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Designing Inter- and Transdisciplinary Research on Mountains: What Place for the Unexpected?

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In recent decades, research on mountains has become more inter- and transdisciplinary, but a greater effort is needed if such research is to contribute to a societal transformation toward sustainability.

Mountain research centers are a crucial actor in this endeavor. Yet, the literature has not paid sufficient attention to how these centers should (re-)design inter- and transdisciplinary research. In this study, we explored this question with a self-reflexive approach. We analyzed the first 15 months of the Interdisciplinary Centre for Mountain Research (CIRM) of the University of Lausanne (Switzerland) through qualitative data collected via interviews and observation. We used a simple model of inter- and transdisciplinarity at the organizational level of a research center. Special attention was devoted to the individual and collective ability to exploit the unexpected (serendipity). Our results indicate an interdependency between the coconstruction of research

objects and the creation of integrative partnerships. They also shed light on the types of institutional resources and integrative methodologies that enhance inter- and transdisciplinary research, as well as their challenges. Our experience shows that implementing inter- and transdisciplinarity requires deep changes in research evaluation procedures, research funding policies, and researchers themselves. Serendipity is in turn shown to play an important role in inter- and transdisciplinarity due to its potential to change the research process in creative ways. We speculate that serendipity offers unique opportunities to capitalize on hidden resources that can catalyze a radical transformation of mountain researchers, research organizations, and society in the face of unprecedented global change.

Keywords: interdisciplinarity; transdisciplinarity; mountain research; research center; transformation; sustainability; self-reflexivity; serendipity; CIRM.

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Introduction

The rise of mountains in the global scientific and political agenda during the last decades has gone hand in hand with the encouragement of inter- and transdisciplinary research. The mountain project within the Man and Biosphere program conducted by the United Nations Educational, Scientific and Cultural Organization (UNESCO), which

started in the 1970s, stimulated the integration of the natural and the social sciences to reach a balance between ecosystems and human activities (Messerli and Messerli 1978; Messerli 2012). Since then, numerous research centers and programs on mountains have been created. Many of them have a strong emphasis on integrating different scientific disciplines and nonacademic stakeholders for sustainable development (Hurni et al 2003; Glass et al 2013; Attali et al

2014; Liechti 2014; Roux et al 2018; Reynard et al 2020). The organization of frequent international conferences and the creation of peer-reviewed journals like *Mountain Research and Development* were likewise aimed at supporting inter- and transdisciplinary research to promote the sustainability of mountain regions.

Published reviews indicate that mountain research is becoming more interdisciplinary, but greater effort is needed if such research is to contribute to a societal transformation toward sustainability (Bjørnsen Gurung et al 2012; Gleeson et al 2016; Martín-López et al 2019). However, the literature has not paid sufficient attention to how research centers could better design inter- and transdisciplinary research to support this endeavor. The goal of this study was to shed light on this gap by examining the first 15 months of the Interdisciplinary Centre for Mountain Research (CIRM in its French acronym) of the University of Lausanne (Switzerland). In this article, *interdisciplinarity* refers to a dialogue between scientific disciplines whereby a common research object is coconstructed, whereas *transdisciplinarity* refers to an integration of scientific disciplines and other knowledge types mostly aimed at solving complex problems; see Appendix S1 (*Supplemental material*, <https://doi.org/10.1659/MRD-JOURNAL-D-20-00036.1.S1>). We focused specifically on serendipity (ie the ability to exploit the unexpected) within inter- and transdisciplinary research centers. Whereas serendipity is an important creative process in science, which has led to crucial discoveries for humanity, it has received almost no attention in inter- and transdisciplinary studies on mountains and in general.

Inter- and transdisciplinarity in mountain research

The literature reviewed in this study identified several factors that enable successful inter- and transdisciplinary collaborations. At the project level, active management of communication among participants was considered necessary to create common trust when scientists from different disciplines or nonacademic stakeholders are involved (Höchtl et al 2006; Sheate et al 2008; Ritter et al 2010; Brand et al 2013; Huber et al 2013; Renner et al 2013; Mitchell et al 2017). Appropriate conflict management through facilitation was found to be crucial for enhancing the transformative capacity of transdisciplinary projects (Otero et al 2018). Accurate selection of stakeholders' representatives and strategies to ensure their active participation were likewise key factors (Renner et al 2013). Developing common research questions fruitful to all disciplines involved in a project was also considered a key feature, as was joint problem definition with nonacademic stakeholders (Höchtl et al 2006; Huber et al 2013; Mitchell et al 2017). The selection of an approach that appealed to these stakeholders was likewise stressed. For instance, addressing crucial aspects, such as farming (Shakya et al 2019) or livelihoods (Sheate et al 2008), and collaboratively creating tools that could help them to adapt to climate change (Deléglise et al 2019; Welling et al 2019) had a strong appeal. However, as the time needed for building contacts with stakeholders can slow the research process, flexibility by funding agencies regarding project delays was also considered to be important (Höchtl et al 2006).

At the level of research centers and programs, several articles reported on factors that facilitated inter- and transdisciplinarity: multi-stakeholder partnerships combining research, planning, and decision-making for sustainable development (Hurni et al 2003; Liechti 2014); seminar series for academics and stakeholders (Bergier 2006; Roux et al 2018); joint books on a common research topic allowing the reinterpretation of disciplinary knowledge (Attali et al 2014); the use of graphic time lines as “boundary objects” that could facilitate dialogue between disciplines (Bergeret et al 2015); the availability of “contingency funds” to adjust to emerging ideas (Mitchell et al 2017); and international cooperation in more or less formal agreements, such as the Mountain Partnership and the Alpine and Carpathian conventions (Ross 2006; Veit and Scheurer 2006; Messerli 2012; Scheurer et al 2013).

