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Article

Interdisciplinarity as an Emergent Property: The Research Project "CINTERA" and the Study of Marine Eutrophication

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Abstract: Research projects combining different disciplines are increasingly common and sought after by funding agencies looking for ways to achieve environmental, social, and economic sustainability. Creating and running a truly integrated research project that combines very different disciplines is, however, no easy task. Large-scale efforts to create interdisciplinary or transdisciplinary research efforts have reported on their experiences in trying to achieve this goal. This article shares the methods, challenges and achievements experienced by a smaller group of researchers who have developed an interdisciplinary approach based on former results of Norwegian and Chilean experiments. The project "A Cross-disciplinary Integrated Eco-system Eutrophication Research and Management Approach" (CINTERA), funded by the Research Council of Norway (RCN, project 216607), brings together the fields of political science, economics, marine biology/oceanography and marine bio-geo-chemistry to improve the understanding of marine eutrophication and its possible socio-economic impacts. CINTERA is a multidisciplinary project that evolved into an interdisciplinary project and in so doing, transformed the attitudes of participants. The transformative process was generated particularly by the need to work closely together in making the CINTERA project useful for policy-makers.

Keywords: multidisciplinary; interdisciplinary; transdisciplinary; eutrophication; salmon aquaculture; Chile; Norway; fjord ecosystems; planktonic communities; adaptive capacity; research project

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1. Introduction

Research projects combining researchers from different disciplines are increasingly common—and increasingly sought after by funding agencies looking for ways to manage natural resources in ways that are environmentally, socially, and economically sustainable (see for example [1–3]). The management of coastal marine resources is a case in point, as fisheries, aquaculture, and coastal zone management have all embraced the ecosystem approach (at least theoretically).

Creating and running a truly integrated research project that combines very different disciplines is, however, no easy task. Large research projects tackling issues of sustainability have taken many years, a multitude of researchers and, sometimes, a substantial budget, with the explicit goal of transcending such boundaries and we still find genuine interdisciplinarity to be a substantial challenge [4]. Researchers from such projects as the Earth Science Partnership (ESSP), the Millennium Ecosystem Assessment and its outgrowth, the Program on Ecosystem Change and Society (PECS) have described these challenges [4–6]. However, the meta-project of research integration should ideally take place on several levels. A more modestly-sized project such as CINTERA can build a taste for and experience with interdisciplinarity and even transdisciplinarity from the bottom up and on a smaller scale, offering insights into the integration process along the way.

This article is intended to share the methods, challenges and achievements experienced by a smaller group of researchers who struck out on their own to work together across disciplinary lines. As such it constitutes a case study as that called for by Nenseth *et al.* [7] and Harris & Lyon [3] and contributes to the compiling of narratives telling the story of interdisciplinary research as called for by Haapasaari *et al.* [2]. The project "A Cross-disciplinary Integrated Eco-system Eutrophication Research and Management Approach" (CINTERA), funded by the Research Council of Norway (RCN, project 216607), compares conditions relating to marine eutrophication and its impacts close to a fjord in South Trøndelag in mid Norway and in two fjords in the Chilean Patagonia, and the adaptive capacity of local communities located in those areas. Atlantic salmon aquaculture, one source of eutrophication, is carried out near the Norwegian fjord and in the Chilean fjords. Norway and Chile are the world's leading producers of farmed Atlantic salmon, making a study of eutrophication in their coastal systems of particular significance. The wide-spread economic and social difficulties experienced in Chile in the wake of the 2007 outbreak of a disease that devastated the industry there underscore the importance of good basic knowledge of natural and social conditions. CINTERA is an offshoot of an earlier RCN project, WAFOW (WAFOW: Can Waste Emission from Fish Farms Change the Structure of Marine Food Webs? A comparative study of coastal ecosystems in Norway and Chile. RCN project number 163661), which studied the impacts of nutrient emissions from fish farms on the coastal ecosystems and water microbial community of the two countries (see [8] for more details).

CINTERA brings together researchers in the fields of political science, economics, marine biology/oceanography, and marine bio-geo-chemistry in an effort to improve the understanding of marine eutrophication and its possible socio-economic impacts. The eight principal researchers represent five different nationalities, six different academic disciplines, five different research institutions, and two different departments within one of the latter. It is roughly equally split with respect to gender: the project accordingly has potential cultural divisions along national, institutional, linguistic, gender, and disciplinary lines. This paper focuses on the issues arising from knitting together the various disciplines represented. As far as we can tell, this is the most relevant cleavage within the group, and it cuts across the potential divisions of nationality, institution, and gender.

The CINTERA project can be seen as a multidisciplinary project that evolved, at least in part, into an interdisciplinary project and in so doing, transformed the attitudes of participants. The transformative process was generated particularly by the need to work closely together in making the CINTERA project useful for policy-makers. Progress towards interdisciplinarity can be made in projects that are not constructed according to the prescribed best practice for achieving that quality, but it is not easy. Success requires an open mind, great patience, and willingness to risk, just occasionally, asking a really "stupid question".

2. The Task at Hand

The need for collaboration among researchers from many disciplines in order to achieve sustainability is now broadly recognized [3,9–12]. In the management of marine resources, such collaboration has in effect become policy: the ecosystem approach to management (EAM) has now been adopted in Norway [13], the European Union [14] and, in principle, the United States' federal marine management agency, the National Oceanic and Atmospheric Administration (NOAA) [15]. The EAM not only requires a multi-sectoral approach to management—that is, the management of sectors such as fisheries, tourism, and shipping in an integrated way—but is also an approach that comprehends the human and natural components of the ecosystem as inextricably coupled (this is here termed the socio-ecological system (SES) approach) [16–18]. The SES idea lies at the heart of work on climate change (the IPCC) (see for example [19]) and the Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) initiated by the International Geosphere-Biosphere Programme and the Scientific Committee on Oceanic Research [20].

The resulting scientific and policy missions are accordingly highly complex and require a greatly expanded amount, spread, and integration of knowledge to realize. This means, first, that research must transcend the academic disciplines that have traditionally broken complex problems into smaller, more easily handled components: systems cannot be understood as merely the sum of their parts and are not readily managed by simple interventions that focus on a single factor. Research questions, designs, and methods that truly integrate the various disciplines must be devised. Finally, publically-funded projects are frequently problem and application-oriented and require solutions that take a wide variety of objectives and possible consequences into consideration depending on the stakeholder. These tasks require work that not only brings the work of many disciplines together but actually integrates them.

The CINTERA project addresses just the kind of issue that calls for collaborative work. Formally entitled "A Cross-disciplinary Integrated Eco-system Eutrophication Research and Management Approach", CINTERA explores the reaction of marine systems to eutrophication such as that which could result from aquaculture and the adaptive capacity of local communities should they be faced with the effects of eutrophication–effects such as the deterioration of their surrounding environment. The higher goal of the project is to contribute to better management of coastal zones in light of the eutrophication issue. CINTERA is very much a "place-based" project: it compares the effects of Atlantic salmon aquaculture in two coastal areas: in Trøndelag, Norway, and in two northern Patagonia fjords in Chile.

