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The Organization and Dynamics of Clustering and Innovation

in the ocean technology sector in Newfoundland and Labrador and the St. John's city-region

Dr. Josh Lepawsky, Department of Geography, Memorial University

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Dr. Josh Lepawsky
Department of Geography
Memorial University

With research assistance by
Kathryn Goetting
Chris McNabb
Jeffery Simms

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Executive Summary

- The ocean technology sector operates as a cluster of inter-related business firms and other organizations according to national benchmark criteria for inductively identifying clustering activity.

- The cluster is predominantly outwardly organized, that is, toward other firms/organizations outside the region in terms of buyer/supplier relationships.

- The sector operates as a learning and innovation system. Substantial collaborations exist between business firms and other organizations in the cluster.

- There is clear evidence of labour flows between firms and organizations in the cluster that indicate a circulation of knowledge ('brains') is occurring within the cluster.

- Memorial University (MUN) plays a substantial role in buyer/supplier networks and within collaboration networks within the cluster.

- The network of buyer/supplier relationships internal to the cluster, other than those related to MUN, focuses on only a few firms.

- The cluster's outward orientation coupled with the dominance of only a few firms within the cluster suggests the cluster is vulnerable to external economic shocks.

- Important gaps or barriers to a more effective cluster and LIS include the difficulty of attracting both the shear number of staff and staff with the appropriate qualifications to firms in the sector. Challenges of funding and financing of R&D and innovation activities also remain important.

- Key observations and recommendations from study participants include:
    - Some government strategies are highly regarded. Recent policy initiatives are a source of optimism.
    - Industry sees a role for government.
    - Industry wants clear and consistent policy direction from government.
    - Industry needs to use existing programs more effectively.
    - Government needs to leverage the capacity of industry more effectively.
    - Initiatives that enhance possibilities for business cooperation and business mentorship need to be developed further.
    - Develop policies and supports with enough variety and flexibility to accommodate the diverse ecology of firms comprising the ocean technology sector.
    - Consider more targeted funding for the oceans technology industry, such as a non-solicited proposal fund.
    - Examine tax structures as sources of R&D funding.
    - Develop the human resources for the ocean technology sector by supporting the education of more than just science and technology students.
    - If research is to become a major activity of MUN, public funding formulas need to better reflect that goal.
    - Get beyond the work term and the co-op student. Develop structures that enable industry and academia to partner together more effectively for commercializing R&D.

- To grow the sector in the long term, get beyond an exclusive focus on college and university students. Get primary and secondary students excited about oceans and ocean technology.
- Develop more intensive, coordinated image management strategies for the sector as a whole.

Introduction

The organization and dynamics of industry clustering and innovation are key factors in contemporary regional economic development.[1] In Newfoundland and Labrador generally, and the St. John's city-region specifically, industries in the ocean technology sector are perceived to be of special importance to the region's present and future economic performance.[2] Yet, the dynamics of clustering and innovation in this sector are not well understood.[3] Region specific clustering initiatives such as Oceans Advance exist, but to what extent are clustering activities present? Is a learning and innovation system present? Also, while Oceans Advance represents a large number of firms engaged in a wide range of activity in the ocean technology sector, other firms and organizations not currently part of the Oceans Advance initiative may nevertheless be important contributors to Newfoundland's ocean technology sector.

This study analyzes the organization and dynamics of clustering and innovation in the ocean technology sector and suggests possible recommendations to stakeholders in government and industry for enhancing the sector's competitiveness. The study is organized around three main research questions each with follow-on sub-questions:

1. **Does a cluster and/or learning and innovation system (LIS) exist in the Newfoundland ocean technology sector?**
   - 1.1. If a cluster exists in the Newfoundland oceans sector, how is the cluster organized?
   - 1.2. If a learning and innovation system exists in the Newfoundland oceans sector, how is it organized?

2. **What are the gaps and/or barriers to the Newfoundland ocean technology sector operating as an effective cluster and/or LIS?**
   - 2.1. Assuming a cluster and/or LIS exists, what is the character of cooperation between firms in the cluster and/or LIS?
   - 2.2. If an oceans sector cluster and/or LIS are *absent*, would there be positive benefits to be gained from fostering clustering and LIS processes in terms of sector performance (e.g., measured in terms of profitability and competitiveness)?

3. **Assuming a Newfoundland ocean technology cluster and/or LIS exists, what needs to be done to take one or both to the next level?**
   - 3.1. What policy relevant, normative recommendations can be made?

[1] See for example, Bathelt, H. (2007). "Buzz-and-Pipeline Dynamics: Towards a Knowledge-Based Multiplier Model of Clusters." Geography Compass **1**(6): 1282-1298, Wang, T. Y., S. C. Chien, et al. (2007). "The role of technology development in national competitiveness - Evidence from Southeast Asian countries." Technological Forecasting and Social Change **74**(8): 1357-1373.

[2] Colbourne, B. (2006). "St. John's ocean technology cluster: can government make it so?" Canadian Public Administration **49**(1): 46-59. Atlantic Canada Opportunities Agency (2006). The Ocean Technology Sector in Atlantic Canada, Volume 1: Profile and Impact. Halifax: 1-65, Atlantic Canada Opportunities Agency (2006). The Ocean Technology Sector in Atlantic Canada, Volume 2: Public Sector Demand. Halifax: 1-75.

[3] For comparison, see Doloreux, D. and S. Dionne (2008). "Is regional innovation system development possible in peripheral regions? Some evidence from the case of La Pocatiere, Canada." Entrepreneurship and Regional Development **20**(3): 259-283.

Context

Clustering and learning and innovation systems (LISs) are similar but different phenomena. Though clustering and LISs are broadly recognized within the literature, there remain important debates about their significance, their key features, and how to measure their organization and dynamics.[4] In the broadest sense, clusters and LISs are similar in that they are comprised of linkages between firms and other organizations engaged in economic activity. They differ in what comprises these linkages. Within the academic debates, some general features of each are commonly recognized.

Clusters can be understood as groups of systematically co-located firms and other organizations (e.g., government, research institutes, trade associations, universities) that exhibit strong inter-organizational ties or linkages. These linkages may be comprised of, for example, buyer-supplier relationships, labour market specializations, and product or service specializations, among other possibilities. The organization and dynamics of clusters depends on the quantity and quality of such linkages as well as their orientation i.e., whether linkages are predominantly inward (toward other co-located firms/organizations within a region), outward (toward other firms/organizations outside a region), or some combination thereof.

Learning and innovation systems are similar to clusters in that they are comprised of linkages between firms and other organizations. However, where LISs differ is in what comprise these linkages. Generally speaking, rather than focussing on the movement of products or services between firms/organizations, LISs are comprised of flows of knowledge that lead to the creation of novel goods and services. Thus, analyses of the organization and dynamics of LISs tend to focus on such factors as labour flows between firms/organizations, labour force educational characteristics, R&D collaborations, strategic alliances, and patenting activity, among other possibilities.

Whatever form inter-organizational linkages might take, it is the linkages themselves that determine the presence or absence of a cluster and/or LIS. In this sense, clusters and LISs are not necessarily bounded by physical territory. Also, any given cluster or LIS exists in relation to other clusters and LISs, where the relation(s) between them are strongly conditioned by connection or disconnection from one another. An implication of this theoretical stance is that physical proximity is a necessary, but not sufficient, condition for clusters and/or LISs to exist and function.[5] What this means is that clusters and LISs might be usefully conceptualized as both physical and social spaces comprising networked archipelagos of inter-organizational and inter-regional linkages.[6] Thus, factors such as network centrality and

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[4] For recent critical reviews of the debates on clustering and LISs see for example Turok, I. (2004). "Cities, Regions and Competitiveness." Regional Studies **38**(9): 1069-1083, Jonas, M. (2005). "Bridges to regional cluster research - A sociological approach to an economic explanation." Zeitschrift Fur Soziologie **34**(4): 270-287, Malmberg, A. and P. Maskell (2006). "Localized learning revisited." Growth and Change **37**(1): 1-18, McCann, P. and T. Arita (2006). "Clusters and regional development: Some cautionary observations from the semiconductor industry." Information Economics and Policy **18**(2): 157-180, Yeung, H. W.-C. (2006). Situating Regional Development in the Competitive Dynamics of Global Production Networks: An East Asian Perspective. Regional Studies Association Annual Conference, London, Asheim, B., L. Coenen, et al. (2007). "Face-to-face, buzz, and knowledge bases: sociospatial implications for learning, innovation, and innovation policy." Environment and Planning C-Government and Policy **25**(5): 655-670, McDonald, F., Q. H. Huang, et al. (2007). "Is there evidence to support Porter-type cluster policies?" Regional Studies **41**(1): 39-49, Uyarra, E. (2007). "Key dilemmas of regional innovation policies." Innovation-the European Journal of Social Science Research **20**(3): 243-261, Van Rooij, A., E. Berkers, et al. (2008). "National innovation systems and international knowledge flows: an exploratory investigation with the case of the Netherlands." Technology Analysis & Strategic Management **20**(2): 149-168.

[5] Giuliani, E. (2007). "Towards an understanding of knowledge spillovers in industrial clusters." Applied Economics Letters **14**(2): 87-90, Sternberg, R. (2007). "Entrepreneurship, proximity and regional innovation systems." Tijdschrift Voor Economische En Sociale Geografie **98**(5): 652-666, Carroll, M. C., N. Reid, et al. (2008). "Location quotients versus spatial autocorrelation in identifying potential cluster regions." Annals of Regional Science **42**(2): 449-463.

[6] Gluckler, J. (2007). "Economic geography and the evolution of networks." Journal of Economic Geography **7**(5): 619-634.

peripherality (e.g., type, strength, and direction of linkages) or social proximity and distance (e.g., social cohesion, cooperation, tolerance) may be factors that strongly influence the organization and dynamics of clusters, LISs, and their constituent firms/organizations.

Methods

At the outset, it should be acknowledged that no single agreed upon methodology exists for identifying and measuring the organization and dynamics of clusters or LISs.[7] The research questions posed in this study point to the benefit of combining quantitative and qualitative methods.[8] Wolfe and Gertler (2004) recommend focussing on the dynamics of hypothesized clusters and LISs and using these dynamics to confirm the presence or absence of clusters and LISs. Such an approach would examine the inflows (e.g., labour, capital), outflows (e.g., exports, product licensing, patent citation), social dynamics (e.g., labour circulation, institutions for associative governance, competition and collaboration), and geohistorical path dynamics (e.g., resilience of regional clusters over time to economic downturns) from which genuine clusters and LISs can be identified inductively.[9]

Useful approaches that combine quantitative and qualitative methods have been developed in the Canadian context.[10] Combined methods were adopted for this study for two reasons. First, they offer a rigorous, quantitative method for identifying clusters that allows the existence of a cluster to be treated as a testable hypothesis rather than an *a priori* assumption. Second, these quantitative approaches can easily be complemented with qualitative approaches (e.g., semi-structured interviews). Indeed, substantial work on clustering and innovation systems in the Canadian context incorporates combined methods of this kind.[11]

Quantitative methods

Quantitative data were gathered via a web-based survey of firms in the Newfoundland ocean technology sector. Potential participants were contacted through four industry associations: 1) Newfoundland and Labrador Association of Technology Industries (NATI); 2) Newfoundland Environmental Industries Association (NEIA); 3) Newfoundland Offshore Industry Association (NOIA); and 4) Oceans Advance.

