagons represent single actions or projects that act on one of the phases of the causal chain (Salafsky et al., 2003 taken from Battisti, 2023 modif.).

This analysis allows assigning a weight to each threat based on its regime (for example, considering attributes such as extent, duration, frequency, intensity, etc.), enabling the identification of the most urgent threats rather than addressing those selected opportunistically or based on charismatic species (Battisti et al., 2016).

Threat ranking is a procedure within the TAN process, carried out by a group of professionals with in-depth knowledge of a specific issue. Given the tendency of operators to assess the relevance of a threat based on subjective analysis, threat ranking aims to reduce extreme subjectivity and improvisation. This approach is applied when it is not possible to use analytical and objective tools and methods, especially in situations of urgency, uncertainty, and resource scarcity.

The threat ranking process starts by identifying the threats present in a site and defining the criteria that will be used to assess each threat; these are then classified according to IUCN (2012). Once the criteria are defined, they are systematically applied to the direct threats at the site, leading to a prioritization (ranking) of threats according to their significance. This evaluation is conducted using an "expert-based approach", where judgments are converted into scores (ratings) by professionals. Considering the possible selection of key attributes used to evaluate the regime of each threat, a score from 1 (low) to 4 (high) is assigned by experts (sensu Battisti, 2023), based on the following attributes:

- Extent: Expresses the proportion of the area affected by the threat at the site.
- Severity/Intensity: Refers to the level of past, present, or future pressure likely to be caused

by the threat event, which may affect the target (e.g., its composition, structure, vitality, integrity). This pressure, within a predetermined time frame (e.g., the next 10 years), may lead to an alteration of the target. The severity/intensity attribute can be expressed in numerical terms (absolute or percentage), and can be calculated for each target or for the site as a whole. Generally, "intensity" is preferred to refer to the absolute pressure of the threat, independent of the effects on various targets (absolute intensity), while "severity" refers to the relative and target-specific impact of the threat on one or more specific targets (relative intensity).

- Frequency: Refers to the number of anthropogenic events occurring within a given timeframe.
- Duration: Describes the length of time the threat persists in a given period.

The attributes mentioned above (extent, duration, frequency, severity/intensity, or others that may prove useful) can be summed to provide a Magnitude score (in the absence of field data or experimental conditions, and under urgency and uncertainty). This represents the overall pressure capacity of a threat event (Tab.1.3).

	A	D	F	INTENSITY (SEVERITY)						M
THREATS				AI	WA	SO	WL	PL	HP	(TOT: A+D+F+I)
X	1	1	2	1	2	3	2	3	1	7
Y	3	4	2	1	1	2	2	3	4	13
Z	3	3	1	2	3	3	4	2	1	11
A	4	4	4	1	2	1	1	1	2	14
B	1	1	1	2	2	4	1	1	2	7

Table 1.3 - Evaluation table assigned to each expert. Scores are assigned from 1 (low) to n (in this case the maximum assignable corresponded to 4 - high) relating to the extension (A), duration (D), frequency (F) and intensity (INTENSITY). The total value (arithmetic sum) corresponds to the Magnitude (M). In this case it was decided to assign an intensity score separately to different target categories (AI: air component; WA: water; SO: soil; WL: fauna; PL: flora; HP: human perception) (from Battisti, 2023 modif.).

Other regime attributes that can be considered are:

1. Risk or Probability (secondarily, Hazard): This expresses the likelihood that a threat will manifest on a target (to which an intrinsic value has been assigned) within a predefined time interval during which the prediction is considered valid. This attribute can be expressed in terms of relative frequency (ranging from 0 to 1) or as a percentage (from 0 to 100).
2. Urgency: This indicates the level of urgency required to address a threat through appropriate actions or strategies. It is also expressed in terms of the speed with which a threat could manifest (whether sudden or gradual). This attribute may vary depending on whether the threat is imminent or if it refers to the likelihood of its occurrence in the near future. However, some threats (e.g., invasive alien species) may be considered of very high urgency even if they have not fully manifested yet. Urgency indicates the need for actions to be taken immediately or within a specified time frame (e.g., 1, 2, or 5 years).

The use of this relatively simple and rapid method is particularly suitable for sites where a large number of threats and targets are present.

Threat Reduction Assessment

An additional useful tool for monitoring the effectiveness of a project is the TRA (Salafsky & Margoulis, 1999; Margoulis & Salafsky, 2001).

The quantification of threat regimes through scoring can also be used to conduct a before-and-after comparison: To monitor whether specific threats have been significantly reduced by the project and, consequently, to assess the effectiveness of the measures (Rome, 1999; Battisti et al., 2008; Katswera et al., 2020).

The method is non-experimental and based on expert judgments from professionals with an adequate level of knowledge about the site, the target biodiversity values, and the actions implemented. This procedure has been successfully tested in operational contexts and allows for the generation of an index that synthesizes the effectiveness of the project (in percentage scores) in reducing the magnitude of priority threats to the objectives (see for example Battisti et al., 2023). According to this approach, monitoring the state of threats can be considered a proxy measurement of the project's success, meaning it describes the behavior of a phenomenon that is not directly measurable (Tucker, 2005).

The methodology is often chosen for adjusting conservation strategies during the implementation phase (adaptive management understood as the plan-do-monitor-adjust cycle) and for establishing (or reconsidering) intervention priorities when drafting or updating the management

plan of a PA (for instance, if a threat has been downgraded or a new one has emerged during the period) (Pollutri, 2013).

The basic procedural approach of TRA has been well established (Rome, 1999; Salafsky & Margoluis, 1999; Mugisha & Jacobsen, 2004; Okot, 2011; Pollutri, 2013) according to the following basic assumptions:

- All phenomena of biodiversity damage or loss are caused by human activity. Losses of species or habitats due to natural causes are not considered pressures. However, increases in the frequency or severity of catastrophic natural events driven by human behavior may be considered pressures at any given moment. It is possible to determine the threat/pressure factors affecting biodiversity at the site level; it is also possible to separate their effects and classify them in terms of "extent" (the area affected), "intensity" of impact, and "urgency" of intervention.
- Positive (or negative) variations in all threats can be measured or at least estimated by assigning scores: the degree of reduction of all threats at a given moment can be quantitatively or qualitatively evaluated.

The use of the TRA tool offers several advantages:

- It provides a quantitative result: The Threat Reduction Assessment Index (TRA-I), expressed as a percentage, which reflects the management performance in addressing pressures during the analyzed time period and in relation to the set objectives.
- When applied regularly, TRA-I scores can be used to monitor changes within a PA and compare management performance between PAs under similar conditions (such as time frame, project replication, and similar management realities).

The tool is user-friendly and practical, both in terms of cost and time, and its utility is enhanced when it involves individuals with the necessary knowledge about the area, current and potential human pressures, and their impacts on biological components. Since monitoring focuses on indicators not strictly related to biodiversity-specific measures, there are two main disadvantages associated with this approach:

1. Risk of Subjectivity: The possibility of recording a subjective perception rather than an objective assessment of the action's performance, expressed through the estimated percentage reduction of the threat in relation to the set objective (Salafsky & Margoluis, 1999; Margoluis & Salafsky, 2001; Persha & Rodgers, 2002; Mugisha & Jacobson, 2004).
2. Exclusion of "Pressure Increase" Conditions: The classification mechanism does not account for the increase in pressure (rather than its reduction) or the emergence of new threats

(Anthony, 2008; Matar & Anthony, 2010). To address these limitations, some authors have clarified terms and introduced modifications to the tool (Anthony, 2008; Okot, 2011; Milatovic, 2017; Wilmot, 2020).

In general, the risks associated with the subjectivity of judgments can be mitigated by combining quantitative data with qualitative, perception-based insights.

The TRA tool is fundamentally composed of two worksheets:

1. **Project Definition and Analysis Details:** The first worksheet defines the project and provides some analytical details (e.g., geographic area, time period). It also includes a technical sheet for:
 - Listing the main threat factors.
 - Classifying them based on three criteria (extent, intensity, urgency).
 - Assigning a percentage reduction score for each pressure.
 - Performing calculations that integrate the classification score with the pressure reduction score to obtain a final score, called the TRA-I, which expresses the overall reduction in pressures as a percentage.
2. **Pressure Description and Objective Setting:** The second worksheet is a table used to describe each pressure and set the maximum reduction objective, which is typically the 100% reduction achievable through the action. The method involves the following seven steps:
 1. **Define the Area of Interest:** Spatially and temporally (target area), and set the start and end dates for the evaluation process. The analyst must define the time period over which threats will be assessed before beginning the evaluation. The period must be sufficiently long to allow for the detection of changes (if any) and must be documented in writing.
 2. **List All Significant Direct Threats:** Identify and list all the direct threats (considered significant for the target biodiversity values) present at the site from the project start date. Indirect factors (driving forces) that generate and/or fuel direct pressures are not considered.
 3. **Classification (Ranking) of Each Threat:** Each threat is ranked based on three criteria:
 - **Area of Influence:** This is the percentage of habitat or target affected by the threat, relative to the total area or targets in the intervention zone.
 - **Intensity:** This measures the degree of impact (severity) the pressure has on biodiversity value at the intervention site.
 - **Urgency:** This refers to the immediacy of the pressure's effects and, thus, the necessary speed of response.

It is important to note that before starting the analysis, a standardized methodology for data collection should be designed in order to produce the classification for each threat criterion. This

methodology may vary depending on the specific site and threats, and for each threat, it could result from a combination of different methodologies (Persha, 2001; Leisher et al., 2022).

4. Simple Sum of the Values Assigned to the Three Criteria for Each Threat: This determines the total ranking for each threat. By doing this, equal weight is implicitly assigned to each of the three criteria.
5. Estimation of the Percentage Reduction for Each Threat: After the strategy has been implemented within the given time frame, an estimate is made of the percentage reduction for each threat, with the 100% success target serving as a reference.
6. Calculation of the Raw Score: The raw score is calculated by multiplying the total ranking value (from step 4) by the percentage reduction of the threat (from step 5), then dividing by 100. The total of all raw scores is then summed.
7. Calculation of the TRA-I Index: The overall TRA-I index, expressed as a percentage, is obtained by dividing the sum of the raw scores by the sum of the total rankings and then multiplying by 100.

Finally, an evaluation of the scores was conducted, including the calculation of the mean values and measures of dispersion. To compare the average threat magnitudes across more than two samples, we performed the non-parametric Kruskal-Wallis test for equal medians, obtaining H values using the PAST software version 1.89 (Hammer et al., 2001; Dytham, 2011).

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Chapter 4: EVALUATING THE EFFECTIVENESS OF A CONSERVATION PROJECT ON TWO THREATENED BIRDS: APPLYING EXPERT-BASED THREAT ANALYSIS AND THREAT REDUCTION ASSESSMENT IN A MEDITERRANEAN WETLAND

Abstract

To promote the reproduction of the Common Tern (*Sterna hirundo*) and Little Tern (*Sternula albifrons*), species of conservation concern, a project was initiated in autumn 2010 by the Managing Authority of the Diaccia Botrona Nature Reserve. The project included the construction of rafts and islands, as well as interventions to regulate water levels.

Following the principles of the “Project Cycle”, in October 2021, a working group comprising 10 experts with both recent and historical knowledge of the site, selected objectives, and local threats was formed. In the TAN, the expert assigned scores to two attributes of the threat regime: Extent and Severity, for each direct threat. In the TRA, each expert was asked to provide scores for the attributes Extent, Severity, and Urgency. The TRA-I value reflects the effectiveness of the conservation actions in addressing these threats.

The values for the attributes of the threat regime indicated that wild boar (*Sus scrofa*) and gulls (*Laridae*) were the most widespread, intense, and significant threats, with a notable difference in their relative severity ($H = 17.37$, $p = 0.003$; Kruskal-Wallis test for equal medians).

The TRA-I (23%) suggests that the conservation actions had limited success. These results can be interpreted in light of the challenges in mitigating certain threats (e.g., demographic growth of wild boar in the area). In particular, the TRA-I results highlight to the expert that the conservation project requires adaptive management, such as adjusting the placement of tern islands, to improve effectiveness.

Article

Evaluating the Effectiveness of a Conservation Project on Two Threatened Birds: Applying Expert-Based Threat Analysis and Threat Reduction Assessment in a Mediterranean Wetland

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Abstract: We applied two recent approaches largely used in biological conservation: Threat Analysis (TAN) and Threat Reduction Assessments (TRAs), assessing the effectiveness of a project focused on two water-related bird species (common tern, *Sterna hirundo* and little tern, *Sternula albifrons*), commonly breeding in some wetlands of Italy. We used the IUCN standardized lexicon for the classification of threats, utilizing a panel of experts to assess a set of regime attributes (extent, severity and magnitude) of each human-induced disturbance. Our aims were: (i) through the TAN approach, to carry out an arrangement and quantification of the main threats acting on our focal species and select the priority ones; (ii) through the TRA approach, to test the effectiveness of an operational project focused on mitigating the threats and improving the breeding success of species (i.e., building rafts and floating islands to encourage their nesting). Using the TAN approach, experts identified the following human-induced threats (IUCN code): 6.1—Generic disturbance; 7.2—Water stress; 7.3—Salinization; 8.8—Vagrant dogs; 8.8—Mediterranean gulls; 8.8—Wild boars, all significantly different in their magnitude. Among them, wild boars and Mediterranean gulls appeared the priority threats with the greatest extent, intensity and magnitude. Using the TRA approach, after the project, we assessed an overall decrease in the threat magnitude of 23.08% (21.42% when considering only the threats directly affected by our project). These data suggest that further efforts should be devoted to achieving greater effectiveness of conservation actions focused on our target species. With limited time and resources to quantify threats, expert-based approaches could be useful for rapidly assessing the effectiveness of small conservation projects by providing a range of scores obtained following an analytical procedure. In this regard, Threat Analysis and Threat Reduction Assessment could be considered useful tools to support adaptive management in project management cycles.

Keywords: Threat Analysis; TRA index; *Sterna hirundo*; *Sternula albifrons*; magnitude; adaptive management; effectiveness

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1. Introduction

When launching conservation projects focused on target species in demographic decline, it is necessary to monitor the effectiveness of the actions aimed at reducing the causes of anthropogenic threats. This can be useful for providing information to correctly achieve the objectives with regards to adaptive management [1].

Project monitoring is a strategy to obtain data about the results and effectiveness (i.e., the success) of our conservation actions focused on targets and threats. In this regard, many technical approaches and tools are available, which aim to monitor the status of the target species of conservation concern. In this regard, it has been highlighted that

project monitoring should not only identify biological targets but also indicate the level of success. Indeed, it has recently emerged that monitoring through biological indicators (see [2]) based on the quantification of the status of the biodiversity targets shows some weaknesses: for example, the biological components often show long response times and are observable on different spatial scales due to their ecological, phenological, and behavioral characteristics. This can make it difficult to evaluate the effectiveness of projects using biological indicators [3]. To overcome this problem, alternative approaches have recently been developed that also focus on assessing the threat events impacting our targets, recording the changes in their regime and considering specific attributes (e.g., extent, intensity, magnitude; [4]). In this regard and following a DPSIR framework (Driving forces–Pressure–State–Impact–Response; [5]), the focus shifted from the status indicator (demographic status of the species) to the pressure indicators (threat events). Having limited time and resources, an assessment of this type can be carried out quickly by a project team using expert-based approaches [6].

Recently, Salafsky et al. [7] introduced the “Threat Analysis” (hereafter, TAN). Through this approach, it is possible to assign a nomenclature (and a standard code) to any threat event, quantifying it using expert-based scores, in order to build a conceptual framework in which the causal relationships between conservation targets, direct and indirect threats and driving forces are explicit with cause–effect chains. The quantification of the regime of each threat allows obtaining a ranking among them to identify the priority ones that require immediate action in a pragmatic and operational way [8]. In this sense, it will be possible to define objectives addressed for the priority threats (i.e., with the highest rank) acting on the selected targets [9]. Through a quick procedure, it will be possible to assign scores to each regime attribute (e.g., extent, intensity, magnitude) by panels of experts, thus obtaining relative ranks and allowing a comparison between different threats among them. Furthermore, the quantification of threats allows obtaining sets of regime attributes that can be compared before and after the conservation actions, therefore evaluating the project effectiveness [10,11].

The Threat Reduction Assessment (hereafter, TRA; [12]) is a further useful tool for monitoring the project’s effectiveness. This approach is based on a procedure aimed to obtain indicators that make it possible to verify the level of threat reduction once the conservation actions have been carried out. This procedure has been successfully tested in operational contexts and allows obtaining an index that summarizes the effectiveness of the project (in percentage scores) in reducing the magnitude of priority threats on the targets (examples in [13–16]).

In this paper, we carried out a TAN approach on two selected water-related birds of conservation concern breeding in a Mediterranean wetland (common tern, *Sterna hirundo* and little tern, *Sternula albifrons*), selected as focal targets. This analysis provides us scores in regime attributes that are useful for identifying a set of priority threats. This first assessment allows defining an operational project that aims to reduce its magnitude, considering it a proxy of threat impact on the targets [7]. After this analysis, we performed a TRA procedure to assess the level of threat reduction induced by the conservation project, using a percentage score. Due to the difficulty of obtaining analytical data about the threat regime, we used an expert-based technique. Although the TAN approach has been applied in other Mediterranean contexts (e.g., [10,11,17]), to our knowledge, this is the first application of both these two approaches (i.e., TAN and TRA) in an operational project carried out in a Mediterranean wetland.

2. Materials and Methods

2.1. Study Area

The “Diaccia Botrona” wetland [42°47′ N–10°55′ E], located in the municipalities of Grosseto and Castiglione della Pescaia (Grosseto, Tuscany, central Italy), is a coastal wetland area of about 800 ha in size area (Special Area of Conservation SAC and Special

Protection Areas SPA) “Padule di Diaccia Botrona”, code IT51A0011 and Ramsar Convention), located within a Regional Reserve. This area is managed by the Tuscany Region Public Agency. The marsh preserves one of the most important coastal lagoons in Tuscany with 327 floristic of conservation concern and phyto-geographic interest as, for example: *Ranunculus trilobus* Desf., *Salicornia dolichostachya* Moss., *Mantisalca salmantica* (L.) Briq. et Cavillier and *Juncus subulatus* Forskål [18,19].

Frequent floods in the innermost areas involve the deposition of terrigenous materials and historically affirm this geographical context with the formation of coastal dunes and back-dunes (Lake Prile). Anthropogenic changes in the wetland have taken place in historical times since the Roman Age and, more recently, with the land reclamation in the 19th and 20th Centuries with the triggering of a salinization process due to ingression of saltwater with high tides. The current division into two large patches (Diaccia and Botrona) sees for the Botrona the isolation from the remaining wetland and from the nearby watercourses with a strong stress on ecological components [20,21].

Birds are an important component in the Diaccia Botrona Reserve [22,23]. Considering only the wet habitats in the area, 45 species breed, while the entire SAC-SPA includes 22 of high conservation concern (Annex I of Directive 147/2009/EC) (e.g., pied avocet *Recurvirostra avosetta*, black-winged stilt *Himantopus himantopus*, Kentish plover *Charadrius alexandrinus*, and others).

Among these species, we selected two focal targets (common tern, *Sterna hirundo* and little tern, *Sternula albifrons*), following a conservation criterion: these species showed a localized distribution and a declining abundance at the regional level in recent decades [24,25]. Regarding terns, Tuscany host populations separated from their respective Italian ranges, with reports of breeding for the first time in this period of the year in 1998 from the nearby Orbetello Lagoon [26,27]. Moreover, a criterion linked to the effectiveness of field sampling (these are of medium size species, easily detectable, in particular regarding the nesting sites) also allows obtaining reliable and representative data.

Since these two terns show a comparable nesting ecology [28], we considered both as a single conservation unit.

2.2. The Logic of Project Cycle

The staff managing the Diaccia Botrona Reserve have had to face a series of local human-induced threats. Therefore, in view of the IUCN conservation project cycle [29], it was decided to form a working group made up of a panel of experts in order to: (i) analyze the context by identifying and quantifying the local threats and ranking them to select the priority ones; (ii) define actions to mitigate the priority threats in order to favor two selected target species breeding in the wetland; (iii) once the project has been completed, monitor its effectiveness by adopting the TRA as an assessment approach.

2.3. Identification of Stakeholders

To identify the experts qualified for both the TAN and TRA procedures, we selected 10 operators and researchers belonging to members of a local non-profit organization ($n = 4$), personnel belonging to the Departments in charge of national strategies for protected areas ($n = 4$) and private consultants involved in protected area management ($n = 2$) (see list in the Acknowledgments). We selected the project management team as the most appropriate people to apply both the TAN and TRA procedures because they had adequate recent and historical knowledge on (i) the wetland site, (ii) the selected targets and (iii) the local threats. Moreover, they have all been involved in a conservation project, so they possess the knowledge useful for assessing the management progresses, following the logic of adaptive management [30].

This panel of experts carried out both the TAN procedure (threat naming, magnitude assessment, ranking in priorities) and the TRA procedure (percentage scores in effectiveness).

2.4. Threat Analysis

After identifying the two focal water-related bird species (common tern and little tern) as targets in this case study (Diaccia Botrona nature reserve), the panel of experts identified the local threats acting on them. In this regard, they defined “threats” using the meaning reported in [6], i.e., “as any human-related process that negatively affect specific components of biodiversity (species richness, habitat condition and area, ecosystem functioning) in a ‘real world’ context”.

To name these threats, experts used the IUCN unified classification of direct threats [7], assigning a standardized taxonomic code to any anthropogenic threat (review in [9]).

After this step, we asked the experts the following questions: (i) what are the threats acting on common tern and little tern in the Diaccia Botrona reserve? (ii) Once classified (sensu IUCN; see [7]), which of these threats can be reduced (i.e., mitigated in their impacts on targets) with a project? For each direct threat, the panel of experts assigned a score to two regime attributes (extent and severity) using a scale from 1 (low) to 4 (high). “Extent” can be measured as the proportion in the species habitat that has been, is or will be affected by the threat when compared to the total surface available (all the suitable areas of habitat for the two focal species; [31]). “Severity” constitutes past, present or future pressure levels that are estimated to be caused by the threat event and may affect the target (for example, by altering its composition, structure, vitality and integrity), leading to an impact on our targets, i.e., to a potential or real specific alteration (see [32]). Finally, for each threat, the two scores (extent and severity) have been summed, obtaining a score for the total magnitude—a compound variable. “Magnitude” represents the capacity of a threat to exert a general pressure (and a consequent impact) on the selected targets [7].

When the experts assigned a score for the extent and severity and after we obtained the values of magnitude, we calculated the averaged values (and standard deviation) for each attribute (extent, severity and magnitude) of each threat. Finally, the experts ranked the threats when regarding the magnitude values, obtaining a list of threat magnitudes in decreasing order. The threats showing the highest values in mean magnitude represented the priority threats.

Experts based their judgement both on local expertise and on the available local (“grey”) literature [22,33–34].

2.5. Conservation Actions

To mitigate the human-induced threats, in 2010, a project focused on the two focal species (common tern and little tern) was started. This project envisaged the construction of rafts and islets in only the Diaccia area, as well as some interventions to regulate the water levels, to favor the reproduction of the two target species and mitigate the effects of threats. There is evidence indicating the isolation of the nest structures from terrestrial predators and human disturbance can favor these species [35–37]. Floating rafts (1.5 × 1 m to 2 × 2 m and 1.5 × 2 m in size; $n = 8$) and islets (6 × 6 m in size; $n = 7$) were built until 2020.

2.6. Threat Reduction Assessment

After the TAN, and when the project has been closed, we carried out a TRA procedure [12–14]. First, experts were contacted, requesting them to choose a suitable assessment period. After, we conducted the open-ended interviews ($n = 10$ experts) in October 2021.

We asked the experts the following questions: (i) regarding the local threats obtained from the TAN procedure, what score (from 1 = low to 4 = high) would you assign to the attributes of the area (i.e., the portion of habitats in the site that the threat affects), intensity (i.e., the effect, or severity, of the threat) and urgency (i.e., the immediacy of addressing actions against the threats), keeping the effects on the two selected targets (i.e., common tern, *Sterna hirundo* and little tern, *Sternula albifrons*) in mind?; and (ii) how

much you consider the reduction in each threat following the realization of the project (assessing a percentage score, from 0 to 100)? [Details in 6, 14].

After each step, the collected data were statistically processed to obtain the averaged values (and standard deviation) of each threat regarding area, intensity, urgency and percentage in reduction after the project.

The average values were used to rank the threats according to their relative importance (from 1 the lowest to 6 the highest). A total threat score was computed after all the threats were ranked. Finally, we added the value of the mean percentage reduction for each threat.

After the ranking and scoring exercises, the total ranking scores for each threat were multiplied by the percentage of the threat met to yield a raw score for that threat. The Threat Reduction Index (TRA-I) value was derived by dividing the sum of the raw scores for each threat by the total possible rankings of all the threats and multiplying by 100, i.e., $TRA-I = \text{total raw scores} / \text{total rankings} \times 100$ (details in [12]). Thus, the TRA-I value indicates the response to all the combined threats to the overall conservation project over the assessment period. All calculations were conducted automatically with Microsoft Excel software.