Eutrophication as used here relates to inputs into and the effects of organic and inorganic nutrients in aquatic systems [21]. Inputs of mineral nutrients, primarily nitrogen and phosphorus, to specific waters increase the rate of supply of organic matter to an ecosystem, enhancing primary production [22]. Consequently, eutrophication deals with both the process of nutrient input and its associated effects. Inputs may be of both natural and "cultural" origins [23]. Aquaculture is one of many cultural sources of eutrophication (via the feeding of fish and resulting excretion), but there are many others; run-off from agricultural land, discharges into the water system from factories, and households and atmospheric depositions originating from a variety of human activities are significant sources of nitrogen and phosphates [24]. While it is usually the nutrient inputs of cultural origin that draw the attention of researchers [21], there are also significant natural sources, which vary significantly by water system. This in turn means that the effects produced by the cultural addition of nutrients to an aquatic system will vary by system. Because experiences with the introduction of, for example, aquaculture will accordingly vary by location [23,24], impacts on human communities and stakeholder awareness of the potential for eutrophication and its associated effects will also vary.

The major impacts of eutrophication can be changes in the structure and functioning of marine ecosystems (potentially resulting in algae blooms), reduced biodiversity, and degraded water quality, including reduced oxygen levels. These effects may in turn lead to reduced income from fisheries, mariculture, tourism, and the poisoning of animals and people by algal toxins [24]. Eutrophication can, then, potentially have a significant impact on both human livelihoods and health.

Understanding the potential impact on humans of eutrophication requires understanding among other things, the likelihood that eutrophication will occur in a given area, how extensive it may be (exposure), and the vulnerability and adaptive capacity of local communities with respect to the associated effects of eutrophication. Policy-makers need to be aware of the potential for, the potential effects of, and stakeholder concerns regarding eutrophication if they are to prevent or limit its harmful effects: the CINTERA project seeks to understand the exposure and sensitivity of local marine ecosystems on the one hand, the adaptive capacity of local communities on the other and ultimately, to assist decision-makers in the management process.

One of the new ventures launched in the 1980s that was designed to draw Chile out of its economic difficulties, salmonid aquaculture (the farming of Atlantic salmon and related species) developed into a major industry [25–27]. In its first, highly dynamic phase, the industry was centered in the Los Lagos Region (Region X) of the country. It became an important employer in a depressed region and produced a critical export product. Chile soon came to be the second largest producer of the species (after Norway). The outbreak in 2007 of Infectious Salmon Anemia (ISA), a highly contagious viral disease that requires the destruction of all fish at the infected site, was a disaster for the industry and for the people reliant upon it for jobs. The importance of understanding the potential for eutrophication and its possible impacts with respect to current aquaculture areas is underscored by the dramatic social impact of the collapse of the industry in 2007. The industry has recovered significantly since then, but is now eager to move further south, to new areas (Coyhaique and Magallanes regions) untouched by the troublesome disease. The proposed movement of the industry into relatively pristine areas is of concern because of the paucity of scientific information about these areas. Monitoring the impact of aquaculture will not be possible without good knowledge of the baselines against which change could be measured.

Understanding the potential for and potential impact of eutrophication requires just the sort of close work that sustainability projects demand. How has CINTERA tackled the challenge of integrated and collaborative research and has it succeeded?

2.1. Integrated Research and CINTERA

Just what is integrative and collaborative research? The jumble of words with finely shaded meanings that have been used to refer to collaborative work testifies to just how difficult it is to describe and prescribe what has, can, and should be done. Despite the title of the CINTERA project ("A Cross-Disciplinary ... Approach"), a review [2–5,7,12,28–36] of the growing literature on building collaborative projects that transcend academic disciplines reveals that the term "cross-disciplinary" is not much used and is, at best, vaguely defined (For example, Nenseth *et al.* 2010 [7] define "cross-disciplinary" as the borrowing of methods and perspectives by one discipline by another). As it turned out, this term actually fit our project as it was originally conceived, having as it did the goal of bringing together some very different disciplines but leaving the nature of the collaboration a bit open and underspecified.

To bring the necessary precision to the discussion of CINTERA's collaborative work, we discuss the project using the terminology offered by Stock and Burton's review of the literature [12] (pp. 1095–1101), [28] (p. 24). Their work suggests that a rough consensus is emerging to designate projects with varying ranges of integration as "multidisciplinary", "interdisciplinary", or "transdisciplinary" [28–33]. Multidisciplinary projects have the least degree of integration; they are essentially a set of separate projects gathered under a single project theme but with only some dialogue among the various components at best, perhaps towards the end of the project. "Interdisciplinary" projects have a higher degree of integration: representatives of several disciplines come together to formulate the problem and agree upon a methodological framework.

Interdisciplinary research is furthermore broken down into "small" and "large" varieties: the small version is the transcendence of boundaries between supposedly closely-related disciplines—say within the natural sciences—and the "large" version takes place across only distantly-related disciplines (classically across the social-natural science divide). This terminology is not meant to trivialize the challenges that researchers in either the natural or social sciences may face in working with their supposedly closely-related kin: even sub-disciplines within a given academic discipline may not communicate or work well with each other. The terminology does reflect the view popular within the sustainability field that the combined social-natural science work, required to understand the coupling of the socio-ecological system [28,34], is more difficult and elusive still [4,28].

Transdisciplinary research is a different level of integration altogether. Considered the "holy grail" of sustainability research, transdisciplinary work crosses not just disciplinary boundaries but also the divide between academic and non-academic participants [7,9], [12] (p. 1102).

The CINTERA project had its origins in the intellectual curiosity of researchers of various disciplinary backgrounds and represents their first attempt at putting such a varied group together. CINTERA researchers did not approach their project as an exercise in the grand goal of interdisciplinarity as described in the sustainability literature. In its origins and its structure, the project therefore did not accord with the best advice of the sustainability advocates: much of its work is best classified as multidisciplinary because it consists of researchers with varying backgrounds working side-by-side on the same theme rather than working closely together on the same problem [28] (p. 24). CINTERA has, however, elements of both small and large interdisciplinarity and is propelling the participants towards more integrative work, both within the CINTERA project and beyond. A project such as CINTERA can serve as a team-building exercise, forging the experience, knowledge, and trust required for more ambitious projects much in the fashion described in [3]. The CINTERA project supports the general point made in the literature that problem-orientation and policy aspects can drive a project to develop an interdisciplinary character [7,33,34,36]. The evolution of the CINTERA project was also fired in turn by the ambition of the researchers to make a real contribution to their communities.

CINTERA is a project of modest size but relatively great diversity. The eight principal researchers represent five different nationalities (Norwegian, Chilean, Colombian, Kurdish, and North-American), six different academic disciplines (depending on how you count—political science, economics, marine biology/oceanography, and marine biogeochemistry), five different research institutions, and two different departments within one of the latter. It is roughly equally split with respect to gender: four of seven of the core team are men. The project accordingly has potential cultural divisions along national, institutional, linguistic, gender, career achievements and disciplinary lines. This paper focuses on the issues arising from knitting together the various disciplines represented. As far as we can tell, this is the most relevant cleavage within the group, and it cuts across the potential divisions of nationality, institution, and gender.

2.2. CINTERA's Integrative Vantage Point

Reports on experiences in trying to create truly interdisciplinary projects highlight the importance of the very first stages in the formulation of a research project. How the research question is framed and the choice of methodology are essential [4,34]. This is the mark of the truly interdisciplinary project: the integration of theoretical frameworks, models, and methodology and the statement of the problem in a discipline-neutral way [2–4,30]. As researchers in the Global Environmental Change and Food Systems (CECAFS) project, put it, "you can't just 'bolt on' social science" [4] to research frameworks anchored firmly in natural science disciplines. Similarly, it doesn't work to "bolt" natural science work on to research frameworks assembled on the social science side, either. CINTERA's origins were not neutral, but the project shows that useful interdisciplinary work may yet emerge from such a beginning. It was the natural science team that initiated the project, looking in part to further the research methods and results [8] from a previous project in Norway and Chile (WAFOW, noted above).

