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Knowledge Management and Canadian Aquaculture: A Case Study of Public-Private Research Collaboration

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1 Introduction

Genetics and genomics have made noteworthy advances in recent decades, and those advances are now underwriting the creation of a vast range of novel bio-products and processes—from development of crops for bio-fuels to understanding of individual persons’ susceptibility to particular diseases. Governments worldwide have understood that these products and processes have the potential to bring significant social and economic benefits to their citizens, and governments have accordingly deployed a range of policies designed to increase citizens’ share of the benefits of genomics research and development.

One particularly significant set of policies is clustered around the complex business of taking lab discoveries to market. Many governments are attempting to accelerate commercialization of scientific discoveries by policies creating collaborations between public research organizations (PROs) and industry. In 2000 the Government of Canada established Genome Canada as a not-for-profit corporation mandated to “develop and implement a national strategy for supporting large-scale genomics and proteomics research projects, for the benefit of all Canadians” (Genome Canada, 2008a). Genome Canada seeks to both support both high-quality science and the commercialization of that science, channelling much of its research support into PRO-industry research collaborations, operating a model of partnership requiring cash or in-kind commitments from organizations partnered with academic and government researchers who

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receive Genome Canada funding. The dual emphasis placed on discovery and innovation is evident in Genome Canada's annual reports, which note both scientific breakthroughs and commercial outcomes (i.e., patents, licenses, and new firms formed to commercialize research results) (Genome Canada, 2008b). This case study investigates the efficacy of the partnership model through a comparative case study of two Genome Canada funded research projects in the field of aquaculture.

Aquaculture is "the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants," (Working Party of Experts on Aquaculture, 1988). Genome Canada (2008b) has reported that aquaculture is "one of the faster growing segments of the agricultural economy," with Canadian revenues growing 24.6% between 2005 and 2006 (Statistics Canada, 2007). Since the 1980s the aquaculture industry has grown exponentially and surpassed the traditional capture fisheries in size. In 1997, global production of farmed salmon surpassed the yield of global catch of wild salmon (The Standing Senate Committee on Aquaculture, 2001). In the 2000 to 2005 period, the global aquaculture yield was at least five times the size of the capture fisheries (FAO Fisheries and Aquaculture Department, 2007). The size and economic importance of the aquaculture industry is expected to continue to grow driven by rising demands for heart-healthy protein (Genome Canada, 2008c).

The Canadian aquaculture sector is like many sectors in Canada: strong in public research and weak in international market share. The Council of Canadian Academies reports that Canada has a research strength in the area of aquaculture and that this resource is modestly improving from year to year (Council of Canadian Academies, 2006). Despite its research strength and the abundance of natural resources, Canada is not among the top ten aquaculture producers of food fish in terms of quantity or year-to-year growth in quantity; many smaller economies (e.g., Norway) are substantially outperforming Canada (FAO Fisheries and Aquaculture Department, 2007)¹. Since many Canadian industries suffer from similar problems, the case study findings related to knowledge transfer between the partners are expected to capture dynamics likely to occur in these other industries as well.

The aquaculture industry is also of interest because of the weakness of its intellectual property position in Canada. For example, there are no strong intellectual property protections for broodstock enhancements, and Canada does not permit patenting of higher life-forms (*Harvard College v. Canada (Commissioner of Patents)*, 2002). While genetic sequences may be patentable, these patents are rarely used by the aquaculture industry to protect their inventions and innovation (Culver, 2008). Intellectual property protection can also be provided by registration systems but, unlike plant varieties, fish varieties are not registered in Canada. For these reasons, the partnerships investigated in this study are not expected to generate intellectual property, not to be reliant on it to position themselves in domestic and global markets.

¹Finfish is the leading segment of the aquaculture market (FAO Fisheries and Aquaculture Department, 2007)

Since identification and tracking of intellectual property created by PRO-industry collaborations is central to Genome Canada's understanding of the effectiveness of those collaborations, the absence of intellectual property production from aquaculture collaborations leaves us short on the conventional, and approved tools for assessing whether and how aquaculture R&D collaborations succeed. One outcome is that we may be liable to underestimate the value of aquaculture R&D collaborations to the extent that they are susceptible to being misunderstood if measured using inapplicable tools. This case study aims to contribute to understanding how to characterize the kinds of knowledge created by PRO-industry collaborations, with particular emphasis on capturing commercially and socially valuable knowledge ineligible for protection as intellectual property. Deeper understanding of the products of PRO-industry collaboration is critical to effective formation and operation of these collaborations, and equally key to understanding the conditions under which public subsidy of such collaborations is justified.