The survey was divided into four parts. Part 1 gathered basic information about firm characteristics (e.g., firm structure and location of operations). Part 2 focused on labour characteristics of firms (e.g., employee educational attainment and labour circulation). Part 3 investigated firms' capital flows (e.g.,

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[7] Johannisson, B., L. C. Caffarena, et al. (2007). "Interstanding the industrial district: contrasting conceptual images as a road to insight." Entrepreneurship and Regional Development **19**(6): 527-554, Steinle, C., H. Schiele, et al. (2007). "Merging a firm-centred and a regional policy perspective for the assessment of regional clusters: Concept and application of a "dual" approach to a medical technology cluster." European Planning Studies **15**(2): 235-251, Zabala-Iturriagagoitia, J. M., F. Jimenez-Saez, et al. (2007). "What indicators do (or do not) tell us about Regional Innovation Systems." Scientometrics **70**(1): 85-106..

[8] Elliot, S. J. (1999). "And the Questions Shall Determine the Method." Professional Geographer **51**(2): 240-243, Austrian, Z. (2000). "Cluster case studies: The marriage of quantitative and qualitative information for action." Economic Development Quarterly **14**(1): 97-110.

[9] See also Spencer, G. and T. Vinodrai (2005). Cluster, Muster or Bluster? An Inductive Approach to Measuring Clusters in Canada. Innovation Systems Research Network National Meeting. Toronto, Ontario, Innovation Systems Research Network.

[10] Wolfe, D. A. and M. S. Gertler (2004). "Clusters from the inside and out: Local dynamics and global linkages." Urban Studies **41**(5-6): 1071-1093, Spencer, G. and T. Vinodrai (2005). Clustering matters: Evidence from the ISRN's cluster indicators project. Ontario Network on the Regional Innovation System (ONRIS), Ministry of Research and Innovation (MRI) / Ministry of Economic Development and (MEDT) Joint Fall Workshop, Toronto, Ontario, Statistics Canada (2005). Survey of Innovation. Science Innovation and Electronic Information Division, Statistics Canada**:** 1-15.

[11] See the material available from Innovation Systems Research Network. (2008). "Welcome." Retrieved 13 June 2008, 2008, from http://www.utoronto.ca/isrn/.

supplier/customer relationships, financing and access to capital). Part 4 examined the knowledge and innovation characteristics of firms (e.g., nature and organization of innovation activities).

Qualitative methods

Semi-structured, open-ended interviews were used to add depth to the quantitative data collected for this study. The interviews focused on 1) collecting contextual information from firms (e.g., key events that lead to their founding); 2) perceptions about the benefits of, and barriers to, enhanced inter-organizational collaboration (e.g., joint R&D, cooperative marketing strategies); 3) probing respondents' perceptions about gaps or barriers to the performance of the ocean technology sector as a cluster and LIS now and in the future (e.g., strengths, weaknesses, opportunities, and threats); and 4) eliciting ideas about what factors, external supports, or policies would be most helpful for growing individual organizations and the sector as a whole.

Study participants

Potential participants were contacted by e-mail to the membership lists of NATI, NEIA, NOIA, and Oceans Advance and by phone. Potential participants received three e-mail invitations, an initial invitation on 9 June 2009 and two reminder e-mail invitations on 6 July 2009 and 17 August 2009. The members of Ocean Advance, because they are most likely to be relevant to the purposes of the study, were also contacted by phone. Attempts to contact by phone continued until a potential participant accepted the invitation to participate, declined to participate, or could not be contacted after three attempts, whichever came first.

The survey received a total of 44 responses: 40 from firms and four from non-firm organizations. The data sample reported below exclude these non-firm organizations. In addition to the quantitative survey, 13 individuals agreed to participate in in-depth, semi-structured interviews after the survey. These individuals represent 10 firms and three applied research units at Memorial University with strong ties to the ocean technology sector (See Table 1).

Interview participants	Description
C1	Engineering services firm.
C2	Marine electronics sales and service firm.
C3	Aviation firm.
C4	Industrial fabrication and marine equipment firm.
C5	MUN applied research unit.
C6	R&D manufacturing firm.
C7	Production design for marine industries firm.
C8	MUN applied research unit.
C9	Software engineering firm.
C10	Engineering services firm.
C11	Marine technology firm.
C12	Marine product design firm.
C13	MUN applied research unit.

Table 1. Description of interviewees. Interviewees were assigned a case number to preserve anonymity.

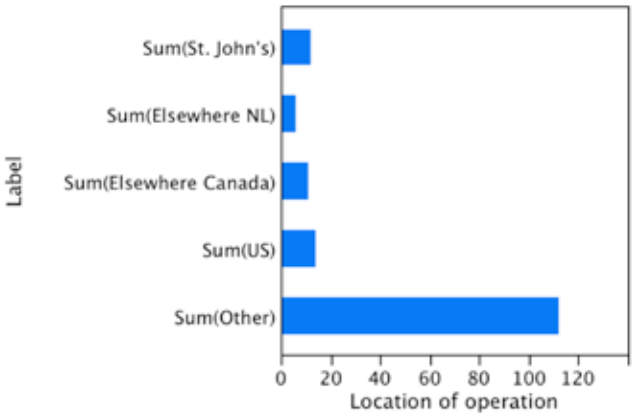
Interview participants were asked a variety of questions designed to provide context to the quantitative data collected from the survey. In addition, interviewees were provided with a list of Oceans Advance member organizations and asked to indicate which, if any, represented their top five suppliers and customers, which organizations they collaborate with, which organizations they have hired employees

from and lost employees to. Each firm in the list was subsequently assigned a number to preserve anonymity. These data were used to construct network maps describing cluster linkages in terms of customers/clients, suppliers, collaborations, and labour flows (see Figure 7, 8, 9, 19, and 20).

Findings

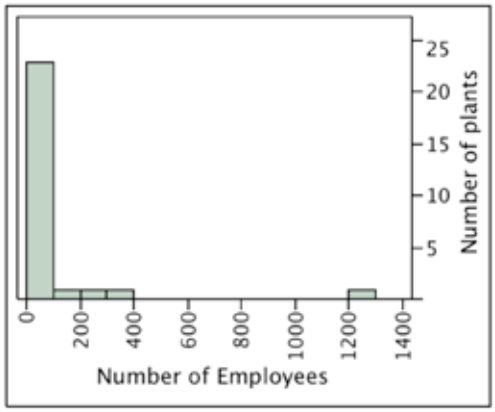
Of the 40 firms responding to the survey, over 93 percent are Canadian owned (10 respondents declined to indicate their ownership status). 23 of the 40 firms are Oceans Advance members, four are non-members, three firms do not know their membership status, and 10 respondents declined to indicate their membership status. Given that Oceans Advance has a total of approximately 51 members (excluding members that are units of Memorial University or a Memorial University separately incorporated entity), the survey sample represents just over 45 percent of Oceans Advance's membership by firms.

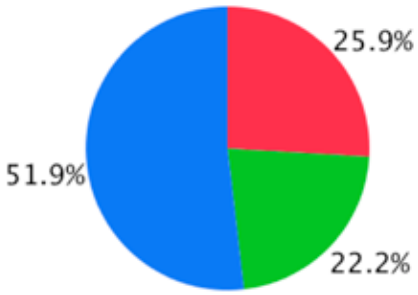
Figure 1. Year respondent firms were established.



A total of 11 respondents indicate their operations are part of a larger firm that has operations in and/or beyond St. John's while the large number of operations in countries other than Canada or the US are related to only two respondents (see Figure 2).

Figure 2. Location of operations.





Mean	87.4
N	27
Declined to answer	13

Figure 3. Distribution of firms by number of employees and percentage of firms by size.

The sample is strongly skewed toward smaller firms. Though the mean number of employees per firm is 87.4, better than half the sample is comprised of small firms with less than 20 employees. Just under one quarter of firms are medium sized with 21 – 49 employees while just over one quarter of firms are large, having 50 or more employees (see Figure 3).

Does a cluster exist in the Newfoundland ocean technology sector?

Yes. Spencer and Vinodrai (2005a) developed the following criteria for identifying clusters in the Canadian context:

- Size/scale: total employment in the sector must exceed 1000 persons.
- Specialization: the proportion of employment in the industries comprising the sector must exceed the national average for those industries (i.e., have a location quotient ≥1).
- Scope/breadth: at least half of the individual industries comprising the sector must exceed the national average for those industries (i.e., location quotient ≥1)

The ocean technology sector in Newfoundland and Labrador matches these national benchmark criteria. The firms sampled in the survey for this study employ a total of 2360 people and the ocean technology sector matches the above criteria in terms of specialization, scope, and breadth.[12] While these criteria are useful for inductively identifying a cluster, they say little about the organization of economic activity in a cluster and nothing at all about the presence or absence of a learning and innovation system. The next sections of the report discuss the organization of the ocean technology cluster and whether an LIS exists.

[12] See: Spencer, G. and T. Vinodrai (2005). Cluster, Muster or Bluster? An Inductive Approach to Measuring Clusters in Canada. Innovation Systems Research Network National Meeting. Toronto, Ontario, Innovation Systems Research Network. Spencer, G. and T. Vinodrai (2009). Innovation Systems Research Network City-Region Profile: St. John's (Update), Program on Globalization and Regional Innovation Systems (PROGRIS): 1-13.

Organization of the cluster

The organization and dynamics of clusters depends on the quantity and quality of inter-organizational linkages as well as their orientation i.e., whether linkages are predominantly inward (toward other co-located firms/organizations within a region), outward (toward other firms/organizations outside a region), or some combination thereof.

The data derived from the survey responses suggests that the Newfoundland and Labrador ocean technology cluster is predominately externally organized. For example, Figure 4 shows the percent of total revenue derived from the sale of goods or services in five geographic regions by firms in the cluster. Few firms derive more than 20 percent of their total revenue from the St. John's city-region or from elsewhere in Newfoundland and Labrador. Most firms derive their revenue from outside the province, either from elsewhere in Canada, the US, or other countries.