The origins of the project meant, first of all that of all issues pertaining to aquaculture, the project would focus on eutrophication. It was this topic that the natural science team had focused on in their earlier project and hoped to continue to work on. The natural science team therefore had a sense of ownership of the project. Secondly, it meant that each team developed its own set of methods and research questions—a situation that does not necessarily bode particularly well for interdisciplinary research. However, project participants approached the project with the explicit intention of working together. That meant that both teams also contributed to and reviewed the third, integrative, work package as well as the overall project description and formulation of project goals. This process resulted in a project with two work packages with specific, separate goals but also a third work package that was explicitly designed to address joint, policy-relevant goals (useful indicators and improving management) where genuine interdisciplinary work was to take place.

Two of CINTERA's three work packages can accordingly be seen as multidisciplinary, a kind of "parallel play", in which the two teams worked side by side rather than together. The natural scientists had their cruises and the social scientists held their workshops, each team independent of the other. However, each of these two work packages can also be seen as an example of small interdisciplinarity. While "large" interdisciplinarity may be the more glamorous goal, the CINTERA project demonstrates the importance of this so-called "small" version. The study of eutrophication requires understanding the pollution aspect within the complex coastal marine ecosystem with respect to its physical (such as currents, water exchange rate, and the stability of pycnoclines), chemical (such as macro and micro nutrients and oxygen distribution in the water column) and biological (such as bacteria, phytoplankton and zooplankton community structure distribution and functional roles) variables. With respect to aspects of social and economic sustainability, the impact of the differing social, economic, and political contexts of aquaculture management in Chile and Norway equally clearly confirms the need for "small" interdisciplinarity in understanding these.

As noted above, CINTERA's ambition to bridge the natural-social science divide and transcend "parallel play", lay behind the creation of its third work package. Building such a work package explicitly into a project of even modest size speaks to the recognized need for a forum specifically dedicated to bridging project divides [7]. CINTERA's interdisciplinary forum was what it called "consilience" workshops (The term "consilience" is here used with the positive intension of according equal value to both sides of social-natural science divide. It is not an embrace of the "reductionist" view in which social sciences and the humanities are seen as mere adjuncts to natural science, a view championed by E. O. Wilson in his book 1998 book, Consilience: The Unity of Knowledge. For a discussion of this issue, see the review of Wilson in [37]). In these workshops, held on a regular basis throughout the three years of the project, each team presented its work to the plenum and worked together on the project's integrative goals. As written, however, the way integration would be achieved was not specified. We were quite certain that once the project was underway we would develop a deeper understanding of each other's work, the demands of that work, the policy relevance of the work being done and the importance of improving our ability to communicate our findings beyond our immediate circles to the broader world of policy makers and stakeholders.

Finally, the CINTERA project recognized the importance of stakeholder views from the outset. CINTERA researchers planned to investigate how stakeholder concerns matched up with those of the natural scientists. In this way, the CINTERA project spoke to the concerns of transdisciplinary research, but, because stakeholders were not involved in the creation of the project, it did not achieve true transdisciplinary status.

2.3. Practical Issues in Application Writing

The actual writing of a project application is always an exercise that forces the research team to recognize and deal with issues relating to research question and design. The writing of a multi- or interdisciplinary application may present particular difficulties. At the same time, the effort to tackle these difficulties, however, can also be a driver of integration.

Creating a project that stands some chance of developing in an interdisciplinary direction requires attention to case selection. This is tricky because what a "case" may mean varies tremendously, even within a single discipline (see for example the discussion of this with respect to Political Science in [38]). CINTERA's case-selection was driven by the needs of the natural science team: their research plan, focused on variables relevant to the natural science questions, drove their selection of sampling sites. These sites constitute a set of cases relevant to the study of the natural conditions that impact eutrophication. In order to link the two sides of the project, the social science team selected communities in the vicinity of the research sites chosen by the natural science team. Because the natural science team related the eutrophication issue to aquaculture, and targeted areas close to important population areas, this pairing happened to work. CINTERA's Chilean social science work focused on communities where aquaculture is now a major industry (in the Puerto Montt region) or where it would like to move (Magallanes region); in Norway it focused on Frøya and Hitra (in county of South Trøndelag in mid Norway) where aquaculture is a major industry. Selecting communities in the vicinity of key aquaculture areas enhanced the possibility that research of direct relevance to stakeholders would be done.

But while CINTERA's work has been fruitful, case selection that is not driven by a mutually-framed research question carries real risk. Social scientific work cannot produce generalizable results (an admittedly controversial goal [39]) if cases are selected according to a research agenda that targets variables irrelevant to its theory regarding, for example, a community's adaptive capacity; natural science is unlikely to prosper if the work is driven exclusively by social science concerns. If the criteria for case selection differ too radically, and the two "teams" cannot find a meeting place in what they study, a truly collaborative project is unlikely to develop. Indeed, they will have little to say to each other. A minimum requirement is that both teams chose cases that in some way contribute to the common project.

On a less abstract, more practical level, the project descriptions that routinely accompany applications to funding agencies are exercises in writing concisely and coherently. It is always difficult to boil down theoretical and empirical work to a few highly-focused pages that cover the research question, the state of the art and the contribution the project proposes to make. Writing an application for a multi-disciplinary project, however, can present a special challenge. The application must cover several literatures from several fields, employing enough of the specialized language particular to each to convince readers of the applicant's thorough knowledge of the field. At the same time, the parts must be woven into a whole and presented in such a way that the work is readily understandable to potential evaluators from a variety of disciplines. Depending on the funding agency, the integrative research project can present a challenge in finding competent evaluators. In addition, while many funding agencies urge collaborative work there are few clear gatekeepers or standards [28,36], [34] (p. 389). Balancing the need for specialized language against the need to make the project comprehensible to a broader audience is difficult and takes practice. One way to accomplish this is for both teams to read and critique the entire application, with each pointing out obscure passages, opaque jargon, and unspoken assumptions to the others. Finding the right balance between informed precision and general accessibility will not only pay off in effective communication to the evaluator, but the exercise can also help project researchers understand each other better.

Communication among different disciplines can be a barrier to creating an interdisciplinary project [2]. Finding common language and reference points is useful in the process. A useful metaphor served to knit the two aspects of the CINTERA project together. The natural science team provided the information that "a salmon cage aquaculture system (CAS) producing 1000 tons of fish a year generates an amount of nutrient waste comparable to a community of approximately 10,000 people" [40,41]. This language made it easy for the social science team to relate to the potential significance of introducing an aquaculture facility of such a size to the target coastal areas and served as a the gateway for natural science explanations about what effects the additional nutrient waste might have. Within the structure of the project, it provided a vantage point for exploring stakeholder concerns about aquaculture. This comparison also served to highlight the policy implications of the research proposed. However, it also led to some confusion between the two teams, as described below.

The common part of the application focused on the need for the project and presented the big picture as to how it all fit together. Much of the most discipline-specific information was reserved for the appropriate work package description. This allowed the researcher to go beyond the general, accessible language of the introduction and speak to the appropriate referee. The natural science team provided much more specialized knowledge about which nutrients would be studied, the potential impact of these on the plankton of the fjord, and they explained their research design. The social science team could explain the concept of the stakeholder workshops and the methods used—the Systems Thinking (ST), Conceptual Probability Tables (CPT), and Bayesian Belief Network (BBN) methods [42] as well as how their case selection corresponded to the natural science side. Each work package spoke clearly to how the work related to the central research question.

