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An Innovative Approach for Subnational Climate Adaptation of Biodiversity and Ecosystems: The Case Study of a Regional Strategy in Italy

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Citation: Pollo, A.; Piccini, I.; Chiara, J.; Porro, E.; Chiantore, D.; Gili, F.; Alba, R.; Barbi, A.; Bogliani, G.; Bagliani, M.; et al. An Innovative Approach for Subnational Climate Adaptation of Biodiversity and Ecosystems: The Case Study of a Regional Strategy in Italy. *Sustainability* **2022**, *14*, 6115. https://doi.org/10.3390/su14106115

Academic Editors: Chiranjeewee Khadka and Pavel Cudlin

Received: 31 March 2022
Accepted: 11 May 2022
Published: 18 May 2022

Abstract: Since climate change impacts are already occurring, urgent adaptive actions are necessary to avoid the worst damages. Regional authorities play an important role in adaptation, but they have few binding guidelines to carry out strategies and plans. Sectoral impacts and adaptive measures strongly differ between regions; therefore, specific results for each territory are needed. Impacts are often not exhaustively reported by literature, dataset and models, thus making it impossible to objectively identify specific adaptive measures. Usual expert elicitation helps to fill this gap but shows some issues. For the Piedmont Strategy, an innovative approach has been proposed, involving experts of private and public bodies (regional authorities, academia, research institutes, parks, associations, NGOs, etc.). They collaborated in two work group, first to identify current and future impacts on biodiversity and ecosystems, and secondly to elaborate and prioritize measures. Involving 143 experts of 46 affiliations, it was possible to quickly edit a cross-validated list of impacts (110) and measures (92) with limited costs. Lastly, a public return of results took place. This approach proved to be effective, efficient and influenced the policymakers, overcoming the tendency to enact long-term actions to face climate change. It could be used internationally by subnational authorities also in other sectors.

Keywords: adaptation strategies; adaptation plans; adaptive measures; biodiversity conservation; climate change; climate impacts; expert elicitation; expert-based evaluation; participatory approach

1. Introduction

Global warming is unequivocally caused by the increase in human-based activities that generate elevated concentrations of greenhouse gasses, GHG [1]. Consequently, its impacts have already been recorded: for example, on agriculture, water resources, biodiversity and ecosystems, human health, infrastructures, etc. [2–6]. Therefore, every human effort to reduce emissions or enhance GHG sinks (mitigation) is necessary [7]; adaptation is also required as soon as possible to make countries climate-resilient [6].

Tackling climate change is a global challenge and actions—especially adaptive ones—are needed at local, subnational, national and international levels [3,8], as reported in Figure 1. The European Climate Law (Regulation EU 2021/1119) formalizes the European Green Deal goals for climate-neutral and climate-resilient EU economy and society by 2050 [6,9,10]. In particular, the New Adaptation Strategy combines climate neutrality for mitigation with the strengthening of resilience and the ability to adapt [6]. At the national level, all European countries adopted National Adaptation Strategy and/or National Adaptation Plans as reported on the European Climate Adaptation Platform Climate-ADAPT. Some of them focus on the sector "biodiversity and ecosystems", e.g., Greece, Ireland, Poland, and Spain [11]. Italy has approved a National Strategy for Adaptation to Climate Change [2], which was followed by the National Climate Change Adaptation Plan [4] that still has to be defined in detail. In these national Italian documents, there are sections on biodiversity and ecosystem.

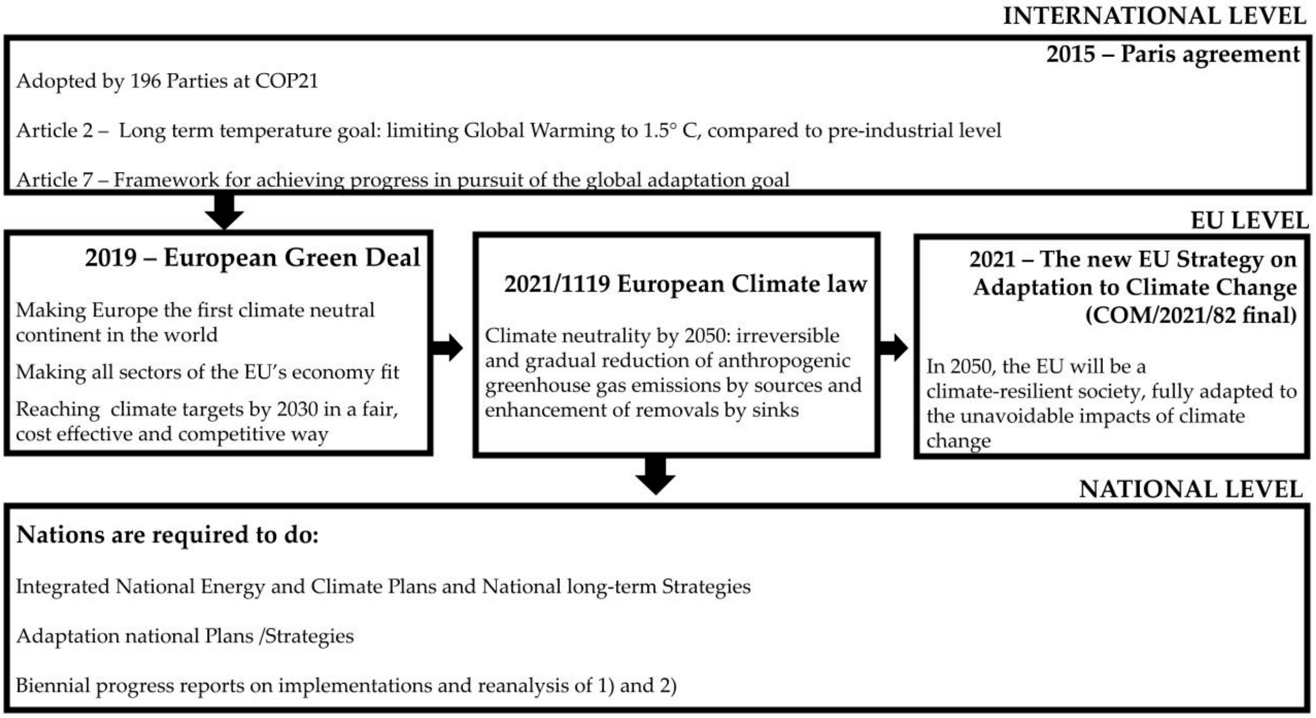

Figure 1. General legal framework of climate change mitigation and adaptation.

Adaptive European and national strategies and plans are not sufficient to make territories climate-resilient: large-scale adaptation approaches have limits and barriers [12]. Advancing climate governance across all levels is crucial: adaptation requires international and national guidelines like strategies or plans as well as complementary adaptation efforts on a local scale [13]. Since climate change has specific impacts at local levels, studying territorial characteristics, particularities, and vulnerabilities is crucial [13]. The proximity to stakeholders and communities also gives subnational authorities (e.g., regions, provinces, municipalities) access to knowledge about place-based vulnerability enabling them to develop solutions tailored to the local needs [14]. Therefore, together with national and international actions, subnational engagement plays an important role in adaptation [13,15].

Even if the drafting of subnational strategies and plans is not mandatory in all EU countries, it is worthwhile to reduce and manage climate change impacts on territories and communities avoiding the worst damages [16]. These documents are suggested at the international level [3], at the EU level [6,11] and at the national level [2,4].

The first level of territorial subdivision authorities of many EU countries is the 'region' [11] corresponding to NUTS 2 level [17]. Regions are normally divided into different areas of expertise, hereinafter defined as regional sectors. Furthermore, the Constitution of some countries, such as Italy, delegates specific tasks to the regions in certain sectors, such as agriculture and nature conservation. Many regional strategies and plans analyze separately different sectors, e.g., agriculture, forestry, energy, biodiversity, and ecosystems [18–23]. Flood protection, water management and urban planning are major response actions [12]. As a matter of fact, impacts and necessary adaptation measures strongly differ not only between regions but also between sectors [24]. Therefore, specific results for each subnational territory are needed.

For most of the EU regions there are no binding guidelines concerning regional adaptation strategy and plan development: several patterns of adaptation were identified among the EU regions [12]. General guidelines for adaptation are given by the first European Strategy for Adaptation to Climate Change [11] and by the new Adaptation Strategy [6]. Moreover, many countries share a general methodology [18,22,23] based on the IPCC guidelines [15]: in general, suggestions include defining climate trends, scenarios and hazards first, and then climate impacts and risks (Box 1). Successively, these suggestions identify sectoral adaptation measures to reduce and manage climate change impacts.