2.7. Statistical Analyses

We compared the averaged values performing the Kruskal–Wallis test for equal medians using the PAST 1.89 software [38]. Alpha level was set to 0.05.

3. Results

3.1. Threat Analysis

Regarding the TAN procedure, the panel of experts identified the following human-induced direct threats and named them following the international IUCN nomenclature:

- 6.1—Recreational activities in the surrounding area too (in particular, un-managed recreational fruition by birdwatchers, hunters and fishermen with consequent disturbance on breeding birds);

- 7.2—Water management/use (in particular: water stress due to alteration of the hydrographic regime following land reclamation and water collection and pumping for agricultural uses in surrounding croplands and others), a threat largely occurring in several wetlands of central Italy [39];

- 7.3—Other ecosystem modifications (in particular, water salinization due to saline ingression from the sea; see [40]);

- 8.8—Problematic species, more in particular: wild boars (*Sus scrofa*), a native mammal largely restocked in Tuscany from historical times; Mediterranean gulls (*Larus michahellis*), a generalist native birds, recently spreading from coastal sites to anthropized inland areas and vagrant dogs (*Canis familiaris*). For their different characteristics and regimes, we considered each of these three threats independently.

The values of the threat regime attributes showed as wild boars and Mediterranean gulls appeared to be the threats with the largest extent, intensity and magnitude (Table 1; Figure 1), with a significant difference in magnitude among threats ($H = 17.37$, $p = 0.003$; Kruskal-Wallis test for equal medians).

Table 1. Threat Analysis (TAN) procedure. Mean values (and \pm standard deviation) in regime attributes (area, intensity and magnitude) for the six human-induced direct threats selected in the Diaccia Botrona wetland.

Threats	Area	Intensity	Magnitude
7.2—Water stress	2.7 (\pm 0.82)	2.7 (0.95)	5.4 (\pm 1.71)
8.8—Wild boars	3.6 (\pm 0.70)	2.8 (0.92)	6.4 (\pm 1.17)
8.8—Mediterranean gulls	3.6 (\pm 0.70)	3.3 (0.67)	6.9 (\pm 1.10)
8.8—Vagrant dogs	1.9 (\pm 0.88)	2.1 (0.99)	4 (\pm 1.82)
6.1—Generic disturbance	2.7 (\pm 1.16)	1.8 (0.63)	4.6 (\pm 1.65)
7.3—Salinization	2.7 (\pm 1.06)	2.4 (1.26)	5 (\pm 2.26)

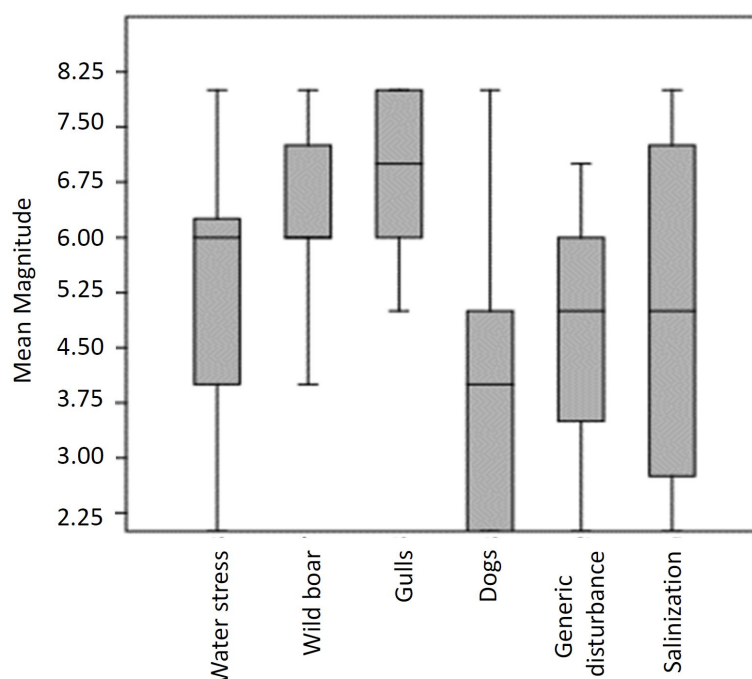


Figure 1. Box plots for magnitude values of the six human-induced direct threats selected by the panel of experts in the Diaccia Botrona wetland.

3.2. Conservation Actions

The islets were ignored by both common tern and little tern because, perhaps, they were more exposed to the risk of being surrounded by vast dry clayey banks, easily accessible by terrestrial predators. Moreover, in some parts of the Diaccia Botrona reserve, their realization was conditioned by the limited accessibility of the operating machines where water is present in the breeding season.

The rafts were regularly occupied for a total of three pairs of common tern (excluding 2013, 2014, 2017, 2018 without nesting; 2010 and 2011: 2 nesting pairs; 2012: 1; 2015: 3; 2016: 2; 2017: 1; 2019 and 2020: 1). Subsequent new installations in other areas did not help in observing the expected increase in their use. Tern populations in the Diaccia Botrona wetland show a discontinuous but increasing trend over the years, with a maximum valuation of 21 pairs for common tern in 2021 and 19 pairs for little tern in 2019.

3.3. Threat Reduction Assessment

After the projects, the panel of experts carried out the TRA procedure, assessing the area, severity and urgency of each threat and obtaining the mean values (and standard deviation) for each attribute (Table 2). Attributes have been ranked and summed: wild boars and Mediterranean gulls showed the highest total rank (≥ 15 ; Table 2). Finally, the experts assessed the percentage in threat reduction following the project. The highest percentage score (≥ 20) has been observed for water stress, wild boars and vagrant dogs. The procedure showed a total TRA-I = 23.08% considering all the threats affecting the breeding of the target birds. However, considering only the three main threats directly involved by the project score in effectiveness was 21.42% (Table 3).

Table 2. Threat Reduction Assessment (TRA) procedure. Regime attributes of area, intensity and urgency and related ranks for the Threat Reduction Assessment and procedure to calculate the TRA-I index. (1): sum of ranking of area, intensity and urgency. (2): estimated percentage of threat mitigation over the assessment period. TRA-I index = Σ (raw score/total ranking) \times 100 = 23.08%.

Threats	Area	Rank	Intensity	Rank	Urgency	Rank
7.2—Water stress	2.7 (± 0.82)	2	2.7 (± 0.95)	4	3.5 (± 0.53)	6
8.8—Wild boars	3.6 (± 0.70)	6	2.8 (± 0.92)	5	3.3 (± 0.82)	5
8.8—Mediterranean gulls (predation by)	3.6 (± 0.70)	6	3.3 (± 0.67)	6	2.9 (± 0.99)	3
8.8—Vagrant dogs (predation by)	1.9 (± 0.88)	1	2.1 (± 0.99)	2	1.4 (± 0.70)	1
6.1—Generic disturbance	2.7 (± 1.16)	2	1.8 (± 0.63)	1	1.8 (± 0.79)	2
7.3—Salinization	2.7 (± 1.06)	2	2.4 (± 1.26)	3	2.9 (± 0.99)	3

Threats	criteria ranking			total ranking ¹	Percent threat reduced ²	Raw score
	Area	Intensity	Urgency			
7.2—Water stress	2	4	6	12	32	3.84
8.8—Wild boars	6	5	5	16	27	4.32
8.8—Mediterranean gulls (predation by)	6	6	3	15	16	2.4
8.8—Vagrant dogs (predation by)	1	2	1	4	21	0.84
6.1—Generic disturbance	2	1	2	5	17	0.85
7.3—Salinization	2	3	3	8	20	1.6
				60		13.85

Table 3. Attributes of area, intensity and urgency and related ranks for the Threat Reduction Assessment (TRA) and procedure to calculate the TRA-I index, considering only the three threats directly involved in the project. (1): sum of ranking of area, intensity and urgency. (2): estimated percentage of threat mitigation over the assessment period. TRA-I index = Σ (raw score/total ranking) \times 100 = 21.42%.

Threats	Area	Rank	Intensity	Rank	Urgency	Rank
8.8—Wild boars	3.6 (± 0.70)	3	2.8 (± 0.92)	2	3.3 (± 0.82)	3
8.8—Mediterranean gulls (predation by)	3.6 (± 0.70)	3	3.3 (± 0.67)	3	2.9 (± 0.99)	2
8.8—Vagrant dogs (predation by)	1.9 (± 0.88)	1	2.1 (± 0.99)	1	1.4 (± 0.70)	1

Threats	criteria ranking			total ranking ¹	Percent threat reduced ²	Raw score
	Area	Intensity	Urgency			
8.8—Wild boars	3	2	3	8	27	2.16
8.8—Mediterranean gulls	3	3	2	8	16	1.28

(predation by)						
8.8—Vagrant dogs (predation by)	1	1	1	3	21	0.63
				19		4.07

4. Discussion

The Diaccia Botrona wetland is a biodiversity hot spot, particularly for bird species and communities. Similar to many other Mediterranean wetlands, these ecosystems are embedded in anthropized landscapes (see [41]) where, since historical times, a series of human-induced driving forces acted, modifying the environmental matrix: in the last two centuries, land reclamation has transformed these wetlands into agricultural areas, and, in recent decades, urbanization and infrastructures (and consequent habitat fragmentation) have given rise to several threats and related impacts on biodiversity, as observed also in many other Mediterranean wetlands (e.g., [9,42]).

Many of these threats can act on birds, even of high conservation interest. Through the TAN approach, a panel of experts with a specific skill and context-related background selected a set of main human-induced events that act locally on two local bird species, which were selected as conservation targets.

These threats are all directly or indirectly linked to the presence of humans. For example, the occurrences of vagrant dogs were due to an uncontrolled frequentation of people (e.g., birdwatchers, hunters, fishermen) or derived from escaped/abandoned farm dogs. Differently, wild boars frequent the area due to a demographic increase at a regional scale induced by continuous re-stocking of animals due to poaching activity (for Tuscany, see [43,44]). In this regard, there is a lot of evidence of wild boars' impact on nests of wetland-related birds [45,46].

Analogously, the increase in Mediterranean gulls is indirectly linked to the landscape anthropization, as these species are increasingly linked to urban waste landfills, a recent phenomenon largely known (e.g., [47]). The water stress and the consequent process of water salinization were due to long-time saline ingression due to complex historical processes linked to land reclamation, water pumping by agriculture and lack of water management at landscape scale [48]; for this effect on birds, see [49–51]. Finally, the disturbance from uncontrolled frequentation of wetland by people may also affect the ecology and behavior of bird species, especially during the breeding period (e.g., [52]; review in [53]).

However, the ranking procedure in the TAN procedure showed that the experts considered Mediterranean gulls and wild boars the threats with the highest magnitude. In this regard, the project actions, which involved the creation of suitable substrates for nesting for the two focal species (floating rafts and artificial islands), aimed at reducing the effects of these threats, focused on these priority threat events.

Once the project was implemented, the panel of experts assessed how effective this may have been on the target species through the TRA procedure. The value obtained in percentage effectiveness (about 20%) suggests how these actions had a weak success, both considering all the threats affecting the focal species and considering only the threats directly interested in the project. These results can be attributed to the difficulty of mitigating some of these threats and the delay in response in terms of the demographic increase and reproductive success of the two focal species, a problem largely known in conservation studies (see [54]). However, we think that the low predictive power may be also a result of a lack of information on the threat magnitude: when these data are lacking, the experts had little confidence in their predictions (or, however, divergent opinions about the relative importance of the threats).

The results obtained by monitoring using the TRA-I index make the experts aware that the project needs an adaptation (for example, changing number, location and size in structures).

The use of the TRA approach made it possible to obtain a given percentage value (TRA-I) using an expert-based approach. Although expert-based procedures show weaknesses [55], they also show points of strength [56] as highlighted in the TRA tool, with many examples in conservation arenas worldwide (see [13–16,57]). For example, when the time and resources are limited or the events to monitor are complex and not analytically measurable, pragmatic and quick expert-based approaches can allow the project team to focus by orienting judgment on specific questions (see [58]). In this regard, the scores in threat regime attributes, overcoming anecdotal judgments, political considerations and non-technical dynamics, allow addressing the project with priorities and related solutions [7]. In our case, the scores in TRA-I percentages will be useful to support decision-making along the future development process of the local project, following a logic of active adaptive management [30].

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Take-home message

- The conservation project for two threatened bird species in a Mediterranean wetland demonstrates the importance of a holistic approach that integrates TAN and TRA.
- Expert-based analysis allowed the identification of key threats to the target species, providing clear guidance for conservation actions to be taken and highlighting the need for continuous and adaptive monitoring.
- The results emphasize that a collaborative approach, involving local experts and the scientific community, is crucial for optimizing protected area management and maximizing the outcomes of conservation actions.

Chapter 5: *DO ACADEMIC STUDENTS OVERSTIMATE MARINE LITTER POLLUTION? A THREAT ANALYSIS USING PLOVER BIRDS AS A TARGET IN A MEDITERRANEAN SITE*

Abstract

Through an initial before step conducted in the classroom, followed by a after phase involving fieldwork, the study aimed to investigate whether comparing the information gathered at these two distinct stages on potential threats to a sandy coastline with dunes in the Maremma Regional Park (Grosseto, Tuscany) would yield valuable results regarding the TAN procedure. For this area, the target species is the *Charadrius alexandrinus* (Kentish Plover), which is also a breeding species in the region. In May 2022, in line with the “Project Cycle”, ten environmental science students from the University of Siena were appointed as experts and were tasked with identifying potential threats to the area without conducting any site visits. We hypothesize that students will overestimate charismatic (mass-media driven) threats when compared to local ones. They identified several threats, including trampling, coastal erosion, marine litter, presence of dogs, and collection of flora. Following the TAN procedure, each expert assigned scores to the attributes Extent and Intensity for each identified threat, which were then used to calculate Magnitude. The next day, the same group of experts conducted the field survey and proposed revised scores based on their direct observations. The field survey revealed that some highly publicized threats, such as marine litter, were overestimated during the before phase. While marine litter can pose a threat to *Charadrius alexandrinus*, it was significantly overestimated at the local level. This overestimation could have been influenced by extensive media exposure of the issue, which likely shaped the students' initial perceptions, leading them to assign high scores before confirming the actual scope and intensity on-site. The students subsequently assessed trampling on dunes as the second most significant threat both before and after the field investigation. A large number of beach goers frequent these areas, and when the issue of *Charadrius alexandrinus* breeding is not adequately addressed, it may further compromise these reproductive sites.

Short Communication

Do academic students overestimate marine litter pollution? A threat analysis using plover birds as a target in a Mediterranean site

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Abstract Marine litter is known to pose a threat to biodiversity. In this work, we wanted to verify if marine litter was overestimated as a threat by academic students when compared to other threats acting on a specific conservation target, a coastal bird of conservation concern, breeding on Mediterranean coastal dunes (Kentish Plover, *Charadrius alexandrinus*) in a site of central Italy (Maremma Regional Park, Tuscany). To test this hypothesis, before conducting any direct local survey (*a priori*), a panel of academic students in Ecotoxicology and Environmental Sustainability (Second cycle degree; Siena University) collected indirect information on a set of threats (trampling, coastal erosion, marine litter, presence of dogs and illegal plant collection), known as impacting on the target, assigning a score (from 1: low to 4: high) to two selected threat regime attributes (extent and intensity), and obtaining a magnitude score based on the judgment only on general information communicated by park operators. After a field survey on the plover's breeding site, students were newly assigned a posteriori scores ('after' phase). The before-after comparison showed that no threat showed a significant difference in scores, except for marine litter, which was significantly *a priori* overestimated. Although marine litter is known to threaten plover birds, it has been significantly overestimated at the local level suggesting a prejudice in student evaluation. This biased overestimation could be due to the high media exposure of the marine litter as a threat, making it charismatic, affecting the *a priori* judgment.

Keywords threat analysis; *Charadrius alexandrinus*; magnitude; charismatic threat; marine litter

Introduction

Conservation strategies targeting declining biological species should include threat analysis protocols enabling to define which anthropogenic disturbances must be mitigated, controlled, or eliminated as a matter of priority (Salafsky and Margoluis, 1999; Salafsky et al., 2002; Salafsky et al., 2008). These approaches provide for an expert-based assessment that allows to quickly obtain some information on specific attributes of the threat regime (first of all, extent and intensity; Battisti et al., 2016). Through a simple procedure, it is thus possible to obtain threat magnitude scores so as to carry out a priority ranking that can urgently orient managers towards the most impacting threats on environmental targets (Anthony, 2008; Alhirsh et al., 2016; Giovacchini et al., 2022).

One of the critical points of these approaches is related to expert threat assessment, which requires local knowledge of the threat events, without which the assessment

can show inaccuracies (e.g., cognitive bias: Catalano et al., 2018). For example, many 'charismatic' threats, emphasized by social- and mass media and for which experts have only indirect information, could be overestimated, despite their actual impact on a local scale (Battisti et al., 2009).

In this regard, it may be helpful to investigate which threats, among those acting on specific conservation targets, may be overestimated in indirect assessments carried out before (i.e., *a priori*) of direct knowledge in specific real contexts. These non-contextualized expert-based evaluations can be compared with analogous evaluations carried out posteriori (i.e., after field surveys), the latter useful to locally contextualize the threats and allow an assignment of scores in terms of threat regime (extent and intensity). The before-after comparison in scores assigned by experts can provide information on how much the threat itself can be considered 'charismatic', that is, such as to

attract the attention of experts, regardless of true impact in real contexts. For example, some threats may be noticed by the mass media as having an impact and, therefore, perceived as urgent to be solved at a general level, even if they may not be a priority in specific real contexts (Battisti et al., 2009).

Coastal dune ecosystems are a suitable habitat for many animal and plant species (MacLachlan, 1991). Among the animal species, the plovers represent a group of ground-nesting birds (Aves, Charadriidae) that nest on the ground on the dunes and show a peculiar ecology and behavior (Fraser and Catlin, 2019). The coastal dune environments are highly frequented by people, and therefore, these birds are very vulnerable to anthropogenic threats linked to the high attendance of these environments (trampling, owner dogs, mechanical cleaning, plant collection, marine litter: e.g., Burger, 1994; Montalvo and Figuerola, 2006). Among these threats, marine litter stranded on the beaches can be trapping for these small birds (Battisti et al., 2019). These threats are added to other disturbances of natural origin (predators, extreme weather events), making the plovers extremely vulnerable and in demographic decline on a continental scale (Loegering and Fraser, 1995).

In this paper, a group of academic students carried out a threat analysis, with a before-after evaluation, on a coastal dune system utilized by a species of beach-nesting plover bird (considered as conservation target) as a breeding site, in order to rank any threat in decreasing order and verify which threats were *a priori* overestimated. In particular, the panel of students assigned scores on threat magnitude (as a sum of extent and intensity) at first only based on general information (*'a priori'* phase), without having carried out a direct field survey in the breeding areas; subsequently, they re-assessed the same set of threats, after carrying out a field survey (*'a posteriori'* phase), which allowed them to contextualize and evaluate the threats, according to their local magnitude (*'after'* phase).

Our working hypothesis is that, in the absence of a field survey, i.e., having available only indirect information, a group of academic students can overestimate the *'charismatic'* threats for which there is a wide availability of information (e.g., emphasized by the social- and mass-media). Specifically, we hypothesize that among all the threats considered as acting on plover birds in coastal ecosystems, the marine litter, showing a high media exposure in the last decade (Jambeck and Johnsen 2015), could be significantly overestimated in the *a priori* evaluation, when compared with the *posteriori* one.

Methods

Study area

The Maremma Regional Park (hereafter, MRP) is a protected area established in 1975 by the Tuscany Region and extended to 8,902 ha in the coastal sector of the province of Grosseto, southern Tuscany, in which the 296 bird species found represent the most evident biological peculiarity (Giovacchini, 2019).

In a schematic definition of the most important habitats, we find: (i) the reliefs of the Uccellina Mountains,

extending over 3,200 ha, with the highest peak reaching 417 m a.s.l. They have rather heterogeneous forest vegetation, conditioned by the nature of the soils and by the exposure in which *Quercus ilex* dominates; (ii) the agricultural areas, also addressed to livestock activities, destined to collect in the vast innermost successions of the pastures and arable land, up to the edge of a large occupied plain to the hydrographic left of the Ombrone river from the "Granducale" pinewood with *Pinus pinea*, for 600 ha; (iii) the wetland areas, mainly gathered around the "Palude della Trappola", at the mouth of the Ombrone river and the Macchiozze ponds, which exercise a significant ornithological hot-spot; (iv) a beach-dune system in a phase of coastal erosion. The dune environment appears, however, well preserved with psammophilous species such as *Cakile maritima*, *Calystegia soldanella*, *Ammophila littoralis*, *Eryngium maritimum*, *Pancratium maritimum* and *Euphorbia paralias* (Del Prete and Tosi, 1985; Arrigoni, 2003).

In the dunal coastal system, Kentish Plover (*Charadrius alexandrinus*), occurring with at least one breeding pair (Giovacchini, 2019), is the species with the highest conservation concern in this coastal system for its demographic decline at the continental level (Staneva and Burfield, 2017). In this regard, in many countries, specific and context-declined conservation projects have been carried out (e.g., Montalvo and Figuerola, 2006; Ferreira-Rodríguez and Pombal, 2018; Battisti et al., 2022).

The threat analysis with before-after comparison was conducted at the Marina di Alberese beach (Grosseto, central Italy; 42°65' N – 11°35' E).

Target species

The threat analysis with before-after comparison has been carried out on one beach-nesting bird species Kentish Plover (*Charadrius alexandrinus*), as a target in this case study (sand dunes in MRP).

The Kentish Plover is a small Palearctic migrant shore-bird (Aves, Charadriidae; Montalvo and Figuerola, 2006). Usually, to lay its eggs, the Kentish Plover prefers sandy dune areas consisting of low vegetation, often with nests positioned near halo-psammophilous plants, used to partially hide the eggs (Norte and Ramos, 2004), mainly in habitats near water. In Italy, 2,400–3,200 wintering individuals and 1,500–1,850 very localized nesting pairs have been estimated (Biondi et al., 2014).

Kentish Plover is a species listed in Annex I of Directive 2009/147/EC (Birds Directive) of the European Parliament, in Annex II of the Bern Convention, and Annex II of the Bonn Convention. Furthermore, it is a species considered SPEC 3 (unfavorable conservation status in the European territory) by Staneva and Burfield (2017). At the European level, there has been a large decrease in the number of individuals between 1990 and 2000. The Italian wintering population, on the other hand, is moderately stable (Zenatello et al., 2014). Nationally, a breeding population of 1,300–2,000 pairs is estimated along the entire perimeter of the Italian peninsula, Sicily and Sardinia, but very localized in restricted sites (Spina and Volponi, 2008; Pietrelli and Biondi, 2012).

The panel of experts and threat analysis

In this work, we defined “threats”, as “any human-related process that negatively affects the specific components of biodiversity in a real context” (Salafsky et al., 2008). Here, we analyzed the set of threats to the target species selected (Kentish Plover), locally acting in a selected study area (dunal system of Marina di Alberese; MRP), i.e., people trampling, coastal erosion, marine litter, domestic dogs, illegal collection of halo-psammophilous plants. These threats are generally known as impacting nesting plovers with different patterns along the Mediterranean coasts (Ferreira-Rodríguez and Pombal, 2018; Galasso et al., 2021).

The threat analysis procedure has been carried out by a panel of students ($n = 10$) of the Master’s degree in “Ecotoxicology and Environmental Sustainability – University of Siena (Italy)”, considered here as ‘experts’, carrying out a before-after threat assessment in the study area (see list in the Acknowledgments). Previously panels carried out worldwide for threat analysis procedures involved a number of 10–15 experts, assuming this amount as representative and allowing reliable data (see Alhirsh et al., 2016; Battisti et al., 2008, 2009, 2020a; Giovacchini et al., 2022).

We selected academic students in environmental disciplines as ‘experts’ because they may represent an interesting panel in this regard. Indeed, they may have relatively good general skills in biological targets and related threats but poor expertise in target-threat relationships in natural contexts (Battisti et al., 2009): therefore, they were selected as a panel of experts to test possible overestimation of charismatic threats, whose regime is emphasized by mass and social media.

In the ‘before’ phase (*a priori*), the students were brought together and given a 4-hour lesson about the study area (MRP) and the specific dune system where the Kentish Plover nest. After the main threats to this target species have been listed, the students were asked to generate *a priori* assessment of how much each threat may potentially impact the targets considered (considering two threat attributes: extent and intensity); therefore, only based on indirect information, without the students ever having visited the site.

Subsequently, the students were taken by park rangers to the study area, and a 6-hour field survey (May 2022) was carried out so that they could obtain direct information on the extent and intensity (and the magnitude as a sum) of each threat in the actual site. After the inspection (“*a posteriori*”), the students were again given the evaluation form for the threat analysis.