This study investigates two collaborative aquaculture research projects funded by Genome Canada, allowing useful comparison of two projects in similarly focussed research with a common beneficiary, the Canadian aquaculture industry. The cases investigate the ways in which the organizations generate, transfer and track knowledge. The cases also investigate the accountability practices used to assess the projects as investments of public funds, and the impact of these practices upon the research projects themselves.

This paper is structured as follows. The next section describes the methodology employed in the study. The subsequent five sections present the two cases in terms of five themes: 1) Organizational Context; 2) Knowledge Generation; 3) Knowledge Transfer; 4) Knowledge Tracking; and, 5) Accountability. The last section provides summary observations and conclusions.

2 Methodology

This study employs case study methods to perform in-depth analysis of knowledge transfer and accountability in PRO-industry partnerships. Yin (2003) has defined this research method as an empirical investigation of a "contemporary phenomenon within its real-life context", which employs multiple sources of evidence. In this study, the contemporary phenomenon is PRO-industry research partnerships. The multiple sources of evidence are: 1) documents that defined the partnerships and summarized the progress of the research collaborations; and, 2) semi-structured interviews with project principals, including management of the firm, primary investigators within the research institutions, project managers and administration from the relevant granting agency. The interview protocol was devised to address the five themes listed in [Section 1](#). It is comprised of fifteen open-ended questions, and it is included in [Appendix A](#). A total of eleven interviews were conducted, each at least forty-five minutes long: seven with principals of Case 1, and four with principals of Case 2.

To investigate the cases in context and in-depth, case studies often describe

and analyze a small number of events or conditions and their relationships (Yin, 2003). In this methodology, a small sample set ($n=2$) is both typical and appropriate. The two cases compared in this study were selected because they are similar in many ways. First, they were both approved and awarded research funds by the same publicly-funded agency, Genome Canada, and administered by its regional subsidiaries. In addition to being funded by the same agency requiring the same reporting of scientific, financial, and commercialization activities from each project, the projects were of similar duration and scale. Cases 1 and 2 are of projects scheduled to run for between three and four years. Both projects have multi-million dollar budgets; Case 2 has more funding than Case 1 by a factor of about five. Second, the projects were engaged in similar scientific study. Both are involved basic research that is expected to enable further scientific and applied work downstream. In both cases, the realization of economic and other social benefits is likely to require additional development of the research beyond the end of the current projects. Since the projects are performing the same type of scientific investigation and are of the same timeframe and type of science, they can be expected to produce similar types of outcomes. Commensurate with its higher budget, the Case 2 project is expected to be more productive than the Case 1 project. Thirdly, both research projects have implications for a species of finfish actively farmed by the Canadian aquaculture industry. The two projects focus on different species but, in each case, the relevant species are farmed in the same region as each of the projects. Therefore, the projects both appear to have an opportunity to contribute to regional development, by facilitating broodstock enhancement by regional partners.

The principal difference between the two cases is the way in which the partnerships were structured. In Case 1, two government research PROs were partnered with a single firm. The project was funded by Genome Canada and matching resources were supplied by the project partners. In Case 2, the funds matching the Genome Canada investment were provided by a provincial Canadian government. This provision meant that the project did not require any investment on the part of the local aquaculture firms that were expected to make use of the research developments achieved through the project. The project partners are researchers at two universities. In lieu of a dedicated industrial partner, the project plan included outreach activities designed to involve the local aquaculture industry. The comparison of the two cases will seek to identify the impact of this difference in structure in terms of both performance and accountability practices.

3 Organizational Context

The interviewees were asked to describe their organization in terms of: 1) the focus of its activities on a spectrum from pure research to applied research to commercialization of research; and, 2) its goals and mission. These responses were used to assess the extent to which the PRO and its partners were aligned in pursuit of shared goals.

3.1 Case 1

The interviewees were asked to locate their organizations on the continuum between pure and applied research. Their responses indicated that the project was a good fit for both contributing PROs. “[The first PRO] has a majority of projects on the applied side of the continuum. It does some discovery and some basic research.” The other PRO, “targets research that can be applied within a five- to ten-year time frame, but within [this PRO] there’s quite a spectrum of pure research to applied research. [This project] hits reasonably well the five- to ten-year time frame type.” The industry partner identified is further towards the development end of the spectrum than the PROs but quite actively so:

Everything that we do is based on good science. If we want to make a change, we’ll set up a trial and carry that out before we actually make a change. Every day there’s some type of research going on. There have been criticisms in the past that aquaculture doesn’t have enough technology. We would argue that the technology hasn’t even come close to being where it needs to be.