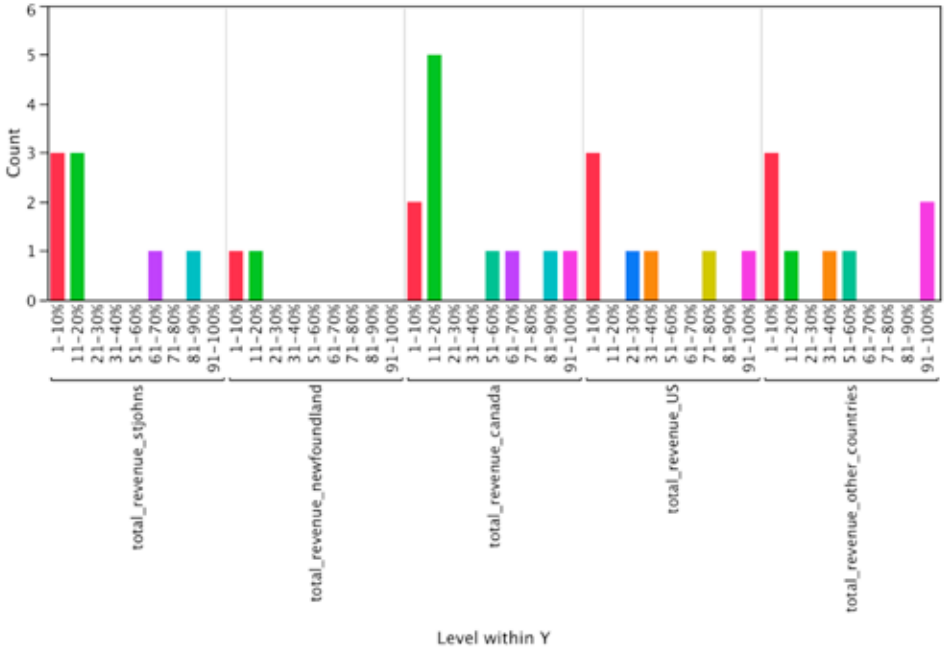


Figure 4. Number of firms (Count) with percent of total revenue from different geographical sources.

Further evidence of the outward orientation of the cluster is found in Figure 5 which shows the location of respondents' top five clients ranked in terms of the client's contribution to the firm's total revenue. Note that most firms ranking their number one client indicate that client is located in a country other than Canada or the US (location_client1). Firms' second most important client in terms of revenue tend to be located elsewhere in Canada. Not until the third, fourth, or fifth tiers of client rankings does the St. John's city-region begin to become important in terms of revenue for these firms.

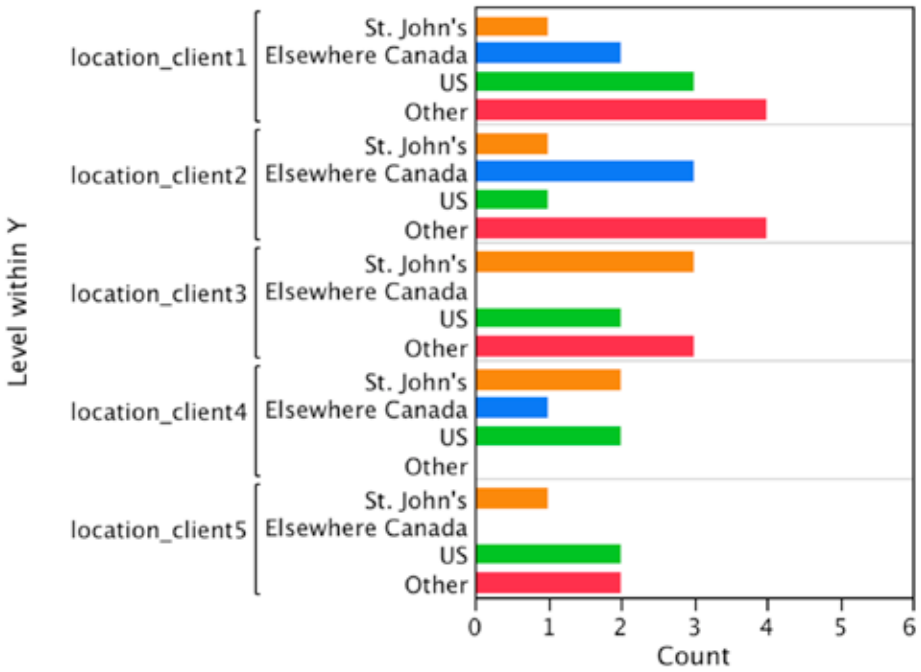


Figure 5. Location of Top Five Clients.

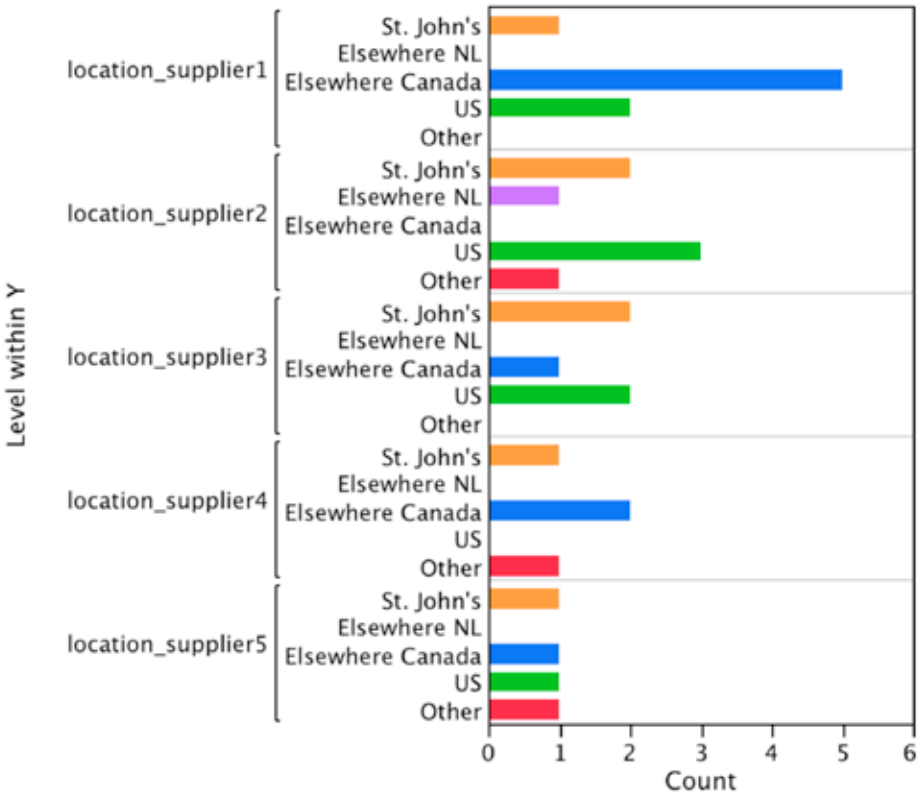
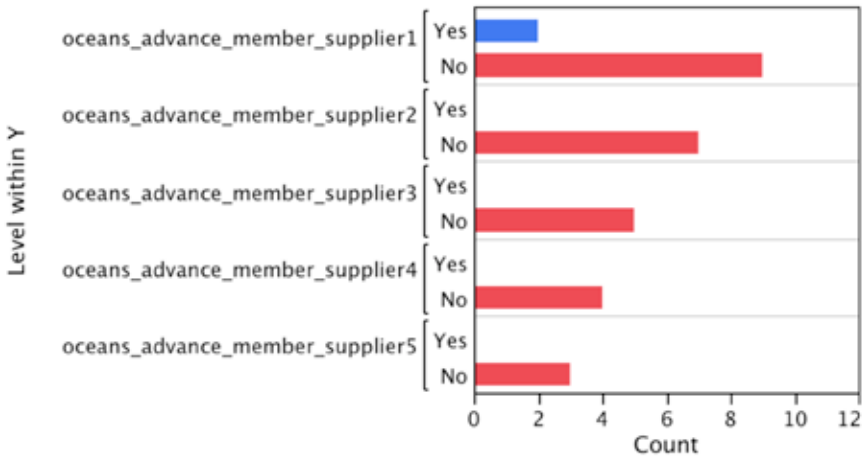


Figure 6. Location of Top Five Suppliers.

Firms in the ocean technology cluster are also predominately oriented outward from the perspective of their relationships with suppliers (see Figure 6). Respondents were asked to rank their suppliers in terms of the firms' total expenditures on raw materials and components. They were then asked to provide the location of each ranked supplier. Firms' most important suppliers tend to be located outside

Newfoundland and Labrador. The organization of these buyer-supplier relationships indicates a predominantly outwardly oriented cluster.



Only two firms indicate that any of their top five suppliers, ranked in terms of the firms' total expenditures on raw materials and components, are Oceans Advance members.

These findings hint at an issue that becomes more evident in Figure 7, 8, and 9: the outward orientation of the cluster coupled with its structural reliance on relatively few firms for internal linkages between buyers, suppliers, and collaborators suggest the cluster is vulnerable to external economic shocks.

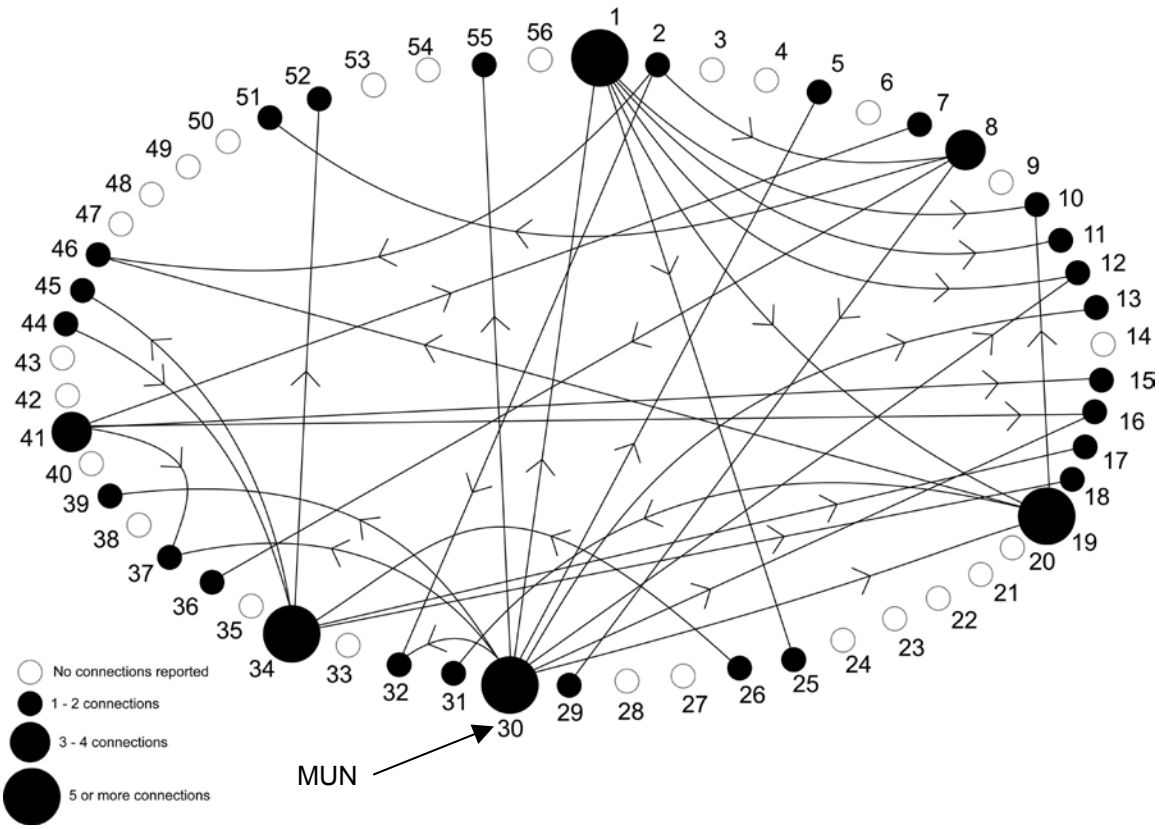


Figure 7. Supplier relationships among Oceans Advance members.