As regards the approach, several regional adaptation strategies and plans in Europe are based on institutional work teams [18,22], which resort to scientific literature, published data, models and expert involvement [8,19,21,25]. Expert elicitation helps in coping with science uncertainty [15].

For example, with regard to the "biodiversity and ecosystems" sector, this approach has many important applications in conservation and natural resources management, including threatened species management, environmental impact assessment and structured decision-making [26–29]. It underpins some of the most influential global environmental policies, including the IUCN Red List [30] and IPCC Assessments [31], but also local environmental goals, such as for the identification of priority conservation areas in the alpine region [32] and in even smaller territories [33]. Expert elicitation is generally conducted with few sectoral experts (e.g., [34]) who mainly belong to academia and/or research institutes (e.g., [5,19]). Specifically in Italy, regions that resorted to expert elicitation to edit adaptation strategies involved few experts who belonging to public institutions such as regional authorities, research institutes and universities (pers. Obs.).

This approach can be prone to contextual biases [29] and runs the risk of obtaining incomplete and unvalidated observations. An analysis of the regional activities carried out by the 28 EU countries outlines the difficulties encountered by policymakers and scientific research institutions while collaborating: policymaking needs more applicable scientific knowledge [11]. A structured approach mitigates these problems [29].

Considering these issues and the general methodology suggested by IPCC, an innovative approach has been applied by the Piedmont Region (Italy) developing the Regional Strategy on Climate Change (SRCC). This work presents an effective and efficient approach, which has been developed for the SRCC sector "biodiversity and ecosystems". Current and expected climate change impacts on local plant and animal biodiversity have been assessed and cross-validated thanks to an advanced expert elicitation. The latter has made it possible to identify adaptive measures to reduce and manage regional impacts, which have been pointed out in the same way. To share the results, a public return to policymakers, technical administrative personnel, stakeholders, and society has taken place.

This case study is focused on "biodiversity and ecosystems" and consists of an innovative approach aimed at creating specific adaptation strategies for subnational territories capable of taking exhaustively into account local vulnerabilities and characteristics.

Box 1. International risks and impacts definition.

Impacts are defined as "the consequences of realized risks on natural and human systems and generally refer to effects on lives; livelihoods; health and well-being; ecosystems and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure" [7]. In assessing the potential effects linked to climate change, the concept of risk is also crucial. The risk is defined as "the potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems" [24]. The assessment of risk is based on the analysis of its components (Figure 2), which are thus defined [15]:

- Hazard: "The potential occurrence of physical events associated with climate or trends or their physical impacts";
- Exposure: "The presence of people, livelihoods, species and ecosystems, environmental functions, services, and resources, infrastructures, or economic, social, cultural assets in places and contexts that could be negatively affected";
- Vulnerability: "The propensity to be negatively affected. It encompasses a variety of concepts and elements including sensitivity to harm and a lack of coping and fit capacity".

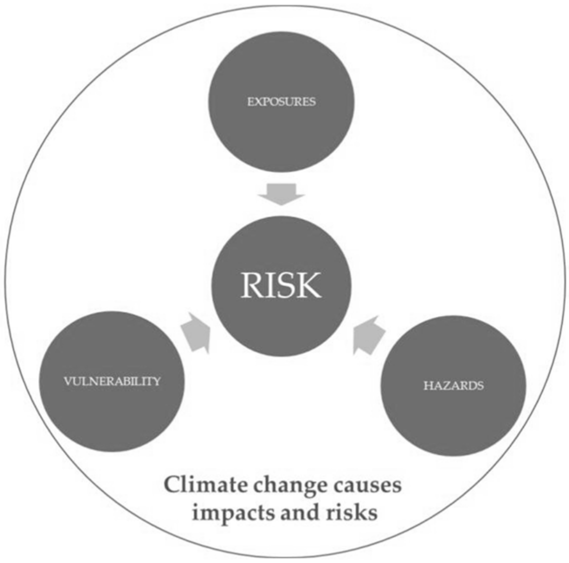

Figure 2. Risk as a function of hazard, exposure and vulnerability; redrawn from [24]. The adaptive capacity intrinsic to the system and specific adaptation options lead to a risk reduction by acting both on vulnerability decrease and resilience increase.

2. Regional Approach for a Sectoral Adaptation to Climate Change Impacts

Scientific literature and dataset often do not have homogeneous, shared, and updated evidence on regional and local impacts of climate change on biodiversity and ecosystems. Indeed, reliable long historical series related to local plant or animal species are often absent or insufficient in order to determine reliable trends of impacts [35]. Moreover, many studies highlight the high complexity of designing models to predict the possible consequences of future climate change on biodiversity and ecosystems, especially on a small scale [36–40].

Considering these difficulties, subnational authorities struggle to assess climate change impacts and point out adaptive measures specific for the considered territory.

Consequently, we suggest an innovative approach (Figure 3) useful for subnational institutions that have to develop adaptation strategies and/or plans on climate change. Based on national guidelines, a subnational analysis should point out impacts and measures for several sectors, such as biodiversity and ecosystems but also agriculture, forests, water resources, energy, etc.

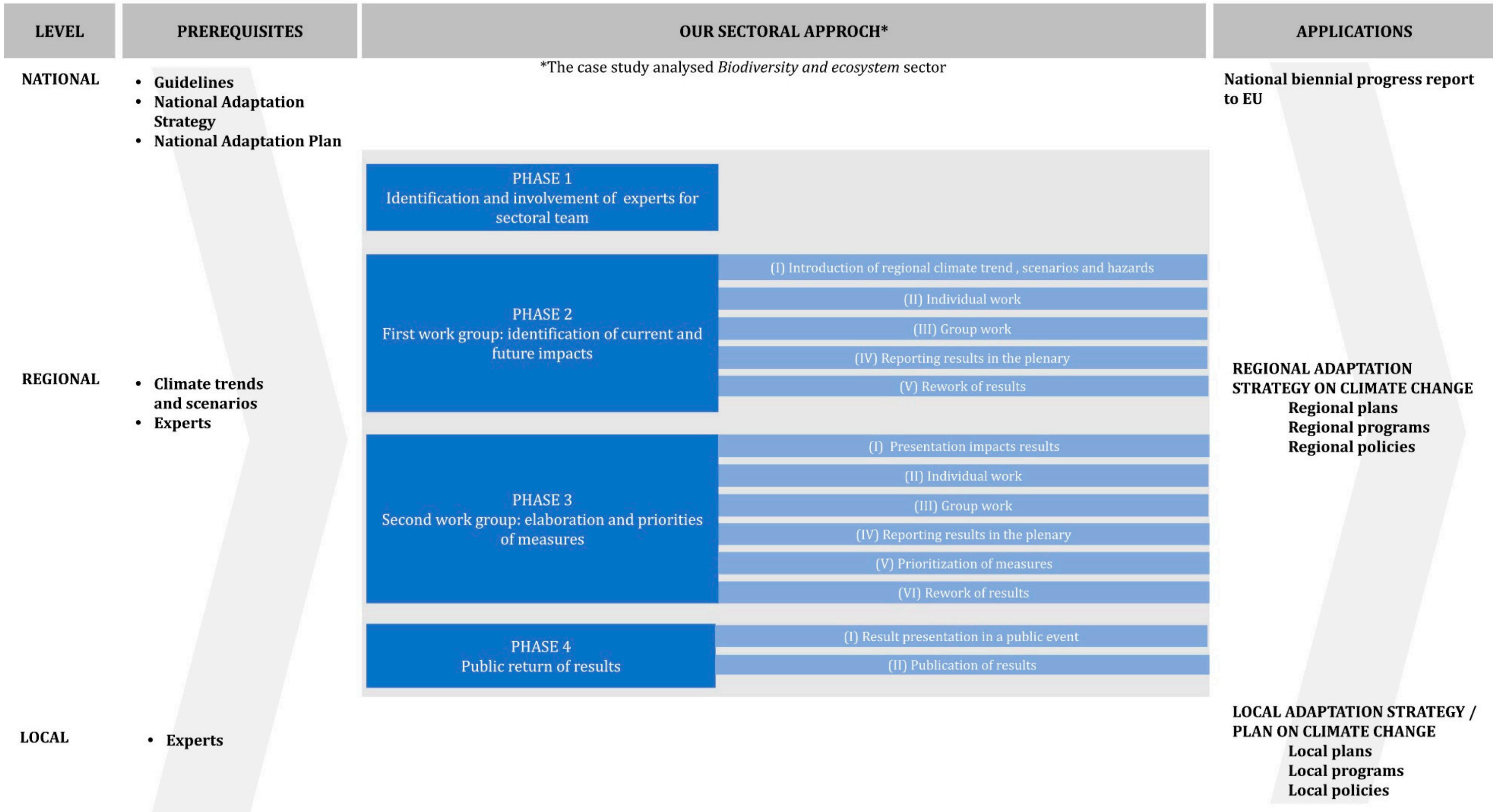

Figure 3. Multilevel framework of the approach used and related prerequisites and applications of the results.