The mandates of both PROs’ emphasize strengthening Canadian industry and creating social and economic benefits for Canada. As a result, their organizational goals were compatible with the industry partner’s objective to “build a strongly technological aquaculture company that is a world leader” and with the Genome Canada’s mandate to seek both scientific and commercial outcomes from genomics and proteomics research. Perhaps the best illustration of this focus on creating economic benefit is the way in which a PRO principal described the role of PRO scientists:

Industry focuses on the bottom line. How are they going survive right now? How are they going to get the dollars and cents, and keep a business going; pay the bills and pay the salaries? It’s very difficult for them to think about how ten years down the road they’d be really better off if they had a new diet formulation, or if they had improved stocks in a particular way... That’s where the scientists come in: predicting what some of the benefits would be for the future. You only get a grasp of what they need and what you can do for them by staying in close communication, working closely.

For a PRO-industry partnership, the partners’ goals are surprisingly compatible because the PROs have a strong mandate to support industry. The gap between their usual research activities is relatively small (i.e., applied research at the PROs and extensive testing and development activities at their partnered firm).

3.2 Case 2

There appears to be a significant disparity between the research-intensity of the Case 2 PROs and the anticipated future developers of their research, that is,

aquaculture firms in the region. There is some evidence that these firms may not be scientifically advanced. They were described by a principal as “limited” and multiple interviewees suggested that they had concerns that the region’s aquaculture industry was not well-positioned to make use of innovations. One noted:

I was on a phone call yesterday with a scientist at a company in [the region] and he said, “It would be nice if something that I developed stayed in [the region] because what happens is everything gets exported. The basic science goes out, it gets added value in somewhere like Norway or Chile or wherever and then the local companies buy that product. The value gets added outside. I’m trying to learn about this myself but I would attribute that just to the relative size of the industry. [Regional firms are] not investing in R & D to the level that the Norwegians are. . . There will be commercialization out of some aspects of this [research project]; [but] it might be all off shore.”

This observation suggests that the Case 2 aquaculture firms lack the in-house knowledge required to identify and capitalize on technological innovations. There is a large gulf between the research intensity of these firms and the PROs in the partnership. The PROs were both described as very highly research-intensive with a focus on “basic science” as opposed to applied research: “we’re very, very much on the side of pure data generation.”

3.3 Summary of Organizational Context

Case 1’s PROs and partners appear to share closely aligned goals and activities. Case 2’s PROs and potential receptors of technological innovations appears to be rather less well aligned in goals and activities, as Case 2 PROs appear to more tightly focussed on basic research than the Case 1 PROs, and firms in the Case 2 region are reported to have low research intensity than the partner firm in Case 1. Elements of poor PRO-partner alignment such as mismatches in knowledge and focus make it difficult for public and private organizations to discuss the value of the science in mutually understood terms. The implications of this finding will be reviewed in the context of knowledge transfer discussed below.

4 Knowledge Generation

The interviewees were asked to report the types of knowledge they generate and their answers were very similar. When this study was conducted, both research partnerships were still in progress so final project outcomes were not available. The partnerships were making good progress towards completion of foundational genetic work that was expected to facilitate broodstock development after the project’s completion. Fundamental genetic data on each of the species of interest

had already been published in academic articles and through contributions to genetic databases. Both projects appeared on track to meet scientific objectives.

5 Knowledge Transfer

5.1 Case 1

Both industry and PRO principals indicated that the partnership had frequent, bidirectional knowledge transfer. When asked how knowledge usually moved back and forth between the firm and the PROs (e.g. email, phone, site visits), an industry partner noted that it was “a combination of everything. [The partners] have an extremely good working relationship and have had that for many, many years.” When asked about knowledge exchange with firms, especially the partner firm, a PRO principal noted:

I do it all the time. I’m always in touch with industry and, actually, [this project’s partners] have been an exceptionally close group to work with. We know everybody. We’ve worked really, really closely together; we’re always in touch; we exchange ideas and problems and fish. [You have contact by email, phone] and then you have visits. Like this week-end, I’m going down to visit [the other PRO partner]. You’re friends also so you’re going to go down and visit and see what they’re doing... We’ll sit there and talk about various things. You stay in touch with people and you exchange ideas and [find out] what their problems are.”