Notice that in Figure 7 only a few firms account for the bulk of supplier relationships internal to the cluster (e.g., Firm 1, 19, and 34). MUN, as public institution, is relatively insulated from downturns in the broader economy. Firms are not. The failure of Firm 1, 19, and/or 34 could significantly interrupt the supplier relationships within the cluster if alternatives outside the cluster could not be found.

Furthermore, as the adjacent figure shows, only two respondents indicate that any of their top five clients ranked in terms of the client's contribution to the firm's total revenues are Oceans Advance members.

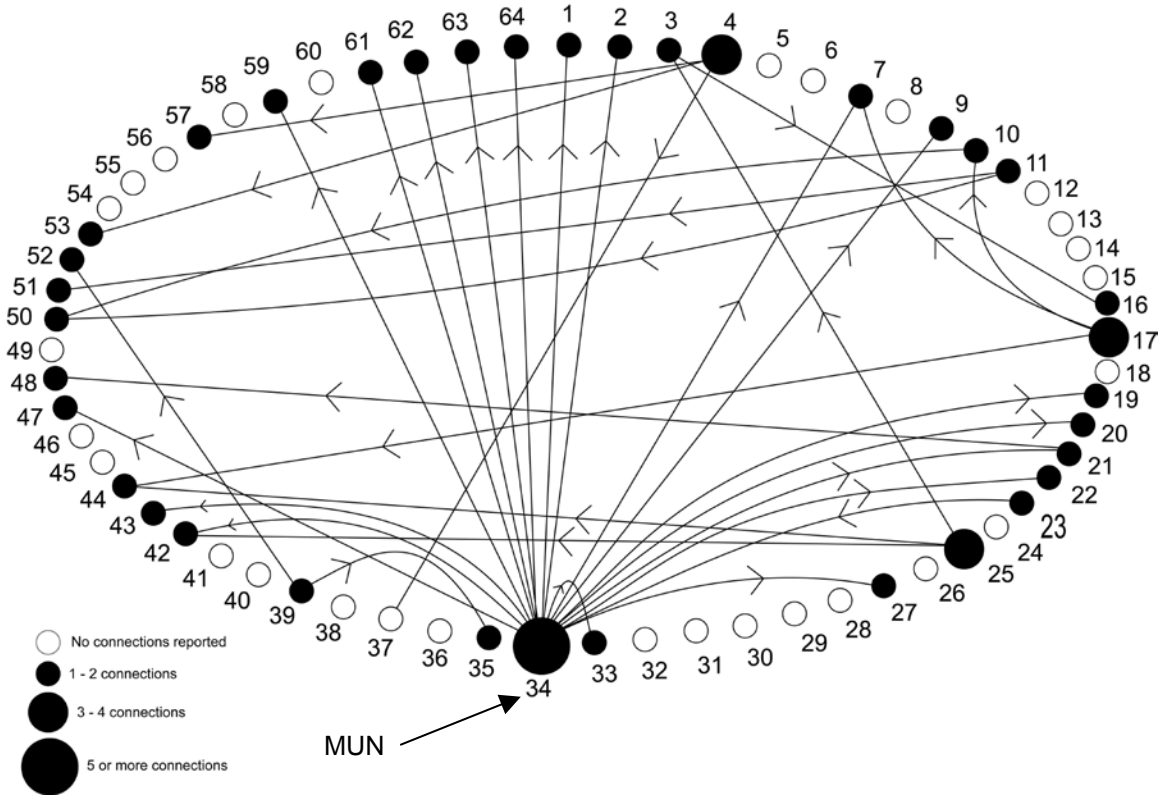


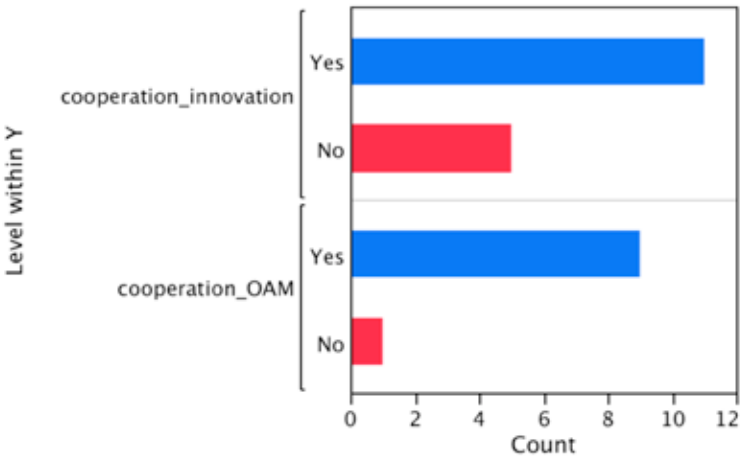
Figure 8. Client/customer relationships between Ocean Advance members.

It would appear that members of the cluster are linked much more strongly to suppliers and clients/customers outside the region than inside. This predominantly outward orientation of the cluster is in keeping with Ocean Advance's own visioning process represented in the association's report, *Outward Bound 2015*.[13]

Many firms engage in cooperative relationships with other firms and organizations to develop novel goods or services (see Figure 9). The majority of these innovation activities involved cooperation

[13] Oceans Advance (2008). Ouward Bound 2015: Accelerating the Growth of the Ocean Technology Sector in Newfoundland and Labrador. St. John's, Oceans Advance: 1-46. Note that at the time of writing, Oceans Advance was due to release its strategic plan based on the Outward Bound report on 8 October 2009.

between Oceans Advance members (cooperation_OAM). Again, however, a relatively small number of firms account for most of the collaborative relationships in the cluster (e.g., Firm 1, 17, 19, and 26).



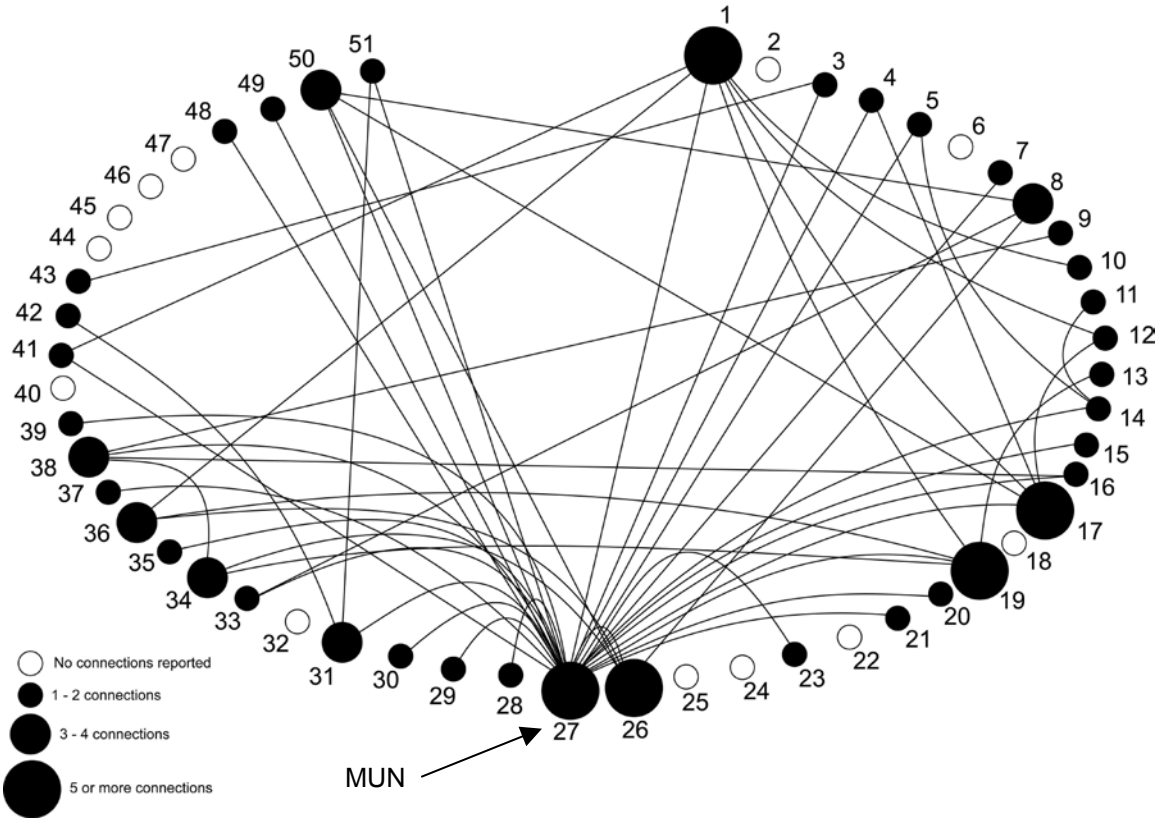
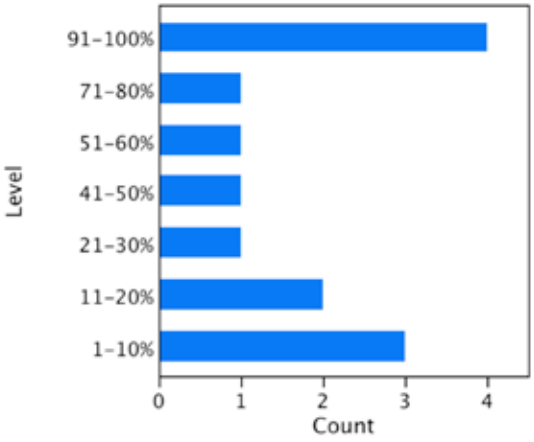


Figure 9. Collaboration linkages between Oceans Advance members.

The cluster's outward orientation coupled with the dominance of only a few firms within the cluster in terms of buyer/supplier relationships and collaborations suggests the cluster is vulnerable to external economic shocks.