Specifically, in both the “*a priori*” phase (before the survey, without having visited the coastal site) and “*a posteriori*” phase (after the inspection), the students answered the following question: ‘What is the extent and intensity of any threat? To respond to this question, for each direct threat, the panel of experts assigned a score to two regime attributes (extent and intensity) using a scale from 1 (low) to 4 (high). Magnitude as an arithmetic sum of the extent and intensity scores ranged from 2 to 8 (see Salafsky et al., 2008).

‘Extent’ can be measured as the proportion of the species’ habitat which has been, is, or will be affected by the

threat, when compared to the total surface available (all the suitable area of the habitat for the focal species: i.e., locally, all the coastal dune system in the MRP; Ervin, 2002). ‘Intensity’, as a proxy of threat intensity on the target, constitutes an evaluation of the past, present, or future pressure, which are estimated to be caused by the threat event and may affect the target leading to an impact on our target, i.e., a potential or real specific alteration. After this step, the two scores of extent and intensity, calculated for each threat, have been summed to obtain a score in magnitude. ‘Magnitude’, as a compound variable, represents a proxy of the threat pressure (and consequent impact) of any threat on the selected target (Salafsky et al., 2008). When the experts assigned scores to any threat attribute (extent, intensity, and magnitude), we calculated their averaged values (and standard deviation). Finally, experts ranked the threats regarding the magnitude values, obtaining a list in decreasing order. The threats with the highest average value represented the priority threats.

Threat nomenclature has been carried out using the IUCN unified classification of direct threats (Salafsky et al., 2008), where any anthropogenic threat factor or process has been named and coded (review in Battisti et al., 2016).

For each direct threat, the mean (and standard deviation) and median values (with interquartile range, IQR) of magnitudes before (“*a priori*”) and after (“*a posteriori*”) the field survey were compared using the Wilcoxon signed-rank non-parametric statistical test (`wilcox.test`) for dependent variables. R provides a value of the test statistic, and based on the p-value, the null hypothesis of equality of the ranks between the two samples is accepted or rejected. The significance level was set at $\alpha = 0.05$.

Results

The students considered coastal erosion (code 7.3 – Other Ecosystem Modification) as the priority threat (i.e., with higher magnitude) both in the before and after phase (Table 1, Fig. 1). In the before phase, the other threats were in descending order: trampling (1.3 – Tourism and recreation areas); marine litter (9.4 – Garbage and Solid Waste); plant collection (1.3 – Tourism and recreation areas), domestic dogs (8.2 – Problematic native species; Table 1, Fig. 1). In the after phase, the other threats were in decreasing order: trampling, plant collection, domestic dogs, marine litter.

In the ‘after’ phase, the marine litter showed the lowest value. The non-parametric Wilcoxon signed-rank test showed no differences in the ranking of mean values of the *a priori* and *a posteriori* magnitudes, except for the marine litter ($p = 0.004$; Table 1, Fig. 1).

Discussion

This study focused on the threat analysis of a plover bird as a conservation target, carried out by a group of academic students before and after a field survey. We observed as students evaluated threats differently. More particularly, coastal erosion was considered the priority threat for plover birds before and after the field survey. Effectively, a

Table 1. Mean scores (± 1 standard deviation) and median values (with IQR ranges) in magnitude for the different threats to the conservation target (plover birds), evaluated before and after the field survey by the panel of academic students. p: probability level (Wilcoxon signed-rank test). See Methods for details.

threats	<i>a priori</i> mean scores (before)	<i>a priori</i> median values (and IQR ranges)	ranking	<i>a posteriori</i> mean scores (after)	<i>a posteriori</i> median values (and IQR ranges)	p
1.3 – Trampling	5.4 (± 1.07)	6 (1.75)	2	4.5 (± 1.26)	4 (1)	ns
7.3 – Coastal Erosion	6.3 (± 1.25)	5 (2.5)	1	7.2 (± 1.93)	2.5 (1)	ns
9.4 – Marine litter	4.8 (± 1.62)	6.5 (2)	5	2.8 (± 1.03)	8 (1.75)	0.004
8.2 – Domestic dogs	3.9 (± 1.37)	4 (2)	4	3.2 (± 1.55)	2.5 (2.5)	ns
1.3 – Illegal plant collection	4.4 (± 2.01)	4 (3)	3	3.8 (± 1.39)	4 (1)	ns

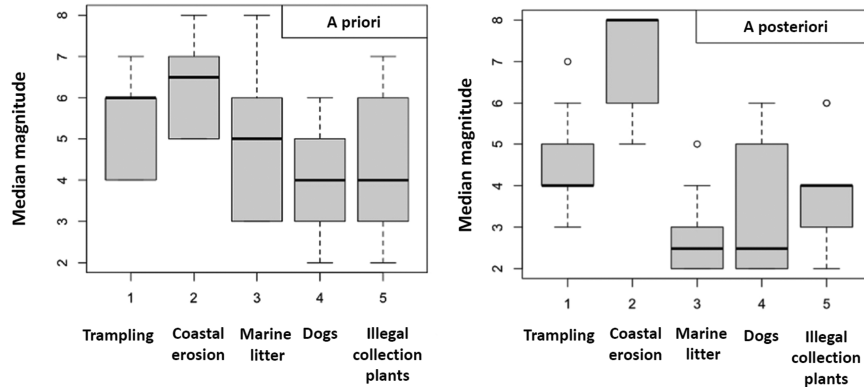


Figure 1. Boxplots for median magnitudes (bold lines in boxes representing the upper and lower quartiles of the distribution of mean values), evaluated “*a priori*” (before the field survey; on the left) and “*a posteriori*” (after; right) for the selected five anthropogenic threats on plover birds (Marina di Alberese beach; MRP). See Methods for details.

high proportion of the Tuscan coast (36.7%; Ciccarelli et al., 2011) is subject to coastal erosion due to anthropogenic activities, and the stretches in which this process is more dramatic correspond to those located near the river mouths, due to the decrease in the sedimentary supply (Ciccarelli et al., 2011). High risks are the mouth of rivers and Ombrone with a retreat of the shoreline up to 20 m in the last decades: this can be considered a priority problem to be addressed both for ecosystem damage and for the target considered that nest in these habitats, such as plover birds.

Students assessed the dunal trampling as the second-ranked threat before and after the field survey. A large number of bathing people occurs along the beaches of the natural park and when not addressed, this fact may affect the breeding sites of plovers, which are highly sensitive to this threat (Schlacher et al., 2016; Ferreira-Rodríguez et al., 2018).

Illegal collection of plants may be considered an indirect threat to plovers, and students evaluated its magnitude similarly before and after the survey. People collecting plants remove some attractive halo-psammophilous species (as for example, *Pancratium maritimum*): this may alter the structure of the breeding sites and the neighboring areas. Plants, in addition to being a resource for the nest construction, play an essential function of shelter from predators and as a habitat for prey insects, a trophic resource useful for plovers (Pietrelli and Biondi, 2012).

Domestic dogs were another critical threat for plover birds (Montalvo and Figuerola, 2006; Gómez-Serrano, 2021). However, students have been informed before the field survey of the strict local park regulations that prohibit the presence of dogs. Therefore, in the *a priori* step, students evaluated the domestic dogs as having a low magnitude.

The marine litter may pose a threat to plovers by entanglement (Battisti et al., 2019). This threat has been evaluated differently in the before-after comparison. Although the students were trained with an *a priori* briefing, they significantly overestimated the marine litter before the survey. The study area, extremely distant from both inhabited urbanized areas, receives litter of mainly agricultural origin, mainly from the Ombrone river, whose mouth is located immediately further north (Cannas et al., 2017; Guerranti et al., 2017; Federigi et al., 2022). The litter of agricultural origin consists of pesticide containers and rigid PVC irrigation pipes (polyvinyl chloride; UPAC: poly(1-chloroethylene), and expanded polystyrene (*aromatic hydrocarbon styrene*), two types of polymers primarily known as litter threatening biodiversity in marine ecosystems and commonly stranded on the coastal dunes (e.g., Kwon et al., 2014; for Mediterranean coasts: Poeta et al., 2014; Cresta and Battisti, 2021). Finally, there is a deposit of litter of marine origin (fishing nets), even if limited due to the distance from the nearest fishing mariners and the reduced number of active fishing boats (Zeichen et al.,

2022). The study area is also locally frequented by fishermen who use fishing lines and hooks, often abandoned on site, consisting of long-term degradable materials (fluorocarbon, PFC), these last trapping plovers and other birds (Battisti et al., 2019). However, fishing by private people is regulated by the Maremma Regional Park, and the contribution of abandoned fishing lines is extremely limited (G. Anselmi, pers. comm.). Moreover, bathing ordinances have completely prevented this type of fishing in spring and summer. Consequently, in recent years there has been an apparent substantial decline in plastics, even if quantitative data is lacking locally (G. Anselmi, pers. obs.).

Our results suggest as the student's *a priori* overestimation of the marine litter for plovers may be due to the high media/social exposure to this anthropogenic threat (Hartley et al., 2018), which may have influenced the pre-judgment of the students, which assigned significantly higher scores in the before phase, ascertaining the actual extent and intensity directly on the real context. After the field survey, the students assessed how the beach was not as impacted as assumed before. This cognitive bias (pre-judgment and availability bias; Catalano et al., 2018) may show political and scientific implications in threat assessment: indeed, when this approach is carried out by a panel of 'experts' (in our case, academic students) having only a technical background in environmental sciences, but without an actual perception of the natural context, the judgment may be biased toward threats having a higher charisma (see also Battisti et al., 2009). This fact highlights the need for the involvement of experts having both technical and context-based expertise (including local 'wise-people'; Battisti et al., 2020b), when assessing threats on environmental targets in sites of conservation concern. These explorative data obtained by a pilot study should be improved in the future in other contexts and focusing on other conservation targets to corroborate our conclusions.

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Take-home message

- This project demonstrated that, in the TAN procedure, a priori threat assessment for a target species breeding on Mediterranean coastal dunes can be affected by biases resulting from estimation errors.
- Academic student, as experts appointed for a specific conservation objective, indicated marine litter as the most significant threat to the conservation of the species in the area before the survey.
- The subsequent survey showed a reduction in marine litter scores that, a priori, had been significantly overestimated. This condition improves the assessment of the project management effectiveness, reducing exposure to cognitive biases.

Chapter 6: *APPLYING THREAT ANALYSIS APPROACH IN A SMALL FOREST URBAN PARK (NORTHERN ITALY): LOCAL EXPERT-BASED ASSESSMENT TO PRIORITIZE THE MANAGEMENT ACTIONS*

Abstract

For urban park managers, threats to biodiversity can significantly affect species and biological communities, particularly in semi-natural environments on a small scale. The "Giardino delle Capinere" Park, managed by the Municipality of Ferrara in collaboration with the Italian League for the Protection of Birds, represents a segment of traditional rural landscape within an urban ecosystem, featuring species such as *Fraxinus excelsior*, *Quercus robur*, *Quercus ilex*, and *Morus alba*. In this area, slightly over one hectare in size, 69 bird species have been recorded, six of which are listed under the BD.

The application of the TAN involved a panel of six experts in the autumn-winter of 2022, who possessed a strong knowledge of both ecological values and local threats (at least 5 years of site knowledge). Threat events were identified and categorized according to the IUCN standardized nomenclature. The expert group assessed two attributes of the regime extent and severity using a scale from 1 (low) to 4 (high). Subsequently, the "knowledge" score, representing the sum of the extent and severity scores for each threat, was calculated, followed by the magnitude variable, which serves as a composite indicator of the impact of any given threat on selected objectives.

Once the experts had assigned scores for extent, severity, and magnitude, the corresponding mean values (and standard deviations) were calculated. Finally, the threats were ranked in descending order based on their magnitude values. Following the IUCN classification, it was determined that the experts' knowledge of the threats was comparable, with no significant differences between them ($H=3.083$, $p=0.471$). However, Storms and Floods (IUCN category 11.4) and Roads and Railways (IUCN category 4.1) were identified as the threats with the highest level of expert knowledge. Conversely, Herbaceous Vegetation Management (IUCN category 7.3) was the least well-known threat and exhibited the lowest magnitude. Invasive Alien Species (IUCN category 8.1) represented the direct anthropogenic threat given the highest priority.

The TAN approach demonstrates several strengths, even in urban semi-natural areas. The evaluation, through pre-and post-project scoring, allows for comparison and assessment of the project's effectiveness, facilitating the adaptive management process. This initiative could serve as a valuable feedback mechanism for public policies related to the provision of ecosystem services.

Applying threat analysis approach in a small forest urban park (Northern Italy): local expert-based assessment to prioritize the management actions

Short communication

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Abstract

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To overcome the human-induced threats impacting on ecosystems, managers should focus on priorities. Here, we applied the expert-based Threat Analysis (TAN) in a forest urban park (Northern Italy), involving experts which ranked local threats, from the more to less impacting and following the IUCN classification. We also evaluated the level of knowledge of operators about these threats. Experts identified five priority target-specific threats: Roads and Railroads; Invasive-Non Native/Alien species; Other Ecosystem modifications; Recreational Activities, and Storms and Flooding. Storms and Flooding and Invasive-Non Native/Alien species appeared the threats with significant highest magnitude. Knowledge of threats is comparable without significant difference among them. However, Storms and Flooding and Roads and Railroads are the threats having both the highest level of knowledge by experts and the highest magnitude. At the opposite, Mowing was the less known threat regarding its regime and showed the lowest magnitude. TAN approach should be routinely used to build conceptual frameworks, ranking threats from the more to less impacting, therefore optimizing the management effort and developing local projects.

Keywords

conceptual framework, IUCN, management actions, threats, urban park

Introduction

Conservation projects and actions can lead to effective results in countering human-induced

threats to species and biological communities (MARGOLUS and SALAFSKY, 1998; SALAFSKY et al., 2008). To evaluate the effectiveness of these actions, managers can use specific biological indicators to compare the changes that

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have occurred following your projects (BATTISTI, 2018). However, project effectiveness monitoring focused only on biological indicators may show some weaknesses, for example due to the long response times of species and communities. Indeed, the effects of conservation measures on biological targets are often observable on different spatial and temporal scales (NOSS, 1990). To overcome these weaknesses, SALAFSKY et al. (2008) suggested that managers and professionals should also focus their monitoring on human-induced threats, shifting attention from the state of biological targets to the pressure induced by anthropic threats (DPSIR framework: Driving force-Pressure-State-Impact-Response; MAXIM et al., 2009).

Using specific regimen attributes such as extent, intensity, duration, frequency (review in BATTISTI et al., 2016), each threat could be quantified following the disturbance ecology theory (SOUSA, 1984; PICKETT et al., 1989). In this procedure, the threat regime assessment is expert-based. Compared to biological monitoring, threat monitoring based on expert evaluation shows interesting strengths having available short times and reduced human, economic and technological resources. This fact is particularly strategic since time and economic resources are often scarce in conservation (MARGOLUIS and SALAFSKY, 1998; JOHNSON et al., 2012).

Project managers and practitioners use the IUCN 'Threat Analysis' (hereafter, TAN) approach to make an expert assessment, assigning a standardized code to each threat. Furthermore, experts can assign a score that allows an assessment of the threat regime, namely: extent, intensity, and magnitude (MARGOLUIS and SALAFSKY, 1998; BAUER et al., 2022). In this way it will be possible to obtain a ranking among the threats (from the most to the least impactful), defining the priorities among them (i.e., the threats that deserve to be resolved urgently), thus supporting the decision-making process (SALAFSKY et al., 2008). The quantification of threat regimes through scores can also be used to carry out before-after monitoring, to verify the effectiveness of the measures (BATTISTI et al., 2008). In this paper, first we carried out a TAN on a small urban park in Northern Italy.

In this work, we have identified a set of threats acting locally in a northern Italian urban park, structuring a conceptual framework, with driving forces-threats-targets as causal chains. This framework will be useful for defining specific conservation measures to be implemented to counter local threats. Through a panel of experts, we quantified the threats using the scores assigned to obtain a classification in extension, intensity, and magnitude (SALAFSKY et al., 2008). We also evaluated the level of knowledge of operators about these threats, comparing this level of awareness to the score in threat magnitude.

Methods

Study area

The Naturalistic Garden "Le Capinere" (11°36'53"E / 44°50'58"N) was in the city of Ferrara (Emilia-Romagna,

Northern Italy) where the climate is wet-temperate, and the average temperature is 20 °C while during the year rainfall can peak 1,107 mm (<https://it.climate-data.org/europa/italia/emilia-romagna/ferrara-3207/>). The Garden was established in 1992 in the former Municipal Camping (10,000 m²), in collaboration with the Municipality of Ferrara and the Lipu-BirdLife International (hereafter 'Lipu'). At first, in 1995, the most urgent environmental interventions were carried out following an award-winning project approved by the ERA (Emilia Romagna Region Award for the Environment), such as the intervention to make trees likely to fall safe, an artificial lake, and the re-proposition, in an urban forest ecosystem, of a part of the rural landscape with also the planting of trees (e.g., *Fraxinus excelsior*, *Quercus robur*, *Quercus ilex* and *Morus alba*) and the zoning of spaces according to their natural vocations of the individual areas. Sixty-nine species of birds have been found in the Garden, of which six (*Falco peregrinus*, *Egretta garzetta*, *Ardea alba*, *Nycticorax nycticorax*, *Alcedo atthis* and *Ficedula albicollis*) pursuant to Directive 147/09/CE. Now the management of the "Le Capinere" Naturalistic Garden - Lipu is still in collaboration with the Municipality of Ferrara, the Province of Ferrara and the Emilia Romagna Region and the Wild Bird Rehabilitation Center and the Wildlife Education Center (Lipu Ferrara, unpublished data).

The panel of experts

To carry out the assessment of the local threat regime, we selected six experts (two managers, two operators, and two volunteers) belonging to a local non-profit organization (Lipu-BirdLife International) for the TAN procedure.

All these experts participated in the operational selection phases of the conservation measures adopted. Each of them has a good knowledge of both the project site (ecological values and surrounding social context) and the local threats. This has proved to be useful to have all the evidence to carry out the naming of the threat, the evaluation of the magnitude, the classification into priorities.

Threat analysis

By "threat" we mean "any anthropic process that negatively affects specific components of biodiversity (species richness, habitat condition and area, ecosystem functioning) in a real local context" (SALAFSKY et al., 2008). In this work, for the study area, the set of threats defined a priori by a panel of experts in an urban park located in a city in northern Italy (Ferrara) was analysed.

Threat nomenclature was reported in 2022 using the IUCN unified classification of direct threats (SALAFSKY et al., 2008; reviewed in BATTISTI et al., 2016).

Once the target-specific threats were named, we asked the experts the following questions: (i) What are the local threats acting on the small urban park that can be reduced (mitigating their impacts)? To answer this question, the experts analyzed all the factors and processes that act locally on a set of local ecological targets (list in Table 1). Subsequently, these factors/events were named and classified using the IUCN coded nomencla



Table 1. Matrix with threats (with IUCN code), effects and potential mechanisms and biological targets in the study area (“Le Capinere” urban park, Ferrara, Italy)

Threat	Effects	Potential mechanisms and targets
Road (Porta Catena’s street) [4.1 - Roads and Railroads]	Accumulation of rubbish on the border of the “Giardino delle Capinere”.	‘Trap effect’ on small mammals and invertebrates.
	Noise.	Interference on singing activity of nesting birds.
	Road-killing.	Direct impact on European green toad (<i>Bufo viridis</i>), European hedgehog (<i>Erinaceus europaeus</i>), Hare (<i>Lepus europaeus</i>), birds.
Alien/domesticated species (parakeets, tree species) [8.1 - Invasive-Non Native/Alien species/Diseases]	Feral cats.	Predation on European green toad (<i>Bufo viridis</i>) and birds.
	Rose-ringed Parakeet (<i>Psittacula krameri</i>).	Direct competition for nesting-holes (in hole-nesting species, locally occurring: Scops-owl (<i>Otus scops</i>), Great Spotted Woodpecker (<i>Dendrocopos major</i>), Eurasian Green Woodpecker (<i>Picus viridis</i>), tits etc.
	Robinia sucker (<i>Robinia pseudoacacia</i>) and Ailanthus (<i>Ailanthus altissima</i>).	Competition to native herbaceous vegetation/shrub/tree vegetation.
Grass mowing in the immediate surrounding [7.3 - Other Ecosystem modifications]		Direct (killing) and indirect (reduction in habitat suitability) impact on Hare (<i>Lepus europaeus</i>), Common Pheasant (<i>Phasianus colchicus</i>), European hedgehog (<i>Erinaceus europaeus</i>), European green toad (<i>Bufo viridis</i>) and other open-habitat (crop land) and edge species.
Uncontrolled use by people [6.1 - Recreational Activities]	Annoying noises especially during the holidays beginning of the year, rubbish.	Wintering wild birds, irrecoverable birds in aviaries, animals being treated in the BirdLife International ‘Wild Bird Rescue Centre’.
	Break in attempts and related damages.	Doors, gates, padlocks.
Extreme atmospheric/climate events [11.4 Storms and Flooding]	Severe thunderstorms can prevent the sewage system to work properly and cause the accumulation of foul-smelling waste.	Herbaceous vegetation and wild animals that feed on the ground.
	Severe thunderstorms can bring down trees or large branches and cause extensive damage.	Wooden or masonry structure (animal aviaries unrecoverable, inpatient aviaries for those under treatment, trails) and/or the animals themselves.
	Drought and related water stresses.	Herbaceous vegetation, shrub and native tree.
	High temperatures and scarcity of rain for long periods can contribute to accumulation of botulinum toxin on the bottom of the pond.	Waterfowl.



ture (BATTISTI et al., 2016); (ii) What is their extent, severity, and magnitude? How are they ranked in order of priority? To answer this question, for each direct threat, the expert panel scored two attributes of the regime (extent and severity) using a scale from 1 (low) to 4 (high). Considering the different regimen attributes, extent, and severity (i.e., the perceived intensity of the targets) seem the easiest to calculate using an expert-based approach (SALAFSKY et al., 2008). “Extent” can be measured as the proportion of “area” that has been, is, or will be affected by the threat, relative to the total available land area. “Severity”, as a proxy for the intensity of the threat on the targets: this constitutes an assessment of the past, present or future pressure, possibly caused by the threat event and which can affect the target by causing a specific potential or actual alteration, i.e., a negative impact on the target (see TNC, 2000). After this step, “Magnitude” is the sum of the two extent and severity scores, calculated for each threat. “Magnitude”, as a compound variable, is a proxy for the pressure (and subsequent impact) of any threat on selected targets (SALAFSKY et al., 2008). Once experts have assigned a score to any threat attribute (extent, severity, and magnitude), their mean values (and standard

deviation) are calculated. Finally, the experts sorted the threats in descending order (ranking) according to their magnitude values. Threats with the highest average value were prioritized; (iii) What is the level of local knowledge about the threat magnitude? To respond to this question, for each direct threat, the panel of experts assigned a score to the individual level of knowledge about each threat using a scale from 1 (low) to 4 (high).

To compare median values of threat Magnitude, due to not normal (asymmetric) distribution of data, we used the non parametric Kruskal-Wallis test (DYTHAM, 2011). We performed an Ordinary Least Squares regression between scored values in threat Magnitude and Knowledge. For statistical analyses, we used the PAST software (HAMMER and HARPER, 2001). Alpha was set at 0.05 level.