Budgets are always contentious issues, as every political scientist knows (the authoritative division of resources within a community is the essence of politics). Here is a potential source of unhappiness in this kind of collaborative project, since the natural science team tends to require relatively large sums for its basic research and potential funding is always limited. In the case of CINTERA, while the social team needed funding for travel, meeting localities and conferences and congresses, the natural scientists not only needed these budget items but also research vessel rental, purchase or rental of sophisticated technology for sampling and analysis of samples, the purchase of expensive chemicals and the transport of samples. Such expenses are hardly luxuries for the natural science team but can lead to a budget that looks disproportionate in favor of the natural science team. In a world in which budget share can be a measure of the importance accorded a given task, this can create a sense of frustration within the research group. The antidote to this is for everybody to understand going in that this sort of research simply can not be done without this basic funding: leaving budget details to the closing phase may result in sticker shock for the social science team.

The writing of an interdisciplinary application also brings up administrative and other issues that can impact the project down the road. Who should be the leader of such a collaborative project? Can the project leader exercise the necessary quality control over the whole of the project? What institution will host it? While these questions are common to most research applications, they may be more difficult to resolve for institutions that are not used to working with each other and which may have very different research and administrative cultures. Finding a solution for these using a short-term, problem-solving perspective is sometimes required, but researchers should not be naïve: while researchers are often mostly concerned with getting on with their work, these decisions have real consequences, matter quite a bit in some quarters and can complicate the future administration of the project.

2.4. Getting Started: "Chicken-Chicken" and "The Kindergarten Approach"

When great ideas have to be put into effect, the really hard work starts. The kick-off meeting is important in setting the tone for the work to come.

CINTERA's origins in a natural science project were clear in its kickoff meeting, which followed directly upon the heels of the concluding meeting of its all-natural-science predecessor. In a minor way, this development mirrors a common pattern in sustainability research, which often starts with what have been called the "environmental" sciences to which social science is later introduced (see for example, the IMBER program) [20].

Once the kickoff meeting began, CINTERA project members became aware of just how large the gulf separating the two teams actually was. As the natural scientists presented their work on the impacts of nutrients from aquaculture on coastal systems using terms such as CNLR, NH_4, PON, DOC, and POC (critical nutrient loading rate, ammonium, particulate organic nitrogen, dissolved and particulate organic carbon). The social scientists struggled to follow the conversation. These terms were as obscure to the social science team as the concepts of stakeholder workshops run using ST, CPT, and BBN (Systems Thinking, Conditional Probability Tables and Bayesian Belief Networks) techniques were to the natural science team. The economist's approach to exploring trade-offs among stakeholders using terms like "Pareto optimality" was baffling to the natural science team—and some of the social science team. For each non-specialist, presentations seemed much like Doug Zongker's [43] humorous "chicken-chicken" paper and subsequent presentation to the AAAS humor session in 2007: presentations in recognizable form and style but utterly incomprehensible in content.

The major challenge at such an interdisciplinary workshop is then to present work that is useful to the specialist while being accessible to someone who is highly educated—but in another field. This requires that the presenting specialist take a step back and get back to basics—including definitions and assumptions—and that those with other specialties be open to what essentially amounts to learning a new language. In handling the constant stress that the effort to explain "the obvious" can produce, humor can be a useful tool. The CINTERA participants revised their presentations to pitch the information at a more basic level. We collectively came to call this—with fondness and respect—"the kindergarten approach". Presentations that seemed particularly impenetrable to one group or another brought on mumblings of "chicken, chicken, chicken…".

At the consilience workshops, CINTERA researchers strove to speak in such a way that all could follow. This proved to be difficult to sustain over time. It is after all hard to explain "everything" all the time. In addition, it is easy to offend someone unintentionally. The off-hand remark about something being "obvious" can ruffle a feather or two while the need to explain "the obvious" can be frustrating. Personal trust is critical in keeping tempers in check and participants on speaking terms [3]. On the whole, however, the pressure to make ourselves comprehensible to each other has served us well, since it is also a funding agency demand that we make our work assessable to both policy makers and the general public (an increasingly important part of a publically-funded project). The project as a whole is furthermore helped immensely by the personalities that participate in it. Having the right team of researchers is essential [3,36]; having an open mind and the willingness to work at communication are highly useful characteristics for the researcher engaged in interdisciplinary work. For example, our marine-biogeochemist has a passion to explain his work to those outside his field and our economist has the eternal patience of a teacher used to explaining the basics of his work to the uninitiated.

But despite the best efforts of all, there continued to be layers of miscommunication. The metaphor cited above about the potential impact of salmon cage aquaculture was helpful for the social scientists to grasp and communicate the policy implications of the natural science side of the study, but initially hindered the understanding on the part of social scientists as to the role aquaculture was thought to play in the relevant systems. The research areas—the coastal areas surrounding the islands of Hitra and Frøya in Norway and the Reloncaví Fjord in the Los Lagos region of Chile—have strikingly different characteristics (see Figure 1 for an illustration of some of these differences). While it is in any case a mistake to extrapolate from general, laboratory findings to the effect that the addition of nutrients might have in a natural setting; it is even more problematic to extrapolate from these to different natural settings. This may be crystal clear to the relevant specialist, but the significance of the differences may not be immediately apparent to someone outside that field. Ironically, social scientists frequently argue in their own work that (socio-economic-political-cultural) context matters and that you can not necessarily extrapolate from a single case, but here didn't immediately grasp that this is also the case for sea water—even if it became obvious with a little thought.

The metaphor also proved misleading about the degree to which the natural science team was prepared to extrapolate from the findings resulting from their samples to making statements about the larger systems from which the samples were taken. The general reluctance of the natural science team to extract the policy relevance of the findings from their samples emerged for the first time during the kickoff meeting. That realization demonstrated the usefulness of the consilience platform of the project but also the lesson that metaphors and illustrations must be chosen and used with care.