The literature also highlighted several challenges for inter- and transdisciplinary research. A major challenge identified across different levels stems from the integration of heterogeneous scientific cultures. In their evaluation of a research program in the Australian Alps, Mitchell et al (2017) reported a lack of a shared conceptual framework as well as epistemological misunderstanding between disciplines, despite having hired a facilitation team. Besides facilitation, other approaches that proved useful to improving interdisciplinary integration were: establishing an “interdisciplinary workflow” that clarifies the interactions between the disciplines involved in the project (Huber et al 2013); having a “chronicle” that documents the interactions through which research is done (Deffontaines et al 1982); and being explicit about temporal overlaps when integrating heterogeneous data sources (Nadal et al 2009; Otero et al 2015).

At the project level, a crucial challenge is how inter- and transdisciplinary research can support the implementation of appropriate governance systems for mountain sustainability (Huber et al 2013; Martín-López et al 2019). Models synthesizing the dynamics of mountain social-ecological systems were deemed useful to support efforts for societal transformations in this direction (Klein et al 2019). In addition, policy network analysis was found to be suitable for understanding the governance structures preventing the implementation of sustainability policies (Huber et al 2013). Joint work with stakeholders was highlighted as crucial to integrate local decision-making processes in models of social-ecological systems and to project realistic scenarios (Huber et al 2014). In particular, a strategic mobilization of the expertise of stakeholders at different scales, together with a combination of bottom-up and top-down decision-making in the project partnership, was considered to enhance the project's transformative potential (Otero et al 2018). A crucial condition identified for successful inter- and transdisciplinary research was to ensure the long-term continuity of project partnerships once the funding finishes (Deffontaines et al 1982; Brand et al 2013; Otero et al 2018).

At the level of research centers, a challenging question that remains open is: To what extent is the transdisciplinary research they promote able to trigger true sustainability transformations (Schneider, Giger, et al 2019)? A key need identified for research centers is to move from rewarding only disciplinary work to also rewarding inter- and transdisciplinarity (Taylor and Krause 2004; Bjørnsen Gurung et al 2012). This could reduce researchers'

reluctance to work on interdisciplinary papers because they perceive them as being less valuable for individual career progression (Sheate et al 2008). However, for this to be possible, a shift in science funding policy toward a stronger support for inter- and transdisciplinarity seems necessary (Gleeson et al 2016). To sum up, a considerable amount of information on inter- and transdisciplinary research on mountains exists for projects, but it is scarce for research centers.

Serendipity: welcoming the unexpected in organizations

Inspired by Khusro's tale *The Three Princes of Serendip*, Walpole created the term "serendipity" in 1754. Since it was coined, serendipity has been considered a double-trigger process: The researcher accidentally confronts an unexpected phenomenon, object, or idea that s/he was not looking for and, thanks to her/his intellectual sagacity, is able to use it to create a new theory, method, or technology (Andel 1994; Merton and Barber 2004). Chance is not enough for serendipity to occur; it is also necessary to be cognitively ready (individually and collectively) to turn it into something that advances knowledge. All discoveries made by serendipity, including Archimedes' principle, deoxyribonucleic acid (DNA), aspirin, nylon, Post-it notes, X-rays, and Velcro®, are characterized by a moment of surprise or astonishment followed by a correct interpretation of this moment.

The relationships between serendipity and interdisciplinarity are just starting to be explored (Darbellay et al 2014). The exploitation of unexpected findings is an opportunity to develop a disciplinary paradigm, to transform a disciplinary paradigm (by bringing it in contact with concepts, theories, or methods from other disciplines), or even to create new interdisciplinary fields. Serendipity is thus likely to make a discipline evolve more or less radically. For example, Fleming's discovery of penicillin had a strong influence on bacteriology and therapeutic applications, and the discovery of DNA revolutionized biology by creating contacts with physics and chemistry.

Serendipitists have a taste for interdisciplinarity, or even indisciplinarity, as questioning a disciplinary paradigm makes the detection of the unexpected possible (Darbellay 2020). The question arises, though, as to which conditions favor serendipity in an academic organization, namely, the means and environment provided so that researchers can open themselves to the unexpected, detect it, and use it in inter- and transdisciplinary research (Cunha et al 2010; Murayama et al 2015; Darbellay 2020). Whereas, by definition, it is impossible to plan for the unexpected, it seems worth asking how a research center on mountains should be designed to capitalize on it when it occurs.

The Interdisciplinary Centre for Mountain Research of the University of Lausanne

The Interdisciplinary Centre for Mountain Research (CIRM) of the University of Lausanne (UNIL) is a 4 year pilot center inaugurated in November 2018. It is one of UNIL's 5 interdisciplinary centers that aim to bring together researchers from various faculties around a common

research object. It has 3 goals within the overall mission of contributing to the sustainability of mountain regions: (1) promoting disciplinary and interdisciplinary research on mountains; (2) developing projects oriented toward the expectations of mountain communities (transdisciplinarity); and (3) disseminating research results. The annual budget is CHF 500,000 (approximately US\$ 564,600; 75% for research and outreach, 25% for administration).