There was also strong evidence that the knowledge transfer between the partners had an impact on the research project. Principals from all three of the partner organizations described specific instances in which communication between the partners changed the focus of the research. For example, the industry representative noted:

From an information standpoint, we’re providers of advice as to what things are important to moving the industry or moving production... The work that we did with [a particular trial] is an example. We helped say, “Yes, that information would be useful to us.” The trial came up that was looking at [a specific trait], which we don’t believe to be an issue; we said, “No. We don’t think that that is a valid experiment to participate in because it doesn’t have an economic outcome.”

The project principals were asked to identify outcomes from their work and those likely to benefit from these outcomes. The PRO researchers noted that graduate students benefited from the research opportunities afforded by the project and other students were provided exposure to the research through tours and lectures. The research was expected by all parties to facilitate the industrial

partner's broodstock enhancements; however, the firm didn't expect to benefit from a competitive advantage for another five to eight years after the completion of the project because breeding cycles in the species of interest are quite long. Despite the high likelihood of successfully completing the scientific research, the industrial partner considered participation in the project, "a big leap of faith... We've assumed that the firm will still be in business at that time and able to start using [results of the research. . . If we are,] we'll have accelerated the work that we would have had to pay and undertake ourselves probably by about 5 years." Another industry representative discussed the potential long-term benefits of this accelerated research program:

We were very keen that that it would give us a strong competitive advantage which we thought we could turn into job opportunities. It's something we're really proud of. We moved [to a rural area some years ago] and people were moving out of those areas. We brought in about 10, 15 young families, with technology backgrounds, educated people. We like to think that we can attract talent to the area, that we can create employment in an area. It may not be able to replace something like a fishery when it is small but, once you build biomass, what the hell's the difference whether you catch the fish or grow the fish?

A representative of the funding agency also discussed the ultimate impact on the region, suggesting that a key outcome of this and related projects may be catalyzing further investment in technology-based firms in the area:

[The funder] with a host of other partners has enabled genomics and proteomics research in this region to the tune of about 45 million dollars over the last five years. We now have a [state of the art genomics facility] that wouldn't exist in the absence of these projects; we have some core competency across three different sectors, all of which have laid a foundation of knowledge such that further investment in these projects should enable some significant amount of impact... If I was trying to raise venture capital money, that's an elevator pitch that would need to be fine tuned. One of the things that I have to do in my role is to reflect on how [the funder] positions itself. . . I think a catalyst, an enabler, an investor, and a manager really sums up what we're trying to do.

In summary, the project has generated academic outcomes in the form of student training and increased expertise on the part of the researchers both in the PROs and the firm. Commercial outcomes are significantly less certain but this appears to be an unavoidable result of the nature of the enterprise. Firms can fail or change direction so this long-term project may not yield economic and social benefits to the region. All measures indicate that the industrial partner has the necessary competences to successfully make use of the research results. The project principals appear to agree; none of the interviewees expressed concerns

that the industrial partner lacked the know-how to benefit from the research results.

5.2 Case 2

In Case 2, interviews with project principals suggested limited knowledge flows between researchers and firms. When asked if the PRO researchers interacted with regional aquaculture firms, one researcher responded, “Not so much. Interaction with [finfish] farmers is basic interaction; it’s just informing people what we’re doing.” This and other responses also suggested that any knowledge flows were one-way. Since Case 2 did not involve a formal industry partner, the project was required by the funding organization to host out-reach activities but these events provided few opportunities for collaboration between the researchers and regional firms. The outreach activities were facilitated by someone outside the core research team and had the goal of providing the public with “science-based workshops with a focus on sound policy for sustainable resource management.” In one of the few instances in which a primary investigator provided information on the science being conducted to an audience including firms, the format was that of a brief presentation rather than a more interactive setting. Unlike Case 1, there was no history of interaction between the PRO researchers involved in Case 2 and their regional aquaculture industry. Overall, there was little evidence to suggest that there was knowledge transfer in progress between regional industry and PROs.

Unlike the researchers in Case 1, the Case 2 researchers did not mention any instances in which their research direction or approaches were modified in response to knowledge gained from industry. This is consistent with the observation that the Case 2 researchers did not appear to be engaged in learning from industry.

When asked to identify the beneficiaries of the project, the principals all mentioned other academic researchers interested in related topics both within Canada and internationally. Graduate students, co-operative education students, and post-doctoral fellows were also identified as important beneficiaries because of the training received by participating in the research:

One of the most important things coming from the [PRO] is people... It’s great to produce chips and technologies, but I’m sure that five years from now the technologies will be dead; there’ll be another technology but the people will be there.