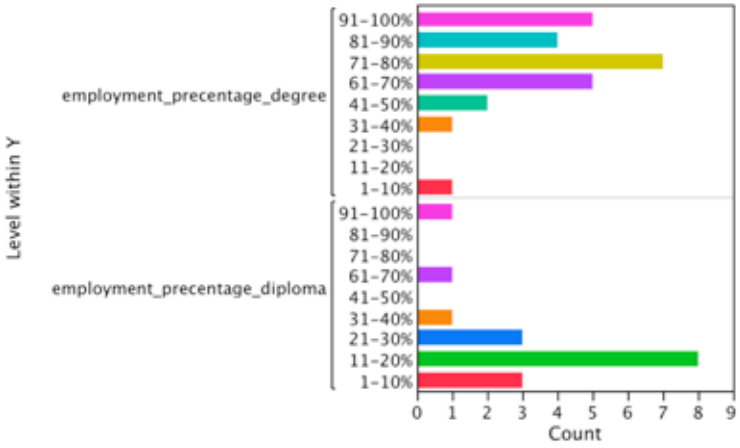
Is the ocean technology sector a learning and innovation system (LIS)?

Yes. There is ample evidence to suggest that the Newfoundland and Labrador ocean technology sector comprises a learning and innovation system (LIS). LISs are similar to clusters in that linkages between firms and other organizations constitute them. However, where LISs differ is in what forms these linkages. Generally speaking, LISs are comprised of flows of knowledge that lead to the creation of novel products or services. To measure the extent to which the Newfoundland and Labrador ocean technology cluster is also an LIS, data were collected about, *inter alia*, labour force educational characteristics, labour flows between firms/organizations, and inter-organizational collaborations.



Generally speaking, firms in the ocean technology cluster spend heavily on R&D activities. The adjacent figure shows that seven firms spent up to 50 percent of their total revenues on all innovation activities in 2008 and six firms spent more than 50 percent of their total revenues on such activities (27 respondents declined to provide information about spending on innovation activities).

Figure 10. Percent of total revenues spent on all innovation activities.



Ocean technology firms are predominantly staffed by full time employees with a university degree as opposed to a diploma from a college/technical institute.

Figure 11. Percent of full time employees with university degree versus those with college/technical institute diploma.

During the last three years, firms predominantly engaged in R&D linked to new or significantly improved goods or services (see Figure 12, RD_improved_products). This activity was mostly 'in-house' R&D given that few firms purchased R&D services from other organizations (RD_other_purchased).

The next most important R&D activity was the acquisition of advanced machinery, equipment, or computer hardware or software to produce new or significantly improved goods or services (see Figure 12, acquisition_equipment).

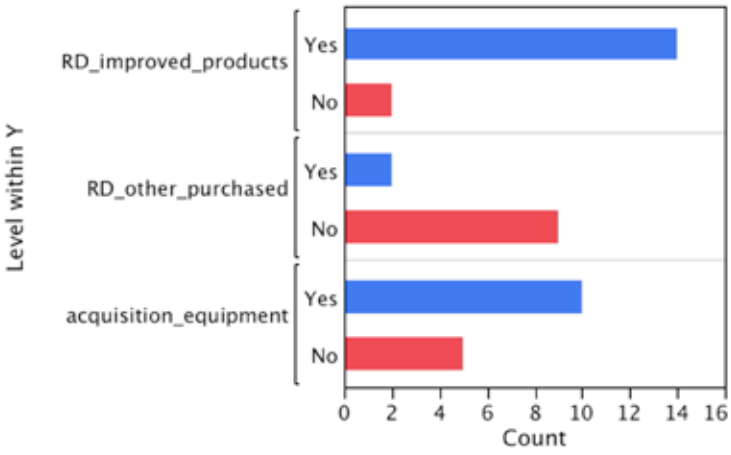


Figure 12. R&D activities.

Internal and external sources of knowledge for innovation

Perhaps unsurprisingly, the importance of R&D staff as sources of knowledge for innovation is of the highest relative importance for firms' innovation activities (see Figure 13, RD_staff).

More surprising is that firms indicate that management and sales/marketing staff outrank staff recently hired from colleges or universities as important sources of knowledge for innovation (see Figure 13). Responses from interviews suggest two reasons for this: 1) that there is often a steep learning curve for newly hired college and university graduates who usually require 1 – 2 years of specific company training before they are considered 'up to speed' by their employers in the ocean technology sector; and 2) management and sales/marketing staff often have significant contact with customers (i.e., 'the market'), information from whom is a major source of ideas for innovation.

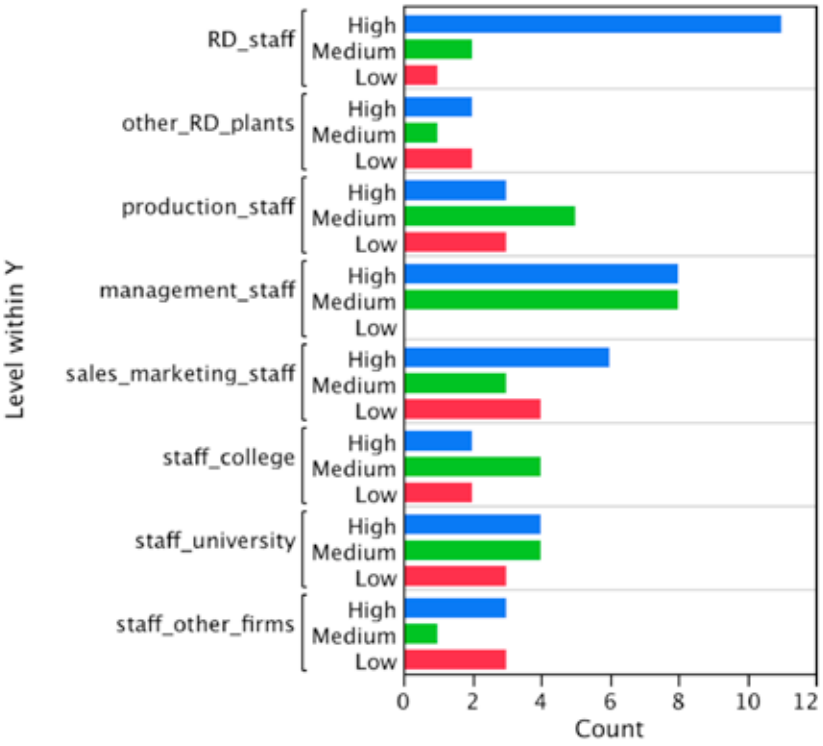


Figure 13. Relative importance of different internal sources of knowledge for innovation activities.

Figure 14 corroborates the finding that 'the market' is a significant source of ideas for firms' innovation activities. The majority of respondents ranked clients/customers as having high importance as a source of knowledge for innovation activities (clients_customers).

The next most important external sources of knowledge for firms' innovation activities are firms' suppliers followed by firms' interactions with universities. It is worth noting that firms' perceive their interactions with universities to be of higher importance relative to those with colleges or technical institutes.

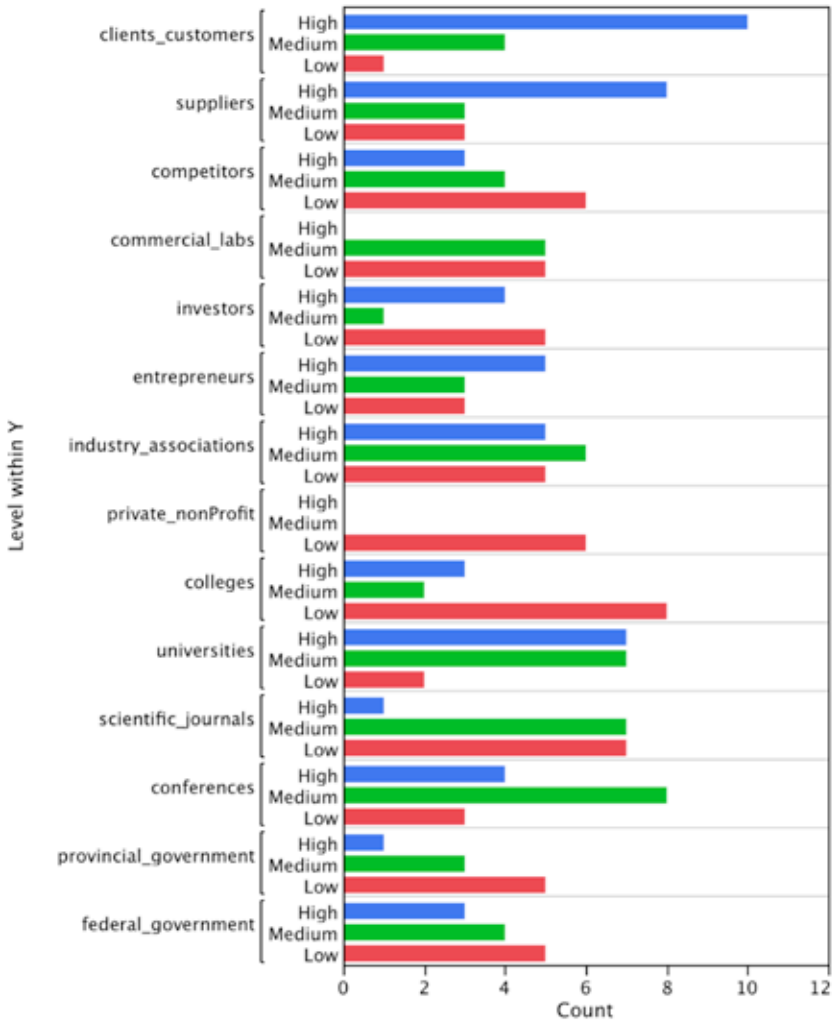
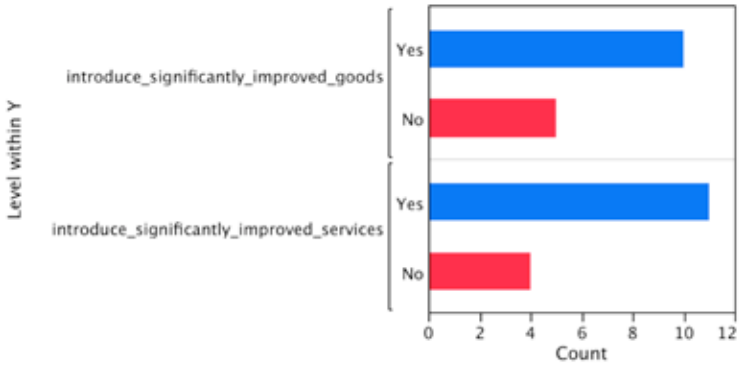


Figure 14. Relative importance of different external sources of knowledge for innovation activities.

Product Innovations

A product innovation is the market introduction of a new good or service or a significantly improved good or service, excluding the simple resale of new goods purchased from other firms and changes to products of a solely aesthetic nature.