The center was built on the basis of 3 existing projects: (1) RechAlp, which aimed to concentrate research efforts in the Alps of the Canton of Vaud to encourage interdisciplinarity (Von Däniken et al 2014); (2) Ebibalpin, aimed to enhance bibliographical resources for students in a valley of the Canton of Valais; and (3) inAlpe, a series of popular science actions in the Alps of the Canton of Vaud. During the preparatory phase of CIRM (2018), a survey among UNIL's professors created an initial network of 45 members from 5 faculties, and the center's management structures and 2 priority regions (Alps of Vaud and Valais cantons) were validated.

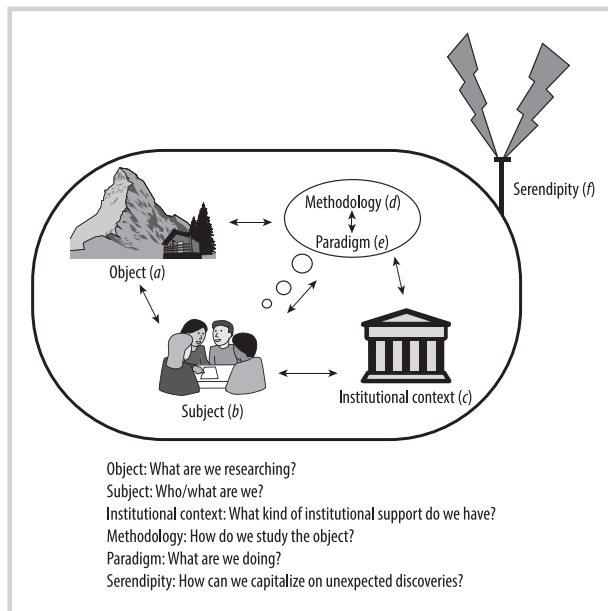
The center has a board, an assembly, and an executive staff. The board is the body that makes all strategic decisions and meets twice a year. It includes academic representatives from the 5 faculties involved, and political and social representatives from the 2 priority regions. One aim of the board is to promote dialogue between research efforts and the concerns of society. The assembly brings together CIRM's members once a year. It does not have a decision-making role but gathers members' concerns and ideas. The executive staff includes the center's employees (in charge of coordination, communication, and administration) and a director. They implement the policy adopted by the board and the ideas expressed at the assembly. As of May 2020, CIRM had 82 members (UNIL's professors, researchers, and doctoral students) and 14 partner institutions.

CIRM has developed a number of instruments to promote inter-/transdisciplinary research and outreach: (1) an annual call for members and partners to propose projects for seed funding (4 projects were funded in 2019; see Appendix S2, *Supplemental material*, <https://doi.org/10.1659/MRD-JOURNAL-D-20-00036.1.S1>, and 4 were funded in 2020, not analyzed in this article); (2) a call for 2 year postdoctoral positions (4 were selected in 2019; see Appendix S2, *Supplemental material*, <https://doi.org/10.1659/MRD-JOURNAL-D-20-00036.1.S1>); (3) funds for the organization of events, available to members and partners; (4) a seminar series; (5) workshops; and (6) a dissemination conference series in towns and villages of the 2 priority regions. See Reynard et al (2020) for an extended description of the center.

Methods

We used a self-reflexive approach to explore the inter-/transdisciplinary research we are engaged in at CIRM and identify how to improve this effort. *Reflexivity* is "the fact of someone being able to examine his or her own feelings, reactions, and motives (...) and how these influence what he or she does or thinks in a situation" (CUP 2020). In social sciences, a *reflexive* approach considers the effect of the presence of the researcher (subject) on what is being investigated (object), and a *self-reflexive* approach fuses subject

FIGURE 1 Model of inter- and transdisciplinary research. For a description of each component, see Appendix S3 (*Supplemental material*, <https://doi.org/10.1659/MRD-JOURNAL-D-20-00036.1.S1>). (Source: Our own ideas and Darbellay et al 2016)



and object (Popoveniuc 2014). Self-reflexive approaches are deemed useful for the continuous evaluation of transdisciplinary research processes (Lang et al 2012). In particular, they have been used to diagnose research centers because they allow for an in-depth analysis of inter-/transdisciplinarity while fostering learning on how to improve it among participants (Otero et al 2017; Schneider, Giger, et al 2019).

As a basis for our self-reflexive exercise, we collected qualitative data via semistructured interviews and observation notes (Bernard 2002). Data were collected by the first author (CIRM's coordinator) and span from CIRM's inauguration (November 2018) to the end of the first seed funding program (January 2020). Data collection was embedded in CIRM's daily activities where self-reflexivity by participants was encouraged via different means explained below.

Semistructured interviews were conducted with a sample of 8 CIRM researchers to explore the inter- and transdisciplinarity under way, including: researchers' motivations, projects' goals, integration of disciplines and stakeholders, learning, challenges, success factors, and serendipity. Interviews were thus used as both data sources and self-reflexive devices. Interviewees ranged from PhD student to full professor and belonged to 4 different faculties. They comprised 6 men and 2 women (gender ratio of CIRM). All were active in at least 1 CIRM activity. Five are coauthors of this article (M.-E.P., G.P., A.F., M.d.V., C.C.). Interviews were conducted in French or English by the first author between March and December 2019. They lasted about 30 minutes each and were summarized based on notes taken during the interviews and/or audio recordings. In January 2020, written follow-up questions were posed to those interviewees who were leading a project under the first seed funding program ($n = 4$).