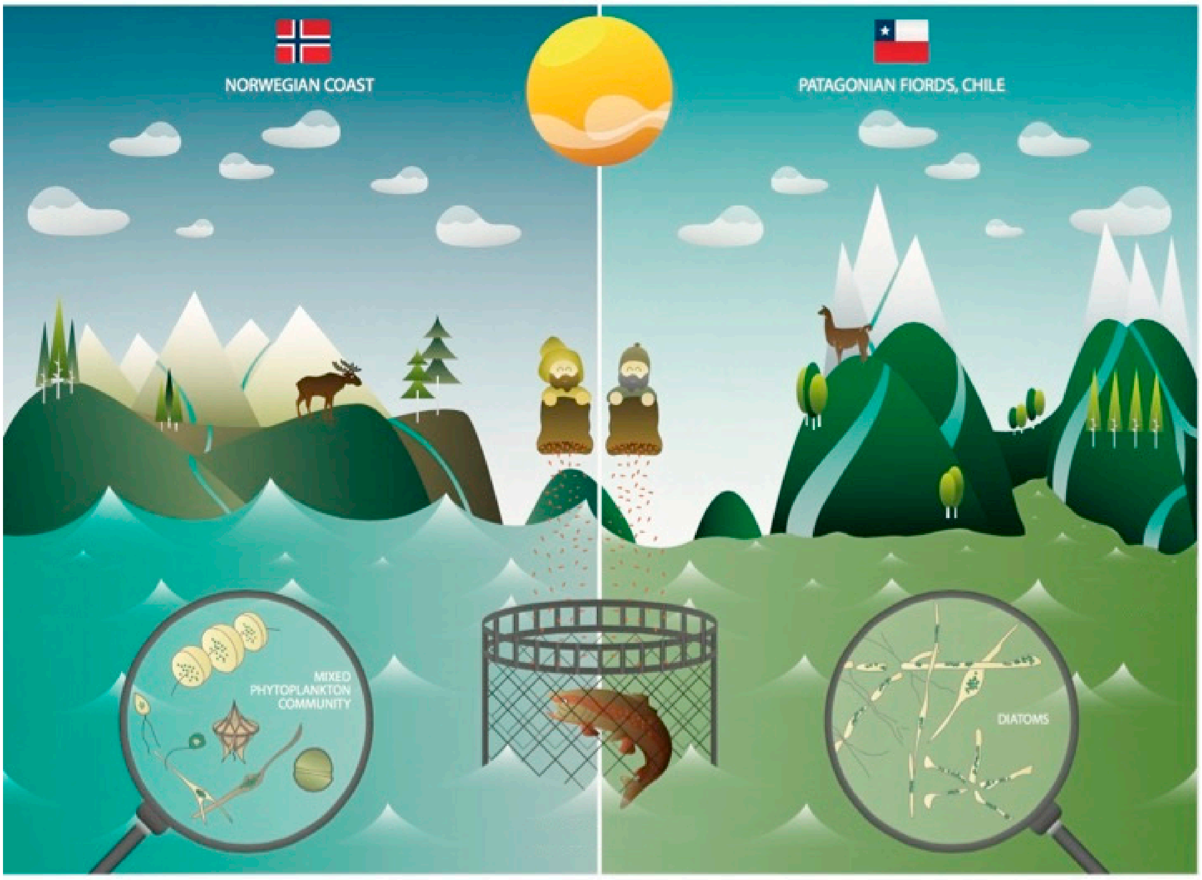

Figure 1. Comparing fjord systems in Chile and Norway. Water chemistry, geography, and the structure of planktonic communities vary between the two, resulting in different impacts (pollution or dispersion) when nutrients such as silicate, phosphorous, and nitrogen concentrations are altered. Therefore as a result of the change of nutrient concentration the structure of the phytoplanktonic communities of a system can be significantly changed (see [8]).

2.5. Building Integration

The first stage of work on the CINTERA project was largely multidisciplinary although "small" interdisciplinarity work took place on each side of the natural-social science divide. Each team focused for the most part on its component projects: understanding the impacts of nutrients on planktonic communities and identifying the concerns of stakeholders given the scenario of a ten-fold increase in aquaculture. The next step was the big challenge: "large" interdisciplinary work.

As others suggest [6] (p. 1305), [12] (p. 1096), [44], [45] (p. 376), it is precisely problem-specific and policy orientations that can provide a major impetus behind genuinely interdisciplinary work. As noted, the CINTERA project always had a real commitment to addressing policy questions. While the CINTERA project was initiated by the natural science team, which had very clear ideas about the scientific work that project would do, that team nonetheless had a bit of an activist disposition. It often expressed the meaning of CINTERA's work in relationship to a larger, policy context. Concern for conditions in Chile was particularly acute, although salmon aquaculture is significant in both Chile and Norway. The natural science team was very much aware of the history of the Atlantic salmon industry in Chile and the attempt of the industry to move to new areas. The CINTERA project was accordingly formulated with the goal of contributing to management: finding indicators that are "useful to managers," helping to achieve of Good Environmental Status (an EU policy goal specifically relevant in the Norwegian context but which could serve as a useful goal or measure in the Chilean context) and anticipating the adaptive capacity of communities.

The policy part of CINTERA's work package three was, specifically, to "bring all of the participants together to coordinate efforts and exchange ideas and input for the construction of indicators and management tools." These policy-relevant ambitions, in turn, required real interdisciplinary work. As noted above, however, how this was to happen was underspecified. The lack of specificity in the application had the advantage of allowing flexibility in addressing policy issues, but the disadvantage of not acknowledging and addressing the real differences between the two teams as to how to do this. This meant that these real differences in approach emerged only in the closing phases. We can take some solace in the observations of Balsiger [33] and Oughton & Bracken [34] that this lack of specificity is common to projects such as ours, but that this openness can maximize the flexibility that researchers can have in addressing such tasks.

It became clear that finding a reliable indicator of eutrophication would be difficult. There may be no single, reliable, and straightforward metric. We also realized that finding such an indicator might not be enough. To be truly "useful to managers," indicators would have to be cost efficient and easily understandable. More information is needed about the management system and to whom indicators should be targeted. Here is an area where the combined CINTERA team could truly work together, and was the focus of joint effort towards the end of the CINTERA project. Our work however, revealed very different views about how to approach this work. This divide was also apparent in our preliminary discussions about crafting a research application to follow CINTERA. Attempting to address policy relevance more directly from the outset is very difficult. As a broad generalization, the social science team tended to press for firm statements about what the proposed research will tell policy makers, while the natural science team remained very reluctant to scale up the findings of their samplings and analyses to general statements about the local ecosystem and focused on the needs of basic science. It is one thing to evoke the spirit of policy relevance, it is quite another to link basic research directly to the achievement of policy goals.

At this point the potential value of transdisciplinary work became apparent. While the two teams were focused on difficulties of making the work they were doing policy relevant, the workshops of the social science team made it very clear that management issues regarding aquaculture transcend the danger represented by eutrophication. Given the origins of the project, social scientists approached stakeholders with the issue of the dangers of eutrophication that increased aquaculture might bring foremost in their thinking. Stakeholders in both Norway and Chile, however, had quite different issues foremost in their minds.

Happily, the workshop methodologies used by the social science team are designed to elicit stakeholder concerns, rather than to tell them what these should be. The most relevant methodology in this context is Systems Thinking (ST), a group-level discussion methodology designed to distill a common understanding of how a socio-ecological system works from the various perspectives of the participants. Figure 2 illustrates the process of distilling the shared conceptual map at a workshop in Chile run by Dr. Hugo Salgado. Participants are posed a question or are asked to imagine a specific situation and are then invited to explore how they would be affected or what they would do in that situation. While researchers start off the discussion by specifying a set of systemic "drivers" prepared in advance by experts, this simply gives the discussion a starting point. The workshop leader poses some questions based on the initially specified drivers but then follows the lead of the workshop participants. The experience of those running the workshops is that stakeholders feel quite free to take the discussion in the directions they think it should go, adding their own drivers to the mix of those provided at the outset or simply taking the discussion in an unanticipated direction.

Figure 2. Creating a shared conceptual map using Systems Thinking at a Stakeholder workshop in Chile. The workshop was facilitated by CINTERA researcher Hugo Salgado.

In Chile it became rapidly apparent that many stakeholders were most concerned with the lack of the ability of the Chilean state to monitor and enforce its own management measures. Norwegians, living in a country where confidence in state institutions is much higher as a rule, were concerned more about the social issues that an increase in aquaculture would likely bring: the need for labor has already resulted in a large influx of foreign labor, posing challenges for local communities. More aquaculture is likely to bring greater challenges. In these cases, then, there were poor matches between the concerns of key experts and those of local stakeholders [46,47].