Results

The panel of experts identified the following local human-induced direct threats (classified following the IUCN Threat Nomenclature in Table 1): Roads and Railroads: locally represented by Road (Porta Catena’s street); Invasive-Non Native/Alien species/Diseases, locally repre-

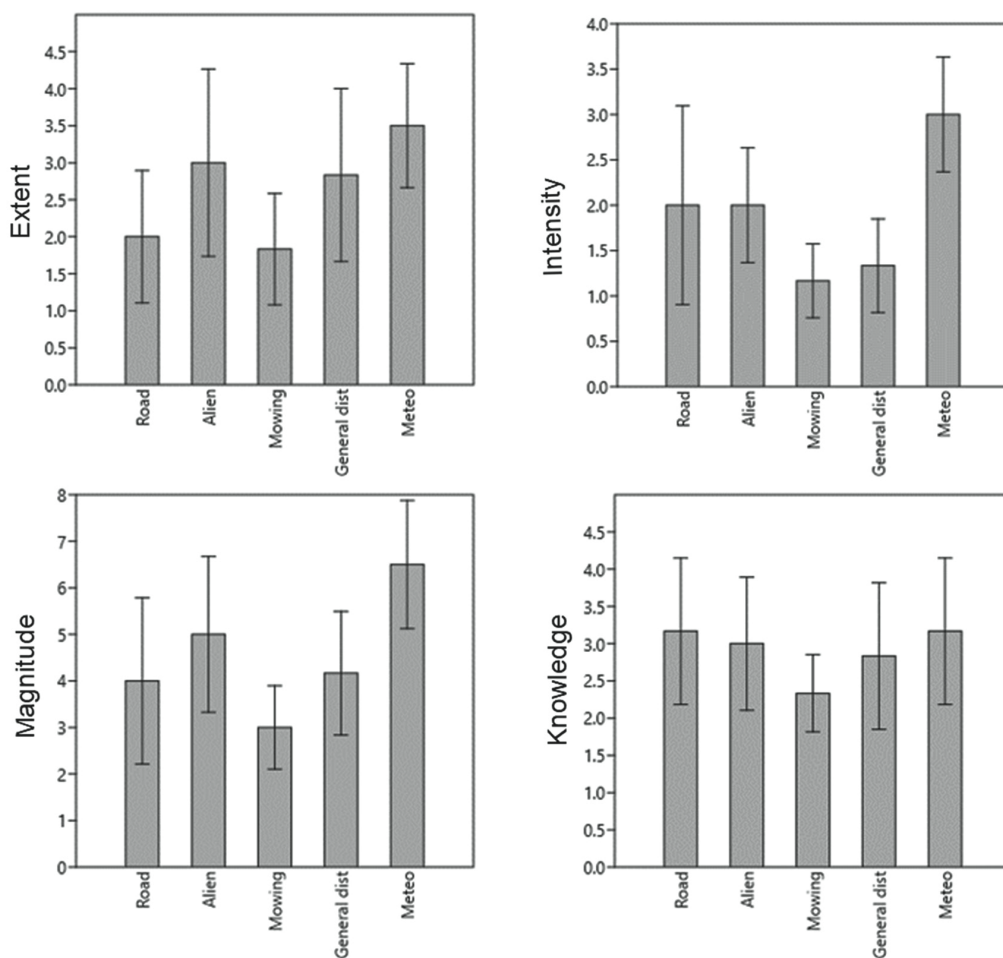


Fig. 1. Threat Analysis (TAN) procedure. Histograms reporting mean values (and \pm standard deviation) in regime attributes (Area, Intensity, and Magnitude; see Methods for details) for the human-induced direct threats selected in the small urban park studied (Northern Italy).



Table 2. Threat Analysis (TAN) procedure. Mean values (and \pm standard deviation) in regime attributes (Area, Intensity and Magnitude; see Methods for details) for the human-induced direct threats selected in the small urban forest park studied (Ferrara, Northern Italy)

Threats	IUCN category	Area	Intensity	Magnitude	Knowledge
Road (Porta Catena's street)	4.1 Roads and Railroads	2.0 (\pm 0.89)	2.0 (\pm 1.09)	4.0 (\pm 1.79)	3.17 (0.98)
Alien/domesticated species (parakeets, tree species)	8.1 Invasive-Non native/ Alien species/Diseases	3.0 (\pm 1.26)	2.0 (\pm 0.63)	5.0 (\pm 1.67)	3.0 (0.09)
Grass mowing in the immediate surrounding	7.3 Other Ecosystem modifications	1.8 (\pm 0.75)	1.1 (\pm 0.40)	3.0 (\pm 0.89)	2.33 (0.52)
Uncontrolled use by people	6.1 Recreational Activities	2.8 (\pm 1.16)	1.3 (\pm 0.51)	4.17 (\pm 1.33)	2.83 (0.98)
Extreme atmospheric events	11.4 Storms and Flooding (climate change)	3.5 (\pm 0.83)	3.0 (\pm 0.63)	6.5 (\pm 1.38)	3.17 (0.98)

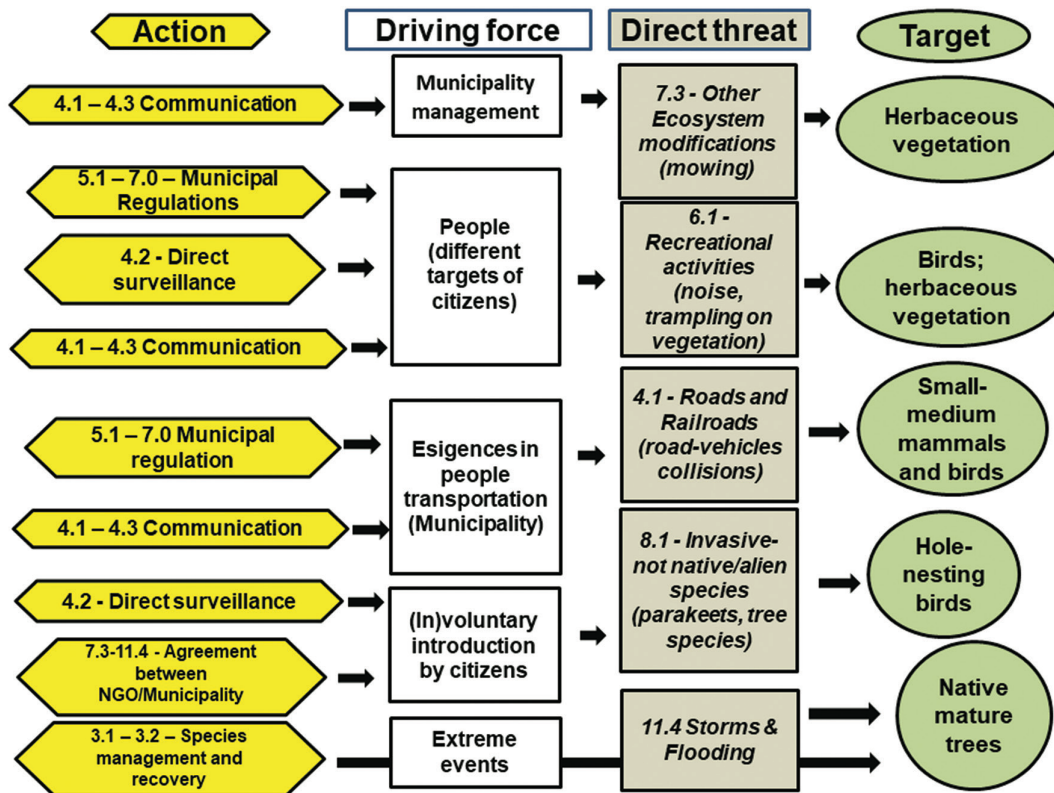


Fig. 2. Threat analysis (TAN) in the small urban park, with causal chain driving forces (social actors)-threats-targets. Actions (and their IUCN code) have been reported in exagons. IUCN nomenclature of threats follows SALAFSKY et al. (2008); review in BATTISTI et al. (2016).

sented by Alien/domesticated species (parakeets, tree species); Other Ecosystem modifications, locally represented by Grass mowing in the immediate surrounding; Recreational Activities, locally expressed by Uncontrolled use by people; Storms and Flooding, i.e., Extreme atmospheric events (Fig. 1). All these local threats show specific driving forces (Tables 1 and 2, Fig. 2).

After expert-based quantification, we showed as local threats differ significantly in magnitude among them

($H = 11.73$; $p = 0.017$; Kruskal-Wallis, test for equal medians), with highest magnitude showed by 11.4 Storms and Flooding and 8.1 - Invasive-Non Native/Alien species/Diseases.

Knowledge of threats is comparable without significant difference among them ($H = 3.083$, $p = 0.471$). However, Storms and Flooding and Roads and Railroads are the threats having the highest level of knowledge by experts and, at the same time, they have been assessed

as threats having the highest magnitude. At the opposite, Mowing was the less known threat regarding its regime and showed the lowest magnitude. Regression between total scores assigned by experts both in magnitude and in knowledge showed a medium-low variance ($R^2 = 0.53$) but not significance ($r = 0.73$, $t = 1.85$, $p = 0.16$) Ordinary Least Squares Regression: K-M, 95% bootstrapped confidence intervals ($N = 1,999$).

Discussion

The panel of experts selected a set of main (direct and indirect) human-induced threats acting locally, using the TAN approach in a small forest urban park of Northern Italy.

Considering the judgment of the experts, the park is mainly affected by extreme climate events, which can be classified as an indirectly anthropogenic threat, as it is influenced by larger-scale climatic phenomena that have been occurring for some years in the Mediterranean (“Medicane”; BAKKENSEN, 2017) and which show heavy implications on biodiversity (e.g., PINNA et al., 2022). Regarding severe climate events, the city of Ferrara and all the North-Eastern Italy has suffered in recent years from extreme climate events (BRUNETTI et al., 2001; STRAFFELINI and TAROLLI, 2023).

The nature of extreme meteorological events, especially if markedly widespread on a scale, often makes it difficult to contain. In this regard, urban forest planners should adapt the urban forest to become more resilient in the face of such events (MARSHMAN, 2018). Actions focused on the recovery of damaged plants can constitute further options useful for responding to a threat whose causes cannot be locally controlled. The staff managing the park should carry out a census of the tree species most susceptible to these impacts, as has already been done in other areas (e.g., FORAN et al., 2015).

Alien species represent the direct anthropogenic threat that was prioritized. In lowland anthropized areas, simplified ecosystems are highly vulnerable to invasions by these species. In this sense, a large part of the Po Plain, where the city of Ferrara is located, is characterized by a high presence of non-native species, belonging to various animal and plant groups (LURZ et al., 2001; CASTALDELLI et al., 2013; BIANCO, 2014; VERLOOVE and ARDENGHI, 2015; FALASCHI et al., 2018). These species may act impacting on native vanishing fauna (e.g., FERRI et al., 2017).

Specifically, the expert group locally considered as worthy of attention the local breeding colony of Rose-ringed parakeets (*Psittacula krameri*), nesting on the mature trees. The competition of these species during the reproductive period for cavities ecologically suitable for native hole-nesting birds (e.g., woodpeckers, tits, nutchatches, starlings, owls) is known from literature (STRUBBE and MATTHYSEN, 2007; DODARO and BATTISTI, 2014; MENCHETTI and MORI, 2014) and represents a cause for concern. Furthermore, parakeets show a very marked competitive behaviour (bullying; LE LOUARN et al., 2016), also towards species of conservation interest (e.g., hawks; BATTISTI and FRATICELLI, 2023). The management of the park in an ecological sense will have to take this threat into account as a priority: specifically, it may be neces-

sary to define a control plan for this species and communication actions aimed at preventing parakeets from being released into the wild. Among the alien species, there are also recently introduced tree species, even unintentional ones (*Ailanthus altissima*, *Robinia pseudoacacia*) which can interfere with local plant successions (HALABUK and GERHÁTOVÁ, 2011; CSISZÁR et al., 2020; GRIGORESCU et al., 2020; for Italy, see MONTECCHIARI et al., 2020).

A targeted control of this vegetation with operational actions of eradication and replacement with hedges and rows of native species can be planned (e.g., NUNES, 2022). Finally, non-native species include feral cats that can pose a threat to many animal species, especially birds (MORI et al., 2019). Both in the case of non-native tree species and feral domesticated species, a control and eradication plan may be useful, as already implemented in other contexts (SABO, 2000; NATOLI et al., 2006; LIESS and DRESCHER, 2008).

Note how the first two priority threats in the park can be interconnected. For example, it is known that invasions of non-native species can be facilitated by the occurrence of extreme climatic events (DIEZ et al., 2012).

Other threats are not a priority, but staff may still be able to take steps to mitigate them. The road adjacent to the urban park is at the origin of three impacting mechanisms (sensu BALMFORD et al., 2006): accumulation of rubbish, noise, and direct impact by motor vehicles. The presence of perimeter roads in natural areas causes a series of impacts that can generally be included in the category of road edge effect (FUENTES-MONTEMAYOR et al., 2009; review in COFFIN, 2007). Each of these processes can impact specific components (e.g., rubbish can trap small mammals and invertebrates; FERRI et al., 2023; motor-vehicles can kill many amphibians, reptiles, small mammals, and birds by impact; BATTISTI et al., 2012; noise at roadsides can influence the presence of birds at roadsides; PIERETTI and FARINA, 2013).

Among the threats considered to be of minor magnitude was grass mowing in the immediate surroundings. This activity has been indicated as having an impact on different biological species (VICKERY et al., 2000; VICKERY et al., 2001; HUMBERT et al., 2009; HYVÖNEN and HUUSELA-VEISTOLA, 2011). In this regard, the staff of the urban park should adopt some guidelines for grass management (e.g., VICKERY et al., 2000).

Finally, the unmanaged people fruition by citizens can cause impact if not addressed (GIOVACCHINI et al., 2022). The management effort, already started some years ago by the park staff, is aimed at defining a network of paths to prevent uncontrolled use (and therefore, trampling on the vegetation and general disturbance). However, the effects of uncontrolled use are little known to the group of experts as shown by the knowledge analysis.

It has been underlined how the expert-based threat analysis procedure can show some weaknesses: among these, the lack of analytical data that can influence the general judgment through bias related to subjectivity (see JOHNSON et al., 2012). However, the assessment was carried out by experts who have long demonstrated a high local knowledge of the threats and their regime.

However, the expert-based TAN approach may

show some strengths (FAZEY et al., 2006). When budget and economic resources are scarce and threats are difficult to compare with each other, the use of an expert method can provide a preliminary assessment, useful for decision-making and planning strategies according to an order of priorities (MARGOLUIS and SALAFKSY, 1998; MILATOVIĆ et al., 2019).

Furthermore, the evaluation through scores assigned before and after a project can allow a comparison and an evaluation of their effectiveness, facilitating the process of adaptive management (MCCARTHY and POSINGHAM, 2007).

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Take-home message

- A threat assessment has been carried out in an urban park of Northern Italy.
- Local experts indicated Invasive Alien Species (IUCN category 8.1) as the most significant threat to the conservation of the species in this urban park.
- Storms and Floods (IUCN category 11.4) and Roads and Railways (IUCN category 4.1) were the threats showing the highest level of expert knowledge.
- TAN may be useful for experts managing urban parks, to select priorities of action.

Chapter 7: APPLYING A BEFORE–AFTER THREAT ANALYSIS AND THREAT REDUCTION ASSESSMENT: CHARADRIUS ALEXANDRINUS AND CHARADRIUS DUBIUS

Abstract

Following the nesting of Kentish Plover (*Charadrius alexandrinus*), a species listed in the Birds Directive, and Little Ringed Plover (*Charadrius dubius*), the managing authority of the "Torre Flavia" Natural Monument, a coastal area including dune habitats, implemented conservation measures after 2017 to mitigate threats affecting these species.

In autumn 2021, TAN and TRA procedures were conducted to evaluate the effectiveness of the conservation management strategy in an area subjected to high anthropogenic pressure. A panel of local experts assessed the attributes of direct human-induced threats, ranking them from most to least impactful.

In the TAN procedure, two key regime attributes (Extent and Intensity) were scored. The results identified domestic dogs, dune trampling, and synanthropic predators as the most urgent threats, with significantly higher magnitude scores when compared to the others. A significant difference in severity was observed ($H = 19.01$, $p < 0.001$; Kruskal-Wallis test for equal medians).

The TRA procedure further confirmed that domestic dogs and dune trampling had the highest total scores. Experts estimated the percentage reduction in threats due to conservation actions, with mechanical beach cleaning (IUCN category 4.1; >80%), dune trampling (IUCN category 1.3), and synanthropic predators (IUCN category 2.2; >60%) showing the highest average impact reduction. In contrast, fishing line and hook removal (IUCN category 9.4) had the lowest effectiveness.

Overall, the project demonstrated a moderate-to-high effectiveness in threat mitigation, with a TRA-I of 63.08%. These findings highlight the importance of targeted conservation actions and structured assessment frameworks in managing highly anthropized coastal environments.

Introduction

Human activities trigger a series of factors and processes named anthropogenic threats (Salafsky et al., 2008) that are capable of altering ecosystems at any hierarchical level (populations, communities, landscapes, and processes), at different spatial and temporal scales (Margoluis & Salafsky, 1998). Recently, these human-induced processes have been classified in taxonomic categories (urban settlements, agricultural and aquaculture, energy production and mining, transportation and service corridors, biological resource use, human intrusions and

disturbance, natural system modifications, invasive and other problematic species and genes, pollution, and climate change and severe weather), each with many sub-categories of specific threats (Salafsky et al., 2008).

To mitigate the impacts of human-induced threats on biological targets of conservation concern (population/species, communities, ecosystems, and ecological processes), environmental managers develop projects and actions (hereafter, “measures” Margoluis & Salafsky, 1998; Salafsky et al., 2012) to obtain effective outputs and outcomes (Battisti, 2018).

Moreover, the effects of conservation measures on biological targets are often observable at different spatial scales, due their eco-behavioral patterns (Noss, 1990). To overcome these weaknesses, Salafsky et al. (2008) suggested that managers should focus the monitoring not only on biological targets, but also on human-induced threats, partially shifting the focus from the status of the biological targets to the pressures induced by the anthropogenic threats (see the Driving forces-Pressure-State-Impact-Response—DPSIR—framework) (Maxim, 2009). In this regard, any threat could be quantified using specific regime attributes (extent, intensity, duration, frequency, and so on) (Sousa, 1984; Battisti et al., 2016), e.g., for shorebirds (Pearce-Higgins, 2017).

The assessment of threat regime is expert-based. When compared to biological monitoring, threat monitoring shows interesting points of strength, since an expert-based evaluation (based on the local expertise of practitioners and managers) may be conducted, having available short times and reduced human, economic, and technological resources. This fact is particularly strategic, since time and economic resources are often scanty in conservation (Margoluis & Salafsky, 1998). Moreover, for a cost/benefit balance, these strengths may overcome the points of weaknesses in this type of evaluation (as the lack of analytical data to understand the severity of threat magnitude) (Johnson, 2012).

To carry out an expert evaluation of human-induced threats, project managers and practitioners use the IUCN approach of TAN, assigning a standardized code and providing a quantification of human-induced events impacting on specific local conservation targets (Bauer et al., 2022). This approach is useful for defining threat specific measures. The relationships among targets, threats, and conservation measures allow for the building of conceptual frameworks, including all of the components of these cause–effect relationships (Margoluis & Salafsky, 1998). Moreover, experts may assign a score allowing for an assessment of threat regime, i.e., of the extent, intensity, and magnitude, defining priorities among them (i.e., threats deserving to be solved with urgency), and therefore supporting decision-making (Salafsky et al., 2008). The quantification of threat regimes using scores may also be used to carry out a before–after comparison to monitor whether specific threats have been significantly reduced by the project, and therefore, to assess the effectiveness of measures (Battisti et al., 2008). With this expert-based procedure TRA (Salafsky & Margoluis,

1999), the project team obtained a synthetic value (TRA-I index) expressing how much the human-induced threats have been reduced once the conservation measures have been completed (Anthony, 2008; Lamsal et al., 2015).

We carried out a TAN on a case study representative of a conservation project focused on two threatened beach-nesting waders birds of high conservation concern (Kentish Plover, *Charadrius alexandrinus*; Little Ringed Plover, *Charadrius dubius*), breeding in Torre Flavia wetland, coastal SPA of central Italy. These two species showed a strong decline in the last few decades, mainly due to the action of anthropogenic threats acting on their breeding sites (Biondi et al., 2000; Biondi et al., 2020).

For this purpose, we identified a set of threats locally acting on these targets, to the aim of building a conceptual framework, with driving forces-threats-targets as causal chains. We quantified the threats using scores assigned by a panel of experts to obtain a ranking in extent, intensity, and magnitude, i.e., three attributes of its regime (Salafsky et al., 2008). After TAN, we developed a conservation project with a set of specific measures oriented toward the reduction in human-induced threats. Finally, we performed a TRA procedure to monitor the level of threat reduction obtained through the project (Salafsky & Margoluis, 1999; Battisti et al., 2008; Alhirsh et al., 2016; Giovacchini et al., 2022). Therefore, using these approaches, our aims were to respond to these two questions. First: What are the threats that have the greatest impacts (expressed in total magnitude) on our conservation targets (bird waders)? Second: What has been the overall effectiveness of our measures carried out inside this specific conservation project? To our knowledge, this is the first application of both these two approaches (i.e., TAN and TRA) in a coastal Mediterranean site, hosting habitat types of conservation concern (embryonic shifting dunes), and two rare bird species.

Methods

Threat Analysis

We analyzed the set of threats to the focal species selected and locally acting in our study area. Threat nomenclature was carried out in 2021 using the IUCN unified classification of direct threats (“threat taxonomy”) (Salafsky et al., 2008).

Once assigned an IUCN code to any target-specific threat, we asked the experts the following questions (in this regard, we defined as “experts”, all the professionals, operators and stakeholders having at least two years of local background in the study area).

First: What are the local threats acting on the two birds (targets) in the Torre Flavia SPA, and specifically, which can be reduced (mitigating their impacts) with a specific local project? To

respond to this question, the experts analyzed all of the factors and processes acting locally on these two targets. After, these factors/events were named and classified using the IUCN coded nomenclature.

Second: What is the extent, severity, and magnitude of any threat? How can any threat be ranked in order of priority? To respond to this question, for each direct threat, the panel of experts assigned a score to two regime attributes (extent and severity) using a scale from 1 (low) to 4 (high). Among the different attributes, extent and severity (i.e., intensity as perceived by targets) seemed the easiest to calculate when using an expert based approach (Salafsky et al., 2008). “Extent” can be measured as the proportion in species habitat that has been, is, or will be affected by the threat, when compared to the total surface available (all of the suitable area of habitat for the two focal species: i.e., locally, all the coastal dune system in the SPA) (Ervin, 2003). “Severity”, as a proxy of threat intensity on the targets, constitutes an evaluation of the past, present, or future pressure, which are estimated to be caused by the threat event and that may affect the target, leading to an impact in our targets, i.e., a potential or real specific alteration (TNC, 2000). After this step, the two scores of extent and severity, calculated for each threat, were summed to obtain a “Magnitude” score, as a compound variable, representing a proxy of the threat pressure (and consequent impact) of any threat on the selected targets (Salafsky et al., 2008). When the experts assigned scores to any threat attribute (extent, severity, and magnitude), we calculated their averaged values (and standard deviation). Finally, the experts ranked the threats when regarding the magnitude values, obtaining a list in decreasing order. The threats with the highest average value represented the priority threats. All the indicated threats manifested themselves with a yearly based regime articulated in time, space, and pattern: Therefore, the assessments on the regime attribute (area, intensity, and magnitude) expressed by the experts refer to the 2021 project period.

Conservation measures

Since the early 2000s, the local Park Agency carried out a set of ordinary actions (fences, communication by panels, and direct control) without a specific project. During any year, these ordinary and periodic actions started in late winter and early spring, and they were focused to mitigate some of the threats acting on these two beach-nesting birds (dune trampling, dogs, and mechanical beach clean-up). After 2017, the park operators improved measures, also targeting volunteers and guards to control the waders nests. Lastly, in 2021, the Park Agency launched a local conservation project on both the species. Thanks to the TAN procedure, the operators obtained an arrangement of local threats, naming and ranking them, thus defining the priorities and suggesting standardized actions (measures). The formal process of reducing the threats within the project took

place between January 2021 and autumn 2021.

All threat-specific actions were classified using the standard reported in (Salafsky et al., 2008).

This project involved different categories of measures.

Field operational actions: Dune borders demarcation, assembling fences (IUCN category 2.1—site management) aimed to mitigate people trampling on halo-psammophilous plants and nests; the building and location of anti-predatory cages on nests (a wire metal mesh composed of a grid with 76.2-63.5 mm units) and of shelters in dunes (IUCN category 3.2—species recovery) aimed at protecting nest sites and clutches; the manual cleaning of beaches, conducted by removing fishing lines and hooks, a type of litter entrapping waders (IUCN category 2.1) with monthly clean-up (Battisti et al., 2019); clean-ups were conducted before the breeding period in January and February, and using a standardized protocol (Battisti et al., 2020).

Surveillance and control: The Park Agency obtained the emanation of specific regulations (Municipality's Ordinances) that interposed the transit of dogs along the beach and the dunes during the breeding periods (IUCN category 5.2—Legislation, policies, and regulations; moreover, the Park Agency carried out training to improve skills and expertise in volunteers and guards (IUCN category 4.2—training courses and stakeholder education), which monitored the nests, controlling disturbances by people near the nests.

Communication was aimed at improving awareness in two categories of stakeholders (fishermen, as drivers for fishing lines and hooks entrapping waders birds, and dog owners: IUCN categories 4.1. and 4.3); these actions have been conducted, involving scholar students, sending messages to local radios, mass (local TV and magazines) and social media, the reporting of information on panels along park paths, and distributing information leaflets to bathers.

Alliances with Institutions and Associations (IUCN category 7.2) aimed to provide some strategic actions (for example, blocking the mechanical clean-up of dunes: These last actions were promoted seasonally by the local Municipalities).

Threat Reduction Assessment

When the project was closed, we carried out a TRA procedure (Salafsky & Margoluis, 1999), submitting a set of questions to a panel of local experts in October 2021 (Giovacchini et al., 2022). We asked the experts the following questions regarding local threats: (i) what score (from 1 = low to 4 = high) would you assign to the attributes of area, intensity, and urgency (having in mind the effects on the two selected targets)? For “area”, we considered the extent of habitat(s) in the site that the threat affects; for “intensity”, we considered the effect (or severity) of the threat; and for “urgency”, we considered the immediacy of addressing actions against the threats (Anthony, 2008),

and (ii) how much would you assess the project's effectiveness (i.e., the reduction in each threat after the project, assessing a percentage score from 0 to 100)?