Despite this scientific success, it appears unlikely that the project will also meet its commercial objectives, at least within the Canadian finfish aquaculture industry. There was no evidence of knowledge exchange between the project principals and target firms. The little evidence regarding these firms suggests that they are not well-positioned to transform the research findings into competitive advantages. When asked about commercialization possibilities, one project principal observed that he expected to be working with Chilean or Norwegian firms. Another respondent also made this observation and expanded as follows:

I think that the scope of the project doesn't involve the development of applications; however, [the researchers] will likely be able to [achieve outcomes] that will be of interest to commercial entities... those in the world who are interested in improving broodstocks, probably Norwegians or Chileans.

Some of project principals are of the opinion that the project's original commercialization objective is not feasible, that is, to provide an opportunity for finfish aquaculture to "harness the power of genomics" to the benefit of Canada. It was unclear at what point in the research process the principals came to this conclusion. The interviewees did identify alternate commercial prospects. They proposed that their work may find Canadian commercial impact through vaccine development or tests related to environmental monitoring and other sustainability practices; however, no evidence was offered that these possibilities had been explored or developed. All opportunities considered, there was little evidence that Canada would benefit directly from applications derived from the Case 2 research.

5.3 Summary of Knowledge Transfer

The two cases exhibited very different knowledge transfer patterns. As of the end of the data collection phase, Case 1 exhibited frequent and productive knowledge exchange between PROs and industry, while Case 2 demonstrated only infrequent and limited knowledge exchange with industry. Case 1 was on track to meet both scientific and commercialization objectives and Case 2 was on track to meet only its scientific objectives. Project principals expect the commercial advantages stemming from Case 2 research to be realized by non-Canadian firms.

This section compares the two cases to identify possible causes for the different knowledge flow patterns and expected outcomes. A review of the two cases implies that the failure of Case 2 to support constructive PRO-industry dialogue and to support commercial development of their work stems from two factors: 1) the disparity in organizational goals between PRO and industry partners; and, 2) the absence of frequent communications along rich communication channels.

The PROs involved in the two cases differed in terms of the nature of their research. When asked to locate their work on the spectrum from pure research to applied research, Case 1 researchers were in the middle and Case 2 researchers tended towards fundamental science. Yet the work required to support a partnership with industry is more likely to thrive when its focus is applied rather than fundamental. The scientific focus of the researchers may have made it more difficult for them to communicate meaningfully with representatives from regional aquaculture firms.

Where firms have low research intensity and PROs are principally focused on fundamental science, the obstacles to knowledge transfer are expected to be difficult to surmount. This suggests in turn that the partners will require more contact using rich communication channels to learn how to frame their knowl-

edge in terms that are meaningful to principals across the industry-PRO divide. As a consequence of the structure of the partnership, Case 2 formally required less PRO-industry interaction despite effective knowledge transfer appearing to require far more. The combination of the partnership structure and the partnership context significantly reduced the likelihood that the project would have commercial outcomes. Granting agencies should consider stronger formal requirements for interaction in future projects than were required in Case 2, especially when there is little evidence of existing PRO-industry relationships.

6 Knowledge Tracking

6.1 Case 1

The Case 1 PROs track a wide range of activities and outputs. Tracked documents include all academic publications, reports, grant applications, and legal contracts (e.g. material transfer agreements). Tracked activities include outreach activities like guest lectures, workshops, conferences, scientific and industrial collaborations. The researchers use spreadsheets to track biological samples and data libraries. The primary problem that researchers reported with knowledge tracking was the lack of continuity of data: the same data was frequently required to comply with accountability requirements of different partner organizations and needed to be recompiled every time:

We're supposed to have internal tracking. Whenever I submit a paper, a form has to be signed by a number of people and a tracking number is given to that particular publication. That should seamlessly be all going into a database so that management has it for all their grants, and performance reports. We give them the information but it seems to get lost so we're persistently pestered for the same information over and over again.

Another researcher added:

[Tracking] ends up being the burden of individuals' memories and notes. An awful lot is done by e-mail so that there are e-mails one can go back to, to look at requests that have been made, information that's been sent in. In terms of data flow out, if it's going to [the regional Genome Canada centre], for example, they have one quarterly report. We keep copies of all the quarterly reports. If someone else is asking for information, we keep track of where that information goes but it's not centrally organized. It's dispersed among the people who are involved in the actual transfer of that data and sometimes things fall through the cracks. It falls on [the lead researchers] to maintain that stuff and I can imagine ways that might be more efficient and more centralized but I guess it's a trade-off of putting the time and effort into setting those up and following them as compared to doing it the way we've always done it.