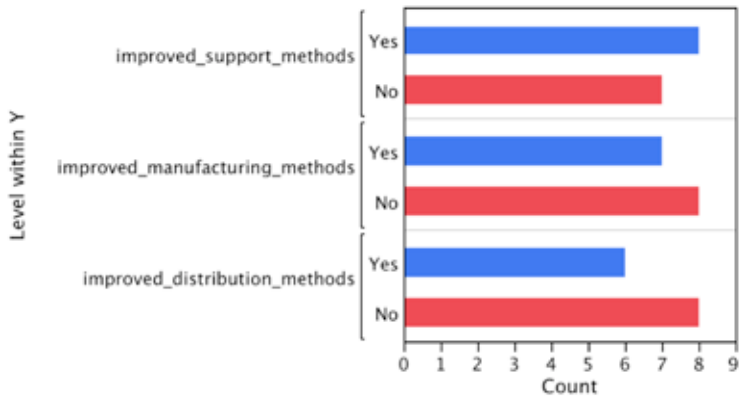


Of the respondents providing information on product innovation activities, 10 firms introduced a new or significantly improved good in the last three years and 11 firms introduced a new or significantly improved service during the same time period. Together these firms introduced a mean of two new goods and 4.2 new services in the past three years. The largest number of new or significantly improved goods introduced to the market by a single firm was three. For services the largest number introduced by a single firm was 22.

Figure 15. Did firms introduce a product innovation in the last three years?

Process innovations

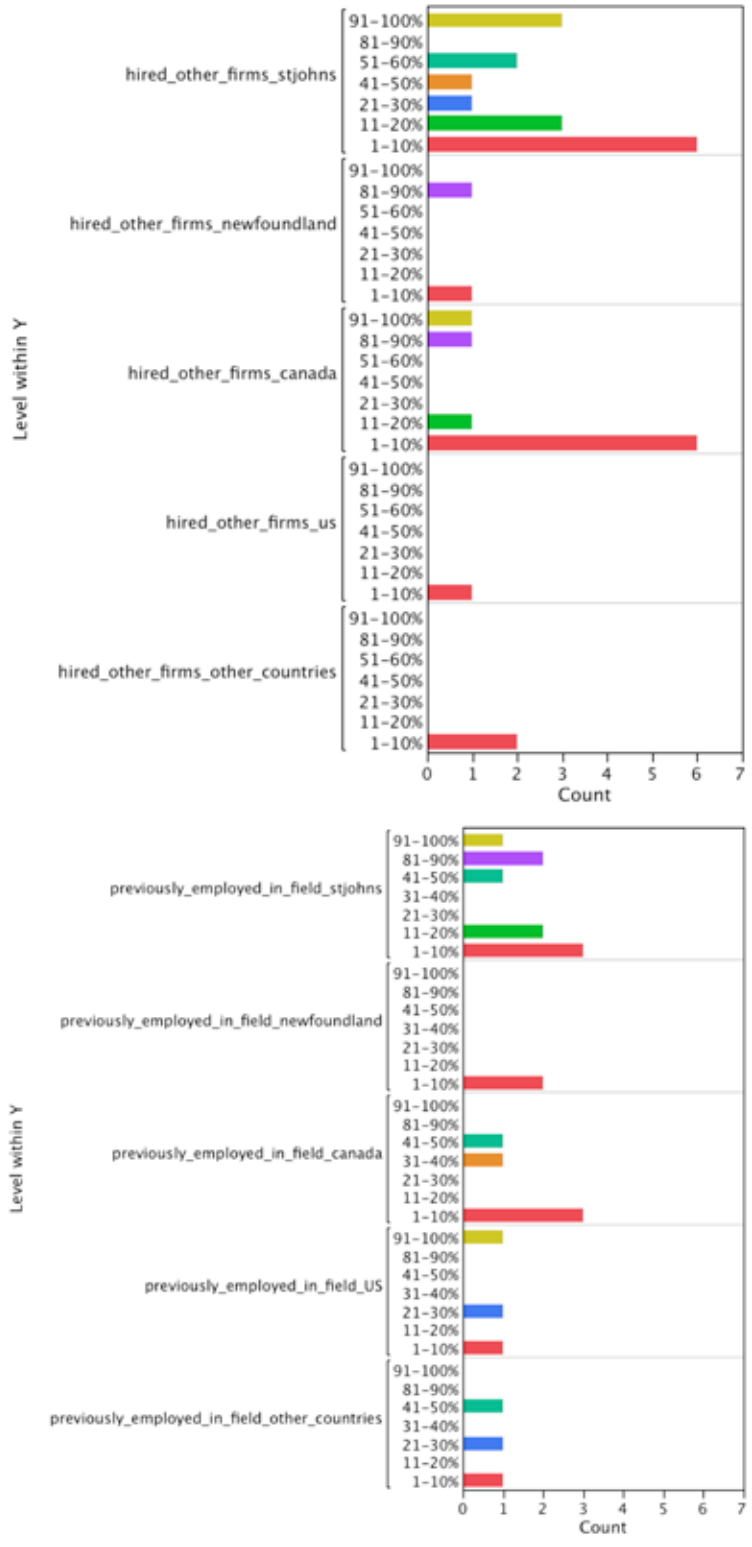
A process innovation is the implementation of a new or significantly improved production process, distribution method, or support activity for a firm's goods or services.



Of the respondents providing information on process innovation activities, eight firms offered improved support methods for their processes, activities that include maintenance systems or operations for purchasing, computing, or accounting. Seven firms introduced new or significantly improved manufacturing methods and six firms introduced new or significantly improved distribution methods for their inputs, goods, or services (see Figure 16).

Figure 16. Did firms introduce a process innovation in the last three years?

Circulating brains: labour flows and the ocean technology cluster



A key feature of LISs is the exchange of knowledge between firms and other organizations. One way to measure such exchange of knowledge is to examine the circulation of labour flows, that is, the movement of people between firms and other organizations. When people move, they bring with them the knowledge they have learned through previous education and employment experiences.

The adjacent figure shows patterns in the flows of labour into firms in the ocean technology sector (see Figure 17, top). The majority of ocean technology firms have hired from other firms in the St. Johns-city region. Of the respondents who provided employment information, five indicate that 50 percent or more of their employees were hired from other firms in the St. John's city-region (hired_other_firms_stjohns).

Furthermore, the majority of firms have employees who were previously employed in an ocean technology organization in the St. John's city-region. Of the respondents that provided employment information, four firms have hired 50 percent or more of their employees from other organizations within the ocean technology sector in the St. John's city-region (previously_employed_in_field_stjohns).

Together, these findings suggest that labour circulation within the local ocean technology labour market is an important feature of the ocean technology cluster. It further suggests that the cluster constitutes a LIS where firms learn from one another as employees move from one firm to another.

Figure 17. Labour flows into ocean technology firms.

Figure 18. Labour outflows from ocean technology firms.

Figure 18 and Figure 19 show labour outflows from ocean technology firms. The findings corroborate the idea that the sector represents a LIS. Ocean technology firms that have lost full time employees in the last three years have predominantly lost them to firms within the St. John's city-region. Of the respondents providing employment information, 10 firms have lost up to 10 percent of their full time employees to other firms in the St. John's city-region, while seven firms have lost 10 percent or more of their employees to firms in the St. John's city-region.

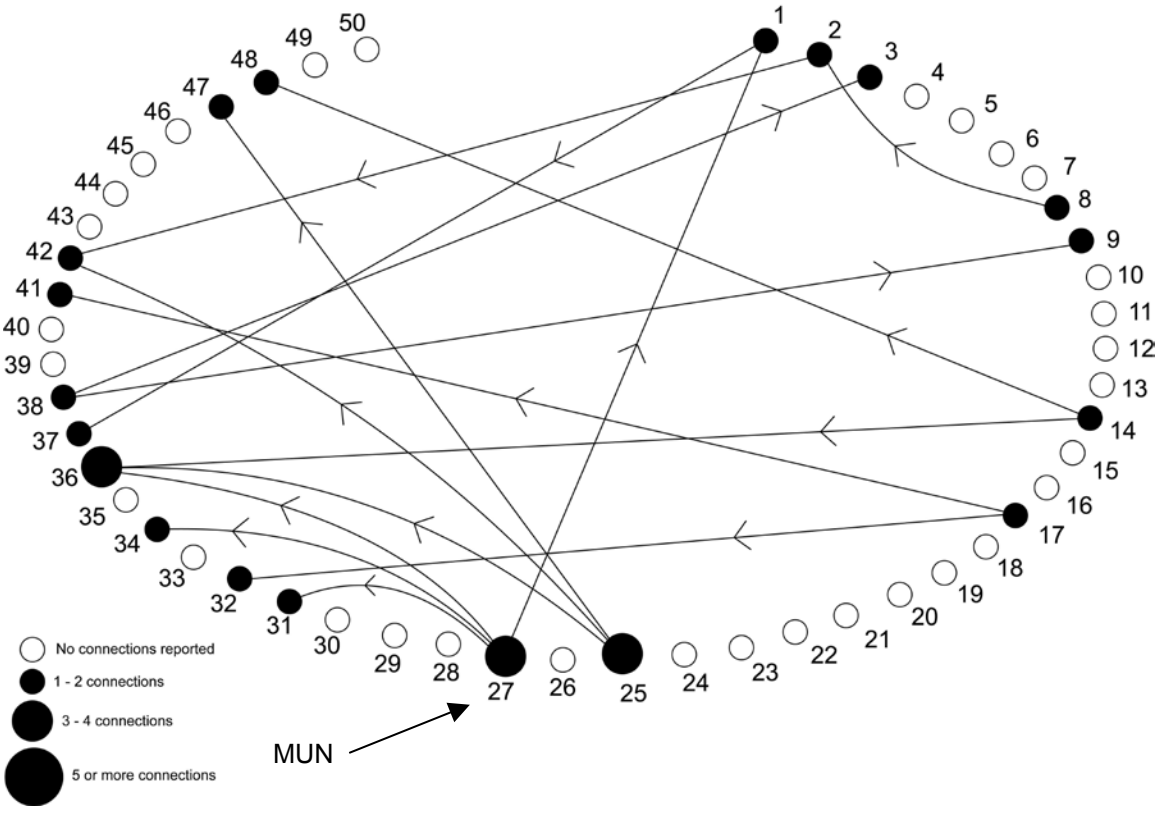


Figure 19. Labour flows within the ocean technology cluster (hired from).