The proposed approach consists of four phases:

1. Identification and involvement of experts for the sectoral team (1 month);
2. First work group: identification of current and future impacts (1 month);
3. Second work group: measures elaboration and priority setting (1 month);
4. Public return of results (1 month).

The work groups should be conducted following an advanced expert elicitation and should involve regional and local experts with knowledge and experience on the focused territory. In order to outline sectoral current impacts and risk of future impacts [7], our approach suggests proceeding in the following way. During the first workgroup, the current impacts should be easily reported by regional and local experts. Moreover, they should assess the risk of future impacts, considering every risk component (as reported in Box 1). Hazards are normally elaborated by technical regional agencies, who hold the territorial climatic data and the technical skills to process them. After their sharing of this risk component, exposures and vulnerabilities should be elaborated too. Regional and local experts should point out both exposures and vulnerabilities thanks to their knowledge and experience. Once the sectoral impacts have been outlined, the same experts should identify and prioritize the sectoral measures. To develop shared and feasible climate change strategies and plans, we recognize the importance of collaboration among different institutions (academia, parks, regional authorities, NGOs, private bodies . . .) in defining impacts and measures.

Thus, these results that come out from this approach in subnational adaptation strategies or plans should be integrated in regional and local policies, in binding plans and programs, in local adaptation strategies and plans and should address the public funds assignment. They should also find application in the national biennial progress reports that each EU country has to present to the European Union (Regulation EU 2021/1119).

3. The Case Study of Regional Strategy on Climate Change of Piedmont

Unlike some EU Member States [11,22], regional adaptation strategies and plans are not mandatory in Italy and there are no binding guidelines. In order to set up a sectoral analysis for the Piedmont SRCC, we started from the information reported in the “National Strategy on Climate Change” [2] and in the “National Adaptation Plan for Climate Change” [4]. Moreover, we considered the “Methodologies for defining regional strategies and plans for adaptation to climate change” [23] published by CReIAMO PA, i.e., an Italian Ministry of Ecological Transition project that aims to support regions in adapting to climate change.

Since 2017 Piedmont has been developing a Regional Strategy on Climate Change (SRCC). It is a strategy document aimed at integrating the challenges of both mitigation and adaptation, trying to orientate, synthesize, and compare the various regional policies, programs, and plans [41]. Many sectors are vulnerable to the effects of climate change considered by this strategy: agriculture, geological, hydrogeological and hydraulic instability, biodiversity and ecosystems, energy, forests, highly polluting industries and infrastructures, urban settlements, cultural heritage, water resource, health, sport, transport, and tourism [41]. The definition of these strategy sectors is based on those already identified by the national adaptation strategy and plan.

To develop the SRCC in Piedmont, the first sector analyzed has been “biodiversity and ecosystems”, which is the prerogative of the “Sustainable development, biodiversity and natural areas” department of the Piedmont Region. This sector gained priority because Piedmont is a plant and animal hotspot in Italy [42]: it is the second Italian region with the highest number of species protected by the Habitats Directive (Piedmont Region data). Italy in turn holds the primacy in Europe [43]. Such biodiversity richness reflects some geo-morphological and bio-climatic features of this area, including high gradients both in latitude and altitude, as well as the presence of three biogeographical regions: Alpine, Continental and Mediterranean [44]. Moreover, considering that Piedmont has shown much higher warming trends than the global average [45], the biodiversity and ecosystems are currently strongly threatened by climate change. The current and expected impacts on biodiversity and ecosystems, as well as the interdependence between the climate crisis and the loss of biodiversity, make it urgent and necessary to tackle these two aspects jointly [46]. While climate change affects and threatens biological diversity, natural processes provide a key contribution to mitigation and adaptation to climate change [24,46,47].

For the considered territory, there are very long data series for some species such as the Alpine ibex (*Capra ibex*), in the Gran Paradiso National Park with 45-year time series of annual censuses [48,49]. Analyses have been carried out of the effects of climate change on the local distribution and fitness of many species, also combining an empirical population modelling approach and stochastic simulations of the population dynamics [50,51]. These are just some of the examples of the published scientific data. Many data have also been collected through the project "Animal Biodiversity Monitoring on Alps" carried out by some parks since 2006. However, these data were not sufficient to define future impacts of climate change on biodiversity and ecosystems in Piedmont.

Therefore, the analysis of the sector "biodiversity and ecosystems" followed the previously presented approach with its four phases.

3.1. Phase 1: Identification and Involvement of Experts for the Sectoral Team

In order to have a more proficient and heterogeneous discussion on impacts and possible measures, experts on biodiversity and ecosystems have been selected among people belonging to different public and private bodies. Moreover, they were identified for the relevance of their expertise at the regional and local scale. To select them, we have considered two criteria: their long-term knowledge concerning the relationship between biodiversity and climate change on the regional territory and their experience in research and/or in the field. All the entities of experts with these prerequisites (national and regional parks, university departments, research centers, NGOs, associations, etc.) have been involved, paying attention to the heterogeneity of knowledge in different environments, regional territories, and taxa. This approach is innovative because it involves national and regional parks, private sector, NGOs and volunteers of associations with fieldwork experience and/or elaboration of biodiversity field-data showing biodiversity changes, even if unpublished. Everyone equally contributed to the work groups, having the same time and way of reporting own contributions.

To allow effective work groups, the Piedmont Region clearly communicated the goals and the expert elicitation approach since the beginning. Moreover, due to the limited budget and the urgency of obtaining an output, the experts were required to collaborate for free. All experts were able to freely decide to participate based on their expertise, knowledge and experience. The experts that have not been able to participate in the work groups could send their contributions to the organizers.

Once the experts were identified considering different components of biodiversity, habitats and ecosystems present in Piedmont, they were invited to the two work groups.

3.2. Phase 2: First Work Group: Identification of Current and Future Impacts

The aim of the first meeting was to identify the current impacts and the risk of future impacts for biodiversity and ecosystems due to climate change at the regional level. In order to discuss more efficiently and to allow cross-validation, we organized two different work groups: one table for vegetational biodiversity (both cryptogams and phanerogams), which took place face-to-face during the pre-COVID19 period, and the other for animal biodiversity, which took place online during the COVID19 period. This phase consisted of five sub-phases.

(I) The climatologists of the Piedmont Regional Environmental Protection Agency (ARPA) reported the regional climatic trends [45] and scenarios [52], outlining climatic hazards to the experts. They remained at disposal during the whole session to answer to questions and clarify possible issues. At this point, the experts started to work on impacts, answering the question, "Which are the current or foreseen impacts of climate change on plant/animal biodiversity in Piedmont?". This question was tested with the facilitators, who are quasi experts to assure that formulations were workable and could be understood.

(II) In order to better stimulate contributions without conditioning the other participants, the work group started with an individual elaboration of the current and expected impacts known and predicted by experts in Piedmont. In this way, the experts made a first list of impacts. Moreover, each expert specified if their impact awareness derived from published data, reports, gray literature, etc. or from personal observations.

(III) Later, work groups were formed in a heterogeneous way, including experts with different background in the same group. Then, to identify a first dataset of impacts, groups discussed the initial individual outputs with particular attention to the most shared and controversial impacts. To moderate the discussion, the work groups were directed mostly by young experts (PhD students, research fellows, early career scientists, etc.). They reported on a poster (when in presence) or on a shared document (when online) the individually identified impacts to show them to each expert of the group. After, the entire group decided to keep, modify or delete the other experts' contribution, and then synthesized and re-elaborated it, validating the final results.

(IV) Each group reported their outputs in the plenary, thus allowing another cross-check with the outputs of the other groups and validating the results.