After each step, we collated the data, obtaining the averaged values (and standard deviation) for each threat regarding the area, intensity, urgency, and percentage reduction after the project.

From the averaged values, we ranked the threats according to their relative importance (from 1: the lowest, to 6: the highest). A total threat score was computed after all of the threats were ranked. Finally, we added the value of mean percentage reduction for each threat (Salafsky & Margoluis, 1999).

After the ranking and scoring exercises, the total ranking scores for each threat were multiplied by the percentage of the threat met to yield a raw score for that threat. The (TRA-I) value was derived by dividing the sum of the raw scores for each threat by the total possible rankings of all the threats, and multiplying by 100, i.e.: $TRA-I = \text{total raw scores} / \text{total rankings} \times 100$ (details in Salafsky & Margoluis, 1999). Thus, the TRA-I value indicates the response to all of the combined threats to the overall conservation project over the assessment period. All calculations were carried out using Microsoft Excel software for Windows.

Statistical analyses

We used a score evaluation, obtaining the averaged values and dispersion measures. We applied the test for the homogeneity of variances to test if the variances among groups were homogeneous, therefore, allowing the Kruskal-Wallis test to be applied. To compare the averaged threat magnitudes among >2 samples, we performed the non parametric Kruskal–Wallis test for equal medians, obtaining H values (n=10 experts). We used the PAST 1.89 software (Hammer, 2001; Dytham, 2011). The alpha level was set to 0.05.

Results

Target species and Threat Analysis

We found and brought under protection six nests, with 21 eggs laid (18 of Little Ringed Plover and three of Kentish Plover) and 8 eggs hatched (three of Kentish Plover and five of Little Ringed Plover).

Regarding the TAN procedure, the panel of experts identified the following human induced direct threats: Fishing lines and hooks (IUCN category 9.4—Garbage and solidwaste), Dune trampling (IUCN category 1.3—Tourism and recreation areas), Domestic dogs (IUCN category 8.2—Problematic native species), Synanthropic predators (IUCN category 2.2—Invasive/problematic species control; IUCN category 8.2—Synanthropic predators), Mechanical beach grooming (IUCN category 4.1—Roads and infrastructures), all having specific driving forces.

The values of threat regime attributes showed as domestic dogs and dune trampling, and synanthropic predators appeared as the threats with the largest magnitude (Tab.1.7).

We observed a significant difference in magnitude among the threats ($H = 19.01, p < 0.001$).

Threats	Area	Inter	Magnitude
9.4 –Fishing lines and hooks	2.1 (± 0.88)	2.6 (± 0.97)	4.7 (± 1.57)
1.3 – Dune trampling	3.4 (± 0.70)	3.7 (± 0.48)	7.1 (± 0.74)
8.2 – Domestic dogs	3.8 (± 0.632)	3.7 (± 0.48)	7.5 (± 0.97)
2.2 – Synanthropic predators	3.7 (± 0.68)	3 (± 0.94)	6.7 (± 1.16)
4.1 – Mechanical beach grooming	1.9(± 1.20)	4 (0)	5.9(± 1.2)

Table 1.7 – TAN procedure. Mean values (and standard deviation) in regime attributes (area, intensity, and magnitude) for the human-induced direct threats selected in the “Torre Flavia” SPA.

Direct threats differ significantly in extent and severity (both of them, $H = 14.18, p < 0.001$), with domestic dogs and synanthropic predators being the most largely diffused (extent), and with domestic dogs and dune trampling being the most intense (Tab.1.7).

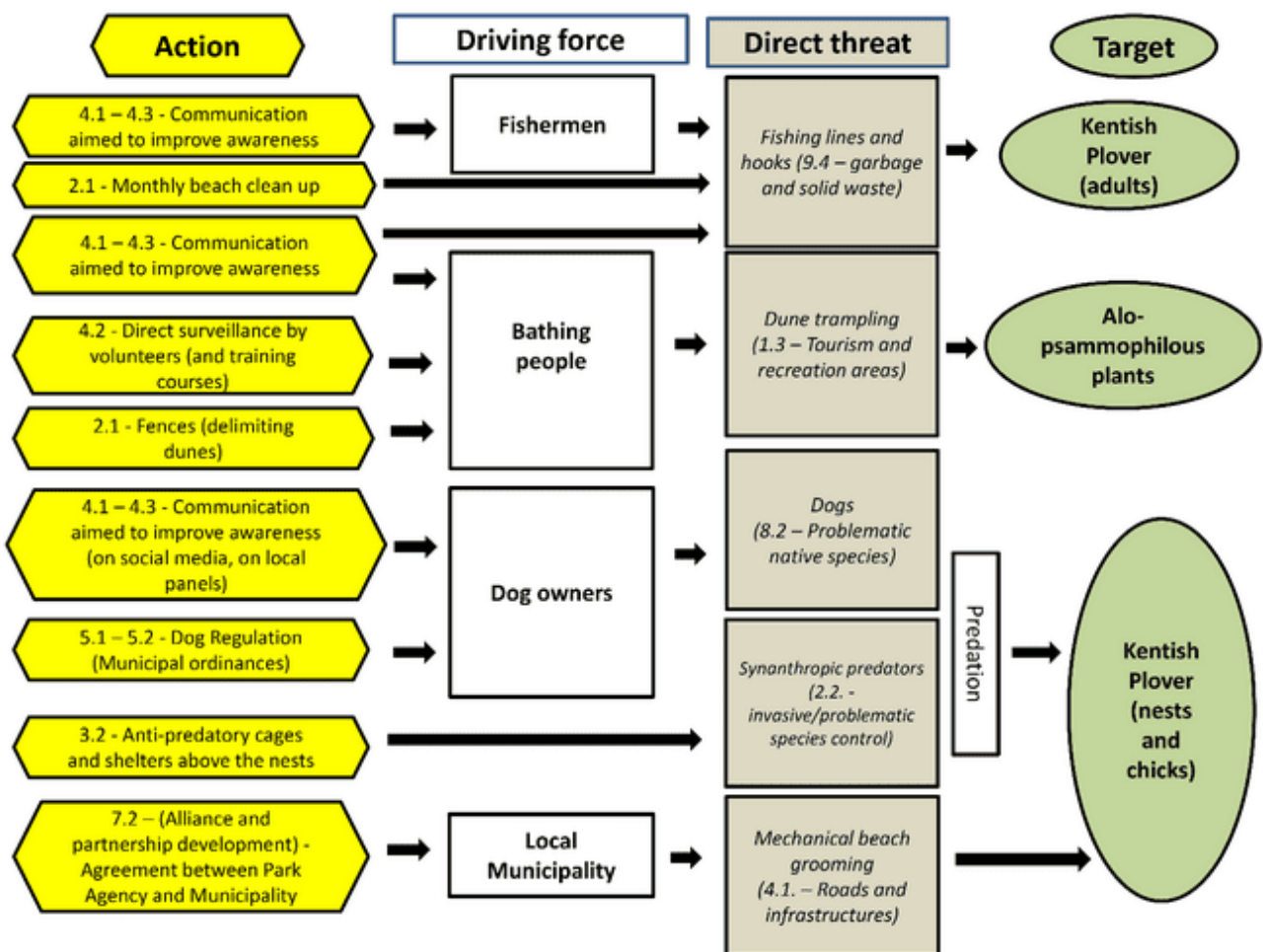


Figure 1.7 - TAN in the “Torre Flavia” Special Protection Area, with causal chain driving forces (social actors, white boxes)—threats (grey boxes)—targets (green circles) and measures (yellow hexagons). IUCN nomenclature of threats and conservation measures follow Sousa (1984) and Battisti et al. (2016).

For any threat, a set of conservation measures has been carried out, as outputs of the project (Fig. 1.7).

Field operational actions: about 800 m of fences demarcated dunes to mitigate people trampling on halo-psammophilous plants and waders nests; moreover, we located six cages on active nests; we also built and located occasional shelters in dunes to protect nest sites and clutches; from December 2020 to February 2021, we actively manually removed 5122 litter items stranded on the beach, among them, 106 (2%) were potentially entrapping materials (i.e., fishing lines and hooks); however, although these standardized clean-ups removed a large amount of entrapping litter, these materials were continuously deposited after sea-storms and by fishermen, making a total clean-up of the sand dunes difficult (Battisti et al., 2020).

Field surveillance and control: Seventy volunteers have been trained with a course conducted by professional ornithologists and providing a kit with an identification card, information leaflets for bathers (>5000 printed copies), and the Municipal Ordinances.

Communication (locally promoted or via social and mass-media): we involved fishermen, dog owners, bathing people, and scholar students (five primary and secondary schools of Cerveteri and Ladispoli), explaining information about the breeding ecology of the two species, and the attentions to be kept at the dunes; to this purpose, we sent messages to the local radio and mass-and social media, reporting information on small and large panels (n = 150) along park paths, and distributing information leaflets to bathers.

Alliances with Institutions and Associations aimed at providing some strategic actions: We blocked the mechanical grooming (i.e., cleaning) of beaches carried out by an alliance between ONGs (LIPU—Bird Life International; MareVivo, WWF—Italy) and the Municipality of Ladispoli. In this regard, the Municipality helps with change toward good dune management.

Threat Reduction Assessment

After the projects, a panel of experts carried out the TRA procedure, the assessing area, the severity and urgency of each threat, and obtaining the mean values (and standard deviation) for any attribute. The attributes were ranked and summed: domestic dogs and beach trampling showed the highest total rank (Tab.2.7). Finally, experts assessed the percentage in threat reduction following the project. Experts assessed as mechanical beach grooming (>80%), dune trampling, and synanthropic predators (both >60%) showed the highest averaged percentage of impact reduction; fishing lines and hooks showed the lowest percentage of impact reduction (Tab.2.7)

Threats		rank	intensity	rank	urgency	rank
9.4 – Fishing lines and hooks	2.1 (± 0.88)	2	2.6 (± 0.97)	1	2.8 (± 1.03)	1
1.3 – Dune trampling	3.4 (± 0.70)	3	3.7 (± 0.48)	3	3.9 (± 0.32)	5
8.2 – Domestic dogs	3.8 (± 0.632)	5	3.7 (± 0.48)	3	3.9 (± 0.32)	5
2.2 – Synanthropic predators	3.7 (± 0.68)	4	3 (± 0.94)	2	3.1 (± 1.45)	2
4.1 – Mechanical beach grooming	1.9 (± 1.20)	1	4 (0)	5	3.5 (± 0.85)	3
Criteria ranking				total ranking	Threat reduced	Raw score
	area	intensity	urgency			
9.4 – Fishing lines and hooks	2	1	1	4	49.5	1.98
1.3 – Dune trampling	3	3	5	11	69	7.59
8.2 – Domestic dogs	5	3	5	13	49	6.37
2.2 – Synanthropic predators	4	2	2	8	60.5	4.84
4.1 – Mechanical beach grooming	1	5	3	9	84.5	7.605
				45		28.385

TRA-I index = Σ (row score/total ranking) \times 100 = 63.08%

Table 2.7 - TRA procedure. Regime attributes of area, intensity, and urgency, and related ranks for the SPA “Torre Flavia” Special Protection Area. TRA and procedure to calculate the TRA-I index. (1): sum of ranking of area, intensity, and urgency. (2): estimated percentage of threat mitigation over assessment period. TRA-I index = S (raw score/total ranking) \times 100 = 63.08%.

The procedure showed a total TRA-I that was equal to 63.08%, considering all of the threats affecting the target birds. Domestic dogs and dune trampling appeared as the threats that were most urgent to solve.

Discussion

Our study highlighted how the anthropogenic threats on the selected target species were due to three main categories of social actors (i.e., fishermen, bathing people, and dog owners), all acting as driving forces.

More, domestic dogs and people trampling represented the human-induced threats with the highest magnitude on waders, consequent to the high pressure of bathing people on these fragile ecosystems. The disturbance from uncontrolled frequentation of beaches by people may impact on halo-psammophilous dunal plants (Defeo et., 2009; Gómez-Serrano, 2021), important resources (shading, shelters, nesting materials) for nesting plovers, and therefore on their behaviour and breeding ecology (Montalvo & Figuerola, 2006), leading also to the destruction of nests and eggs (Santoro et al., 2012).

Domestic dogs also constitute a stress factor since they act as predators on eggs and chicks or disturbing the hatching adults. In this last case, when dogs are present near the nests (approximately

< 15 m), waders can move away from the nest exposing to the predation of eggs/chicks or to sun exposure, compromising the hatching success (Ruhlen et al., 2003).

To mitigate dune trampling and presence of domestic dogs, the project team developed a set of actions that have greatly reduced the impact of these threats (communication for dog owners, fences, cages on nests), as observed using the expert-based TRA procedure. We assumed that our efforts mitigated the magnitude of these threats. However, to confirm this assumption, a sampling design using “control” areas (where plovers are present, but no conservation actions have been implemented) should be carried out to carry out a before-after-control-impact (BACI) design (Smith et al., 1993). Indeed, in our case no comparable controls were available in the surrounding.

The frequentation of fishermen is at the origin of the accumulation of fishing lines and hooks on the beaches, a type of litter entrapping birds. We actively removed this litter before the nesting period of waders (December-February periods). Nevertheless, since the continuous deposition of litter by seas-storm events, and to the presence of fishermen that abandon fishing lines and hooks in situ, experts evaluated as poor effective these removal actions.

Natural predators (crows, gulls, rats and foxes) constitute a further threat assessed by experts as relevant. The presence of these animals is however largely and indirectly linked to the frequentation of bathing people: indeed, abandoned waste locally attracts scavengers and synanthropic generalist species. Particularly, *Rattus rattus* represented the only species able to enter the cages to prey on the eggs, therefore explaining the predation even in the presence of cages. Excluding these rodents could be a further improvement of the project, allowing to increase the hatching success of the two species.

Finally, mechanical cleaning is another threat linked to the need to keep beaches aesthetically attractive for bathing people but impacting on coastal biodiversity (Zielinski et al., 2019). In our case an alliance between Park Agency and Municipality of Ladispoli allowed to obtain effective outputs, blocking the mechanical cleaning, locally.

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Take-home messages

- Public Agency managing species of conservation concern could use TAN and TRA procedures to rank threats and evaluate the project effectiveness.
- In the conservation of two plover species of conservation concern nesting on embryonic dunes, TRA procedure showed as domestic dogs and dune trampling were the threats with the highest total scores.
- After the conservation project, experts estimated as mechanical beach cleaning (>80%), dune trampling, and synanthropic predators (both of them>60%) showed the highest average impact reduction. In contrast, fishing line and hook removal showed the lowest effectiveness.
- These findings highlight the importance of targeted conservation actions and structured assessment frameworks in managing highly anthropized coastal environments.

Chapter 8: THE IMPORTANCE OF THE CONTEXT IN THE PROJECT CYCLE FOR THREAT ANALYSIS ON THE WORLD'S MOST ENDANGERED TURTLE: SWINHOE'S SOFTSHELL TURTLE (RAFETUS SWINHOEI)

Abstract

Swinhoe's softshell turtle (*Rafetus swinhoei*) is the most endangered freshwater turtle in the world, historically occurring along river systems in Vietnam and China, but currently almost extinct. We conducted a comprehensive TAN of this turtle. Our goal was to identify the pressures along two main rivers in Vietnam (Black and Red rivers, both extending into Yunnan, People's Republic of China) and adding first descriptive data for China.

A panel of experts have identified two priority direct threats in Vietnam, classified following the IUCN standard taxonomy, and showing the highest Magnitude: (i) Habitat loss at nesting sites (LOS; code 1.2 - Commercial & industrial areas) and, (ii) Land conversion due to settlements (LAN; code 1.1 - Housing & urban areas). Threats showed a comparable (i.e., not significantly different) Magnitude in the two rivers (Red River: $p = 0.961$, Black River: $p = 0.807$; Mann-Whitney U test).

Experts also identified the underlying driving forces behind these threats: (i) Demographic drivers (due to a rapid population growth in the last decades) causing LAN and LOS, as the priority threats, but also sand mining, and water pollution; (ii) Economic drivers induced by high poverty in local populations and causing harvesting (fishing activities and related markets), the needs of power supply for economic activities (e. g., dams), and recreational activities; (iii) Ethical drivers linked to conservation project teams (limited funds and divergent points about strategies to carry out). Although no quantitative data are available for China, first evidence suggest as HAR (Harvesting by native fishers; code 5.4) and POL (water pollution; code 9.2) were the priority threats.

TAN is an useful tool in the early stages of a conservation project during the context analysis, helping to define priorities for conservation and management.

Introduction

Globally, turtles are in the midst of an extinction crisis with more than 50 % of species considered to be Threatened (Redlist status: Critically Endangered, Endangered, Vulnerable) by the IUCN (IUCN, 2023). These declines are associated with many threats such as habitat loss, consumption for food and traditional medicines, and collection for the pet trade (Rhodin et al., 2018; Stanford et al., 2020).

Turtles from Asia have the highest percentages of Threatened species (83% Threatened) primarily due to exploitation (Rhodin et al., 2018). Therefore, the current status of chelonians is particularly catastrophic in Vietnam due to a combination of factors such as habitat loss and overexploitation for

meat and the International pet trade (IUCN, 2024).

Swinhoe's softshell turtle (*Rafetus swinhoei*) is currently considered the most threatened turtle in the world (Stanford et al., 2018). This species occurred historically along the Red and Black Rivers of China and Vietnam and the lower Yangtze River of China, and the associated floodplains and habitats (Pritchard, 2005). However, current knowledge is that it is almost extinct with few individuals still surviving in the wild (Liu et al., 2019; Wang et al., 2021). The near extinction of this large species is due to a plethora of reasons but is primarily driven by the negative impacts of dams on the nesting habitats, overfishing, and isolation effects (Le Duc et al., 2020).

The application of TAN in ecosystem management serves as an invaluable framework for informed decision-making, ensuring that conservation actions are strategically directed to address the most pressing challenges facing our natural world (Salafsky et al., 2008; Balmford et al., 2009). TAN serves as a valuable tool for conservation strategy planning, especially in contexts like nature reserves or projects focused on endangered species in crisis situations.

We conduct a TAN on the Swinhoe's softshell turtle with the objective to identify threats specifically affecting the target species within its habitat. We quantified these threats by using scores assigned by a panel of experts who have been actively engaged in research on the field ecology on the species during the last decade. We ranked threats based on their extent, intensity, duration, and frequency – four attributes of their impact regime, then aggregated these scores to calculate a Magnitude score, representing the total pressure exerted by all anthropogenic threats (Salafsky et al., 2008; Battisti et al., 2016). This methodology has been largely applied worldwide (AlHirsh et al., 2016; Bauer et al., 2022; Battisti et al., 2023; Giovacchini et al., 2024; Luiselli et al., 2024).

Our paper stands out as one of the most comprehensive applications of this method in Asia.

Materials and methods

This study is based on field surveys that were carried out in both northern Vietnam and southern China, the known areas of occurrence of the target species. We carried out the field surveys between 2019 and 2022. We conducted a surveys along the Red River from Yuan Jiang county to the Vietnamese border. These surveys were conducted in the 13 Vietnamese provinces. Additionally, in China, between 2011 and 2015, we also surveyed the Yuan Jiang (Red River) and some of its tributaries between Hekou and Yuanjiang and the Lixian Jiang (Black River) in the area between the Vietnamese border.

In northern Vietnam, the field surveys consisted of a suite of approaches including face-to-face questionnaires to local fishers (Le Duc et al., 2020) and former *Rafetus* professional hunters (Pham et al., 2020), camera trapping (Le Duc et al., 2024), examination of specimens (and parts) caught by fishers (Ducotterd et al., 2023) and opportunistic records.

In China, researchers interviewed fishery, wildlife, and nature reserve management authorities, experienced fishers and turtle farmers with semi-structured interviews.

Threat Analysis

The TAN procedure was carried out by several experts (professional researchers) belonging to both research institutes and local non-profit organization. Each one had a good degree of knowledge, both on the study site(s), the biology of the target species, and on the local species-specific threats (Tab.1.8).

Acronym	local threat	code	IUCN taxonomy threat specific name	category
HAR	Harvesting by native fishers	5.4	Fishing & harvesting aquatic resources	5: Biological resource use
MIN	Sand mining	3.2	Mining & quarrying	3: Energy production & mining
LOS	Habitat loss at nesting sites	1.2	Commercial & industrial areas	1: Residential & commercial development
IND DAM	Industrial dams Small-scale dams	7.2.10 7.2.9	Large dams Small dams	7: Natural system modifications (code 7.2 - Dams & water management/use)
CON	Internal conflicts among conservation groups	12.1	Other threats	12: Other options
LAN	Land conversion	1.1	Housing & urban areas	1: Residential & commercial development
POL	Water pollution	9.2	Industrial & military effluents	9: Pollution
BOA	Disturbance by boats	6.1	Recreational activities	6: Human intrusions & disturbance

Table 1.8 - Human - direct threats on Swinhoe’s softshell turtle (*Rafetus swinhoei*). We include acronyms, local threat, and IUCN taxonomy.

First, we named any threat using the threat nomenclature reported in the IUCN unified classification of direct threats (“threat taxonomy”; Salafsky et al., 2008). In this paper, all anthropogenic threats have been named and coded.

Second, we asked the experts the following question: what is the extent, severity, frequency, and duration of any threat (these last being considered “regime attributes”)? To respond to this question, for each direct threat, each expert assigned a single score to the four regime attributes using a scale from 1 (low) to 4 (high) (Battisti et al., 2016). More particularly, (i) “extent” has been considered as the proportion of species habitat that has been, is, or will be affected by the threat, when compared

to the total surface available, i.e., all of the suitable area of habitat for Swinhoe's softshell turtle; (ii) "severity", represents an assessment of the past, present, or future pressure caused by the threat on target (i.e., a proxy of threat intensity); (iii) "frequency" indicates the number of anthropic events within a time unit (here, corresponding to event/year); and (iv) "duration" expresses the time span of expression of the threat (Ervin, 2002).

After this step, the four scores of threat attributes, i.e., extent, severity, frequency, and duration, calculated for each threat by any expert, were summed to obtain a "Magnitude" score, as a compound variable, representing a proxy of the threat pressure of any threat impacting the selected targets. When the experts assigned scores to any threat attribute, we calculated their averaged values and standard deviation. After evaluation, the experts ranked the threats when regarding the Magnitude values, obtaining a list in decreasing order. The threats with the highest average value represent the priority threats. Finally, we built a conceptual framework which, starting from the target species, shows the relationships with the direct threats. To complete the framework, experts named the indirect driving forces, i.e., the indirect political, social, and economic processes at the origin of the anthropogenic threat (Margoluis et al., 2009).

Statistical analyses

We used a score evaluation, obtaining the averaged values and dispersion measures. We applied the test for the homogeneity of variances to test if the variances among groups were homogeneous, therefore, allowing the Kruskal-Wallis test to be applied. To compare the averaged threat Magnitudes among >2 samples, we performed the non-parametric Kruskal-Wallis test for equal medians (Dytham, 2011), obtaining H values using the PAST 1.89 software (Hammer et al., 2001). To compare averaged values between 2 samples, we used the pairwise Mann-Whitney *U* test. To perform the box plots, we used the quartile method. The alpha level was set to 0.05. For China, we had just two experts so we could not apply statistical analyses. However, we decided to present the data because of the severe endangered status of this species, so that any available data can be available to future researchers or conservation practitioners.

Results

Starting from the nine human-induced local direct threats identified by the panel of experts, we obtained the Magnitude values for the various threats in the two rivers (Red River and Black River) (Fig.1.8). The threats appear to have the largest Magnitude on the Black River and Red River were LOS (Commercial & industrial areas; IUCN code 1.2) and LAN (Housing & urban areas; IUCN code 1.1) (Tab.2.8), with no significant difference between them in both of rivers (Red River: $p = 0.961$, Black River: $p = 0.807$; Mann-Whitney *U* test; Tab.2.8).