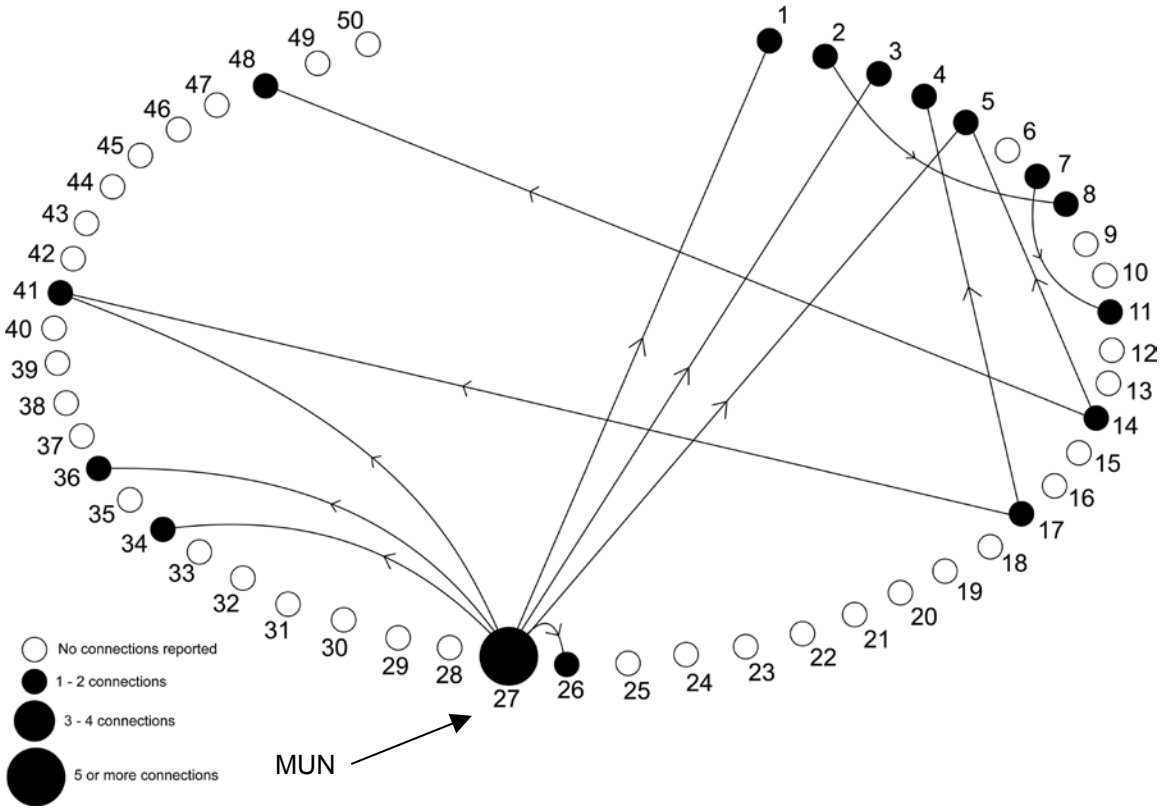


Figure 20. Labour flows within the ocean technology cluster (lost to).

Taken together Figures 17 – 20 suggest that brains are circulating within the ocean technology cluster in the St. John city-region, not only out of institutions of higher learning, but between firms as well. This circulation of knowledge embodied in people is a key feature of LISs.

What are the key gaps and barriers to a more effective cluster and LIS?

The Newfoundland and Labrador ocean technology sector operates as a cluster and a LIS. However, there are important gaps and barriers identified by study participants that, if they could be overcome, would benefit the sector. Two principle areas of problems and obstacles were identified: 1) those related to innovation; and 2) those related to the commercialization of innovation.

Problems and obstacles: development of innovation

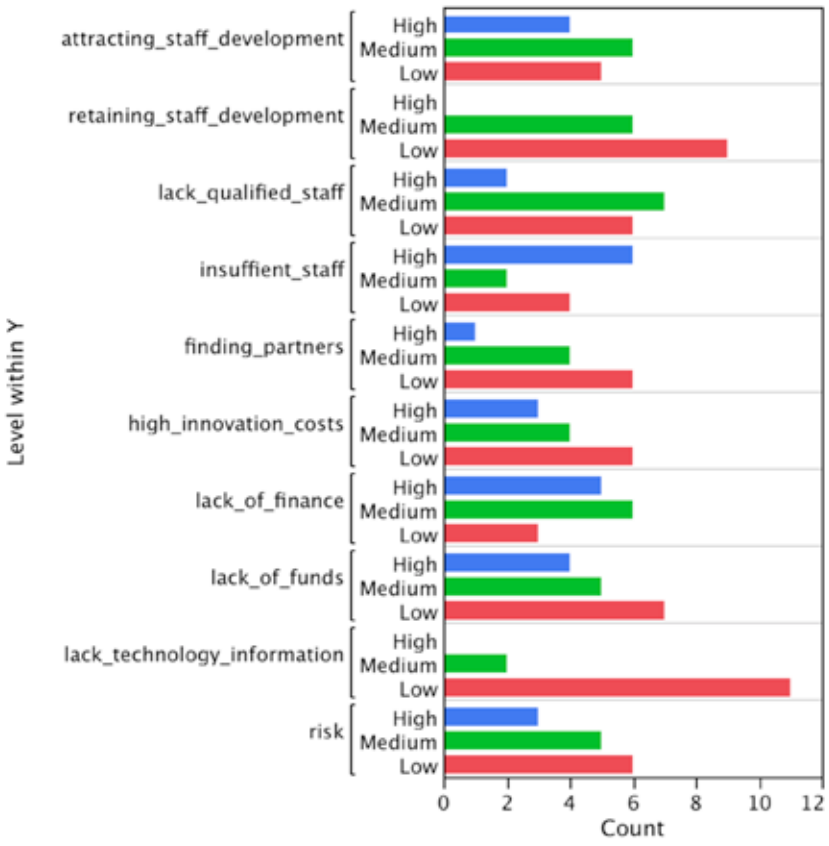


Figure 21. Relative importance (high, medium, low) of different obstacles to firms' innovation activities.

Figure 21 shows the relative importance of various types of obstacles experienced by firms in the last three years that slowed down or caused problems for firms' innovation projects. It appears that the shear lack of staff (insufficient_staff) and attracting appropriately trained R&D staff (attracting_staff_development) are the most important obstacles for firms in the oceans technology cluster. Closely following these obstacles are a lack of funds available within the firm (lack_of_funds) and lack of finance from sources outside the firm (lack_of_finance) to carry out innovation projects.

Problems and obstacles: commercialization of innovation

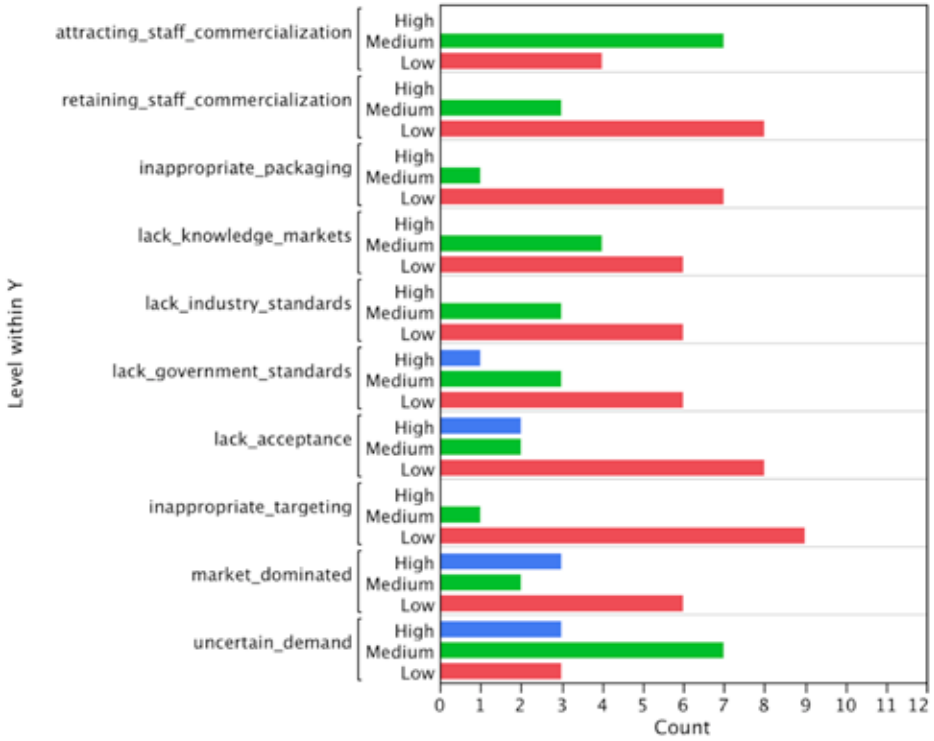


Figure 22. Relative importance (high, medium, low) of different obstacles to firms' commercialization of innovation activities.

Figure 22 shows the relative importance of various types of obstacles experienced by firms in the last three years that hindered commercialization of their innovation activities. The picture here appears more equivocal. While the difficulty of attracting appropriately trained staff (attracting_staff_commercialization) is ranked of medium importance, the only factors ranked of high importance are uncertain demand for innovative products (uncertain_demand), that the market is already dominated by established firms (market_dominated), there is a lack of consumer acceptance of innovative products (lack_acceptance), and/or a lack of government standards (lack_government_standards). Similarly, firms indicate that uncertain demand for innovative goods is of medium importance. The rankings of these factors suggest that firms might lack sufficient market knowledge when it comes to commercializing their innovation activities. Yet, most firms rank a lack of knowledge of markets as being of low importance in terms of the problems they have experienced when trying to commercialize their innovation projects.

What needs to be done to take the ocean technology cluster and LIS to the next level?

There are some key observations and policy relevant recommendations voiced by study participants. This section reports these observations and recommendations using quotations from interviews with participants to provide some context. The observations and recommendations are made by a diverse group of people directly involved in the ocean technology sector (see Table 1). In some cases, their views may appear to ignore existing factors, external supports, and policies. However, to the extent that these themes emerged in interviews suggests that even in cases where factors, external supports, and policies exist they would benefit from continual review and refinement. These themes also suggest a need for increased awareness on the part of business, government, and academia about existing factors, external supports, and policies.

1. Some government strategies are highly regarded. Recent policy initiatives are a source of optimism.

   "… the provincial government's oceans innovation strategy is a very good start…" (C1).

   "… So there is government support from IRAP and with ACOA, and now the provincial Research and Development Corporation [RDC] […] there's organization like that that are helpful […] I think the EDGE program is actually brilliant in terms of attracting investment […] (C9).

   "… we're really excited by the RDC, and they have a lot of programs […] you know, the whole oceans opportunities strategy is coming out now and we see ourselves, you know, availing from a lot of those funds, and so that's obviously very important to us" (C10).

   "I would have to say that there has been a tremendous increase in government programs that [are] supporting industry, so I wouldn't be negative. There will never be enough because this type of work is very expensive, but I can't say anything negative because I do have to say they have in the last five years increased their commitment to R&D in the province" (C11).