(V) The results of all groups were then elaborated by the Piedmont Region team, dividing them into macro-categories of impacts.

(VI) This elaboration and subsequent discussions with experts and facilitators made it also possible to identify flag species for climate change in accordance with what emerged from the work groups.

3.3. Phase 3: Second Work Group: Measures Elaboration and Priority Setting

The same experts collaborated on a second work group with the aim of identifying measures to adapt regional biodiversity and ecosystems to climate change impacts. In order to discuss the topics more efficiently, we organized again two different work groups: one table for vegetational biodiversity (face-to-face) and the other for animal biodiversity (online).

(I) In order to create a clear background useful for making measures proposals, the results concerning the impacts were presented to the experts.

(II) As for the first work group, also the second meeting had a first moment of individual elaboration answering the question, "Which are the measures to mitigate current or foreseen impacts of climate change on plant/animal biodiversity in Piedmont?". This question was tested with the facilitators, who are quasi experts, to assure that formulations were workable and could be understood. The individual work on measures was aimed at better stimulating the emergence of various contributions free from conditioning. In this way, by making a list of measures, the single experts drew indications based on personal experiences and observations.

(III) Later, small groups worked in different work groups on the initial individual outputs. In this way, each group of experts discussed the most shared and controversial measures, identifying a first list of measures. To moderate the discussion, the work groups were directed mostly by young experts (PhD students, research fellows, etc.). They reported on a poster (when in presence) or on a shared document (when online) the individually identified measures to show them to each expert of the group. After, the entire group decided to keep, modify or delete the other experts' contribution, and then synthesized and re-elaborated it, validating the final results.

(IV) Each group reported their results in the plenary session, thus allowing a cross-check with the outputs of the other groups and validating the results.

(V) In order to better define the priority of the identified measures, an anonymous vote was then held.

(VI) The measure results of all groups were then revised by the Piedmont Region, dividing them into impact macro-categories. The Piedmont Region team reworked the results, classifying them into three priority ranges (low, medium, and high).

3.4. Phase 4: Dissemination

The re-elaborated results that emerged during the work groups were presented to a large audience by sharing documents and presenting them in a public event.

(I) First, a full report and a summary have been published on the Piedmont Region website. At national level, all documents have been also shared with the environmental ministry; indeed, those documents can be a useful tool to prepare the biennial updates that member states are required to send to the European Union (Figure 1).

(II) Secondly, a public event was organized. Experts and facilitators returned the results of the working groups. The event was open to the involved experts as well as to stakeholders, policymakers, technical administrative personnel and civil society. It has been advertised and broadcast live on the web to allow everyone to listen and contribute to it. Young local environmental activists from Fridays for Future Piedmont and Extinction Rebellion Turin participated to express their point of view on the topic. During the return of the results, the participants had the possibility to ask questions and attend both face-to-face and online.

4. Results

The results that emerged using this approach for SRCC are shown below.

4.1. Results of Phase 1: Identification and Involvement of Experts for Sectoral Team

We invited 182 experts with several affiliations: 143 experts (79% of all invited experts), affiliated with 46 different bodies, took part in the activities and collaborated actively to define impacts and measures to oppose climate change.

Most of them belonged to academic and research institutions (32.9%) and regional and national parks of Piedmont (22.1%). Other experts' affiliations were regional and local governance (15.7%), technical institutional agencies (18.6%), but also civil society (10.7%) with experts of NGOs, associations, and private sector (Figure 4).

4.2. Results of Phase 2: First Work Group: Identification of Current and Future Impacts

During this step, current and expected impacts have been identified for both vegetation and fauna as well as their habitats due to climate change effects related to the Piedmont Region territory.

The impacts shared by the experts have been summarized in 110 entries and divided into 10 macro-categories (Figure 5). The impacts for vegetation are 46 while for animal biodiversity they are 64. Twenty-four of them apply both to vegetation and animal sectors; therefore, the total was 86 impacts for biodiversity and ecosystems (Table A1). The macro-categories were defined using those presented in the national strategic documents and integrated with the experts' suggestions:

- Changes in physiological processes (PHY);
- Changes in morphology (size, color, etc.) (MOR);
- Behavior changes (reproductive, trophic, etc.) (COM);
- Changes in phenology (PHE);
- Changes in spatial distribution (DIS);
- Changes in communities' species composition and interactions (COM. INT);
- Changes in population structure and dynamics (STR. DYN);
- Alteration of the provided ecosystem services (ECO. S.);
- Direct impacts from sudden anomalous events, such as fires, droughts and extreme temperatures (DIR. I.);
- Impacts related to climate change maladaptation (MAL).

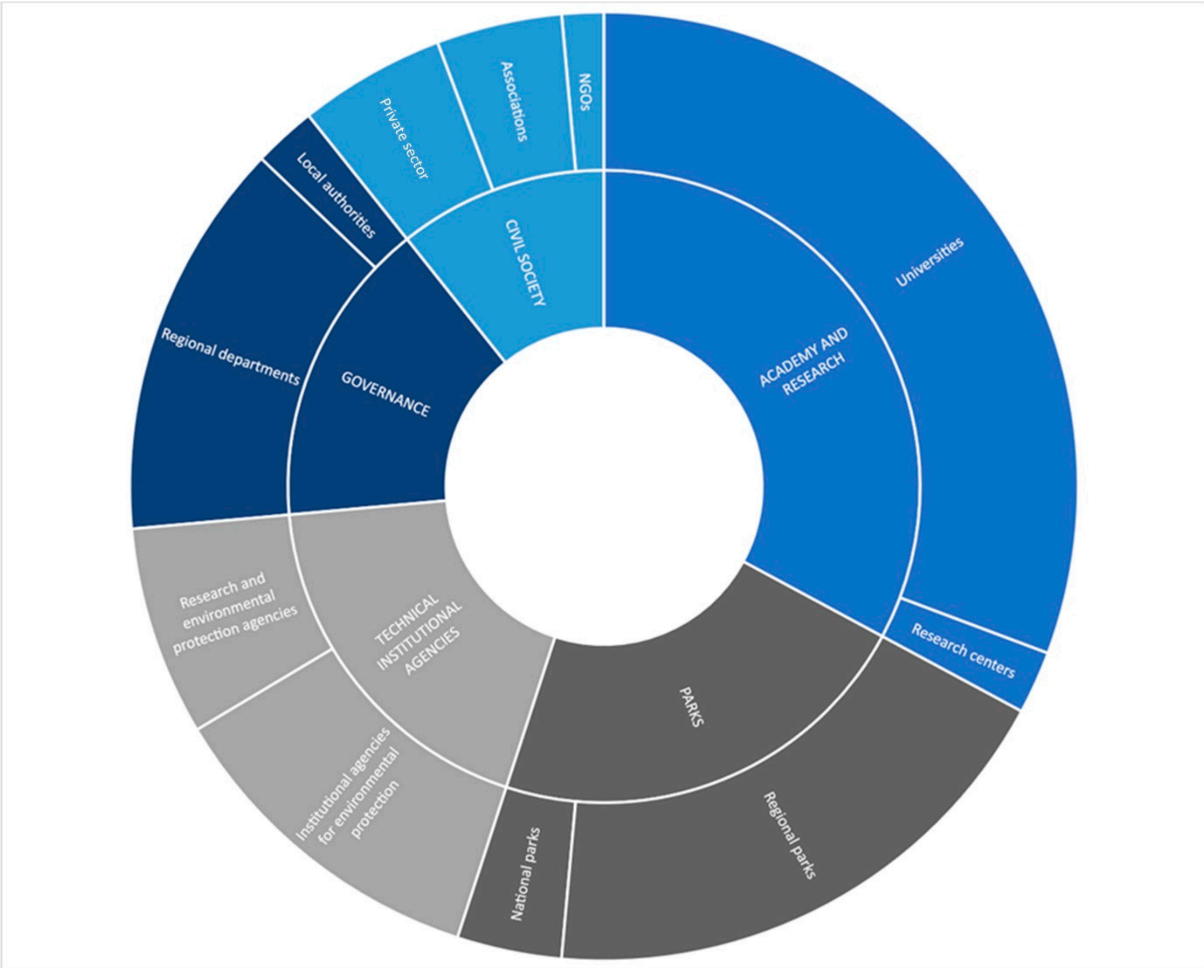

Figure 4. Composition of collaborating experts for each affiliation.