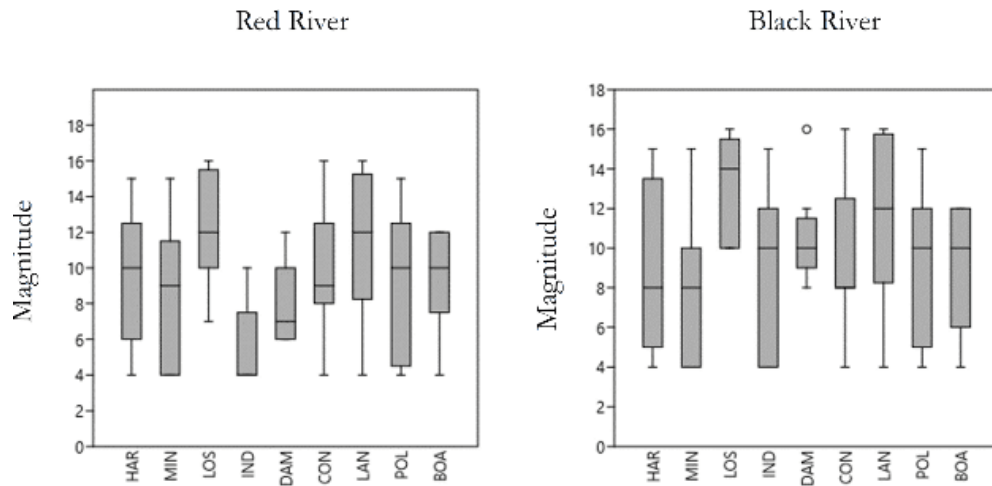


Figure 1.8 - Box plots of Magnitude values for the selected threats to the Swinhoe's softshell turtle (*Rafetus swinhoei*), in the two Vietnam rivers (Red River and Black River). The minimal and maximal values are shown with short horizontal lines ("whiskers"); 25-75 percentiles are drawn using a box; horizontal line shows the median values. HAR: harvesting by native fishers; MIN: sand mining; LOS: habitat loss at nesting sites; IND: industrial dams; DAM: small-scale dams; CON: internal conflicts among conservation groups; LAN: land conversion; POL: water pollution; and BOA: disturbance by boats. See text for IUCN categories and codes.

	Red River					Black River					n
	area	intensity	frequency	duration	M	area	Intensity	frequency	duration	M	
HAR	2.44 (1.24)	2.44 (1.33)	1.89 (1.05)	2.33 (0.87)	9.11 (3.86)	2.44 (1.33)	2.33 (1.41)	1.78(0.97)	2.33 (1)	8.89 (4.28)	9
MIN	1.67 (0.71)	2.22 (1.20)	2 (1.22)	2.22 (1.39)	8.11 (4.14)	1.56 (0.73)	1.78 (1.09)	2 (1.22)	2.22 (1.39)	7.56 (3.75)	9
LOS	3 (1)	3.11 (1.05)	3.11 (1.05)	3.11 (1.17)	12.33 (3.28)	3.22 (0.67)	3.33 (0.71)	3.33 (0.71)	3.11 (1.17)	13 (2.55)	9
IND	1.33 (0.71)	1.56 (1.01)	1.22 (0.44)	1.33 (0.5)	5.44 (2.30)	2 (1)	2.44 (1.24)	2.11 (1.17)	2.33 (1.22)	8.89 (4.23)	9
DAM	3.11 (0.78)	2.67 (0.71)	2.56 (1.01)	2.89 (1.05)	8.11 (2.26)	2.67 (1.12)	2.44 (0.73)	2.56 (1.01)	3 (1.12)	10.67 (2.40)	9
CON	2.78 (1.09)	2.11 (0.93)	2.44 (1.13)	2.44 (1.13)	9.78 (3.56)	2.67 (1.12)	2.11 (0.93)	2.44 (1.13)	2.44 (1.13)	9.67 (3.61)	9
LAN	2.75 (1.04)	2.88 (0.99)	2.88 (1.25)	3 (1.07)	11.5 (4.14)	2.75 (1.04)	3 (1.07)	2.88 (1.25)	3.13 (1.13)	11.75 (4.30)	8
POL	2.44 (1.01)	2 (1.12)	2.22 (1.30)	2.44 (1.33)	9.11 (4.08)	2.33 (1)	2.11 (1.05)	2.22 (1.30)	2.44 (1.33)	9.11 (3.89)	9
BOA	2.22 (1.09)	1.89 (0.78)	2.89 (1.17)	2.44 (1.01)	9.44 (2.74)	1.89 (1.05)	1.78 (0.83)	2.78 (1.30)	2.44 (1.24)	8.89 (3.18)	9

Table 2.8 – TAN procedure applied to the Swinhoe's softshell turtle (*Rafetus swinhoei*), along the Black and Red rivers (Vietnam). Mean values (and \pm standard deviation) in regime attributes (extent, intensity, frequency, duration, and Magnitude, M) for the human-induced direct threats selected have been reported. HAR: harvesting by native fishers; MIN: sand mining; LOS: habitat loss at nesting sites; IND: industrial dams; DAM: small-scale dams; CON: internal conflicts among conservation groups; LAN: land conversion; POL: water pollution; and BOA: disturbance by boats. See text for IUCN categories and codes.

Preliminary data for China suggest HAR (Harvesting by native fishers; IUCN code 5.4) and POL (water pollution; IUCN code 9.2) as priority threats (Tab.3.8). The conceptual framework linking driving forces, direct threats and the selected target (i.e., Swinhoe's softshell turtle) in the two river systems (Vietnam) is given in Fig.2.8. Experts identified three main driving forces of origin for the direct threats.

threats	area	intensity	frequency	duration	M
HAR	4 (0)	4 (0)	3.5 (0.71)	4 (0)	15.5 (0.71)
MIN	2 (1.41)	2.5 (2.12)	1.5 (0.71)	1.5 (0.35)	7.5 (4.95)
LOS	3.5 (0.71)	3 (1.41)	2.5 (0.71)	3 (0.71)	12 (1.41)
IND	2 (1.41)	2 (1.41)	1.5 (0.71)	1.5 (0.35)	7 (4.24)
DAM	1.5 (0.71)	1.5 (0.71)	1 (0)	1 (0)	5 (1.41)
CON	1 (0)	1 (0)	1 (0)	1 (0)	4 (0)
LAN	1.5 (0.71)	2 (1.41)	1 (0)	1 (0)	5.5 (2.12)
POL	3.5 (0.71)	2.5 (0.71)	3 (1.41)	3.5 (0.35)	12.5 (3.53)
BOA	2.5 (2.12)	2 (1.41)	2 (1.41)	2.5 (1.06)	9 (7.07)

Table 3.8 - TAN procedure applied to the Swinhoe’s softshell turtle (*Rafetus swinhoei*) for China.

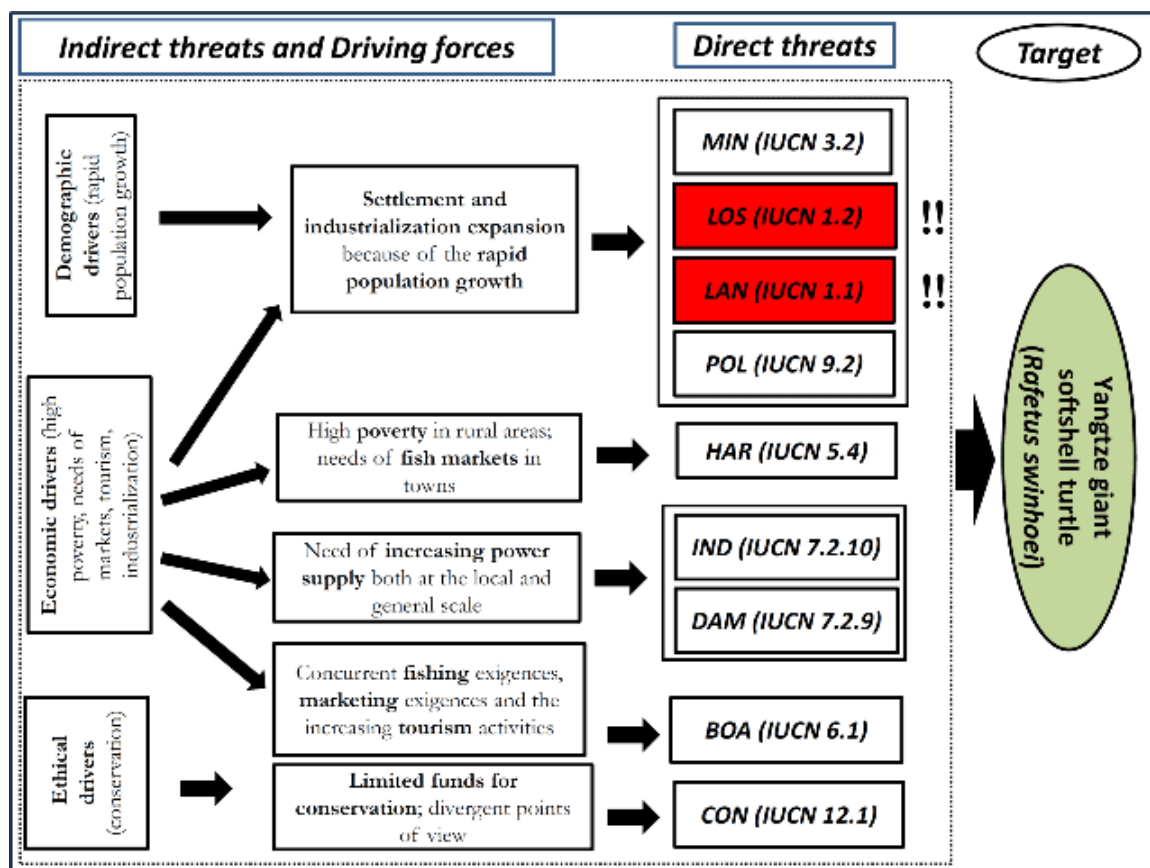


Figure 2.8 - Conceptual framework linking driving forces and direct threats against and the selected target (Swinhoe’s softshell turtle, *Rafetus swinhoei*) in two Vietnam rivers (Red River and Black River). Threats showing priority (highest Magnitude) have been reported in red boxes and with the symbol “!!”.

First, demographic drivers, due to a rapid population growth in the last decades appeared to be the force causing dramatic settlement and industrialization expansion and consequently responsible for a massive increase in buildings (settlement expansion; LOS) and by civil engineering industry (LAN), MIN (sand mining; IUCN code 3.2), and (mainly chemical and water-related) pollution due to increased industrialization (POL).

Second, economic drivers were at the origin of threats caused by high poverty in local populations resulting in unmitigated harvesting associated with fishing activities and related markets (HAR), the needs of power supply to carry out economic activities overall, including mining and dams at different scales: IND (industrial dams; IUCN code 7.2.10), DAM (small-scale dams; IUCN code 7.2.9), BOA (disturbance by boats; IUCN code 6.1) as touristic activities also related to fishing and use of boats for sightseeing.

Finally, ethical issues as driving forces linked to conservation project teams including competition for the limited funds available for the conservation of this species, as well as the existence of divergent points of view concerning what to do with such a charismatic species.

Discussion

Expert-based evaluation highlights habitat loss, i.e. land conversion, representing the main threat impacting Swinhoe's softshell turtle. However, conceptual framework evidence is important as almost all threats are the effects of complex social-economic driving forces mainly originating by three drivers: demographic, economic and ethical. More particularly, experts identified mining economies, settlements and soil consumption, industrialization (by dams and other activities), and pollution as pressures caused by demographic and economic drivers induced by a rapid population growth, increasing poverty and a need for power supply (for China: e.g., Zhang et al., 2018). In this regard, drivers linked to the fishing market (and in part to tourism) may explain the harvesting along rivers and the use of boats for fishing and recreational activities, all factor of anthropogenic pressure.

However, apart from the economic and demographic drivers and related threats, one of the problems that emerged from our TAN approach is the competition for resources among the various conservation organizations attempting to work on *Raphetus swinhoi*. The shortage of available resources surely enhanced the competition between working groups, with the consequence that each group has carried out research and conservation activities separately and without any coordinated programme. We suggest that it would be necessary to create a combined multi-faceted *Rafetus* Task Force of participants and organizational leaders from all the relevant organizations.

Several factor shinder the implementation of effective conservation measures along the Red and Black rivers. These include social and political instability, poor cooperation between conservation groups, and restricted access to certain river areas due to land conversion and provate ownership. In addition, traditional harvesting practices by local communities persist, further complicating conservation efforts.

Expert-based approaches like the one presented here offer an initial assessment and is a highly effective when dealing with critically endangered species. Indeed, using the TAN expert approach we may identify priorities which aid in informing decision-making processes, especially in crisis

contexts (McCarthy & Possingham, 2007; Margoluis et al. 2009), and is particularly helpful during the early stages of a conservation project cycle (context analysis; Hockings et al., 2000; Battisti, 2018).

In theory, having identified priority threats, further steps may be planned as, for example, the application of specific indicators of pressure and impact (DPSIR approach; Binimelis et al., 2009) associated with any priority threat. Finally, knowing the threat Magnitude may be of use for before-after comparisons after carrying out specific projects. In this regards, these data will be useful for procedures of TRA (Salafsky & Margoluis, 1999; Mathar & Anthony, 2010; Giovacchini et al., 2022).

Therefore, if we want *Rafetus swinhoei* to survive, our immediate actions must be to intensify field surveys with more aggressive methodologies, such as the use of an expanded program using floating camera traps, in order to discover a given area where the species is still present and potentially reproducing in the wild. There is promise in this area of focus as reliable interviews suggest that several individuals may still be found in the wild in various areas. Additionally, we need to focus on developing a plan to bring any surviving individuals together at a secure site which can facilitate reproduction and plan follow up conservation measures once they managed to reproduce.

The future of this species, at least in the short term, relies on identifying any surviving animals and bringing them together for a chance to propagate a new generation, and not necessarily in addressing threats according to their priorities identified in this analysis.

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Take-home messages

- We carried out a comprehensive TAN of Swinhoe's softshell turtle (*Rafetus swinhoei*), historically occurring along river systems in Vietnam and China, but currently almost extinct.
- Experts identified two priority direct threats: Habitat loss at nesting sites and land conversion due to settlements.
- Experts also identified the underlying driving forces behind these threats: demographic drivers (due to a rapid population growth in the last decades), economic drivers induced by high poverty in local populations and causing harvesting, and recreational activities, ethical drivers linked to conservation project teams (limited funds and divergent points about strategies to carryout).
- Preliminary data for China suggest harvesting by native fishers and water pollution as priority threats.

Chapter 9: THREAT ANALYSIS FOR A CRITICALLY ENDANGERED SPECIES: NUBIAN FLAPSHELL TURTLE (CYCLANORBIS ELEGANS)

Abstract

The Critically Endangered Nubian flapshell turtle (*Cyclanorbis elegans*) populations have sharply declined, primarily due to human-induced threats, leading to its near-extinction across almost its entire range. The reptile is found in the White Nile River system in South Sudan and northern Uganda.

We present a comprehensive TAN undertaken to pinpoint the challenges confronting the species within its natural habitat, specifically in the only known sites where it currently exists. We aimed to develop a conceptual framework to understand causal relationships among driving forces, threats and the target species. We convened a panel of experts who identified three primary direct threats to the Nubian flapshell turtle: (1) Sand mining (IUCN code 3.2); (2) Overfishing by native fishers and refugees (IUCN code 5.4) and (3) Habitat loss at nesting sites (IUCN code 7.3). Among these threats, overfishing had the largest geographical extension, the highest intensity and duration, while habitat loss occurred at the highest frequency. These threats varied significantly in intensity and frequency. Additionally, when assessing the overall magnitude of these threats, habitat loss and overfishing had the highest impact, with significantly higher scores compared to sand mining (Overfishing vs Sand mining: $U = 5.5$, $p = 0.051$; Habitat loss vs Sand mining: $U = 4.5$, $p = 0.035$; Mann–Whitney U test).

Our experts also identified the underlying driving forces behind these threats: (1) Economic interests driving sand mining activities along the Nile; (2) The influence of civil conflict and refugee populations, which contribute to the demand for bushmeat; (3) The Chinese expatriates, that lead to overfishing; (4) The removal of bank vegetation serves as a catalyst for habitat loss at nesting sites. The resulting conceptual framework serves as a valuable tool for defining targeted conservation measures for each distinct threat.

Introduction

Analyses of threats acting on specific targets have been carried out worldwide, employing different approaches and methodologies (e.g. Ashford et al., 2022; Giovacchini et al., 2023). Known as expert-based TAN, has been proposed in ecosystem management, particularly to identify, characterise and quantify anthropogenic events occurring in areas of conservation concern (Salafsky et al., 2008; as reviewed in Battisti et al., 2016). Consequently, TAN serves as a valuable tool for

conservation strategies, especially in contexts like nature reserves or projects focused on given threatened species in crisis situations (e.g. Jarvis et al., 2010; AlHirsh et al., 2016; Battisti et al., 2020; Bauer et al., 2022; Giovacchini et al., 2022).

We conducted a TAN on one of the most globally threatened chelonian species, the Nubian flapshell turtle (*Cyclanorbis elegans*) (Stanford et al., 2018). This turtle is considered to be on the brink of extinction, since it occupies only a limited number of habitat patches along the White Nile River in South Sudan and northern Uganda (Demaya et al., 2019; Demaya et al., 2023). IUCN classified *Cyclanorbis elegans* as a species in Critically Endangered (IUCN, 2023).

Our objective in this paper was to identify threats specifically affecting the Nubian flapshell turtle within remnant habitats in South Sudan and northern Uganda, using the TAN framework. This published manuscript represents the first global instance of the application of the TAN approach to a highly endangered freshwater turtle species.

We quantified these threats by using scores assigned to a number of attributes by a panel of experts who are actively engaged in research on the field ecology on the species from 2017 to 2023. We ranked threats based on their extent, intensity, duration and frequency – four attributes of their impact regime, then aggregated these scores to calculate a Magnitude score, representing the total pressure exerted by all anthropogenic threats (Salafsky et al., 2008; Battisti et al., 2016).

Materials and methods

The present study is based on field data collected from August 2017 to August 2023 at several localities situated along the banks of the White Nile River in South Sudan. Data on the ecology of the Nubian flapshell turtle, which constituted the foundation of the expert panel's opinions, were based on field work undertaken in different freshwater habitat types available to turtles along the White Nile River course.

Threat Analysis

The TAN procedure was carried out by a qualified panel of experts, comprising seven professional researchers. All experts were involved in conservation of this threatened species, possessing substantial knowledge of the study site, the biology of the target species and local species-specific threats. The set of threats to the selected target species, which are locally relevant to our study area are here analyse.

First, we named any threat using the threat nomenclature reported in the IUCN unified classification of direct threats (“threat taxonomy”; Salafsky et al., 2008). In this report, all anthropogenic threats

have been named and coded.

Second, we asked the local experts the following question: what is the extent, severity, frequency, and duration of any threat (these last being considered regime attributes)? To respond to this question, for each direct threat, the single expert assigned a score to the four regime attributes using a scale from 1 (low) to 4 (high): “Extent” can be measured as the proportion of species habitat that has been, is, or will be affected by the threat, when compared to the total surface available, that is, all of the suitable area of habitat for the flapshell turtle; “Severity”, as a proxy of threat intensity perceived by the targets, constitutes an evaluation of the past, present, or future pressure, which are estimated to be caused by the threat event and that may affect the target, leading to an impact on our target; “Frequency” indicates the number of anthropic events within a time unit, herein considered 1 year; “Duration” expresses the duration of a threat along a time span, herein considered 1 year (Ervin, 2002).

After this step, the four scores of threat attributes (i.e. extent, E ; severity, S ; frequency, F ; and duration, D), calculated for each threat by any expert, were summed to obtain a “Magnitude” score ($M_i = E + S + F + D$), as a compound variable, representing a proxy of the threat pressure, and thus consequent impact, of any threat on the selected targets. When the experts assigned scores, we calculated their averaged values in Magnitude (i.e. ΣM_i /number of experts) and the standard deviation.

Finally, we have built a conceptual framework which, starting from the target species, describes the relationships with the threats. To complete the framework, experts named the indirect driving forces, that is, the indirect political, social and economic processes at the origin of the anthropogenic threat (Margoluis et al., 2009).

Statistical analyses

We used a score evaluation, obtaining the averaged values and dispersion measures. We applied the test for the homogeneity of variances to test if the variances among groups were homogeneous, therefore, allowing the Kruskal-Wallis test to be applied. To compare the averaged threat magnitudes among >2 samples, we performed the non-parametric Kruskal–Wallis test for equal medians (Dytham, 2011), obtaining H values using the PAST 1.89 software (Hammer et al., 2001). To compare averaged values between two samples, we used the pairwise Mann–Whitney U test. To perform the box plots, we used the quartile method. The alpha level was set to 0.05. In addition to the average magnitude scores, the degree of consensus among experts was evaluated through standard deviation and interquartile range (IQR), as shown in the box plots (Figure 1.9). Narrow dispersion indicated strong agreement for specific threats, while wider variability suggested diverging expert opinions.

Results

The whole panel of experts identified the following three main human-induced direct threats: (i) Sand mining (IUCN code 3.2 – Mining and quarrying; that is, exploring for, developing, and producing minerals); (ii) Overfishing by native fishers and refugees (IUCN code 5.4 – Fishing and harvesting aquatic resources; Harvesting aquatic wild animals for subsistence; includes accidental mortality/ bycatch); (iii) Habitat loss at nesting sites (IUCN code 7.3 – Other ecosystem modifications; that is, actions that convert or degrade habitat by humans).

The values of threat regime attributes showed as Overfishing appeared the threat having largest extent and duration, while Habitat loss appeared the threat occurring with the highest intensity and frequency (Tab.1.9). Threats significantly differed among them in intensity and frequency, while for extent and duration, we did not find a significant difference among them (Tab.1.9).

Threat	Extent	Intensity	Frequency	Duration	Magnitude
Overfishing	2.83 (0.98)	3.17 (0.75)	2.67 (0.52)	3.67 (0.52)	12.83 (1.86)
Mining	1.67 (0.82)	2 (0.63)	1.83 (1.17)	3 (1.26)	8.5 (3.15)
Habitat loss	2.50 (0.55)	3.50 (0.55)	3.33 (0.52)	3.17 (0.98)	12.5 (1.64)
H value	4.389	8.316	6.187	0.889	5.933
p	0.084	0.009	0.031	0.58	0.047

Table 1.9 – TAN procedure applied to the Nubian flapshell turtle (*Cyclanorbis elegans*) along the White Nile in South Sudan and Uganda. Mean values (and \pm standard deviation) in regime attributes (Extent, Intensity, Frequency, Duration, and Magnitude) for the human-induced direct threats selected. H and p-values (Kruskall-Wallis test for equal medians) are presented.

All the threats significantly differed in their Magnitude ($H = 5.933$; $p = 0.047$; Kruskal–Wallis test). Habitat loss and Overfishing were evaluated as the threats having highest Magnitude, without a significant difference between them ($U = 24$, $p = 1$, Mann–Whitney U test), but with scores significantly higher when compared to Mining (Overfishing vs Mining: $U = 5.5$, $p = 0.051$; Habitat loss vs Mining: $U = 4.5$, $p = 0.035$; Mann–Whitney U test; Fig.1.9).

Experts identified the following driving forces for any threat: (i) Mining economies of Uganda and South Sudan inducing sand mining along the Nile; (ii) Political and social instability in South Sudan heading to civil war, with consequent immigrations of huge numbers of refugees along the White Nile; (iii) The role of Chinese expatriates (these last as further driver for overfishing), and (iv) Gallery forest and bank vegetation cutting (caused by the need of the native and refugee populations for obtaining wood for fuel purposes, construction, traditional industries and grazing), as driver for habitat loss in nesting sites (Fig.2.9).

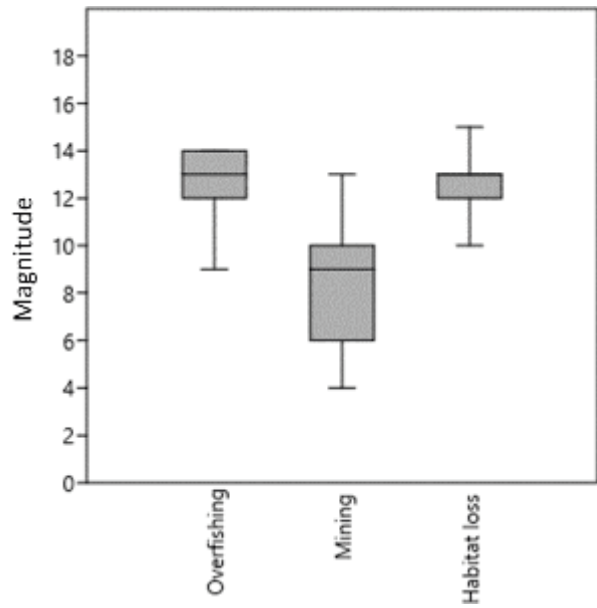


Figure 1.9 - Box plots of Magnitude values for the three main threats identified in the case study for the Nubian flapshell turtle (*Cyclanorbis elegans*) along the White Nile of South Sudan and Uganda. The minimal and maximal values are shown with short horizontal lines ("whiskers"); 25-75 percentiles are drawn using a box; horizontal line shows the median values.