   "… the Research and Development Corporation constitutes a mechanism that was put in place to help the ocean technology [sector] […] it invented programs that are meant to [fill the] need of the local industrial community. Ocean technology was singled out as one of the two sectors of interest. [RDC has] voucher programs, proof of concept programs, and something called directed research programs. These are good programs. So, you know, I think that's a mechanism, I hope, … that'll help" (C13).

2. Industry sees a role for government.

   "… I still think that somehow someone – probably government or whoever, or people involved in the commercial fishing industry – have to get a handle on that industry because, as I said earlier, it's just too unpredictable. You can't

plan from one year to the next, which makes, you know, planning business… makes life difficult. You don't know what to do" (C3).

"…continued support by the government, attempts to create a critical mass of companies in the sector should continue" (C9).

3. Industry wants clear and consistent policy direction from government.

"… tell us what you're going to do and do it. I don't care what it is. Just tell us and do it […] listen to us [industry] and tell us" (C1).

4. Industry needs to use existing programs more effectively.

"I would say the biggest help in that was the Foreign Affairs department, the embassies. It's one of the… nobody ever thinks about them in Canada ever, but they're one of the most under utilized and most effective – I think anyway – business assistance for doing international business out there. I can call up any embassy, get a trade commissioner who will do background checks on potential customers, partners; will give me the lay of the land of laws, doing business, visa information […] after that Export Development Canada has been absolutely fabulous in helping and assisting getting into markets; but again the embassies – I'm always shocked at how little they're paid, how little they're under funded [sic], and how effective they are" (C12).

5. Government needs to leverage the capacity of industry more effectively.

"…if you look a the history of the defence labs, they were established in the 40's when there was no capacity in industry or academia to do the kind of work that the Department of Defence needed. Now there's much more capacity outside of these labs" (C6).

6. Initiatives that enhance possibilities for business cooperation and business mentorship need to be developed further.

"…we obviously [need] to cooperate. To give you an example, [in] one of the countries where we installed [our technology] […] I got a chance to visit that site in this very distant foreign country, and much to my surprise there was a process report made by [Company X] […] So here we were. We're two [Oceans Advance] companies working closely with the same partner installing two different technologies in the same country. Didn't really even know it" (C6).

"There's not a lot of real… at the risk of insulting everyone in the sector, there's not a lot of, you know, real hard core business leadership – you know, people who know how to not only run a business and grow a business, but all the stuff that goes with it. I mean, raising capital – I mean, when it comes to raising millions of dollars in capital, this is a tough thing to do, and you don't do it in MBA school. You learn it by being in business for 20 years […] and

again how big is that ocean technology cluster? Let's say 1,500 people work in the companies, of whom half would be, let's say, of some seniority. So you got like 700 people. There's not many in that group who have the wherewithal and the track record of that kind, that building a company from 10 to 100 to a 1,000 [people]" (C13).

7. Develop policies and supports with enough variety and flexibility to accommodate the diverse ecology of firms comprising the ocean technology sector.

"A lot of these companies are start-ups or small and medium trying to grow, that kind of stuff. Where the money is so difficult in general, going... you know, if you look at almost everything – whether it's a provincial program or a federal program – it requires a substantial investment by the company, and in a lot of cases that's warranted. [...] The problem with that is sometimes there are great projects that need to be done, but the companies can't necessarily put a lot of money into it, if any, so I think a lot of these programs need the flexibility to fund projects a 100 percent" (C6).

"... then I would go to government and say, 'Now let's write policy and let's follow our policy,' okay, 'and let's come out with clear guidelines'; and, you know, in those guidelines, let's look at who we're trying to support. We're trying to support the smaller companies, the smaller R&D companies, right, and, you know, they need different support ..." (C1).

"There is a huge tendency to go with the big guy [...] Dealing with a little guy is seen as a huge risk. Well, there are policies one could implement to mitigate that risk [...] so that a large company could deal with a small guy and [...] policy could help underwrite some of that risk. That would be another huge policy" (C6).

"The biggest challenge individually for companies has been that transition from largely a science or engineering-based enterprise to a commercial enterprise [...] What happens though is those companies tap into [...] public sector funding to support the development of their business. They get into debt to these organizations. When the times come [...] where true venture capitalists [...] might look at them, or other outside investors might look at them and come in and invest in them, the first thing they say, 'Well, your debt/equity ratio is upside down, and we have to resolve that,' so it kind of puts them in a hard position to make the leap to commercial" (C8).

"So if you say, 'Well, we'll subsidize the salaries of those people that you relocate here', I think that's brilliant. That would be great because you'll... you know, you'll grow this entire community. That's a very positive thing" (C9).

8. Consider more targeted funding for the ocean technology industry, such as a non-solicited proposal fund.

" ... they had some big ideas for [...] almost like a funding agency just for ocean industries where it would be funnelled somehow [...] I don't know if it ever

became a proposal or not but, you know, that kind of thinking, I guess, is kind of putting us all into one big… one group, and then that makes us a bit stronger …" (C10).

"There used to be a thing called a non-solicited proposal fund […] It was extremely successful […] they canned it about 15 … 20 years ago. I think all - both federal and provincial programs – should set up the same kind of thing" (C6).

9. Examine tax structures as sources of R&D funding.

"So let's say we developed a new technology and exported it, then have a tax holiday for like five years so that we can take all what we would normally be paying in tax and funnel it right back into the company to develop. That would be extremely beneficial" (C12).

10. Develop the human resources for the ocean technology sector by supporting the education of more than just science and technology students. Just as there is a diverse ecology of ocean technology firms, there is also a diverse ecology of human resource requirements in the sector.

"The development of a human resource base […] stems from an understanding of the other types of professionals that are needed in this industry - not just scientists, not just software developers, not just engineers – but people in the corporate sides […] and in marketing have come to understand this industry better. […] I think there's a model that can be created between academia and industry that we don't use. It's used extremely successfully in Norway and all over Europe. […] I think that's one thing we're lacking: waiting until people get out of university to entice them to come work for you … I think it's a mistake. I think we need to support students while they're in school either academically, financially, summer jobs, whatever; and then where are they going to go to work when they finish? Of course, they're going to come work for you: (a) they've met you; they understand your product or your science or your service; and (b) you've already supported them…" (C11).

11. If research is to become a major activity of MUN, public funding formulas need to better reflect that goal.

"I think there's a real opportunity for value in ocean engineering by growing the faculty […] but, of course, I don't think that we should grow that in the absence of broader growth in MUN. The university is… the whole idea is that it's […] a whole mix of domains and disciplines and interacting, […] ideas, and it's a […] beehive of activity, and so you can't just grow engineering and not grow the rest of the university […] There's just no way to get there on the basis of justifying it by how many so-called bums in seats – you know, undergraduate students" (C5).

12. Get beyond the work term and the co-op student. Develop structures that enable industry and academia to partner together more effectively for commercializing R&D.

    "A better understanding of commercialization and the cost of it, a better relationship or a more workable relationship between business and academics where graduate students could come work for our companies, and where companies can support graduate students. For example, that would be huge, so that we don't have to bring professionals in from outside our province [...] Can we support you as a student to do this research; and when you're finished doing that research in the university, you come work for us and finish it. That's what I mean. That's what I mean by that kind of partnership." (C11).

13. To grow the sector in the long term, get beyond an exclusive focus on college and university students. Get primary and secondary students excited about oceans and ocean technology.

    "I think one of the biggest things missing out of the ocean technology sector is K to 12 education [...] If we look at Smart [Bay] one of the things we've always said is - wow, wouldn't it be great to get a class in ocean technology from around Placentia Bay so that kids can go in and look at the centres and come up with projects, and get them to appreciate the ocean. Until we've done that, we can get to the 10-billion-a-year industry. Hey, that's great, but I say – hey, you get there you still haven't succeeded unless you get [...] that grassroots into the education system" (C1).

14. Develop more intensive, coordinated image management strategies for the sector as a whole.

    "[...] if you speak to anyone outside of Newfoundland, really, [who] comes down here that ... is in the industry, they'll say that there's nowhere that has all these companies and these facilities in one spot. The message has to get out there [...] I think in order to take that next big step there has to be some kind of an identity here in ocean technology, and I'm still not... I know we've come a long way, but I'm still not sure if it's there ..." (C10).

Conclusion

This study analyzed the organization and dynamics of clustering and innovation in the ocean technology sector in Newfoundland and Labrador and the St. John's city-region. The sector matches national benchmark criteria for clustering and is predominately externally oriented towards firms/organizations outside the region. The network of buyer/supplier relationships and collaborative relationships internal to the cluster, other than those related to Memorial University (MUN), focuses on only a few firms. The cluster's outward orientation coupled with the dominance of only a few firms within the cluster suggests the cluster is vulnerable to external economic shocks.

In addition to the clustering dynamics in the Newfoundland and Labrador ocean technology sector, there is ample evidence to suggest that the sector comprises a learning and innovation system (LIS). A key feature of LISs is the exchange of knowledge between firms and other organizations. The majority of ocean technology firms have hired from other firms in the St. Johns-city region. Furthermore, the majority of firms have employees who were previously employed specifically in an ocean technology organization in the St. John's city-region. These findings indicate that labour circulation within the local ocean technology labour market is an important feature of the ocean technology cluster. It further suggests that the cluster constitutes a LIS where firms learn from one another as employees move from one firm to another.

Study participants perceive several key gaps and barriers to innovation and the commercialization of innovation in the cluster and LIS. Firms are challenged in being able to attract the shear number of required staff and appropriately qualified staff. Another key challenge to innovation for firms is insufficient funding and finance for their innovation activities. Challenges to commercialization are more mixed. One issue ranked of high importance by participants is uncertain demand for innovative products. However, most firms rank a lack of knowledge of markets as being of low importance in terms of the problems they have experienced when trying to commercialize their innovation projects. Other issues ranked of high importance by participants include the market being already dominated by established firms, that there is a lack of consumer acceptance of innovative products, and/or that there is a lack of government standards.

Study participants voiced several key recommendations with policy implications. While recent policy directions, such as the Research Development Corporation (RDC), are a source of optimism there is a need for policies and supports with enough variety and flexibility to accommodate the diverse ecology of firms comprising the ocean technology sector. Specifically, participants suggest a non-solicited proposal fund and a fuller use of the tax code as a source of R&D funding. Moreover, if research is to become a major activity of MUN, public funding formulas need to better reflect that goal. From an education stand point, the industry needs well trained human resources that include scientists and engineers, but also corporate managers and marketing personnel. Long term growth in the sector will come from early interventions in primary and secondary education that excites children about the oceans and ocean technology. Finally, the sector needs a coordinated image management strategy that highlights the sector's strengths to international markets.

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THE LESLIE HARRIS CENTRE OF REGIONAL POLICY AND DEVELOPMENT
1st Floor Spencer Hall, St. John's, NL Canada A1C 5S7
Tel: 709 737 6170 Fax: 709 737 3734 www.mun.ca/harriscentre

THE HARRIS CENTRE
Memorial University