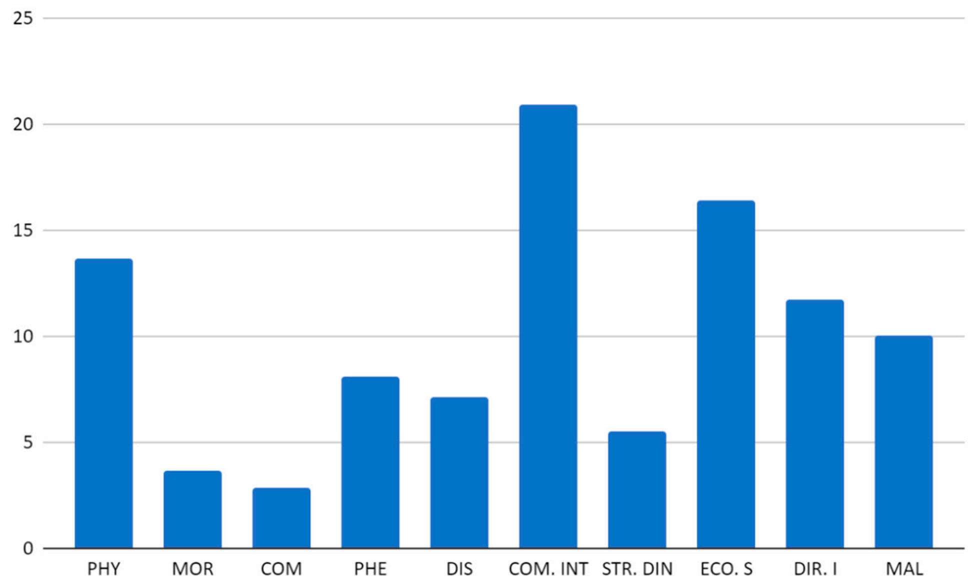

Figure 5. The percentage of the types of impacts divided into the macro-categories for both plant and animal biodiversity and ecosystems.

The results outlined that the macro-categories that show the largest different types of impacts are the following: changes in specific composition and interactions of communities

(20.9%), alteration of ecosystem services (16.4%) and changes in physiological processes (13.6%). However, this result does not outline the abundance of each type of impact. For example, the impact "altitudinal shift towards higher altitudes and latitudes" has been reported by many experts during the individual work as well as by the groups but its macro-category is not very differentiated: indeed, it has only four types of impacts.

The impacts on the regional fauna have been further divided into six taxonomic groups: aquatic invertebrates, terrestrial invertebrates, fish, birds, amphibians and reptiles, and mammals.

In order to clearly communicate the impacts, some flag species/taxa have been chosen and used in the report graphics. This choice has been made by the facilitators based on the expert's indications, choosing charismatic taxa with a high evocative value and attention-drawing characteristics.

4.3. Results of Phase 3: Second Work Group: Elaboration of Measures and Definition of Their Priorities

Ninety-two measures emerged to mitigate the identified impacts (Table A2). Each measure was associated with one/more impact/s and was given a priority (low, medium, high) based on what was discussed by the experts during the work group. The measures were also divided into macro-categories and categories (Table 1; Figure 6) based on the classification made by the draft National Plan for Adaptation to Climate Change.

Table 1. Macro-categories and categories identified for the measures.

Macro-Categories	Categories
Information	Research, evaluation, monitoring, data, models Disclosure, perception, awareness, and education
Governance	Adjustments of regulations, plans, programs, and strategies Economic and financial tools Path
Organizational and participatory processes	Partnership and participation Institutions Organization and management
Nature-based solutions	Integrated solutions Forest, agro-forest, and river ecosystems
Adaptation and improvement of technological plants and infrastructures	Machinery, materials, and technologies

Most measures concern governance (50%), mostly referring to suggested path and adjustments of regulations, plans, programs, and strategies; the macro-category is followed by information measures (30%), most of which concern research, evaluation, monitoring, data, and model. Many common measures emerged from the work groups for plant and animal biodiversity: 24 measures for both plants and animals (48 in total), more than half of the total measures. Therefore, the agreement on the need to implement these actions is high. It shows that the methodology used leads to shared results.

4.4. Results of Phase 4: Dissemination

The results have been reported in two main documents. The first document presents all the technical results derived from the work groups (126 pages). It is useful for experts, regional technical administrative personnel, parks, and all the possible stakeholders also to address future policies, plans and funding distribution programs regarding biodiversity and ecosystems. The second document is a synthetic restitution that aims to report the main results in a clear and effective way; the latter was shared with the press, civil society and policymakers (11 pages). Currently, both documents can be downloaded freely from the Piedmont Region website.

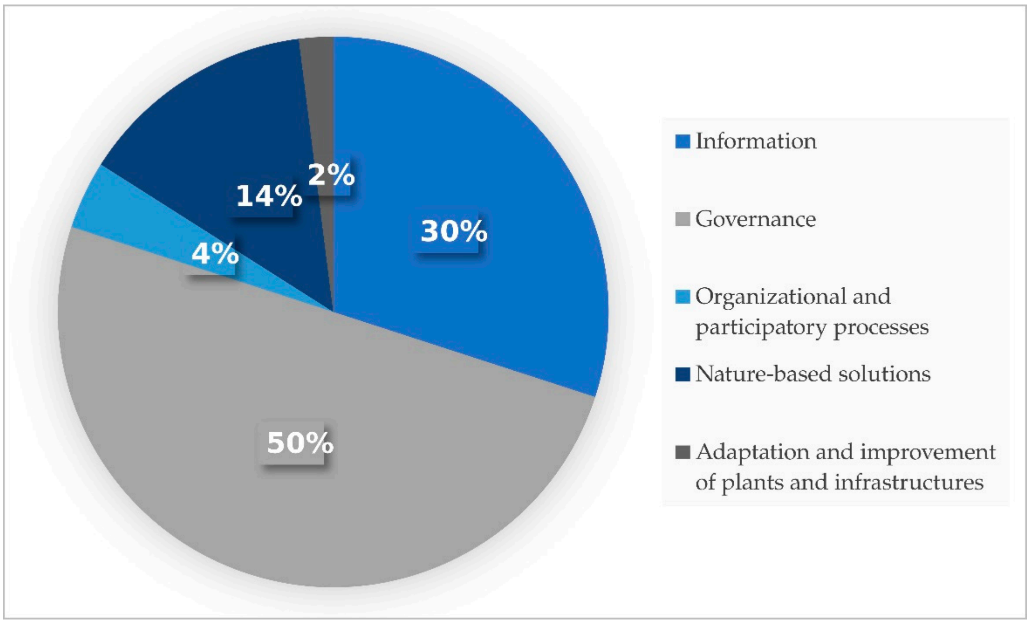

Figure 6. Macro-categories of the identified measures for both animal and plant biodiversity and ecosystems.

The public event involved about 50 people (i.e., the capacity of the room due to COVID19 restrictions), who were present during the event: 78% of them were experts involved in the process and 22% of them were regional administrators and policymakers. The same event was also broadcast live online, open to everybody. More than 2100 people followed the event online with 147 comments and interactions. The event was moderated by a journalist of "Piemonte Parchi" magazine, who was able to make the broadcast more captivating, allowing a more proficient participation of a broad audience.

5. Discussion

Adaptation strategies and plans on climate change must be based on the latest scientific knowledge [6]. For some sectors, like biodiversity and ecosystems, local or regional latest scientific publications are not yet exhaustive about impacts [8,35,53] and models are usually not sufficient or uncertain [39,40,54]. In order to face this uncertainty, expert elicitation is a useful approach, especially if it is structured [15,55]. The approach used for this case study is aligned with the general guidelines often used to involve experts, such as the IDEA's one [30]. However, few experts are usually involved in writing the regional adaptation strategies or plans and they generally belong to academia or public institutions (e.g., [5,19]). This approach, for the first time in Italy, included several experts (N° 143) belonging to public and private bodies.

In this paper we have outlined an approach to analyze a SRCC sector "biodiversity and ecosystems" that showed several advantages: (1) it redefined the role of the "expert" on the basis of both long knowledge and expertise at regional or local scale, giving outputs not only based on official publications, reports, dataset, and models but also on long-term field experience such as in the case of rangers (advanced expert elicitation); (2) it led to cross-validated, updated, homogeneous impacts and measures specific for the regional territory (effective); (3) it is quick and it has very limited costs (efficient); (4) its results are available to all policymakers, technical administrative personnel, stakeholders, and society (disclosure-based). The advantages and limitations have occurred both face-to-face and remotely.