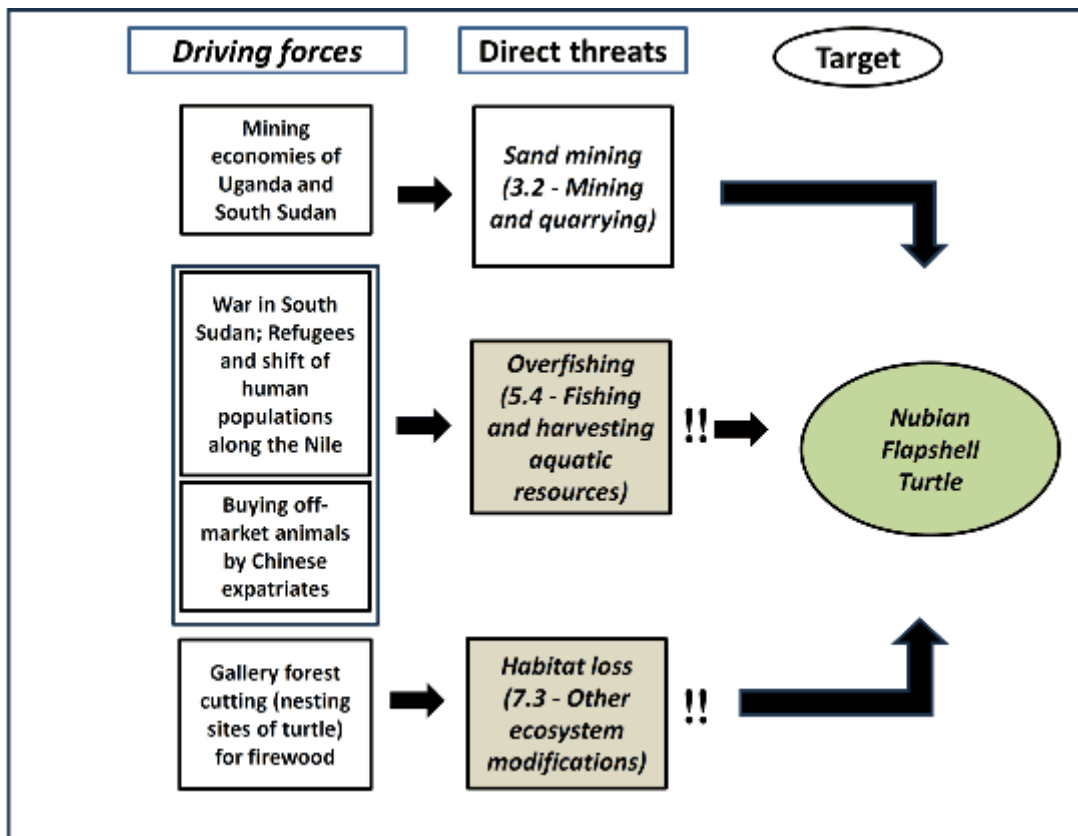


Figure 2.9 - Conceptual framework linking driving forces, anthropogenic threats and the selected target (Nubian flapshell turtle *Cyclanorbis elegans*) in South Sudan and Uganda. Threats showing priority (highest Magnitude) have been reported in grey boxes and with the symbol “!!”.

Discussion

Expert-based evaluation highlights that Overfishing (IUCN code 5.4) and Habitat loss (in turtle nesting sites) (IUCN code 7.3) represent the main threats impacting the Nubian flapshell turtle in South Sudan and northern Uganda.

These two threats are also affecting several freshwater turtle species worldwide, especially those of large size (*Trionychidae*, e.g. Rhodin et al., 2018; Stanford et al., 2020).

However, conceptual framework evidences as any threat is the effect of complex social-economic driving forces. More particularly, experts identified local economies at the study sites in Uganda and South Sudan as being at the origin of sand mining (IUCN code 3.2) along the River White Nile. Sand mining is a highly impactful activity in many sectors in Africa (Mingist & Gebremedhin, 2016; Sanni, 2020).

The threat of Overfishing, carried out by both native fishermen and refugees, presents a complex challenge. This threatened turtle has been extensively exposed to direct persecution and unintentional capture during more traditional fishing practices (Demaya et al., 2019).

Another overlooked factor driving these threats may be linked to the trade in animals specifically targeted to meet the demands of the expanding community of Chinese expatriates, particularly in the Juba region of South Sudan. We have substantiated evidence that certain individuals of the Nubian flapshell turtle were captured and sold by local fishermen to Chinese expatriates who were willing to pay exorbitant prices for these large turtles (Luiselli et al., 2021).

Finally, removal of gallery forest and riverbank vegetation has been identified as the main driving forces acting on habitat loss at the nesting sites. Deterioration of the forested and highly vegetated (*Cyperus* spp.) banks along the Nile river are impacting this ecosystemic hot-spot (Al Alzubairi & Hamdan, 2020; Hamed & Kursi, 2023). The main reasons behind this deterioration were the need of the population for wood for fuel purposes, construction, traditional industries and grazing (Al Alzubairi & Hamdan, 2020).

Expert-based threat analysis is a highly effective method when dealing with Critically Endangered species. This approach proves its efficacy in several crucial scenarios: (1) High Crisis Situations: it excels when conservation efforts are urgently needed due to the precarious state of the species; (2) Limited Time and Resources; 3) Challenges in Data Collection: when traditional data collection methods are impractical or challenging, particularly for rare or elusive species, this approach provides valuable insights; (4) Difficulty in Comparing Threats: it is particularly useful when threats are diverse and hard to compare. Expert-based approaches offer an initial assessment that aids in identifying priorities and informing decision-making, especially in crisis contexts (Margoluis et al., 2009).

In this regard, the TAN approach can be used in the early stages of a conservation project cycle (context analysis; Hockings et al., 2006; Battisti, 2018), to identify the priorities (and therefore the specific objectives) but also in the monitoring phase to verify the effectiveness of the projects (i.e. if the pressure induced by the threats has been effectively reduced on the biodiversity targets). However, analytical approaches can be used when appropriate pressure indicators need to be defined for each threat (DPSIR – approach; Binimelis et al., 2009).

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Take-home messages

- The Nubian flapshell turtle (*Cyclanorbis elegans*) is a critically endangered species living in in the White Nile River system in South Sudan and northern Uganda.
- We developed a conceptual framework aimed to to understand causal relationships among driving forces, threats on this target species.
- We identified three primary direct threats on this turtle: sand mining, overfishing by native fishers and refugees, and habitat loss at nesting sites.
- Economic interests driving sand mining activities along the Nile, the conflict and refugee populations, the Chinese expatriates, the removal of bank vegetation have been highlighted as the main driving forces behind these threats.
- We developed a conceptual framework serving as a valuable tool for defining targeted conservation measures for each threat.

Chapter 10: *A SYNTETHIC FRAMEWORK INTERACTING CONCEPTS AND APPROACHES FOR MANAGING ANTRHOPOGENIC THREATS*

Abstract

A simplified conceptual framework is proposed for the clarification of the complex causal relationships between determinants, threats and objectives and, therefore, for the definition of response strategies and monitoring of the expected results of conservation actions.

This is a mix approach with coarse-grained TAN (expert-based) unified with DPSIR as fine-grained indicators, all included in a single conceptual framework. A simulation of the application of this conceptual scheme to a specific target is presented here: coastal dune habitats hosting plant associations with halo-psammophilous species in Torre Flavia wetland.

In Italy these approaches (TAN or DPSIR) have not been never used in a unified way. Our proposal is based on the logic of problem solving, which could be used to communicate socio-ecological complexities to academic students. A schematic language is then constructed to clearly understand the logic behind conservation strategies. However some critical points should be considered because this framework may oversimplify socio-ecological interactions.

Introduction

Conservation professionals are encouraged to implement management plans for nature reserves and biodiversity measures (Natura 2000 sites) because anthropogenic threats are human activities or processes that cause or may lead to habitat destruction, degradation and species loss; for these reasons they must be assessed (Battisti et al., 2016; Giovacchini et al., 2022). In conservation biology, a mixed and rapid approach that implements a coarse-grained (expert-based) analysis with a fine-grained (analytical) is widely used but never combined.

TAN has been proposed as an framework for decision-making. TAN allows for ranking of the anthropogenic threats in an order of priority using expert-based assessment (Salafsky et al., 2008). After this evaluation, conservation managers may focus on priority threats (i.e., showing the highest ranks in expert-based evaluation) instead of acting opportunistically on random-selected or charismatic threats.

DPSIR is a framework useful to analyze and assess environmental problems through sets of indicators along the threat–target causal chain (i.e., D: Indirect drivers, P: Threat pressures, S: State of the system, I: Impacts on ecological targets, and R: Responses through projects and actions - Maxim, 2009). In contrast with TAN, in the DPSIR approach, it is possible to select indicators

providing analytical measurements (not expert based as in TAN).

These two approaches could be unified in a single and simplified conceptual framework, allowing for clarification of the complex causal relationships among drivers, threats, and targets and, therefore, defining strategies of response (i.e., conservation actions) and monitoring expected outcomes. Therefore, following this schematic approach, it may be possible to quantify threats both at a coarse-grained (1° step, expert-based evaluation) and a fine-grained level (2° step, analytical measurements) (Fig.1.10).

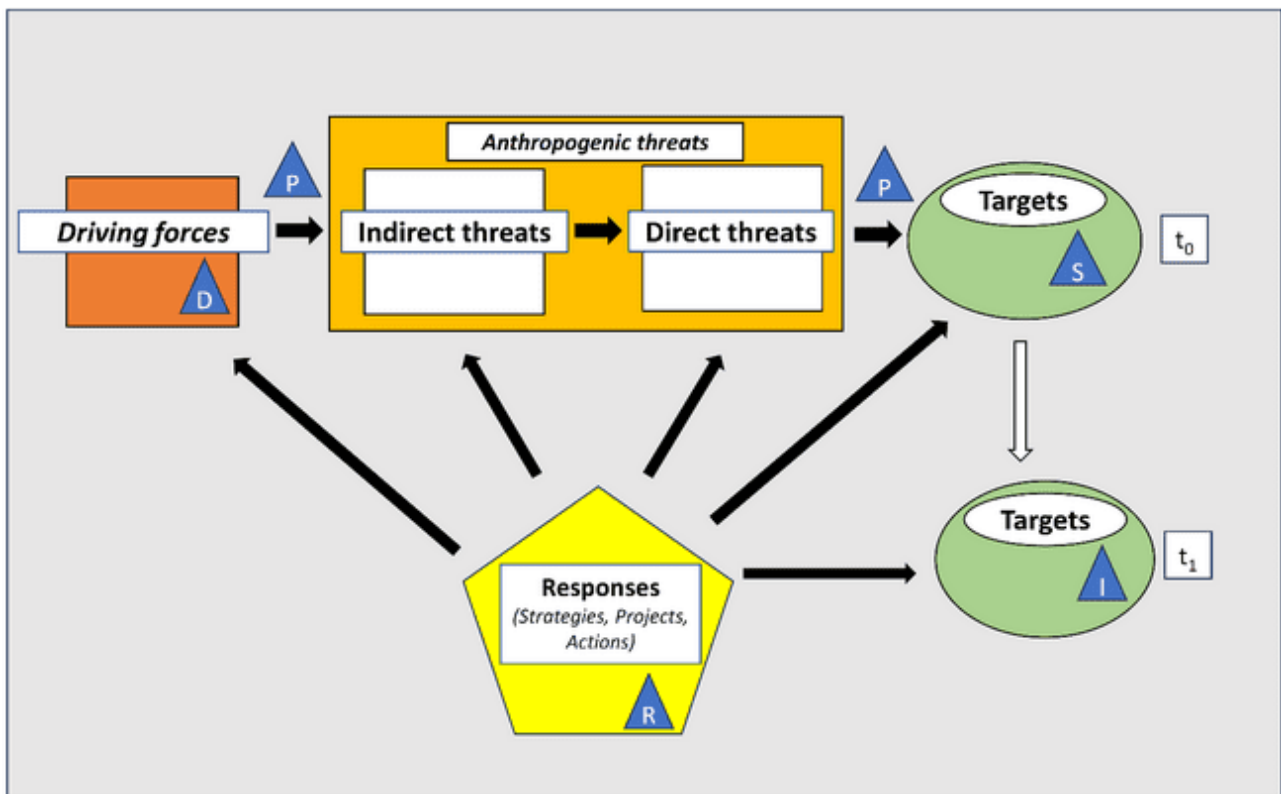


Figure 1.10 - Causal chain in a TAN conceptual framework including DPSIR indicators (represented by blue triangles). See list of abbreviations.

Materials and methods

An integrated conceptual framework

TAN as a conceptual framework is composed of components (drivers, threats, and targets) and relationships along a cause–effect chain. Using expert-based evaluations, it may be possible to obtain values of threat regimes (size area, duration, intensity, and frequency) that, once summed, may express a score of threat magnitude, as a coarse-grained proxy of the threat pressure (Salafsky et al., 2008; Maxim, 2009).

Once the priority threats are obtained (i.e., with the highest magnitude; Fig.2.10 in red), it is possible to apply a set of DPSIR indicators in any step of the causal chain, thus obtaining, for

example, an analytical (and not only expert-based) quantification of both threat pressure/impact and the target status using specific metrics (Fig.2.10).

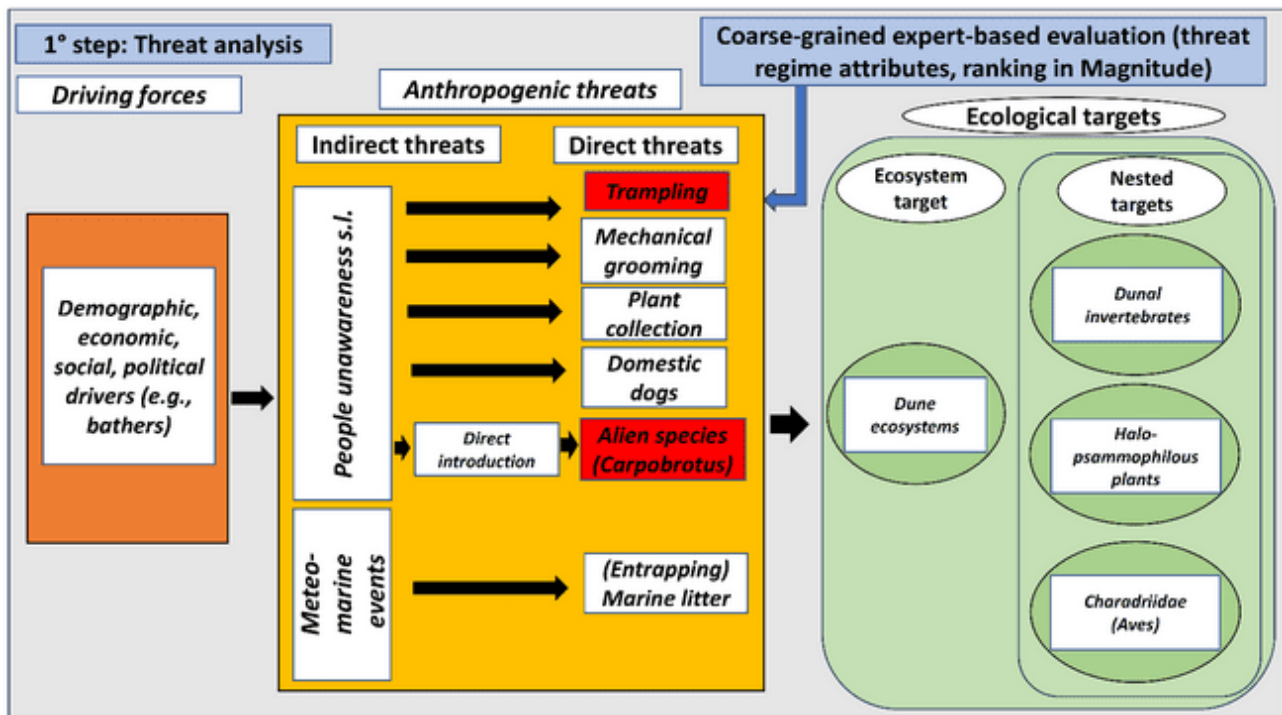


Figure 2.10 - Example for dune ecosystems. First step: causal chains in a TAN conceptual framework including driving forces, indirect and direct threats (orange box), and conservation targets (green box; with nested targets in the dune ecosystem). In this step, evaluation was provided by managers using expert-based approaches (see text for details).

A simulation for coastal dunes: Torre Flavia wetland

A synthetic example of the application of this conceptual framework is simulated to a specific target: coastal dune habitats hosting plant associations with halo-psammophilous species in Torre Flavia wetland (Fig.3.10).

In the first step, a conceptual framework with a causal chain of targets–threats was built. In this framework, the targets are dune ecosystems including a set of components occurring inside dunes: invertebrates, halopsammophilous plants, and waders birds Kentish Plover (*Charadrius alexandrinus*) and Little Ringed Plover (*Charadrius dubius*), breeding on sand dunes (Battisti et al., 2023). Experts may focus on the set of anthropogenic processes acting on coastal dunes and impacting the selected targets (i.e., people trampling, dogs, mechanical grooming aimed to clean the beaches, allochthonous species). In a further step, experts will add target-specific causal relationships among threats and targets (symbolized, for example, by arrows or different colors) where many threats act as a factor of pressure on the same target, expert-based procedures may be applied to define an order of priority with categorical scores and their magnitude how sum of scores for a set of threat regime attribute. This is approach TAN detailed in Salafsky et al. (2008).

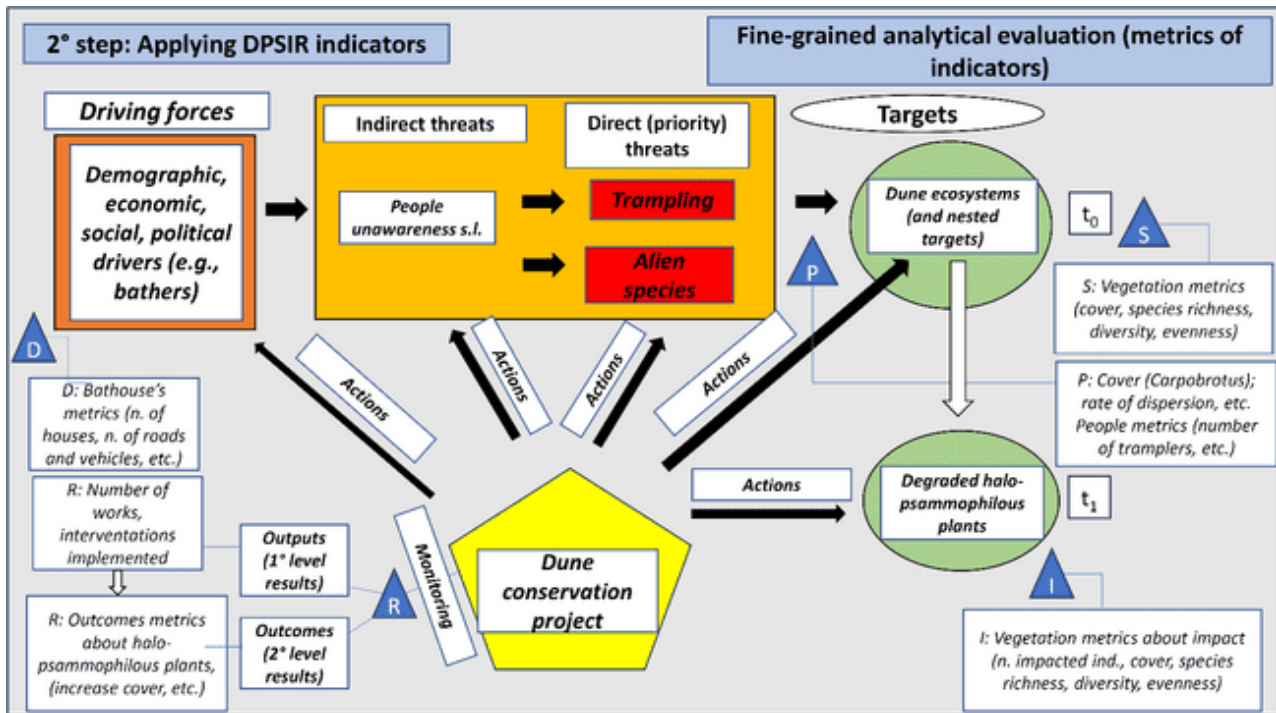


Figure 3.10 - Example for dune ecosystems. Second step including the DPSIR approach providing sets of analytical indicators useful for quantitative measurements. See text for details and list of abbreviations.

If the experts obtained the highest ranks for two threats acting on plants (trampling and alien species), it may be necessary to add analytical pressure indicators such as the number of people trampers/space/time (regarding trampling threat) and metrics of vegetation cover (or rate of propagule dispersion) regarding allochthonous (i.e., non-native) species (such as, for example, *Carpobrotus* sp.). The effect of threat impact on the target status deserves to be quantified using appropriate impact indicators. The DPSIR approach also involves indicators of driving forces (e.g. numbers of bathers) but also a set of response indicators related to results obtained both in terms of outputs (actions provided to solve the threats) and outcomes (effective results for the conservation targets).

All these indicators may be useful to define the specific project goals. Many indicators are available in the arena of plant ecology and some of them may be included in this framework. For example, Ellenberg indicator values have very extensive application in Europe (Bohling et al., 2002), resulting in them being very useful in monitoring a territory and its changes. These indicators may be included among the status indicators or, if evidencing degraded conditions, they may be included among the impact indicators (i.e., focused on pressures: reduction of the X% of number of people trampling on dunes in specific sites and times (threat trampling) or reduction of the X% (or eradicating the 100% of size cover of *Carpobrotus* units in specific sites and times).

However, the effectiveness of the DPSIR framework depends largely on the choice of indicators. In this regard, project managers should involve experts in both ecological targets and anthropogenic threats to select and validate appropriate indicators. In addition, there are some critical points that should be considered because this framework may oversimplify socio-ecological interactions. This

fact may lead to the omission of important details critical for conservation planning and assessment in complex socio-ecosystems.

Conclusions

TAN and DPSIR approaches may serve as a valuable expert-based tool for conservation strategies, for example to (i) Select the priority threats (highest magnitude) acting on specific targets (with TAN); (ii) Select appropriate analytical indicators (with DPSIR); (iii) Define achievable project goals focused on maintaining ecosystem components (status indicators) and reducing or mitigating threats (pressure indicators).

In Italy these approaches (TAN or DPSIR) have not been never used in a unified way. Therefore, this short report aims to stimulate their combined use. Furthermore, our proposal is based on the logic of problem solving, which could be used to communicate socio-ecological complexities to academic students. A schematic and synthetic language is then constructed to clearly understand the logic behind conservation strategies, similar to other approaches, using causal chains and frameworks (Knight et al., 2008; Parkinson et al., 2008; Bertuol-Garcia et al., 2018).

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Take-home messages

- We proposed a simplified conceptual framework to clarify the complex causal relationships between driving forces, threats and objectives and, therefore, for the definition of response strategies and monitoring of the expected results of conservation actions.
- In this approach we include a coarse-grained expert-based threat analysis and a fine-grained DPSIR indicator framework.
- Our proposal is based on the logic of problem solving, which could be used to communicate socio-ecological complexities to academic students with a schematic and synthetic language.

Chapter 11: THREAT ANALYSIS ON LOGGERHEAD SEA TURTLE (CARETTA CARETTA): A STUDY CASE IN CENTRAL MEDITERRANEAN SEA

Abstract

Loggerhead sea turtle (*Caretta caretta*) is a charismatic species, protected by international convention. This marine reptile, in the Mediterranean Sea, is impacted by a large number of anthropogenic threats occurring both in marine and coastal ecosystems such as urban development, recreational activities, fishing activities, marine litter and pollution, and collision by boats. This turtle needing of specific conservation strategies both at local and large scale. It is necessary require a comprehensive “situation analyses” to define and quantify the relationships among threats and conservation of this target species.

Threat Analysis is a useful tool and decision-making process carried out in the situation analysis of conservation projects. In this case, anthropogenic threats in the central Mediterranean are identified and quantified by 10 experts using scores for two threat regime attributes (“extent” and “intensity”) and calculating mean values of pressure magnitude (PM), as a composite variable, thus obtaining different degrees of priority. Similarly, we assessed the expert's knowledge on the same set of regime attributes, obtaining mean values of knowledge magnitude (KM), as a self-assessment of any expert's background and skills regarding the extent and intensity of any anthropogenic threat. Finally, we compared averaged PM and KM values to search for possible relationships between the two Magnitudes and to search for possible gaps of knowledge. This methodology has been applied worldwide but never on conservation targets inhabiting marine contexts.

Regarding PM, we observed as mean scores significantly differ among threats with “Marine pollution and abandonment of solid waste”; “Accidental catches with professional fishing nets” and “Habitat degradation” (with modification of breeding sites) showing the highest values ($H=36.23$; $p<0.001$; Kruskal-Wallis test); “Pathologies” and “Direct persecution” showed the lower mean scores in PM. Regarding KM, experts assessed “Nocturnal light pollution in breeding areas” and “Direct persecution” as poor known, evidencing as these threats deserve more effort in research about their extent. Comparisons between PM and KM values evidence a high gap of knowledge for “Habitat degradation”. This pattern suggests the presence of cognitive biases in threat evaluation.