Observation notes on CIRM's inter- and transdisciplinary research were taken by the first author during 3 workshops and 2 general assemblies. The goal of these activities was to self-examine CIRM and advance inter- and transdisciplinary collaboration. In some cases, they were facilitated by a professional, who used *collective intelligence* techniques to activate the groups' creative potential (Strawberry Fields 2012). These activities were attended both by CIRM members (belonging to UNIL) and representatives of partner institutions. Most of the coauthors participated. Observation focused on collaboration between disciplines, the role of nonacademic stakeholders, and challenges and proposals to advance inter- and transdisciplinarity.

Summaries of interviews and of observation notes were coded in ATLAS.ti for Mac by the first author. Codes were based on a model of inter-/transdisciplinary research (Figure 1) developed from our knowledge of the literature and from the analytical categories used by Darbellay et al (2016) to diagnose interdisciplinarity in Switzerland. A code was created for each model component (Object, Subject, Institutional Context, Methodology, Paradigm, and Serendipity). "Serendipity" was included to explore the productive use of unexpected discoveries based on Darbellay et al (2014). Material coded under each component was synthesized and qualitatively analyzed to capture patterns within and across components. Preliminary results were discussed with coauthors and other CIRM members in several self-reflexive meetings. Their feedback was gathered, and subsequent data collection and analysis were adapted accordingly in an iterative process. The last coauthor meeting was used to brainstorm potential measures to favor serendipity. Data gaps were filled by ex-post assessment, and internal documents, like board minutes, research projects, and reports, were used as supplementary data (not coded). The literature review was done collectively by a subteam of coauthors.

Results

Diagnosing inter- and transdisciplinarity at CIRM: achievements and challenges

The detailed results for model components *a–e* are presented in Table 1 (model components and guiding questions refer to Figure 1). Here, we synthesize their interactions to illustrate how inter- and transdisciplinarity could be (re-)designed in a research center and indicate some of the challenges ahead (for detailed information on projects, see Figure 2 and Appendix S2, *Supplemental material*, <https://doi.org/10.1659/MRD-JOURNAL-D-20-00036.1.S1>).

The coevolution between research object and subject (a–b): At CIRM, the object (*a*) and the subject (*b*) turned out to be interdependent. For example, a better understanding of the Roman period in the Alps (*a*) was enabled by an expansion of the team from a single discipline to several collaborating disciplines (*b*) (project #3), and the need to understand ice deformation patterns at the Gorner glacier (*a*) required the integration of additional expertise in the initial team (*b*) (#9).

CIRM researchers were not only interested in several components of the mountain social-ecological systems (Figure 2), but also in the implementation of interdisciplinarity itself. For example, a limnologist in charge of a seed project (#5) said that her team was

TABLE 1 Summary of results by model components (Figure 1).

Component	Guiding question	Results
Object (a)	What are we researching?	<ul style="list-style-type: none"> • Components of and interactions within mountain ecological systems (Figure 2) • Components of and interactions within mountain social systems (Figure 2) • Interactions between the mountain social and ecological systems (Figure 2) • Inter-/transdisciplinarity and its implementation
Subject (b)	Who/what are we?	<ul style="list-style-type: none"> • Partnerships of different disciplines within the natural sciences (eg glaciology, geomorphology, and geophysics), within the social sciences (eg human geography and political science), or across the natural and social sciences (eg hydrology, limnology, human geography, and tourism studies) • Partnerships of researchers and local/regional nonacademic stakeholders (in projects about climate change adaptation) • Variable and dynamic subject compositions across projects and time • A desire to enable a continuum between basic research and decision-making • Inter- and transdisciplinarity as a risk and an opportunity for academic careers (Box 1)
Institutional context (c)	What kind of institutional support do we have?	<ul style="list-style-type: none"> • Seed funding program: opportunity to conduct inter-/transdisciplinary projects while weighing risks for careers • Financial support for the organization of inter-/transdisciplinary events • Research seminars, seed funding, and postdoctoral workshops: space to learn about interdisciplinarity and to exchange between contrasting perspectives (natural vs social sciences and hypothetico-deductive vs inductive methods) • Governance structure: framework to operationalize inter-/transdisciplinarity • Creation of a network of partners to favor inter-/transdisciplinary collaborations • Need for new evaluative standards rewarding inter-/transdisciplinary experience at UNIL
Methodology (d)	How do we study the object?	<ul style="list-style-type: none"> • Common study site and research questions across disciplines, answered by complementarity • Methodological codesign in participatory workshops, including facilitation techniques • Facilitation and <i>collective intelligence</i> techniques focusing on the personal and collective skills necessary for inter- and transdisciplinarity • Methodological distance between disciplines influences integration effort (eg integrating quantitative and qualitative disciplines is more challenging than integrating methodologically equivalent disciplines) • Need for training on integrative methods across the natural and social sciences, and on communication and conflict management
Paradigm (e)	What are we doing?	<ul style="list-style-type: none"> • Integration of different disciplines as an opportunity or even necessity to advance ongoing (disciplinary) research (eg from a limited to a deeper understanding of a glacier's ice-rock interface), where nonacademic stakeholders and general public are mostly seen as recipients of results via dissemination (\approx <i>interdisciplinarity</i> but close to <i>multidisciplinarity</i>; Appendix S1, <i>Supplemental material</i>, https://doi.org/10.1659/MRD-JOURNAL-D-20-00036.1.S1) • Integration of diverse legitimate stakeholders, including nonscientific ones, in knowledge coproduction, which is considered necessary to tackle complex sustainability problems; question division of experts/lay people; address needs of non-academic stakeholders during projects; undertake self-reflexivity about research usefulness and legitimacy (<i>transdisciplinarity</i>; Appendix S1, <i>Supplemental material</i>, https://doi.org/10.1659/MRD-JOURNAL-D-20-00036.1.S1)