5.1. Advanced Expert-Elicitation Approach

In order to bring out the territorial peculiarities in the best possible way, it was decided to systematically resort to participation (recommended both at European level and in the Italian strategy) which is considered an excellent tool to catch the complex variabilities of territorial biodiversity and its decline.

In other similar expert-based consultations, expert elicitation is often based on the involvement of a few experts, especially on the basis of prestige in academia or research [27,56,57] as for the other Italian regional adaptation strategies. An advanced expert-elicitation approach solves these problems, involving several experts in accordance with both strong knowledge and long experience regardless of their academic relevance at regional or local scale. In this way, experts can interpolate or extrapolate measures of impact when there are no clear metrics to measure in the field [58]. Therefore, our approach aimed to redefine the role of the "expert" not only for their prestige in academia or research. The "expert" has been defined in line with both knowledge and experience at regional or local scale. Therefore, academics, park rangers, freelancers, technicians of the Regional Environmental Protection Agency, members of naturalistic associations, etc. were involved. Thus, people who own a long series of naturalistic empirical observations have been valorized, even if they have never had the opportunity to make their knowledge public and taken into consideration for decisions. Thanks to this inclusive approach, everybody had the same time and way to report personal contributions. Therefore, this allowed obtaining outputs not only based on official publications, dataset, and reports (87 publications analyzed within fauna work groups—which are not listed here—were related to terrestrial invertebrates, birds and mammals), but mostly based on personal observations and valuations of local and regional experts, gray literature, academic works not yet published, etc. In this way, it was also possible to share experience and knowledge between experts belonging to different bodies that are working on the same species or ecosystems. Working in the same worktables and discussing together stimulated new synergies with the aim of contrasting the biodiversity crisis and the impacts of climate change. It encouraged the emergence of new projects that arose from the discussion during the work groups. This approach also made it possible to consider not only widely used taxa (e.g., birds, butterflies and vascular plants) but also other taxonomic groups for which experts were present.

Facilitators should have a working technical knowledge of the topic; they should be neutral and able to diplomatically handle a wide range of people [30]. According to our approach, PhD students and early career scientists have carried out the task of facilitators of the work groups. In this way, the groups were guided by a young expert, who understood the discussion and knew how to manage the interventions, without imposing on people with a longer experience. Therefore, an active involvement of young researchers was carried out enhancing their technical-scientific skills.

5.2. Effective Approach

This approach effectively deals with uncertainties and mixed biases, because it allows to combine different knowledge derived from different communities [59] and thus results are cross-validated. Indeed, expert elicitation faces various uncertainties and mixed biases; however, a well-structured elicitation process can help mitigate some of them [30,60] and allows the building of a comprehensive consensus, essential for the application to the policies. Thanks to our approach, it was possible to get cross-validated outputs as the experts (even those who for personal reasons were unable to participate in the work days) discussed and corrected the suggestions, the opportunistic-data of others and the final results three times: the first time during the work groups, the second time during the plenary, when each group reported their results, while the third time was dedicated to the public return of results. Consequently, the usual biases of expert elicitation were limited.

Moreover, during the work groups the experts discussed and convinced the others about their ideas; therefore, the result was shared by the community of local experts.

In this way, our approach allowed a cross-validated, updated, homogeneous, and complete list of the sectoral impacts of climate change specific to the regional territory; similarly, it allowed the creation of a list of cross-validated adaptive measures specific for the regional case and based on technical-scientific knowledge and experience. Many of these are also useful actions for mitigating purposes. Even if the measures were specific for the Piedmont region and peculiarity, they are aligned with the adaptation macro categories indicated by national documents and represent a declination of the same on the regional environment.

The Piedmont authorities have ratified results of this work with the Deliberation of the Regional Council of 18 February 2022, n. 23-4671. Policymakers recognized the importance of this work because of the great collaborative and inclusive work of such many experts. Indeed, the results were perceived as a shared work derived by the discussion of a large community of scientists, technicians and environmental managers who have adequate knowledge and experience of the territory in question.

5.3. Efficient Approach

To develop CC strategies, the authorities can decide to subcontract external bodies (universities, research institutes etc.) to draft strategies and/or plans for adaptation to climate change [19]. However, the cost for the authority is usually high and for those sectors that need long series of data, this method can't be applied. Indeed, for biodiversity and ecosystems, it is necessary to understand past trends to predict the future. Thus, a huge amount of data is necessary to develop future scenarios. To collect and elaborate these data, a large number of resources and time is necessary (e.g., estimation cost to collect data on farmland in Europe [61]). This approach, through an advance expert elicitation, reduced the expenses and the time need to make those elaborations for the institution and make it possible to fill the past data gaps through expertise and unpublished data of experts. Moreover, the discussion among experts guided towards a more creative approach, being aware that dealing with the climate change impacts is not possible just by learning from the past.

Our approach allowed the achievement of results and the involvement of experts with very limited costs thanks to the experts collaborating for free. It was possible thanks to the sub-national dimension: being at a regional level, most experts had an emotional and working bond for the territory. Moreover, many of these people were both experts and stakeholders.

This approach also allows a quick achievement of results: once they have been defined, the process times are very limited (about 4 months).

5.4. Disclosure-Based Approach

Aiming to cope with the lack of recorded and published data, inputs for complex decision strictly specific to the territory could be built with expert-elicitation [15]. Therefore, our approach wanted to inform regional policymakers thanks to a non-technical summary and technical administrative personnel thanks to the complete report, stimulating them to ratify the results and integrate the identified measures into regional policies, plans, and funding programs. It was one of the aims of publishing results and presenting them in a public event. Moreover, regional action should have the role of supporting national and local adaptation [13]. Our approach allowed the public return of results with the potential to orient both national and local entities (municipalities, cities, parks, etc.), giving them a specific guideline for local adaptation strategies for biodiversity and ecosystems.

The planning and implementation of climate adaptation measures requires the participation of civil society [62]. Indeed, in accordance with the Aarhus Convention, this approach ensured the access to environmental information (Article 4), the collection and dissemination of environmental information (Article 5), and the public participation concerning plans, programs and policies relating to the environment (Article 7) [63]. This approach also allowed the involvement of stakeholders and citizens: they have been informed about the results with the aim of raising awareness about this issue and its solutions; many people followed the public event, i.e., about 2100 people. Piedmont Region allowed the public and environmental non-governmental organizations to make comments, then those observations were taken into account and included in the final document.

Increasing the availability of information on climate change strongly influences the mobilization of youth activists [64]. Therefore, the effectiveness of the disclosure is also demonstrated by the mobilization of many climate movements after the public event. Informed and aware activists have begun to ask regional policymakers for new actions to fight the climate crisis, including the implementation of the results emerged for biodiversity and ecosystems in the SRCC. These requests were then discussed within an open Regional Council focused on climate change on 21 February 2022.

5.5. Limitations of the Proposed Approach

A limitation of this approach is the possible inhomogeneity of the localization of knowledge. The choice of involving experts was carried out to cover the largest number of areas in Piedmont. All the regional protected areas were involved, as well as experts from each Piedmont biogeographical region (Alpine, Continental, Mediterranean). However, the knowledge reported during the work groups could risk not adequately taking into consideration some regional areas, because they are less frequented and studied.

Since the strategies are a set of guidelines that provide indications for adaptation often without binding value, not all the identified measures can be effectively and easily adopted. Implementation depends on multiple factors (costs, feasibility, specific knowledge of technical administrative personnel, political will, etc.), that could face institutional and governance challenges. However, the aim of the approach is not the implementation of the measures, but their identification based on updated, complete and cross-validated reflections. Furthermore, the measures that emerged from the experts have great strength thanks to high sharing, and they offer robust guidance to politicians to assume their responsibilities. Moreover, they have been communicated to a broad audience, including policymakers and technical administrative personnel. In this way, the communication of results is effective and promotes their actual implementation. As a preliminary outcome of this approach, we highlight that the adapted measures are still being implemented in policies, plans and programs in Piedmont Region.

The institutional and governmental challenges of this approach could be the following: the limited presence of institutional staff dedicated to process the costs (even if they are lower compared to other approaches) and to support the organization and implementation of the work groups, the political endorsement, the collaboration between different offices of the same institution and the competence of the institutional staff dedicated to the process.