Introduction

Loggerhead sea turtle (*Caretta caretta*) is a marine reptile, feeding on benthic invertebrates (mainly molluscs and crustaceans but also jellyfish, sponges and sea cucumbers), and on fish. Although representing the most common and abundant sea turtle in the Mediterranean Sea (Margaritoulis et al.,

2003; Tudela, 2004; Luschi & Casale, 2014), this turtle represents a charismatic species, protected by international conventions (e.g., Bern Convention, Annex II; Washington Convention—CITES, Annex II; HD, Annex II) and classified as Vulnerable by the IUCN (IUCN, 2023), needing of specific conservation strategies both at local (e.g. Cardona et al., 2005; Eckert et al., 2008; Casale et al., 2012) and large scale (e.g., Casale, 2010; Bolten et al., 2011). For these reasons every project should contemplate strategies that require a comprehensive “situation analyses” (also named “context analysis”) to define and quantify the relationships among threats and conservation targets using conceptual frameworks (Margoluis & Salafsky, 1998).

TAN (Salafsky et al., 2008) is a decision-making process carried out in “situation analysis” of conservation projects, in which it is ensured that actions are strategically directed to address the most urgent anthropogenic threats impacting on focal targets (e.g. species, communities, ecosystems; Battisti et al., 2016 for a review).

Among turtles, TAN has been applied only to two freshwater species worldwide, namely the critically endangered Nubian shell turtle (*Cyclanorbis elegans*) inhabiting the White Nile River system in South Sudan and North Uganda and the giant softshell turtle Yangtze (*Rafetus swinhoei*; Luiselli et al., 2024a; 2024b). However this approach has never been performed on marine species.

In the Mediterranean Sea, this species is impacted by a large number of anthropogenic threats occurring both in marine and coastal ecosystems such as urban development, recreational activities, fishing activities, marine litter and pollution, and collision by boats (e.g. Ilgaz et al., 2007; Lazar & Gračan, 2011; Blasi & Mattei, 2017; Casale et al., 2018; Casini et al., 2018; Pulcinella et al., 2019).

At biogeographic level, genetic markers indicate that the Mediterranean population of *Caretta caretta* is relatively isolated from the Atlantic population and may show peculiar behaviours (e.g. short migration distances; Laurent et al., 1998; Tiwari & Bjorndal, 2000).

In this paper, we carried out a TAN on the Loggerhead sea turtle (as the conservation target) in the central Mediterranean Sea, using an expert-based approach with a panel of experts which and selected a set of anthropogenic threats, assigning scores to two attributes of threat regime ("extent" and "intensity") and calculating mean values of Pressure Magnitude (PM), as compound variable (Salafsky et al., 2008; review in Battisti et al., 2016). Analogously, we assessed the expert knowledge on the same set of regime attributes, obtaining mean values of Knowledge Magnitude (KM), as a self evaluation of the background and expertise of any expert regarding extent and intensity of any anthropogenic threat (Cole, 1994). Finally, we compared averaged PM and KM values to search for possible relationships between the two Magnitudes and to search for possible gaps of knowledge.

Materials and methods

The Mediterranean region is a relatively closed basin (2.5 million km² in size and 46000 km of coastline).

Mediterranean Sea is a well-known area for marine biodiversity, a crucial point to evaluate the impact of anthropogenic threats in different areas (e.g. Costello et al., 2010; Casale, 2011; Deudero & Alomar, 2015; Pulcinella et al., 2019). Here, we focused on the central Mediterranean Sea (encompassing to Adriatic, Tyrrhenian and Ionian seas surrounding the peninsular Italy).

Threat Analysis

TAN procedure involving a qualified group of 10 expert evaluators (hereafter “experts”) having a large (>10 years) background in the biology, ecology and conservation of Loggerhead sea turtle (here defined as target).

To this purpose, we selected a set of 10 anthropogenic threats to the Loggerhead sea turtle, which are relevant in the central Mediterranean Sea (list in Tab.1.11). Once selected, we renamed each threat using the nomenclature reported in the IUCN unified classification (“taxonomy of threats”; Salafsky et al., 2008). In this report, we named and coded all the higher known anthropogenic threats to the Loggerhead sea turtle.

Secondly, we carried out a “Pressure Magnitude” analysis (PM analysis; comparable to the “Significance analysis” reported in Cole, 1994) to obtain an expert-based evaluation on the total pressure of each threat (i.e., a score in “Pressure Magnitude”, PM) on the target species. More particularly, we posed the following question to the experts: what is the extent and intensity of any threat (as proxy of threat pressure)? To address this, each expert assigned a single score to the two main regime attributes of the threat (i.e., extent and intensity) on a scale from 1 (low) to 4 (high). We considered PM as a compound variable (i.e., extent + intensity, as arithmetic sum; Salafsky et al., 2008).

Specifically, (i) “Extent” refers to the proportion of the species habitat that has been, is, or will be impacted by the threat, in relation to the total available area; (ii) “Intensity” is an evaluation of the past, present, or future impact of the threat on the target (independently from threat extent; Ervin (2003). We summed the scores for both the extent and intensity regime attributes, provided by each expert for each threat, to derive a PM score.

Acronym	General name	code	threat specific name	description
COL	Collision with boats	4.3	Shipping lanes	Transport on and in freshwater and ocean waterways
CAT	Accidental catches with professional fishing nets	5.4a	Fishing and harvesting aquatic resources	Harvesting aquatic wild animals or plants for commercial, recreation, subsistence, research, or cultural purposes, or for control/persecution reasons; includes accidental mortality/bycatch
PER	Direct persecution	5.4b		
TOU	Tourism activities (disturbance along migratory routes and in foraging and nesting areas)	6.1	Recreational activities	People spending time in nature or traveling in vehicles outside of established transport corridors, usually for recreational reasons
DEG	Habitat degradation (modification of breeding sites)	7.3	Other ecosystem modifications	Other actions that convert or degrade habitat in service of “managing” natural systems to improve human welfare
PAT	Pathologies	8.2	Problematic native species	Harmful plants, animals, or pathogens and other microbes that are originally found within the ecosystem(s) in question, but have become “out of balance” or “released” directly or indirectly due to human activities
CON	Contamination by natural and synthetic chemicals	9.1	Household sewage and urban waste water	Water-borne sewage and nonpoint runoff from housing and urban areas that include nutrients, toxic chemicals and/or sediments
POL	Marine pollution abandonment of solid waste	9.4	Garbage and solid waste	Garbage and solid waste rubbish and other solid materials including those that entangle wildlife (e.g. fishing lines, bags)
LIG	nocturnal light pollution in breeding areas	9.6	Excess energy	Inputs of heat, sound, or light that disturb wildlife or ecosystems
TEM	Nocturnal light pollution in breeding areas	11.3	Temperature extremes	Periods in which temperatures exceed or go below the normal range of variation

Table 1.11 - List of human-induced direct threats on Loggerhead sea turtle (*Caretta caretta*) across its range in central Mediterranean Sea, as identified by a panel of experts. We include acronyms, local threat, and IUCN taxonomy (code, threat specific name, general description) are reported. See "Method" for details.

After this evaluation, we posed a second question to the experts: how much do you think you know about the extent and intensity of any threat? We referred to this step as the Knowledge Magnitude (KM) analysis. In this case, KM was a compound variable (i.e., as a sum of extent and intensity) expressing a self-evaluation of the level of expert knowledge of the pressure of any threat affecting the selected target. After the evaluation, the experts classified the threats with regard to the mean values both of PM and KM, obtaining a list in decreasing order. The two analyses (PM and KM) allow for a straightforward and rapid expert-based ranking among threats where threats with the highest mean values represent the priority in terms of (i) threat pressure perceived by experts (PM), and (ii) of level of knowledge about this pressure (KM).

The comparison between PM and KM mean scores may allow to obtain information on the relationship between perceived pressures and the relative level of knowledge, highlighting the knowledge gaps.

Statistical analyses

We obtained, for any threat, the mean values, standard deviation (s.d.) and data variance. We applied the test for the homogeneity of variances to test if the variances among groups were homogeneous, therefore, allowing the Kruskal-Wallis test to be applied. To compare the mean threat magnitudes of >2 samples, we performed the Kruskal-Wallis non-parametric test for equal medians (Dytham, 2011), obtaining H values. To compare the mean values between two paired samples, we used the Mann-Whitney U test. To perform the box plots, we used the quartile method. After, we compared the average scores in PM and KM obtaining a scatterplot and performing an Ordinary Least Squares Regression. To perform the analyses, we used using the PAST 1.89 software (Hammer et al., 2001). The alpha level was set at 0.05.

Results

Regarding PM, we observed as mean scores significantly differ among threats with “Marine pollution and abandonment of solid waste” (POL; IUCN code 9.4), Accidental catches with professional fishing nets (CAT; IUCN code 5.4a) and “Habitat degradation” (with modification of breeding sites; DEG; IUCN code 7.3), showing the highest values (H=36.23; p<0.001; Kruskal-Wallis test; Fig.1.11, Tab.2.11).

Threat	Magnitude		p
	PM	KM	
COL	5.2 (1.03)	6.1 (1.37)	0.969
CAT	6.3 (2.21)	7.2 (0.91)	0.968
PER	2.3 (0.48)	4.3 (2.21)	0.962
TOU	4.5 (1.26)	5 (1.69)	0.969
DEG	6.2 (1.81)	5.3 (1.88)	0.966
PAT	3.9 (1.19)	4.8 (2.34)	0.966
CON	5.3 (1.63)	5.1 (11.91)	0.968
POL	6.5 (1.5)	6.8 (1.61)	0.969
LIG	5.4 (1.64)	5.4 (2.27)	0.969
TEM	4.6 (2.31)	4.3 (2.45)	0.96

Table 2.11 - TAN procedure applied to Loggerhead sea turtle (*Caretta caretta*) in central Mediterranean Sea. Mean values (and \pm standard deviation) in Magnitude (as sum of extent and intensity) (PM: Pressure Magnitude; KM: Knowledge Magnitude; see Methods for details). P-values for differences between paired mean values have been reported (Mann Whitney U test).

However, when comparing paired scores between threats, differences were significantly only between “Pathologies” (PAT; IUCN code 8.2) and “Direct persecution” (PER; IUCN code 5.4b), being the threats

showing the lowest PM (U=13, p=0.003, Mann-Whitney U test).

When performing the KM analysis, we observed as experts evaluated with highest scores CAT, POL, “Collision with boats” (COL; IUCN code 4.3), “Nocturnal light pollution in breeding areas” (LIG; IUCN code 9.6) and DEG, although differences among mean values were significant when comparing all threats (H=37.3, p<0.001; Kruskal Wallis test). However, when comparing paired threats, only threats showing lowest values in knowledge were significantly different “High temperatures” (TEM; IUCN code 11.3 vs PER: U= 21, p=0.02; Mann Whitney U test).

Scatterplot among mean values of PM and KM shows as POL and CAT were threats having high PM and adequately known (high KM); DEG, a threat having high PM but medium KM; LIG, “Contamination by natural and synthetic chemicals” (CON; IUCN code 9.1), TEM, “Tourism activities (disturbance along migratory routes and in foraging and nesting areas)” (TOU; IUCN code 6.1), threats with medium values both for PM and KM; COL, a threat highly known and with medium pressure; PAT and PER, threats considered with low PM and medium KM. Among them DEG, and secondarily LIG, CON, TEM, TOU, evidenced a gap of knowledge (respectively, high and medium) considering our thresholds.

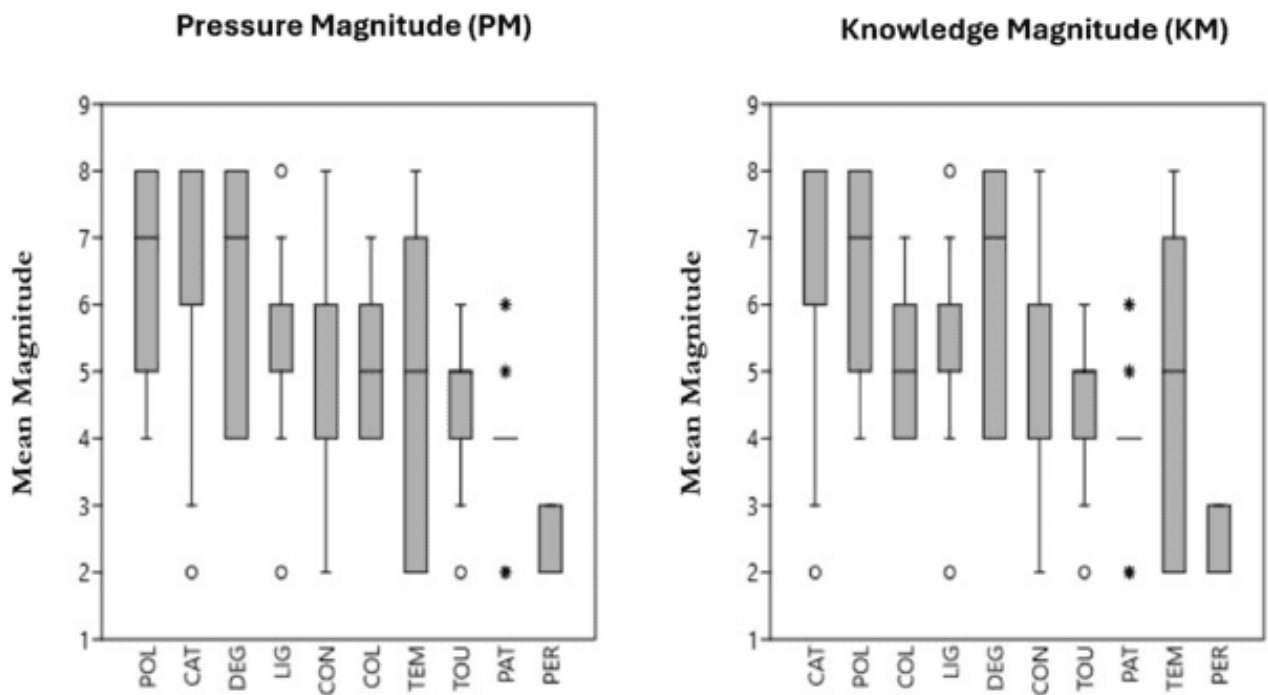


Figure 1.11 - Box plots of Magnitude values for the selected threats to the Loggerhead sea turtle (*Caretta caretta*) in the Mediterranean Sea. The minimal and maximal values are shown with short horizontal lines ("whiskers"); 25-75 percentiles are drawn using a box; horizontal line shows the median values. Acronyms as in Table 1.11. See text for IUCN categories and codes.

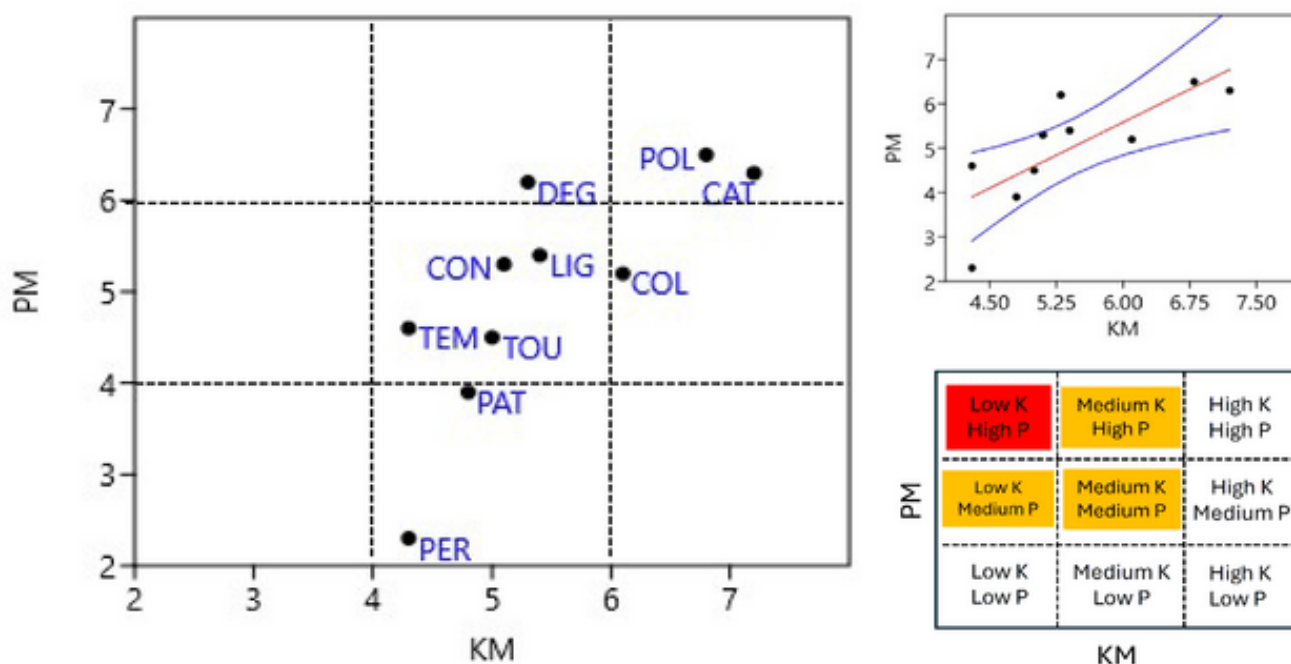


Figure 2.11 - Magnitude scatterplot (Pressure Magnitude, PM vs. Knowledge Magnitude, KM), on the left. Threats have been abbreviated as in Table 1.11. On the right, up: Ordinary Least Squares Regression between PM and KM with 95% interval of confidence; down: matrix of pressure/knowledge with gaps of knowledge (red: high gap; orange: medium).

When correlating mean values in Magnitude for the two approaches (Pressure and Knowledge analyses), we observed a direct significant correlation (Ordinary Least Square Regression: $r=0.77$, $p=0.019$, $R^2 = 0.59$; Fig.2.11), evidencing as more a threat is assessed as well-known in its regime (higher KM scores), the more it is assessed as having a strong pressure on the target (higher PM scores).

Discussion

“Marine pollution abandonment of solid waste” (POL; IUCN code 9.4), “Accidental catches with professional fishing nets” (CAT; IUCN code 5.4a) and “Habitat degradation” (DEG; IUCN code 7.3) represent the main threats impacting Loggerhead sea turtle in the central Mediterranean Sea (PM analysis). These threats on the species has already been highlighted (e.g., Matiddi et al., 2017; Caracappa et al., 2018; Attum & Rabia, 2021), but they have been not never put in a comparative priority. Our work evidences how experts consider these threats as priorities towards which conservation efforts in the central Mediterranean Sea should be focused when budget and time resources are limited.

“Marine pollution abandonment of solid waste” POL and “Accidental catches with professional fishing nets” CAT are also the threats for which the panel of experts reported to have the greatest knowledge (KM analysis) on the two regime attributes here considered (i.e., extent and intensity). This could be due to the fact that, although there are relevant guidelines on the behavior to be followed in the case of carcass

recovery, a national network in Italy that monitors the discovery of dead animals washed up on the beach is lacking (Mo et al., 2013). In this sense, the causes are largely attributable to suffocation by plastic (indirectly linked to POL) and to involuntary catches during fishing activities (CAT; e.g. Arcangeli et al., 2019).

The comparison between PM and KM scores also highlights knowledge gaps of about threats that, although considered impactful (i.e., having high/medium PM) are not yet adequately known (medium KM). Data about “Habitat degradation” should be obtained in large number and also at fine-grained scale. An interesting aspect emerges when comparing the mean scores of PM and KM: in fact, their direct and significant correlation suggests possible cognitive biases in expert evaluation: the more experts are familiar with a threat, the more they tend to assess it as having a high pressure on the target.

The role of cognitive biases in conservation have been recently highlighted (Catalano et al., 2018): these authors highlighted as the interplay of these and other cognitive factors can diminish the objectivity and accuracy of expert evaluations, suggesting the need for a more critical approach to ensure well-informed decision-making. In our case study, we hypothesize that different cognitive biases emerged. The “availability heuristic” where people (in our case, the experts) rely heavily on readily mentally accessible information or recent experiences, often causes an overestimation of the prevalence or significance of certain events or trends (e.g., Pachur et al., 2012).

Expert-based approaches like the one presented here (TAN assessment) offer an initial assessment and are highly effective methods when dealing with critically endangered species. Indeed, using this approach we may identify priorities in informing decision-making processes, especially in crisis contexts (McCarthy & Possingham, 2007; Margoluis et al., 2009), and is particularly helpful during the early stages of a conservation project cycle (situation analysis; Hockings et al., 2000; Battisti, 2018). However, expert-based approaches have notable limitations. Moreover, in the context of our study: first, the evaluation was conducted by each expert individually without collective brainstorming which, in many cases, can be useful to reduce the overconfidence of individual experts and other biases (Battisti & Cerfolli, 2021). Second, although all experts have many years of knowledge of the target, they diverge on the disciplinary level and regarding the access to different information, therefore inducing the emergence of cognitive biases. Finally, our assessment scale has been focused on the Central Mediterranean sea: It is likely that threats have different specific regimes in different seas and that experts have different knowledge for these different marine contexts.

All these considerations suggest that while TAN is a useful tool in the early stages of conservation projects, helping to define priorities for management, and identify areas for further research, experts should be aware of possible weaknesses and limitation in this approach.

This first assessment may deserve attention since it assign a preliminary ranking deserving attention

among anthropogenic threats in a large geographic area on a iconic species of high conservation concern, also focusing on possible gap of knowledge. An awareness on possible emerging cognitive bias in evaluation will make necessary further analysis using new approaches controlling for them.

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Take home messages

- We carried out a context/situation analysis focused on Loggerhead sea turtle (*Caretta caretta*) in central Mediterranean sea, using TAN approach, searching for possible gap in expert knowledge.
- Marine pollution and abandonment of solid waste, accidental catches with professional fishing nets, and habitat degradation showed the highest Magnitude.
- Nocturnal light pollution in breeding areas and direct persecution were the less known, evidencing as these threats deserve more effort in research about their extent.

Chapter 12: FINAL CONSIDERATIONS

The technical tools and methodologies employed by environmental management professionals are becoming increasingly standardized. Over the years, the need to define clear conservation objectives has been widely discussed, with particular emphasis on aligning these goals with available economic resources to ensure their feasibility. In this context, analyzing the root causes of environmental issues, often of long-standing origin also, underscores the importance of understanding the historical ecological values of a given area.

The assessment of disturbances and threats thus provides a robust informational foundation, offering a valuable resource to enhance the expected outcomes of conservation interventions. Two such methods, TAN and TRA, have proven useful for managers of PA, as well as for practitioners involved in targeted conservation projects addressing species, habitat types, or other environmental components.

The analysis conducted by experts provides clear indications for identifying the main threats affecting the target species, highlighting the importance of a holistic and integrated approach. In another case, the TAN and DPSIR approaches can serve as a valuable tools for conservation strategies, with project objectives focused on maintaining ecosystem components and reducing or mitigating threats.

This PhD project has demonstrated that anthropogenic disturbances are part of a causal chain linking primary driving forces, through indirect threats, to those that exert direct impacts on conservation targets. This structured approach helps to move beyond the trial-and-error paradigm that has characterized much of natural site management in recent decades. Despite the complexity and interdependence of these relationships, they can often be modeled using simple conceptual frameworks.

Furthermore, the project highlights the importance of adopting a standardized nomenclature for classifying threat events. A hierarchical classification system, analogous to those used in biological systematics and taxonomy, facilitates integration into broader analytical frameworks and supports the identification of shared features among threats. Such a system is a valuable tool for managers, enabling a clearer understanding of the most relevant characteristics of threats and their similarities. It is hoped that these novel approaches will increasingly support the development of adaptive management processes, where appropriate, grounded in defined criteria and coherent procedures, better equipped to address the complexity of ecological systems and strengthen biodiversity conservation efforts. Through the use of such operational tools and the establishment of a suitably trained team of experts within PAs, institutions can also position themselves as applied research entities, fostering active collaborations with universities and national and international research groups.

This project has also demonstrated how in the all cases involving birds and marine reptiles in the Mediterranean, waste and the degradation of reproductive habitats emerged as significant threats to species conservation in the study area. The collaborative approach, engaging local experts and the scientific community, proved essential in optimizing PA management and maximizing the effectiveness of conservation actions, while also reducing exposure to cognitive biases.

While promoting in that context every type of relationship between the natural world and the human sphere

through a rigorous analytical approach, we also believe we have provided a transversal vision, which is completely necessary in the assessment of threats because it is able to quickly interpret the possible solutions to be implemented.

Ultimately, the cases examined emphasize the importance of maximizing procedural consistency with conservation actions. Within this framework, decision-makers are encouraged to operate proactively by proposing measures aimed at evaluating PA management effectiveness, such as:

- Regularly promoting mandatory assessments of the conservation status of habitats and species in accordance with the HD and BD;
- Verifying the availability of sufficient financial resources allocated to the PA;
- Ensuring the existence of a management plan with updated and measurable objectives;
- Identifying the presence of regulations capable of addressing the most critical issues affecting the area and its species;
- Enhancing relationships with stakeholders, especially those aimed at conflict resolution.

Within this framework, particular significance is given to initiating targeted assessments, including, for the first time, a historical TAN of the “Diaccia Botrona” Regional Reserve and the “Torre Flavia” Natural Monument.