Another researcher suggested that the Case 1 project was subject to less tracking than may be typical because of the nature of the collaboration:

[Tracking for this project] is on a relatively informal basis. [The project] tends to just mostly be tracked in people's lab notebooks. We went to [the industry partner], we sampled forty fish and those samples are stored in this freezer. There doesn't tend to be a formal materials transfer agreement. On the [this project], the IP that's generated will probably be applied by our investment partners like [the industry partner]. We're not planning on selling it to somebody.

6.2 Case 2

The Case 2 researchers track significantly fewer outputs and activities for their home organizations. When asked about tracking, a researcher responded, "I archive e-mails. That's pretty much it." Another observed:

I personally don't [track project outcomes]. We have a couple of very good project managers and that's what we pay them to do. The scientific knowledge that comes in, I track that with the 'little grey cells' as Hercules Poirot would say. As different projects go, we try to define how we will put the information together for publication purposes. It's captured that way: in poster presentations, thesis reports, co-op student reports.

[Project management tracking is not a trigger for progress.] We're constantly going to meetings or preparing and submitting abstracts for meetings. I think that is what is the major trigger for what do we need to accomplish to complete this segment of the project.

In order to manage the distribution of a scientific resource generated by the Case 2 research, the lead researcher on that element of the project had a standard agreement drafted:

I have an agreement of use and it says, "I won't transfer the knowledge, or distribute [the resource]. I'll acknowledge the sources and contribute to cost recovery." More importantly, "We will not hold the providers responsible for anything that ever happens to these things, that kind of stuff. We ask that they read it. No signatures. The minute it becomes legal, there's a whole process that gets involved. Every institution has its own way of dealing with it and rather than deal with every institution, we just have them read it. The minute there's a signature, it ends up going through various levels from the technician, to the lead researcher, to the chair signing it... However long the food chain is. That gets awful. We spend money just to try and get material transfer agreements (MTAs) signed and it's not worth it. All we ask for is cost recovery and if they don't send it in, it's okay, if they can't afford it. We

don't hound anybody. We tell people, "If you don't pay, we may not send it to you any more."

6.3 Summary of Knowledge Tracking

A comparison of knowledge tracking across the two cases suggests that the amount of effort invested in knowledge tracking may be a function of the type of public research organization. Case 1 researchers, who worked within Canadian government research facilities, did substantially more internal reporting than Case 2 researchers, who worked within Canadian universities. It was clear from the participants' comments that standard operations within the government research facilities required more knowledge tracking than was required by the universities in question. In both cases, knowledge tracking appeared to be primarily used to fulfill accountability requirements rather than as a project management tool that guides the collaborative research project. Researchers involved in both Cases 1 and 2 appear intent to avoid paperwork whenever possible, especially as it relates to intellectual property protection, because of the additional layers of bureaucracy involved in managing legal contracts. These findings suggest that accountability requirements need to be handled deftly so as not to deter researchers from engaging in large-scale collaborative projects.

7 Accountability

7.1 Case 1

When asked to whom they are accountable and how, the Case 1 PRO and industry representatives often mentioned their sense of obligation to the partnership. For example, a PRO researcher noted, "you want your research be successful so that the whole project succeeds and there's definitely informal reporting, so to speak, of results, data, problems and so on." These appear to be evidence of a high degree of commitment to the project on the part of the project principals. When asked specifically about formal accountability, most respondents identified the processes required by the funder and by the PROs' animal care review boards. The animal care processes received little further comment. Interviewees devoted much of their discussion to the processes and documentation required by the funder. By the time the interviews were conducted the project principals had experience with the funder's requirements, having completed a number of financial reports, quarterly reports, and a mid-term evaluation, in which the continuation of the project hinged on successfully meeting the expectations of a review panel organized by the funder. Their comments on the funder's oversight had a consistent theme: "The funder has just been consumed with process ... the interim review was extremely onerous and we got nothing out of it; [it had] no scientific review component at all. ... [the midterm review] impinged substantially on my workload ... I could spend that time much more productively writing up publications." Overall, the accountability processes were seen

as burdensome and unproductive.

The accountability requirements were also investigated through a review of content of the various forms and contracts. The only element in the Case 1 reporting forms that relates to commercial potential is the section that calls for the disclosure of “discoveries’ with commercial potential that warrant further discussion.” In the context of the project contract, and especially the disclosure clause, it appears that this section addresses only those discoveries that may warrant the acquisition of intellectual property protections, like patents. The Case 1 PROs’ performance assessments also track a narrow range of measures. The main measure of commercial-relevance is patent counts. Both the PROs’ and the granting agencies’ measures make the incorrect assumption that all work with commercial potential can and should be protected using patents and other legal forms of intellectual property protections.