This point brings us back (again) to the issue of the policy relevance of the CINTERA project, the key driver of its emergent interdisciplinary quality. Eutrophication and its effects are a key issue for our group of natural scientists, but this issue was not on the radar screens of stakeholders. It was also not on the radar screens of the social scientists who routinely work with aquaculture questions. Indeed, after viewing a report on the CINTERA project, a senior Norwegian official external to the project asked informally why we had chosen to focus on eutrophication. In his experience, stakeholders have many concerns about aquaculture but eutrophication barely registers (if at all). The short answer to this was of course, because natural scientists who do see eutrophication as a key issue invited the social science team to participate in *their* project. The longer answer is that natural scientists had identified a gap in knowledge they considered essential. In Chile, the history of the aquaculture industry, its current attempt to move into areas almost untouched by industry and the lack of fundamental knowledge about coastal ecosystems make this work urgent [48,49]. Even so, and as fruitful and rewarding as the resulting project collaboration has been, the focus on eutrophication is seen by some outside the project as peripheral to more pressing stakeholder concerns. This means that taking the project in a policy-relevant direction is a bigger challenge than anticipated.

This point was driven home again in an informative seminar the CINTERA project held in Puerto Montt, Chile. The goal of the seminar was to share the project's work with researchers. While information on eutrophication was presented, stakeholders did not seem to absorb its significance. They were more interested in hearing about what Chilean stakeholders in other workshops had to say, comparing their own views with those of others. Chileans were also particularly eager to hear about conditions in Norway.

The take-home point is that stakeholders (including decision-makers) have a variety of concerns and decision-makers have to respond to these; both groups also have to prioritize the use of resources. This means that the policy relevance of research on eutrophication must be explained not just with respect to its scientific importance but also with respect to how it relates to other pressing issues related to salmon aquaculture. There remains a clear and not entirely resolvable tension between the need for good basic science on the one hand and the need for science that can be immediately and explicitly "used" by policy makers.

2.6. Methodology as a Bridge over the Large Divide

One of the more interesting aspects of working with the cross-disciplinary group is the number of concepts that many of us in fact do have in common, and where our disciplinary differences are bridged. Burton, Rønningen, and Wedderburn [28] make an important point about the differences in ontology and epistemology in the natural and social sciences when they underscore the importance of the "interpretive turn" in social sciences. By this they are referring to the broad rejection by key groups within the social sciences of "positivism" and the idea of the "scientific" study of social phenomena. However, they underplay the potential usefulness of the positivist legacy that remains. A good grounding in positivism and its methodologies is important in social sciences because it provides an important set of concepts and tools for analyzing the empirical claims made every day in the world of politics and policy and because it allows for real understanding of the meaning of the interpretivist turn within social science disciplines. But it has an additional benefit: it can also help the social scientist bridge the gap to natural science. The scientific method can provide a common language for us all even when the content varies. Commonalities come from those aspects of social and natural science work that grapple with establishing causality, including concepts such as variable analysis, control groups, reference points, and sample selection criteria. In addition, the basic ideas about "systems" are nearly universally understood. Social science shares with biology the concepts of evolution and adaption—whence these concepts came. This does not mean that the participating social scientist must necessarily adopt a positivistic, or what Moses and Knutsen [39] term a "naturalist," perspective. It does mean that this common language can serve as a bridge among disciplines and knowledge of it, if only to explain differences in thinking.

The notion that fluency in the language and terminology of positivist or naturalist science can help bridge disciplinary gaps should not be interpreted to mean this will resolve communication problems, only that it can help. Differences in language use among the disciplines are frequently pointed to as creating problems for the collaborative effort [2,3,10,44]. The CINTERA experience confirms this. Some of the language differences were quite obvious: researchers were acutely aware when they failed to grasp the meaning of chemical abbreviations or workshop methodologies. But the borrowing of terms across disciplinary lines can create confusion too, since the same words can be applied in very different ways. In CINTERA, our biologists (and our bio-geo-chemist!) are very concerned about the structure and function of communities just as is the social science team—but it turned out that while the social scientists were preoccupied with human communities, our biologists were talking about planktonic communities. Here is an instance, by the way, in which awareness of the history of the development of the social sciences, specifically that of the heyday of social science structural functionalism, came in handy. The long but now largely out of date tradition of social science structural functionalism sought to transcend western biases by examining societies as composed of social, cultural, and political systems with associated, abstract structures and functions related to the stability of the system. This tradition proved useful to the social scientists, equipping them with the concepts and terminology to grasp the approach taken by the biologists (and the biogeochemist).

3. Conclusions

Research projects that stretch across disciplinary boundaries come in many varieties. Not every project has to achieve the high degree of integration embodied by the increasingly accepted term "interdisciplinary". Moreover, projects can usefully combine both multidisciplinary and interdisciplinary aspects: not every bit of the work done need be integrated, or perhaps better said, equally integrated, nor should the value of "small" interdisciplinarity be underestimated. It is clear that ultimately tackling sustainability will, however, require work that is genuinely integrative, based on theoretical frameworks and methodologies that span and unite disciplines and which generate new knowledge. But even small but genuine steps in the direction of interdisciplinarity can have longer-term pay offs as researchers learn to collaborate and to appreciate the need for true integration.

CINTERA experiences largely confirm many of the points made in the literature on interdisciplinarity. "Large" interdisciplinarity was the larger challenge in the CINTERA project. The social science team and the natural science team worked smoothly in the "small" interdisciplinary aspects of the project. Communication issues did present real difficulties, despite the real work that went into building bridges between the two different teams at the application writing stage. CINTERA's experiences suggest, however, that communication issues are seldom resolved at a single clarifying moment; the experience is more like peeling back layers on an onion. A good grounding in the language of "positivist" science can help in this process of building good communication.

The CINTERA project illustrates that it is indeed questions related to policy that constitute the most direct stimulant to interdisciplinarity. As noted above, it was CINTERA's explicitly policy-oriented aspect, the need to find indicators and assist management, that prompted the two teams to engage most directly with each other. Finding indicators that are useful for decision-makers is only partially a question of natural science—it is also a question of cost-effectiveness, regulatory requirements, and ease of use. This is a task that must be achieved as a team. However, it may be more surprising, perhaps, that the integrating effect of the policy aspect runs throughout the entire project and is not only confined to tasks that are specifically designated as the "interdisciplinary part." This urge emerged spontaneously as the two teams struggled to find common ground from the first day of the project.

The CINTERA project provides a good illustration of how interdisciplinarity began to emerge and the value it can have. Getting real insight into why changes in nutrient levels can have a dramatic impact on planktonic communities—and why that matters—has been invaluable for the social science team, helping them to frame their work on the human communities in question. Focusing on a single question (here eutrophication) has allowed social science researchers to improve their basic knowledge about the relevant natural systems. This is useful because while social scientists tend to appreciate the importance of social, cultural, political institutional contexts of policy, they may easily overlook the ways that differences in natural conditions can impact the success of policy measures. The WAFOW and CINTERA work has very clearly shown that one fjord is *not* pretty much the same as another [8], suggesting that emissions from aquaculture (and regulations) will have different consequences (and create different challenges) for each. Finally, the credibility of social scientists in the context of policy making or when interacting with stakeholders, managers, and natural scientists, is increased when they have a good grasp of the environmental issues to which they apply their own expertise. Real interaction with the natural science team helps the social science team to ask the right questions and pursue issues to which they might not have otherwise paid attention.