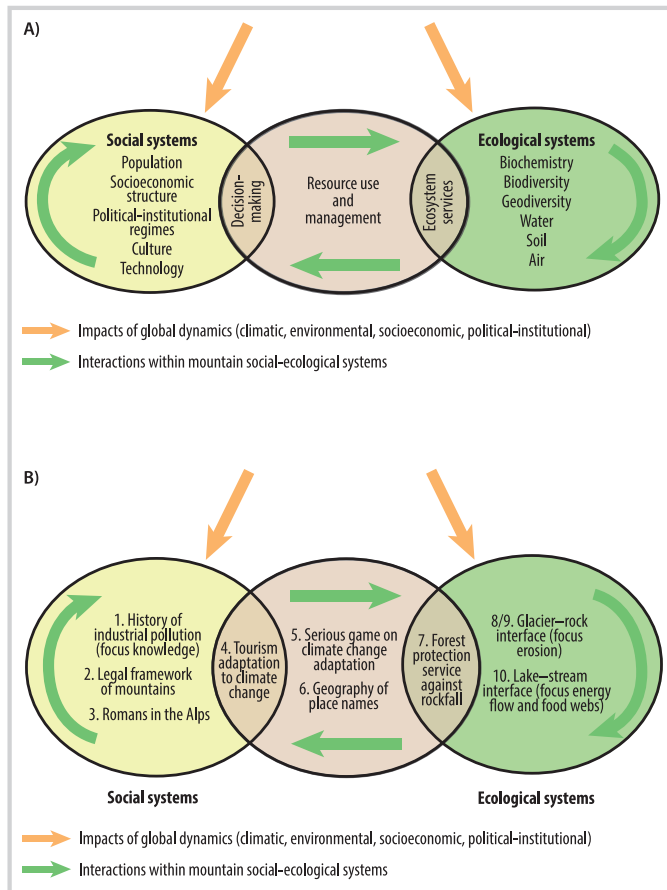
interested in finding out how their knowledge of different components (lake, glacier, vegetation) could be integrated to model a landscape as a whole. Similarly, a linguist leading another seed project (#6) asked himself how linguistics could be integrated with the natural sciences.

In these and other projects, the importance of constructing a research object (*a*) relevant to all participants (*b*) emerged, especially when working with nonacademic stakeholders. In this sense, the limnologist stressed the need to “respect everyone’s expertise, by making an object of study that is of interest to all” in order to tackle complex problems like climate change adaptation. The will to integrate different disciplines and stakeholders in a collaborative subject (Table 1, *b*) was expressed in the position adopted by CIRM in a strategic document, wherein

the center was defined as a “catalyst of fruitful transdisciplinary collaborations” enabling a “continuum” among basic research, applied research, and decision-making toward sustainability.

Yet, despite the creation of a wide network of researchers and partners, the integration of certain knowledge domains (psychology, business) and decision-makers (municipal and regional authorities) will require additional efforts. For this endeavor, our experience suggests that: (1) intermediaries (trusted by both researchers and practitioners) play a crucial role, and (2) getting to know the research needs of nonacademic stakeholders is a challenging task that requires adapting the methods to different geographic and institutional contexts.

FIGURE 2 (A) Representation of mountain social-ecological systems, adapted from Björnens Gurung et al (2012), in turn based on GLP (2005); (B) CIRM's projects analyzed in this article located in the mountain social-ecological systems according to their research object (for information on the projects, see Appendix S2, *Supplemental material*, <https://doi.org/10.1659/MRD-JOURNAL-D-20-00036.1.S1>). Projects #1–3 focus on aspects related to human settlements and socioeconomic activities, while projects #8–10 study biophysical aspects. Two projects focus on the interactions between social and ecological systems while remaining at one of the borders: #4 explores how certain socioeconomic activities adapt to a warming ecological system, and #7 looks at how a change in the ecological system affects the services it provides to the social system. #5–6 are situated at the interface between the two systems.



Institutional support: promoting inter- and transdisciplinary subjects (c–b): Our data suggest that the possibilities that the subject (b) had to conduct inter- and transdisciplinary research were enhanced by CIRM's institutional support (c), in particular, seed funds, financial support for the organization of events, and the governance structure. The seed funds were generally perceived by beneficiaries as a good opportunity to conduct pilot inter- or transdisciplinary projects, which would otherwise have been difficult to develop. One seed project leader (#5) considered this support a “luxury,” as it allowed her team to assess the feasibility of an innovative idea “while weighing the risks for [their] disciplinary careers” (Box 1). She stated that, in so doing, CIRM contributed to changing the way she conducts research. Both she and another seed project leader (#4) considered it helpful that the seed funding program was flexible enough to accept changes in the initial plans of the project, including the possibility of failure, which allowed them to work without pressure and to adapt the methods to (unexpected) contributions from participants.