6. Conclusions

The impacts of climate change are already occurring; therefore, adaptation is necessary and urgent to avoid the worst damages. Subnational authorities all over the world have to play their role in making their territories climate resilient. Since sectoral impacts and adaptive measures strongly differ between subnational territories, specific results are needed. In this paper, an innovative approach is presented, and it could be replicated internationally in other sectors and by other subnational authorities thanks to its advantages (effective, efficient, based on advanced expert elicitation and disclosure) and its limited disadvantages. Strategies, plans or other types of documents at subnational level could replicate the way of analyzing the impacts of climate change on biodiversity and ecosystems and the way of pointing out adaptive measures. This approach could also be used to analyze other sectors that have the same limits of biodiversity and ecosystems (e.g., limited time-series, non-homogeneous data, incomplete and not always reliable modeling). Indeed, it has been similarly applied for the health sector in Queensland (Australia), for which different stakeholders have contributed to develop the regional adaptation strategy [8]. Moreover, it is possible to apply this approach even for the energy sector. The latter is particularly sensitive to climate variability, especially in some regions such as in Africa [65]. Thus, elicitation of local experts belonging to both private and public bodies might be a reasonable approach to identify current impacts and to suggest measures for the territorial realities, introducing new solutions. For example, this approach could be used to identify adaptation choices available on both energy demand and supply sides, their potential, cost and efficiency. By involving all sectoral experts and making them discuss equally (regardless of their institutional role, the notoriety, influence and interests of the private companies), it will be possible to identify adaptation solutions and their existing co-benefits for mitigation [66].

The first application of this approach has been officially recognized by the Piedmont Region with the Deliberation of the Regional Council of 18 February 2022, n. 23-4671. Indeed, the impacts of climate change on other sectors of the SRCC will also be analyzed through the application of this approach. The results of this approach can be implemented in different ways: in regional and local policies, programs, sectoral plans (e.g., Prioritized Action Framework, Rural development programs, Recovery Plan, Action Plans on climate change) in local adaptation strategies and plans, as also suggested by the Covenant of Mayors as well as in the funding distribution programs. Implementation include also the integration of results in the national biennial progress reports that each EU country has to present to the European Union.

Author Contributions: Conceptualization, A.P., S.B., C.S., E.P., R.P., M.B., J.C. and D.C.; methodology, E.P., S.B., C.S. and A.G.; writing—original draft preparation, A.P. and I.P.; writing—review and editing, G.B., A.P., I.P., J.C., E.P., D.C., F.G., R.A., A.B., M.B., R.P., A.D., C.R., E.M., A.G., C.S. and S.B.; visualization, A.P.; supervision, S.B., C.S., E.P., M.B. and I.P.; funding acquisition, A.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Fondazione Giovanni Goria and Fondazione CRT thanks to the scholarship of the project "Talenti della Società Civile". Via Carducci 43, 14100 Asti.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Thanks to all the experts who collaborated in this work. Alberti S., Allegro G., Alma A., Andreone F., Bagnati T., Baltieri M., Barbarino S., Barni E., Barolin D., Baronetti A., Bassano B., Bergero P., Bergò Eusebio P., Bertola A., Bertolino S., Bionda R., Bissacco E., Bissardella F., Bo T., Boggero A., Bonetto D., Borgogno Mondino E.C., Botta Paola E., Bovero S., Buzio S., Caccianiga M., Calvini M., Candiotto A., Caprio E., Celona E., Ceppa L., Cerrato C., Cetara L., Chamberlain D., Chiecchio E., Clemente F., Correggia F., Costa S., Crocetta A., Crua L., Damilano R., Debernardi P., Demeglio B., Domestico A., Donato R., Ebone A., Elia E., Fasano S., Favero Longo S., Fenoglio S., Ferrazzi P., Fila Mauro E., Ferraccini C., Ferregutti A., Foglini C., Franzi L., Fratianni S., Freppaz M., Galvagno M., Garbarino M., Ghigo S., Giaccone E., Giachino PM, Giordano L., Giraudo L., Giuliano D., Giunti L., Gola L., Gottero F., Iacobuzio R., Isaia M., La Morgia V., Lo Conte P., Loglisci N., Lombardi G., Lonati M., Marello L., Marino E., Martinelli L., Marucco F., Masciavè C., Massara M., Maurino L., Mensio F., Meregalli M., Molinari V.M., Motta R., Movalli C., Mucciarelli M., Nazio P., Orusa T., Palestrini C., Paro L., Pastorelli F., Pelassa G., Piano E., Pompilio L., Porporato M., Provenzale A., Quaglio G., Rivella E., Rizzioli B., Rocchia E., Rolando A., Rossi L., Roux Poignant G., Ruco E., Saggese V., Scarinzi C., Selvaggi A., Sgura E., Soldato G., Spada D., Suozzi E., Teppa G., Terzuolo P., Tessa G., Tiso M., Trovò P., Tosi S., Vacchiano G., Varese P., Vercelli M., Vietti D., Viterbi R., Zuffi E.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Current and future impacts for regional biodiversity caused by climate change on vegetation (V) and animals, divided into aquatic invertebrates (IA), terrestrial invertebrates (IT), ichthyofauna (I), avifauna (A), herpetofauna (H), and mammals (M). The identified categories are based on those used in the National Adaptation Plan to Climate Change (PNACC).

	V	IA	IT	I	H	A	M
Changes in Physiological Processes (PHY)							
Changes in photosynthetic activity	•						
Changes in water use and transpiration	•						
Changes in germination biology	•						
Hormonal changes					•	•	
Respiratory process alteration		•		•			
Increase in oxygen consumption rate		•					
Increase in parasitosis vulnerability	•	•	•				
Decrease in time of embryo development				•			
Delay in gonad maturation				•			
Changes in metamorphosis/incubation time					•		
Impacts on aestivation					•		
Changes in neoteny rate					•		
Changes in thermoregulation			•				•
Changes in echolocation							•
Changes in morphology (MOR)							
Changes in wood growth	•						
Changes in size (individuals and/or body structures), in body mass of individuals or structures	•		•	•	•	•	•
Changes in pigmentation					•	•	
Behavioral changes (COM)							
Changes in trophic behavior		•	•	•		•	•
Changes in reproductive behavior			•	•		•	
Changes in locomotion, migration or movement ability		•	•	•		•	•
Changes in phenology (PHE)							
Increase in growing period length and advance in phenology	•						
Advance of migration date					•	•	
Changes in reproductive timing				•	•	•	•
Extension of reproductive period	•			•		•	
Advance of hibernation, wintering end			•		•		•
Advance of metamorphosis, flickering			•	•	•		
Changes in activity period (e.g., peak, fly)			•	•			
Mismatch between molt and habitat						•	•
Changes in spatial distribution (DIS)							
Upshift towards higher latitudes or elevations	•	•	•	•	•	•	•
Colonization of areas previously occupied by glaciers	•						
Decrease or disappearance of habitat linked to water occurrence	•	•		•			

Table A1. *Cont.*

	V	IA	IT	I	H	A	M
Changes in breeding and wintering ranges						•	
Decrease in habitat, microhabitat or ecological corridor availability	•	•	•	•	•		•
Changes in communities' species composition and interactions (COM. INT)							
Community homogenization: increase in generalists and thermophilic species and decrease in specialists	•	•	•	•	•	•	•
Changes in high elevation habitat composition	•						
Changes in the composition of water-linked habitats	•						
Changes in the vertical structure of forest communities	•						
Changes in ecotypes	•						
Laurophyllisation	•						
Selection of broadleaves at the expense of conifers	•						
Decrease in functional diversity		•	•	•		•	
New interspecific interactions (e.g., between previously segregated species or species found in a diminishing habitat)	•		•	•	•	•	•
Increase in hybridization probability				•			•
Increase in predation rate				•	•	•	•
Mismatch between preys and predators						•	
Mismatch between trophic resource and consumer	•	•	•		•	•	•
Local species extinction	•	•	•		•		
Increase in exotic species	•	•	•	•	•	•	•
Increase in parasite damages	•		•				
Increase in algae bloom-induced mortality		•					
Changes in population structures and dynamics (STR. DYN)							
Increase in population fragmentation and isolation				•	•		•
Decrease in reproductive success		•	•	•	•	•	•
Decrease in life expectancy			•		•		•
Decrease in population density			•		•		
Decrease in foraging bee numbers			•				
Decrease in litter size							•
Direct impacts from sudden anomalous events (DIR. I)							
Increase in direct impacts (increase in mortality, decrease in reproductive success) caused by more frequent and prolonged droughts	•	•	•	•	•	•	
Increase in direct impacts (increase in mortality, decrease in reproductive success) caused by more frequent and more severe floods	•	•		•	•	•	
Increase in direct impacts (increase in mortality, decrease in reproductive success) caused by more frequent and extreme high temperatures	•	•	•	•	•	•	•
Increase in direct impacts (increase in mortality, decrease in reproductive success) caused by more frequent and severe fires	•				•	•	•
Increase in direct impacts (increase in mortality, decrease in reproductive success) caused by more frequent and intense hailstorms	•		•			•	