Natural scientists, similarly, can use assistance in answering the question "so what?" Here, the social science team can play a role in helping to translate the highly specialized work of, for example, a biologist/oceanographer or the marine bio-geo-chemist into information about what this work means for the community at large. In the CINTERA project, some of the natural scientists report the good feeling they have in knowing that the research they are doing can potentially contribute to the improving the quality of life of fishermen and aquaculture workers, even if it is, in the words of one of our researchers, just by a "grain of sand". Understanding the socio-political context into which their information will be released can be helpful in helping them understand the impact their current work may have or how they might make a bigger or more directly relevant contribution to the community. After all, human communities are as varied and complex as planktonic communities: varying socio-political and economic structures mean that they too react differently to any given stimulant and or event—just as planktonic communities do. In addition, such structures have their own resilience: simply obtaining and presenting good information is unlikely to change the attitudes and behaviors of the key actors in the system. A related point is that even the best scientific research cannot be adequately used if the state lacks the capacity to formulate, implement, and enforce regulations. Similarly, if stakeholders lack confidence in the aquaculture industry and the regulatory authorities they are unlikely to concern themselves with the intricacies of the scientific work. Finally, the social science side can help the natural science side know and speak to environmental questions with which the community is concerned, even if the natural science team finds these concerns to be misplaced or trivial.

It is clear that while good basic work needs to be done by each team, neither should work in too much in isolation from the other, even if a "consilience" platform is built into the project and intentions are good. Each team needs to have a real appreciation of the relevance to their own work of the other team's expertise. For example, social scientists need to understand the reasons why the natural science team might be reluctant to extrapolate from the results of their work. Similarly, a natural science team could profit by appreciating why social scientists might press for policy relevance or how stakeholder perceptions can impact both natural systems (by affecting human behavior that provides inputs to that system) and, ultimately, the work of the natural scientists (by affecting funding). While regularly scheduled joint discussions are invaluable, cross-participation in the so-called small interdisciplinary parts of the project could well serve to bridge these gaps.

The stakeholder workshops hold lessons of their own that relate both the interdisciplinarity and, less discussed here, transdisciplinarity. With respect to the first, the effort to share the scientific work on eutrophication with the stakeholders suggests that the natural scientists may have an important role in communicating critical information to stakeholders, alerting them to problems that are not highly visible or immediately threatening. Taking on such a role, however, will require real work in learning how to present the information to a general audience in such a way that is it readily understood and its significance properly appreciated. Researchers must be careful to neither needlessly frighten stakeholders nor leave them with a false sense of security. Social scientists might help with that. With respect to transdisciplinarity, the project as a whole would have profited by involving stakeholders at an early stage. This would have helped project researchers understand the position of eutrophication in the hierarchy of stakeholder concerns, allowing them to formulate their work in ways more directly useful to those stakeholders.

The CINTERA project has played an important role both in terms of the research done (and has yet to do) and in educating individual researchers in the joys and challenges of collaborating across disciplines. Tackling the challenges at this level prepares us for the bigger challenges that research on ICZM, fisheries, and aquaculture management or Climate Change have in store for us.

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Author Contributions

Jennifer Bailey is lead author for this article. She did most of the research on the academic discussion of the definitions of multi-, inter-, and trans- discplinarity. She also wrote the draft of the article, solicited contributions from the CINTERA team and did the final integration and review of the article. Murat Van Ardelan reviewed several versions of this article and contributed to the writing of the natural science aspects of it, making sure that all descriptions of the natural science were accurate. He has also been a driving force in discussing the article with his natural science colleagues and encouraging them to contribute. He has contributed his insights on the project and these have been integrated into the article. Humberto E. González was also active in reviewing the article (at least two versions) and ensuring the accuracy of the natural science. He added his insights at various points. He and the other member of the Chilean team have been active in discussing the policy implications of the project, providing material and insights for this aspect of the article. He has participated in the group discussions that helped produce the article. José Luis Iriarte reviewed the manuscript and made substantive comments on the science and policy aspects of this manuscript. He has participated in the group discussions that helped produce the article. Lasse Mork Olsen also reviewed the article in several versions, and has provided substantive editorial input and valuable insights throughout. He created Figure 1. He has participated in the group discussions that helped produce the article. Klaudia L. Hernández also reviewed the various versions of the article and provided substantive and editorial comments and references throughout the writing processes. She has participated in the group discussions that helped produce the article. Rachel Tiller provided editorial and substantive input in her reviews of the article. She has participated in the group discussions that helped produce the article. Hugo Salgado actively participated in the conceptualization, shaping, and formulation of the article through group discussion and individual input.

Conflicts of Interest

The authors declare no conflict of interest.

References and Notes

1. Cooper, G. A disciplinary matter: Critical sociology, academic governance and interdisiplinarity. *Sociology* **2012**, *47*, 74–89.
2. Haapasaari, P.; Kulmala, S.; Kuikka, S. Growing into interdisciplinarity: How to converge biology, economics and social science in fisheries research? *Ecol. Soc.* **2012**, *17*, Article 6.
3. Harris, F.; Fergus, L. Transdisciplinary environmental research: Building trust across professional cultures. *Environ. Sci. Policy* **2013**, *31*, 109–119.
4. Ignaciuk, A.; Rice, M.; Bogardi, J.; Canadell, J.G.; Dhakal, S.; Ingram, J.; Leemans, R.; Rosenberg, M. Responding to complex societal challenges: A decade of earth system science partnership (ESSP) interdisciplinary research. *Curr. Opin. Environ. Sustain.* **2012**, *4*, 147–158.
5. Carpenter, S.R.; Folke, C.; Norstöm, A.; Olsson, O.; Schulta, L.; Agarwal, B.; Balvanera, P.; Campbell, B.; Castilla, J.C.; Cramer, W.; *et al.* Program on ecosystem change and society: An international research strategy for integrated social-ecological systems. *Curr. Opin. Environ. Sustain.* **2012**, *4*, 134–138.
6. Carpenter, S.R.; Mooney, H.A.; Agard, J.; Capistrano, D.; DeFries, R.S.; Díaz, S.; Dietz, T.; Duraiappah, A.K.; Oteng-Yeboah, A.; Pereira, H.M.; *et al.* Science for managing ecosystem services: Beyond the millennium ecosystem assessment. *PNAS* **2009**, *106*, 1305–1312.
7. Nenseth, V.; Thaulow, H.; Vogt, R.D.; Orderud, G. Tverrfaglig Miljøforskning—en Kunnskapsstatus. CIENS-Report 2–2010. Available online http://folk.uio.no/rvogt/CV/Reports/CIENS%20Tverrfag%20Rapport%2004.06.10.pdf (accessed on 8 July 2015).
8. Olsen, L.M.; Klaudia, L. Hernández, M.V.A.; Jose, L.I.; Nicolas, S.; Humberto, E.G.; Nils, T.; Yngvar, O. Responses in the microbial food web to increased rates of nutrient supply in a southern Chilean fjord: Possible implications of cage aquaculture. *Aquac. Environ. Interact.* **2014**, *6*, 11–27.