BOX 1: Inter- and transdisciplinarity: a risk and an added value for academic careers

Inter-/transdisciplinarity and the construction of a collaborative subject were mentioned by some CIRM researchers as a risk. They said that, as they are time-consuming, these activities reduce time available for disciplinary work, which is the basis for career assessment. However, researchers also perceived that the participation in CIRM's projects had an added value for their careers. These projects allowed them to:

- Make important discoveries in their own field;
- Expand their research through new approaches and colleagues;
- Test a new idea or method;
- Acquire complementary skills in project management and participatory research;
- Acquire new knowledge on certain topics and methods within and outside their disciplines;
- Make their knowledge more holistic;
- Make their science more relevant for the general public via alternative communication methods;
- Question the societal interest of their research.

The financial support given to CIRM members for the organization of events was particularly welcome. A historian declared he was “very happy with the support that CIRM gave to the symposium that [he] organized” on the Roman period in the Alps, which complemented other funding sources. A PhD student in evolutionary biology likewise highly appreciated the center's support for the organization of a “knowledge dialogue,” where stakeholders and researchers could exchange their experience on the valley where she was conducting her research. She expressed that such support allowed her to acquire dissemination and participatory skills that would not have been possible within the scope of her PhD (Box 1). Seminars and workshops provided additional learning space (Table 1, c).

CIRM's governance structure was a crucial resource. Iterative decision-making among the members (in the assemblies and workshops), the board, and the executive staff enabled the implementation of inter- and transdisciplinarity. In the first general assembly (November 2018), external researchers were invited to present inter- and transdisciplinary projects and theory. Then, the members' priorities regarding inter- and transdisciplinary research were accounted for, with a view to designing CIRM's future activities. Workshops with a professional facilitator were suggested as a potential way to find out how to encourage inter- and transdisciplinarity. The executive staff subsequently organized workshops with facilitation, which led to a set of proposals that were later approved by the board and (partially, to date) implemented. One proposal was to develop new career evaluation standards at the level of UNIL that value inter- and transdisciplinary experience, including knowledge coproduction with nonacademic stakeholders. This proposal was later approved by the board.

Whether or not it will be developed and how far it will reach in changing the university's current organization will test the transformative potential of a pilot center like CIRM.

Which methods and for what? (-d-): CIRM researchers used a wide array of methods to integrate different fields of expertise, but training on integrative methods (across the natural and social sciences), and on communication and conflict management, was identified as a need to further encourage inter- and transdisciplinarity (*c-d-b*; Table 1, *d*).

Having a common study site around which different disciplines interacted to answer joint research questions turned out to be a key methodological approach. An archaeological site in Entremont valley, for instance, triggered a better understanding of the Roman period in the Alps via the collaboration of historians, archaeologists, linguists, and soil scientists (#3), and a new glacial erosion model was tested at the Gorner glacier through joint work among glaciologists, geophysicists, and geomorphologists (#8, #9). In both cases, research questions were posed that could only be answered through collaboration, leading to insights that would have not been possible with disciplinary research alone (*d-b-a*). These projects adhered to the paradigm of interdisciplinarity, even if they were not very far from multidisciplinary (Table 1, *e* and Appendix S1, *Supplemental material*, <https://doi.org/10.1659/MRD-JOURNAL-D-20-00036.1.S1>).

Another successful approach was methodological codesign, where nonacademic stakeholders contributed to shaping research methods in participatory workshops. This was the case of the seed project on adaptation of high mountain tourism to climate change (#4). According to the project leader, this approach involved a double role for his team, as they had to pull the expertise from nonacademic stakeholders (as facilitators), while also providing their own expertise (as scientists), and then combine both (*d-b*). The development of a prototype of a serious game on adaptation of an Alpine landscape to climate change (#5) was likewise codesigned between researchers and nonacademic stakeholders, but the workshop was conducted by professional facilitators. While explaining that the integration of the expectations of the participants made the prototype very different to what she had in mind at the start of the project, its leader stressed that “the advantage of going through a facilitation team is that one detaches oneself from personal preconceptions” (*d-b-a*). These methods were used by projects falling within the paradigm of transdisciplinarity (*d-e*; Table 1, *e* and Appendix S1, *Supplemental material*, <https://doi.org/10.1659/MRD-JOURNAL-D-20-00036.1.S1>).

Facilitation indeed played a crucial role in the workshops organized by CIRM to enhance inter- and transdisciplinarity. Described as “a very well-structured bottom-up process” by one participant, these workshops used a *collective intelligence* approach. This allowed participants to focus on the personal and collective skills necessary to operationalize inter- and transdisciplinarity: cooperativeness, the ability to understand each other, balance, focusing less on one's own actions, participatory inclusiveness, trust in the collective, leadership, and coordination (*d-b*). The smiles of participants and a general atmosphere of joy reminded the team that working collectively can and should be fun. In the collective evaluation of the first workshop, this approach was

regarded as particularly useful to deal with the human factor, which is crucial for the success (or failure) of a research center. However, it also raised the question of which kind of institutional support and methods should be provided to enable the acquisition of the mentioned skills by researchers, and how this could eventually change their paradigm toward deeper visions of inter- and transdisciplinarity (*c-d-b-e*).

Serendipity at CIRM: what place is given to the unexpected?

Our data revealed early signs of serendipity (*f*) affecting different model components (*a-e*) within projects, across projects, and at the level of our research center.