Table A1. *Cont.*

	V	IA	IT	I	H	A	M
Increase in direct impacts (increase in mortality, decrease in reproductive success) caused by more frequent and violent wind gusts	•					•	
Increase in direct impacts (increase in mortality, decrease in reproductive success) caused by an increase in tropospheric ozone	•						
Alteration of the provided ecosystem services (ECO. S)							
Extinction of iconic species						•	
Decrease in contrast function against parasites			•		•	•	
Changes in the function of organic matter degradation		•					
Changes in water purification function		•					
Decrease in animal resources necessary for fishing practices		•		•			
Changes in pollination function	•		•		•		
Decrease or absence of plant nectar and pollen	•		•				
Decrease in honey production			•				
Impacts on the productivity of pastoral activity	•						
Changes in erosion regulamentation	•						
Changes in soil composition and formation	•						
Changes in carbon storage	•						
Changes in precipitation regimes	•						
Changes in albedo	•						
Decrease in landscape diversity	•						
Bioprotection and biodeterioration of cultural heritage	•						
Impacts related to climate change maladaptations (MAL)							
Changes in water habitats caused by artificial banks and post-flood interventions		•		•	•		
Changes in water habitats caused by an increase in irrigation network concreting	•	•		•			
Changes in water habitats and surrounding vegetations caused by energy generation water sampling	•	•		•		•	
Changes in water habitats and surrounding vegetation caused by agricultural water sampling	•	•		•		•	
Increase in the impacts caused by changes induced by climate change in crop choices and practices in agriculture	•		•			•	
Increase in impacts caused by upshifting of skiing activities						•	
Negative second-degree effects of grazing strategies to counteract climate change	•						

Table A2. Identified measures to manage and reduce impacts for both plant (PB) and animal biodiversity (AB). The identified macro-categories and categories are based on those used in the National Adaptation Plan to Climate Change (PNACC). The impact to be managed have the previously presented acronyms; when a measure helps to reduce or manage all impacts the acronym is A. Priorities are indicated with a color code: red is high, orange is medium and yellow is low priority.

Macro-Categories	Categories	Impact to Manage /Reduce	Measures	Priorities for AB	Priorities for PB
Information	Research, Evaluation, Monitoring, Data, Models	A	Identification and prioritization of populations, species, and target habitats	red	red
		A	Implementation of regionally coordinated monitoring of target populations, species, and habitats based on precise and shared guidelines	red	red
		A	Realization of an atlas of target populations, species and habitats, reporting data and monitoring results	orange	yellow
		A	Integration of climate projections and area predicting models	red	red
		A	Implementation of laboratory research on the impacts of climate change on biodiversity, with a focus on target species	red	yellow
		A	Implement research on ES and economic evaluation	yellow	
		COM_INA	Maintenance and strengthening of germplasm banks	orange	
		PHE, DIS, COM_INA	Investing in an improved pollen network	orange	
		COM_INA	Implement data on wind crashes	yellow	
		COM_INA	Mapping of alien species' ranges	red	
		COM_INA	Define and set up reporting and alert modes	red	
		A	Identify target species/habitat monitoring areas		red
		PHY, MOR	Implement the preparation of reference samples		yellow
		A	Define impact mechanisms and thresholds		orange
		A	Implementing Management Guidelines for Vulnerable Species/Habitat Populations		yellow
		A	Development of future scenarios to predict the effectiveness of the applied measures		yellow
	Disclosure, perception, awareness, and education	A	Professional training and dissemination of good practices, involving both local administrators and land managers; for example improved communication and collaboration with farmers, sector technicians and beneficiaries of Rural Development Program funds	red	red
		A	Implement the dissemination and involvement of citizens (information campaigns, citizen science, school education)	red	orange
		A	Sensitize the users of the territory for recreational activities		red
Governance	Adjustments of regulations, plans, programs, and strategies	A	Expand suitable areas for the conservation of priority species and habitats: expansion of regional and national protected areas, the Natura 2000 network, and the regional ecological network.	orange	red
		COM_IN	Reinforcement of regulations for the management of alien species	red	red

Table A2. *Cont.*

Macro-Categories	Categories	Impact to Manage /Reduce	Measures	Priorities for AB	Priorities for PB
		A	Increased regulation and control of impacting recreational activities and prohibition of hunting of vulnerable species		
		A	Integrate the theme of fighting the impacts of climate change in the Guidelines for the drafting of Natura 2000 Network Management Plans, Action Plans and wildlife management, etc.		
		COM_IN	Realization of an Emergency Plan with steering committee to manage pathogens		
		A	Implement the Water Protection Plan —2018 revision		
		A	Update the Regional Forest Plan		
		A	Update the Civil Protection Plans		
		A	Update the List of plant species under Absolute Protection		
		COM_IN, STR_DYN, ECO. S	Increased regulation of halieutic inputs		
		DIS	Design of new extensions for wildlife-friendly winter sports facilities		
		A	Enter by law the calculation of CO_2 emissions during construction stage		
	Economic and financial tools	A	Improving the management and implementation of climate change-related RDP funds		
		A	Directing compensation for adaptation measures		
		ECO. S	Application of payments for SE under L. 221/2015		
		MAL	Reduction of incentives for new impacting facilities		
		A	Set up implementation of LIFE funding on climate and biodiversity, by private foundations, by PNRR projects		
	Path	A	Promote a suitable pastoral management		
		A	Promote a suitable forest management		
		A	Promote a suitable agricultural management		
		COM_INT	Promote the usage of local hayseed		
		A	Natura 2000 network management, effectively applying conservation measures		
		A	Ensure better management of the amount of water intake: – Strengthening of controls to accurately quantify water intakes – Prioritizing water concessions – Establishment of a register of water-intaking structures – Adjustment of the Environmental Flow calculation – Restructuring of water concessions – Focus on water concession impact assessments – Improved maintenance of the irrigation grid – Counteract water waste		

Table A2. *Cont.*

Macro-Categories	Categories	Impact to Manage /Reduce	Measures	Priorities for AB	Priorities for PB
		COM_INT	Counteract the increase in pathogen damage		
		COM_INT	Encourage the reduction in ozone precursors		
		A	Encourage to stop/reduce land usage		
		A	Prioritization of specific conservation actions		
		A	Increase multifunctionality and multidisciplinarity		
		A	Ensure increased water quality		
		A	Make riverbed interventions compliant with wildlife's needs		
		A	Ensure longitudinal ecological continuity along watercourses		
		A	Promote a more suitable public green management		
		A	Implement and support good practices in beekeeping		
		COM_INT	Develop a strategy to limit the negative impacts of alien species		
Organizational and participatory processes	Partnership and participation	A	Promote interregional coordination		
		A	Improve coordination/collaboration between biodiversity protection related areas		
	Institutions	A	Establish an intervention group for the eradication of alien species		
	Organization and management	A	Establish a permanent working group on "Climate change and biodiversity"		
Adaptation and improvement of plants and infrastructures	Machinery, materials, and technologies	COM_INT	Encourage the realization of fish ladders and check those already in place		
		A	Encourage a new net of passages/crossings		
		A	Encourage a new net of passages/crossings		
Nature-based solutions	Integrated solutions	A	Promote restoration, creation and protection of wetlands		
		A	Implement assisted translocation		
	Forest, agro-forest and river ecosystems	A	Promote restoration and protection of bank's wooded areas		
		DIR. I	Encourage fire prevention with prescribed fire, fender strips, etc.		
		A	Implement green urban infrastructure		
		A	Encourage forestry and sustainable arboriculture		
		A	Encourage naturalistic engineering		
		A	Increase planting of native trees, shrubs, and herbaceous plants		
		A	Promote the redevelopment of secondary areas of the watercourse		

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