9. Mauser, W.; Klepper, G.; Rice, M.; Schmalzbauer, B.S.; Hackmann, H.; Leemans, R.; Moore, H. Transdisciplinary global change research: The co-creation of knowledge for sustainability. *Curr. Opin. Environ. Sustain.* **2013**, *5*, 420–431.
10. Rice, M. Spanning disciplinary, sectoral and international boundaries: A sea change towards transdisciplinary global environmental change research? *Curr. Opin. Environ. Sustain.* **2013**, *5*, 409–419.
11. Clark, W.C.; Dickenson, N.M. Sustainability science: The emerging research program. *PNAS* **2003**, *100*, 8059–8061.
12. Stock, P.; Burton, R.J.F. Defining terms for integrated (multi-inter-trans-disciplinary) sustainability research. *Sustainability* **2011**, *3*, 1090–1113.
13. Olsen, E.; Gjøsæter, H.; Røttingen, I.; Dommasnes, A.; Fossum, P.; Sandberg, P. The Norwegian ecosystem-based management plan for the Barents Sea. *ICES J. Mar. Sci.* **2006**, *64*, 599–602.
14. Commission of the European Communities. *The Role of the CFP in Implementing an Ecosystem Approach to Marine Management*; Commission of the European Communities: Brussels, Belgium, 2008.
15. NOAA. New Priorities for the 21st Century—NOAA's Strategic Plan Updated for FY2005–FY2010. Available online: http://www.ppi.noaa.gov/wp-content/uploads/FY05-10_NOAA_Strategic_Plan.pdf (accessed on 8 July 2015).
16. Busch, W.-D.; Brown, B.L.; Mayer, G.F. Strategic Guidance for Implementing an Ecosystem-Based Approach to Fisheries Management. Available online: http://www.nmfs.noaa.gov/ocs/mafac/meetings/2003_05/mafac_rev_5th_7Finalwref.pdf (accessed on 8 July 2015).
17. Food and Agriculture Organization of the United Nations (FAO). *The Ecosystem Approach to Fisheries: Technical Guidelines for Responsible Fisheries*; FAO: Rome, Italy, 2003.
18. Ostrom, E. A general framework for analyzing sustainability of socio-ecological systems. *Science* **2009**, *325*, 419–422.
19. Wong, P.P.; Iñigo, J.; Gattuso, J.-P.; Hinkel, J.; Khattabi, A.; McInnes, K.; Saito, Y.; Sallenger, A. Coastal systems and low-lying areas. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., *et al.*, Eds.; Cambridge University Press: Cambridge, UK, 2014.
20. IMBER. History of IMBER. Available online: http://www.imber.info/index.php/About-IMBER/History-of-IMBER (accessed on 30 June 2015)
21. Jørgensen, B.B.; Richardson, K. (Eds.) Eutrophication in Coastal Marine Ecosystems. In *Coastal and Estuarine Studies 52*; American Geophysical Union: Washington, DC, USA, 1996.
22. Nixon, S.W. Coastal marine eutrophication: A definition, social causes, and future concerns. *Ophelia* **1995**, *41*, 199–219.
23. Andersen, J.H.; Schluter, L.G. Ærtebjrg. Horizons: Coastal eutrophication: Recent developments in definitions and implications for monitoring strategies. *J. Plankton Res.* **2006**, *28*, 621–628.
24. Ærtebjerg, G. (Ed.) *Eutrophication in Europe's Coastal Waters. Topic Report 7/200*; European Environment Agency: Copenhagen, Denmark, 2001; p. 87.

25. Phyne, J. A comparative political economy of rural capitalism: Salmon aquaculture in Norway, Chile and Ireland. *Acta Sociol.* **2010**, *53*, 160–180.
26. Bustos, B. *Geographies of Knowledge Production in a Neoliberal Setting: The Case of Los Lagos Region, Chile*; The Graduate School of Syracuse University: Syracuse, NY, USA, 2010.
27. Barton, J.; Fløysand, A. The political ecology of Chilean salmon aquaculture, 1982–2010: A trajectory from economic development to global sustainability. *Glob. Environ. Chang.* **2010**, *20*, 739–752.
28. Burton, R.; Rønningen, K.; Wedderburn, L. *A Critical Literature Review of Interdisciplinary and Transdisciplinary Research*; Center for Rural Research: Trondheim, Norway, 2008.
29. Huutoniemi, K.; Klein, J.T.; Brunn, H.; Hukkinen, J. Analyzing interdisiplinarity: Typology and indicators. *Res. Policy* **2010**, *39*, 79–88.
30. Aboelela, S.W.; Larson, E.; Bakken, S.; Carrasquillo, L.; Formicola, A.; Glied, S.A.; Haas, H.; Gebbie, K.M. Defining interdisciplinary research: Conclusions from a critical review of the literature. *Health Res. Educ. Trust* **2007**, *42*, 329–346.
31. Wagner, C.S.; Roessner, J.D.; Bobb, K.; Klein, J.T.; Boyack, K.W.; Keyton, J.; Rafols, I.; Bönrner, K. Approaches to understanding the measuring interdisciplinary scientific research (IDR): A review of the literature. *J. Informetr.* **2011**, *5*, 14–26.
32. Aram, J.D. Concepts of interdisciplinarity: Configurations of knowledge and action. *Hum. Relat.* **2004**, *57*, 379–412.
33. Balsiger, P.W. Supradisciplinary research practices: History, objectives and rationale. *Futures* **2004**, *36*, 407–421.
34. Oughton, E.; Bracken, L. Supradisciplinary research practices: History, objectives and reframing. *Area* **2009**, *41*, 385–394.
35. Beichler, S.A.; Sanin, H.; Bart, J.D.; Sonja, D. The role played by social-ecological resilience as a method of integration in interdisciplinary research. *Ecol. Soc.* **2014**, *19*, Article 4.
36. Broto, V.C.; Maya, G.; Melf-Hinrich, E. Practicing interdisiplinarity in the interplay between disciplines: Experiences of established researchers. *Environ. Sci. Policy* **2009**, *12*, 922–933.
37. Jamison, D. Book review: Consilience. Available online: http://issues.org/?s=consilience (accessed on 15 February 2015).
38. Yin, R.K. *Case Study Research: Design and Methods*; Sage Publications, Inc.: Thousand Oaks, CA, USA, 2003; Volume 5.
39. Moses, J.W.; Knutsen, T.L. *Ways of Knowing: Competing Methodologies in Social and Political Research*, 2nd ed.; Palgrave Macmillan: London, UK, 2012.
40. Olsen L.M.; Holmer, M.; Olsen, Y. *Perspectives of Nutrient Emission from Fish Aquaculture in Coastal Waters: Literature Review with Evaluated State of Knowledge*; The Fishery and Aquaculture Industry Research Fund (FHF): Oslo, Norway, 2008.
41. Olsen, Y.; Olsen, L.M. Environmental impact of aquaculture on coastal planktonic ecosystems. In *Fisheries for Global Welfare and Environment*, Proceedings of the 5th World Fisheries Congress, Yokohama, Japan, 20–24 October 2008; pp. 181–196.
42. Richards, R.; Sano, M.; Roiko, A.; Carter, R.W.; Bussey, M.; Matthews, J.; Smith, T.F. Bayesian belief modeling of climate change impacts for informing regional adaptation options. *Environ. Model. Softw.* **2013**, *44*, 113–121.

43. Zongker, D. Chicken chicken chicken: Chicken chicken. Paper Presented at the AAAS Humor Session, 16 February 2007.
44. Schumann, S. Application of participatory principles to investigation of the natural world: An example from Chile. *Mar. Policy* **2010**, *34*, 1196–1202.
45. Bracken (Née Bull), L.J.; Oughton, E.A. "What do you mean?" The importance of language in developing interdisciplinary research. *Trans. Inst. Br. Geogr.* **2006**, *31*, 371–382.
46. O'Ryan, R.; Pereira, M. Participatory indicators of sustainability for the salmon industry: The case of Chile. *Mar. Policy* **2015**, *51*, 322–330.
47. Ostrom, E. Beyond Markets and States: Polycentric Governance of Complex Economic Systems: Prize lecture. Available online: http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/2009/ostrom-lecture.html (accessed on 10 March 2015).
48. Iriarte, J.L.; González, H.E.; Nahuelhual, L. Patagonian fjord ecosystems in southern Chile as a highly vulnerable region: Problems and needs. *Ambio* **2010**, *39*, 463–466.
49. Klinkenborg, V. The power of Patagonia. Available online: http://ngm.nationalgeographic.com/2010/02/patagonia/klinkenborg-text (accessed on 15 March 2015).