7.2 Case 2

Like the interviewees in Case 1, Case 2 principals noted that it was possible to be overloaded with accountability practices but, unlike the researchers in Case 1, Case 2 researchers did not describe the current requirements as onerous:

If you get overburdened by reporting, you dwell on the minutia and you ask, ‘How many tests did we do this week?’ as opposed to, ‘What does it mean for the genome? I tend to take a higher view than would be necessary if we had to report every single detail. Fortunately, our masters [at the funding agency] are very happy with that.

The other researcher also noted that the requirements had become less time-consuming as the accountability process evolved and as the project principals became familiar with the process over multiple grants from the same funding agency:

I think we’ve figured out how to make them reasonably efficient. The first ones are very difficult. After a few years, they become pretty formulaic. I also think they’re less onerous than they were. They’ve become boxes that you fill in.

This observation suggests that experience with the accountability documents may reduce the project overhead.

Like Case 1, the reporting forms provided by the granting agency to the Case 2 principals suggested that intellectual property protections were expected. The forms had placeholders for intellectual property outcomes. Unlike Case 1, the PROs in question required little or no internal reporting beyond the financial accounting.

7.3 Summary of Accountability

The review of the accountability practices employed in the two cases brought two issues to light. First, the accountability practices created an administrative overhead that principal researchers found to be burdensome and thus disruptive of the research in one of the two projects. Second, the knowledge tracking and reporting required by the granting agency and some of the PROs is unproductively focused on intellectual property protections as a proxy for commercial impact. This section will explore these two issues and provide some recommendations regarding ways in which project stakeholders, especially the granting agency, can improve future collaborations.

With respect to managing the accountability workload, Case 1 researchers found the requirements to be onerous. Dissatisfaction with reporting requirements is important because the funding agency wants to retain access to experienced and successful collaborators. Case 2 researchers were not dissatisfied. This may be because they had already been exposed to the funder's reporting requirements because they had had earlier grants from the funder. It is also the case that the Case 2 research project was large enough to support project management staff to take care of much of the reporting, lessening the burden on the principal investigators. With respect prior experience with the funder allowed the Case 2 project principals find strategies to more comfortably manage these requirements. It seemed that the Case 1 project principals were surprised and unhappy that the knowledge tracking and reporting workload required for their project is higher than that of grants they had received in the past.

It may be possible to reduce dissatisfaction by ensuring early and continued disclosure of accountability requirements, such that project principals know what to expect of the process and workload. The need for early and continued disclosure is likely to be strongest for principals engaged in their first large project with the granting agency. Project principals may also respond well to increased access to information about resource availability, especially project management support. Case 2 had a full-time project manager for the duration of the project. The Case 1 researchers had a part-time project manager for part of the project and were sceptical of the value of a project manager. Project principals may find value in accounts of how past principals have mitigated the burden created by the accountability requirements by accessing these resources. Project principals and, in some cases, novice project managers, may require training in order for the introduction of project management personnel to be effective in the context of the collaborative projects.

With respect to project reporting on intellectual property, more differences between the two projects were found. In Canada, finfish aquaculture and many other types of agricultural biotechnology are subject to narrower forms of intellectual property protection than other fields of practice (e.g. medical therapeutics). Canada does not permit patenting of higher life-forms and fish varieties cannot be registered in Canada (*Harvard College v. Canada (Commissioner of Patents)*, 2002). This calls into question the validity of patent counts and other intellectual property-based measures as indicators of research impact. Case 2

demonstrates that it is possible for research have commercial potential without requiring patent protection, even from the perspective of the industry partners. This suggests that exclusively tracking those discoveries that call for intellectual property protections will not capture a project's commercial potential. Furthermore, it may lead to systematic underestimation of other projects for which intellectual property protections are not generally applicable because of the cost of patent protection, level of trade secrecy in the industry, or because of practices that are endorsed in different sectors.

The primary source of competitive advantage that can be obtained through broodstock enhancements in Canada is ownership of the enhanced broodstock. In Case 1, the industry partner is likely to create a competitive advantage by quickly making use of the scientific outputs, for example the micro-array, to further enhance their broodstocks. The competitive advantage would be derived from speed to market, and ownership of the broodstock. The knowledge exchange in Case 1 also generates value in the form of know-how or tacit knowledge. This know-how is almost certainly more valuable than any such patents that the firm might acquire due to the limitations of the type of intellectual property protection available to protect the results of finfish genomics research. The firms are likely to maintain its know-how by striving to retain knowledgeable employees, training new employees, and keeping trade secrets.