For the leader of the Gorner project (#9), having a common study site across disciplines was intended as a way to favor interactions leading to unexpected outcomes. In his project, geophysical exploration indicated a pattern of ice deformation that was not predicted by theory (*f-a*). After evaluating the unexpected finding, the team concluded that it was due to a methodological limitation and decided to use an alternative method to verify it further. The serendipitous attitude of the team (being alert to and assessing unsought findings with help from different disciplines) was thus part and parcel of interdisciplinarity (Box 2).

Unexpected occurrences were also reported in transdisciplinary projects. In the project on adaptation of high mountain tourism (#4), nonacademic stakeholders questioned the methods that had been planned by the scientists (*f-b, d*). They claimed that the use of a survey to capture changes in tourist practices was unnecessary as better data sources existed. Following this unexpected input, scientists decided to withdraw the survey from the methodology and adapt their approach accordingly. A similar thing happened during the codesign of the serious game prototype on the adaptation of Alpine landscapes to climate change (#5). The prototype turned out to be very different from what scientists initially had in mind (*f-a, b, d*). In both cases, scientists could adapt their project since the codesign principle that they had chosen was based on adapting to (unexpected) contributions from participants. In other words, they were prepared for the unexpected to happen and ready to capitalize on it. This suggests that project codesign, common in transdisciplinarity, is, by definition, a serendipitous endeavor.

With regards to serendipity across projects, the management of teamwork among CIRM's 4 postdoctoral researchers illustrates how some space was given to the unexpected. Top-down and bottom-up decision-making, outdoor workshops, facilitation techniques, and the seed funding program combined to enable an unanticipated research collaboration (Box 3). Such collaboration implied the construction of ad-hoc research objectives and methods, a collaborative subject integrating expertise from the natural sciences and the humanities, and an institutional context supporting interdisciplinary projects (*f-a, b, c, d*).

A sign of serendipity emerging at the level of CIRM was the explicit link between inter-/transdisciplinarity and personal transformation (*f-b*). When discussing inter- and transdisciplinarity in the context of sustainability, several researchers pointed out the need for a deep transformation. The position adopted by the center in one of its workshops emphasized the importance of a transformation in social

BOX 2: Serendipity at the project level: the mystery of ice flow in the Gorner glacier

Understanding a glacier's movement requires work across disciplines. Under a CIRM seed funding project, the Gorner glacier near Zermatt, Switzerland, became the basis for meeting colleagues from different disciplines with whom to discuss new challenges and solutions. This is a situation that seems well suited to sparking the unexpected. As the project's leader put it: "I do think that having a site like a glacier is a good start, you know, having a common site. It is an example of how you can try [to favor] serendipity." A master's student in the research team discovered an unexpected discontinuity in the pattern of ice flow close to the glacier's surface, and the team jumped into gear. The discovery was made with ground-penetrating radar (GPR), an indirect method used to image the subsurface (Figure 3). During a summer season, the team produced high-resolution three-dimensional images of the ice body from GPR surveys carried out on the glacier surface several times at the same coordinates. The deformation and movement of the ice beneath the surface were inferred by tracing the change through time of the position of natural indicators. The existence of a discontinuity was particularly surprising, because it did not fit with theoretical predictions on ice deformation. The team assessed the unexpected discovery by revisiting all of the method's assumptions and analyses. After consultation with experts in geophysics, the unexpected results seemed to stem from a methodological limitation. The team then decided to drill into the ice, involving additional experts in a new exploratory phase of the glacier.

practices and ecosystems as an objective of the center along with inter- and transdisciplinarity. Such holistic transformation was considered to encompass both the ways in which research is conducted and the researchers themselves. Referring to her seed project, one researcher said that "CIRM is a space that contributes to changing the way we do research, where it is necessary to let go a bit of our egos." When asked about her motivation to participate in one of CIRM's workshops on inter- and transdisciplinarity, another researcher said that she would like "to go beyond our limits." A follow-up workshop allowed researchers to explore the skills that are necessary to operationalize inter- and transdisciplinarity while raising the question of how to implement a personal transformation so that these skills can flourish within them. Indeed, when presenting CIRM in several other meetings, its director noted that "we are doing research on ourselves" (*f-a, b*, where *a* and *b* become one).

Discussion and conclusions: (re-)designing inter- and transdisciplinary research on mountains

Our analysis of CIRM has shown how some of the current challenges of inter- and transdisciplinarity play out in the implementation of a research center. We have also explored potential ways to deal with them. A crucial challenge was the

FIGURE 3 GPR measurements on the Gorner Glacier, near Zermatt, Switzerland, on 25 September 2018 (Box 2). The renowned Matterhorn (4478 m above sea level) appears in the background. Data from these measurements were analyzed under the frame of a seed funding project of CIRM. (Photo by Alexis Neven)



(deep) integration of heterogeneous scientific and nonscientific points of view into collaborative research that contributes to the sustainability of mountains. Facilitation and other methodological approaches (eg common research site, codesign) were found to be very valuable, but our results also revealed that such integration was perceived to be related to a multidimensional transformation. While a clear gap identified in the literature is how inter- and transdisciplinary research can support societal transformations in mountains (Huber et al 2013; Martín-López et al 2019; Schneider, Giger, et al 2019), our experience adds that the operationalization of this research requires a transformation of the researchers. This finding resonates with Schneider, Giger, et al (2019), who reported that one of the mechanisms by which transdisciplinarity may generate social impact is the acquisition of *embodied* competences and knowledge in collective processes of self-transformation. This suggests that research centers should not only provide training on integrative methods (ie across the natural and social sciences) and facilitation techniques, but also on self-transformative procedures. Different techniques, like cognitive training or meditation, have been tested in organizational learning and management studies (CEL 2017). We thus propose that they should be applied and that their transformative potential should be systematically evaluated in self-reflexive mountain research centers.