This bias towards intellectual property could be addressed by expanding project reviews to include 'intangibles' like increased understanding of and access to leading scientific research on the part of private partners. The funding agency could ask the industry and PRO partners to collaborate with them in the development of measures that better identify the ways in which collaborative projects create, track and manage value. The collaborative approach to metrics development should ensure that the reporting more closely reflects the value created by the projects without creating an unreasonable reporting workload.

8 Conclusions

This comparative case study provides the opportunity to explore the impact of the structure of a partnership upon: 1) the performance of the research project and thus expectations for the impact of the project; and 2) upon the accountability practices employed by the partnership. A review of the two cases suggests that the difference in structure had the strongest effect on the partnerships' performance and hence outcomes. In Case 1, the PRO researchers were required by the partnership agreement to communicate regularly and exchange resources with representatives from their private partner. The Case 1 principals made it clear that they felt personal obligations to these other project principals and communicated frequently and with ease, often in a social manner. Social capital is the concept used to capture the value that actors derive from their networks of social relationships (Bourdieu, 1986 ; Coleman, 1988). In Case 1, social capital both motivated and sustained the project; interpersonal dynamics seemed to supersede all formal requirements for interaction; the partnership would proba-

bly be equally likely to be successful in the absence of the meetings and reports required by the partnership agreement. In this sense, Case 1 could be taken as evidence that formal requirements for interaction are less critical to continuing PRO-industry relationships than social capital. In Case 2, the researchers at the PRO had no dedicated private partner and few formal requirements for communication with regional firms. If Case 2 had been supported by a similarly strong social network inclusive of regional firms, the absence of formal requirements would probably have had little impact. Since the researchers had little or no pre-existing relationships with private firms and no incentive to develop these relationships during the research project, there had been little knowledge exchange between the researchers and regional firms by the time this research was conducted.

This lack of knowledge exchange is deeply troubling because the participants acknowledged that the regional firms did not have the sufficient knowledge and skills to make use of the research results without external support. PRO-firm communication over the course of the research project could have encouraged firms to invest in these knowledge assets and helped the PRO researchers identify partners for future development of the research. In the absence of this communication, Case 1 can be expected to have little regional social and economic impact. To benefit from the advantages of partnerships with social capital, granting agencies would be advised to target existing PRO-industry relationships when possible. Since the existing formal requirements for interaction do not appear to constrain the interpersonal dynamics, the granting agencies would be advised to continue the requirements for interaction imposed on Case 1.

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A Appendix A.

1. Would you please describe your role in your organization and in this project? Follow on: In that role, what kind of information or knowledge do you generate, give to others, and get from them?
2. What is your organization's place on the continuum between pure scientific research and commercialization of technology? Follow on: If the answer involves research, then ask: what is the balance between pure and applied scientific research?
3. What are the mission and goals of your organization? Follow on: What motivations are there within your organization to pursue its mission and goals?
4. How does your organization guide research and knowledge transfer, by policies or incentives or profit-sharing or similar mechanisms?
5. How effective are the policies bearing on your organization's research/knowledge

transfer? 6. Who are your funders, and at what stage are they involved in research, development and knowledge transfer?

7. How do you track knowledge coming into your organization, and how do you track knowledge going out?

8. How effective are your organization's operations with respect to tracking (internal) and translating/transferring (external) knowledge?

9. When does your organization track (internal) and translate/transfer (external) knowledge - what are the stages and triggers?

10. Who benefits from your R&D activities?

11. What are the most important results of your R&D activities? Why do you feel this is the most important result? Follow on: How important are publications to your organization? Patents or other forms of intellectual property? Development of commercial products, processes or services? Follow on: What incentives are there for your organization to produce publications? Patents or other forms of intellectual property? Commercial products, processes or services?

12. What counts, to your organization, as an unsuccessful R&D collaboration? Follow on: In retrospect, can you identify whether the cause of unsuccessful R&D collaboration is mostly caused by policies, persons, technological failures, or other causes or some blend of these causes?

13. Within the project, to whom are you accountable and in what ways (for example: regulatory approvals, transfer of lab techniques or markers, or feedback regarding the effectiveness of knowledge, processes, or techniques you have been given)?

14. How onerous are these accountability requirements as part of your workload? Follow on: Do the accountability requirements of this project have a good 'fit' with your normal workflow? Follow on: Do particular stages of the collaborative R&D process involve especially difficult reporting or accountability tasks?

15. Overall, have the policies guiding this project's path from pure research to commercial product or process tended to make that process quicker, and more efficient, or slower and less efficient? Follow on: Would you recommend to your organization that you embark on a similar project again?

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