Another major need identified by our examination of CIRM is the development of new career evaluation standards that value inter- and transdisciplinary research at UNIL. This is intended to compensate for the risk taken by scholars doing such research in the current discipline-oriented competitive context. This finding supports calls for more favorable reward systems and for a broader shift in science

BOX 3: Serendipity across projects: facilitating teamwork among postdoctoral researchers

CIRM's executive team decided that 10% of the working week of each postdoctoral researcher would be devoted to interdisciplinarity, contractually. This decision was agreed upon with the postdoctoral researchers' advisors, but they themselves could only abide by it. They were situated in the same office with mandatory office presence at least 2 days per week (the same 2 days for all 4 of them). Two series of workshops were organized and facilitated by CIRM's coordinator. The first one consisted of a workshop led by each of the postdoctoral researchers to present his/her research to the others, in the field, if possible. This allowed them to familiarize themselves with each other's research questions, methods, and philosophy, and to overcome potential communication barriers (Figure 4). The second series consisted of 1 workshop with the goal of finding a common research object. Different facilitation techniques were used, notably the display of interdisciplinary data from a study region about which the postdoctoral researchers were asked to pose questions. These questions triggered a discussion leading in turn to a research topic relevant to all of their disciplines: the effects of the first Swiss forest law (AD 1876) on flood protection. Then, they were encouraged to apply to CIRM's seed funding program 2020 with a project on that topic. The center's board in charge of assessing the seed proposals granted them the project, which was developed in the course of 2020.

FIGURE 4 Postdoctoral workshop of 22 January 2020 at the Valais State Archives in Sion, Switzerland (Box 3). A historian (first on the left) shows to the natural scientists how to search and analyze archival data for mountain research. (Photo by Iago Otero)



policy toward a stronger support for inter- and transdisciplinarity (Taylor and Krause 2004; Sheate et al 2008; Bjørnsen Gurung et al 2012; Gleeson et al 2016). Thus, the criteria used to evaluate applications for academic positions and research projects should be revised at the level of research centers, universities, and national and international funding schemes.

These insights suggest that our self-reflexive approach is useful to diagnose a research center's inter- and transdisciplinarity. In particular, the model allows us to grasp the interactions among 5 key components of research, as well as the main needs ahead. To account for the unexpected, we have incorporated an additional factor called *serendipity* that has the potential to shape the interactions between the other components and to change the research process. We have reported signs of serendipity within projects, across projects, and at the level of CIRM. This suggests that serendipity is (or should be) part and parcel of the design of a center's inter- and transdisciplinary research, as it was shown to be a potential source of: (1) new projects and discoveries across disciplines; (2) flexibility in participatory projects' goals and methods; and (3) creative insights on research priorities (how to transform scientists). We further identified factors that can favor or hinder serendipity, which could be useful when (re-)designing inter- and transdisciplinarity in mountain research centers; see Appendix S4 (*Supplemental material*, <https://doi.org/10.1659/MRD-JOURNAL-D-20-00036.1.S1>). National and international research funding programs could likewise incorporate measures to favor serendipity; for example, allowing project leaders to redefine goals and methods based on interactions with societal stakeholders during the course of a project. The latter has been proposed to increase the capacity of funding programs to enhance transdisciplinarity (Schneider, Buser, et al 2019).

Why should serendipity be considered crucial? In the face of an ever-faster degradation of the vital ecosystem services provided by mountains to highland and lowland populations globally, a radically new approach to research seems urgent. The mountain research community has been lobbying for inter- and transdisciplinary research for decades, and rightly so. Yet, the link between this type of research and the transformation to sustainability is far from evident. One reason could be that such research is not transdisciplinary enough and that more efforts should be invested in enhancing transdisciplinarity (this seems to be the implicit normative position of Bjørnsen Gurung et al 2012; Brand et al 2013; Gleeson et al 2016; Klein et al 2019). However, a direct link between transdisciplinary research and real societal transformations still lacks empirical support (Schäfer et al. 2020; not specific to mountains).

Maybe something yet unknown is missing for inter- and transdisciplinarity to reach its full transformative potential. While we do not claim that we have *the* missing element, we speculate that the notion of serendipity offers a unique opportunity for a research center to find hidden resources, skills, methods, and processes that catalyze this transformation at individual, organizational, and societal levels. Thinking outside the box, putting aside prejudices, turning research problems into collective games, and allowing researchers and societal stakeholders to have free time for the unexpected to sink in can help to break invisible barriers and move inter- and transdisciplinarity in the desired direction.

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Supplemental material

APPENDIX S1 Defining multi-, inter-, and transdisciplinarity.

APPENDIX S2 CIRM's research projects analyzed in the article.

APPENDIX S3 Model of inter- and transdisciplinary research.

APPENDIX S4 Factors that may favor or hinder serendipity in a research center on mountains.

Found at: <https://doi.org/10.1659/MRD-JOURNAL-D-20-00036.1.S1>.