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A thesis submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Doctor of Philosophy.

Reification of space within knowledge production: the case of the circulating idea of resilience internationally and in the context of South African cities.

Serge Ntamack

Declaration

I declare that this dissertation is my own unaided work. It is being submitted for the Degree of Doctor of Philosophy in Town and Regional Planning to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

22nd September, 2017.



Ntamack Serge

Abstract

In this thesis, elements of Crawford Stanley Holling's life history are put into perspective. It provides a historical trajectory upon which the spaces imbued in the various contexts hosting pivotal activities on the production and refinement of resilience idea are explored. These elements are also used as a point of departure from where the idea of resilience originates and circulates internationally and in the context of South African cities. It is the very idea of space and the influence that its articulations have over different stages of the development of the resilience concept which are interrogated. In so doing, the role of human experience and knowledge infrastructures in the formation of scientific knowledge and promotion of global norms is highlighted. The methodology in this thesis is a blend of elements of social constructivism, artefactual constructivism, and life history and critical discourse analysis. Insights from critical discourse analysis are used as an analytical tool for the examination of the data related to the life history of C.S Holling, so as to highlight the multiple connections between spaces and knowledge while looking specifically at ideas of resilience ideas and the variant translation of these ideas across time and space . The thesis' central argument is that different spaces allow the production of knowledge to happen; while inscribing themselves in the knowledge which is being produced they restrict the ways of knowing to a set of methods confined within the parameters they have displayed in advance. For example, it is found that the *fondamentalisation of* economic entomology is manifest in the events, methods and theories couched in the tapestry of Holling's articulation of "nature-culture" relationship. And that such a "nature-culture relationship" which disrupted the ontological division between culture and nature, was materially constituted in what formed the epistemic culture grounding his research from 1960s to 1970s.

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List of acronyms

BI: Beijer International Institute

CDA : critical discourse analysis

CSIR: Council for Scientific and Industrial Research

CSIRO: Commonwealth Scientific and Industrial Research Organization

EPD: Economic Performance and Development

FLP : Forest Limited Protection

GCSSRS : Global Change, Society, and sustainability Research Strategy

GDS: Growth Development Strategy

IBSA: India, Brazil, South Africa Forum

IBP: International Biological Program

ICSU: International Council of Scientific Unions

IGY: International Geophysical Year

IIASA: International Institute for Applied Systems Analysis

MISTRA: Swedish Foundation for Strategic Environmental Research

NDP : National Development Plan

NMOs: National Members Organisations

NPES: National Programme for Environmental Sciences

NRDS: National Research Development Strategy

NRF: National Research Foundation

OECD: Organization for Economic Co-operation and Development

RA: Resilience Alliance

SARchI : South African Research Chairs Initiative

SES: Social-ecological-systems

SCOPE: Society for Conservation and Protection of the Environment

SDC: Stability-diversity-complexity

SMI: Stockholm Mistra Institute

SPLUMA: Spatial Planning Land Use Management Act

SSK: Sociology of scientific knowledge

SRC: Stockholm Resilience Centre

TIM: Technology Innovation and Management

TRUST: Think Tank on Resilience Urban Systems

UNB: University of New Brunswick

UNEP: United Nations Environmental Program

UNESCO: United Nations Educational, Scientific and Cultural Organization

1. Introduction

Knowledge occupies a central position in the ways in which societies and social groups within societies reproduce themselves. Nash (1990:432) notes that "it might be said that they produce in order to reproduce; and in order to manage the regulated inter-generational transmission of real and symbolic capital societies must necessarily develop appropriate structures which enable successful cultural reproduction". Knowledge is, of course, constructed within particular material or spatial contexts. This knowledge is *local* or *situated* until it is *generalised* or *universalised* in some way. The apple that fell on Isaac Newton's head offered knowledge of the behaviour of a particular apple on a particular tree until this knowledge was generalised in Newton's 1687 opus, *Philosophiæ naturalis principia mathematica*.

The thesis' central argument is that different spaces allow the production of knowledge to happen; while inscribing themselves in the knowledge which is being produced they restrict the ways of knowing to a set of methods confined within the parameters they have displayed in advance.In relation to this, the hermeneutical ('interpretive') task requires us to interrogate the construction of knowledge. There are many aspects to the context within which knowledge is constructed and then elaborated, including, for example, the relations of power that have been eloquently explained by Michel Foucault, for example. The aspect which has arguably been underexplored is the spatial context within which knowledge is produced. The spatial context is, arguably, not always innocent or neutral. It may actively shape the ways in which knowledge emerges and evolves. The knowledge we embody, the knowledge we produce and reproduce through our daily practices, the knowledge we store, all, arguably, maintain versions of the spaces (e.g. body, artifact, land, disciplinary space) in which we live in or with, whether they are mere consequences of our own agency or not entirely (Edwards, 2006; Simone, 2004). Through an engagement with planning in terms of knowledge production, this thesis asks the following question: How

do particular conceptions, experiences, and material constructions of space inform the knowledge that is being produced?

The thesis uses as its particular case the construction of ideas of "resilience" which are now commonly used by planners and policy makers internationally, and in South Africa, the context within which I am writing this thesis. In this thesis I ask how the idea of resilience emerged, and how it has subsequently evolved. In terms of resilience thinking, the key personality was Crawford Stanley ("C.S") Holling. In the thesis I ask specifically how the inter-play between space and knowledge construction played out in the work of C.S. Holling and how this shaped the way in which the idea of resilience emerged. The thesis goes on to reveal the dynamism of ideas, and how other influences, including other spatial contexts, engage with the further evolution of an idea in this case, resilience.

Within the scope of these questions, there is an attempt to understand knowledge on two levels. At the more fundamental level it is concerned with the ways in which ideas are produced, and the ways in which these ideas come to be regarded as the truth about the way things are. This is, of course, not an original undertaking as Michel Foucault famously explored the "genealogy of knowledge" in a number of classic works (Foucault, 1966; 1969). The original contribution of the thesis is however in showing how space in its different forms – from a scientific laboratory to a boreal forest to a large city – is implicated in the production and hegemonisation of knowledge. Space is not the inert container within which knowledge is produced but is rather actively implicated in the process of production, and in the ways in which particular forms of produced knowledge acquire authority.

The second level addressed in the thesis relates to the case-study. The way in which the idea of "resilience" was constructed is used as a demonstration of the presence of space in the production of knowledge. However, the study of resilience is arguably a contribution in its own right. The term resilience is now widely used in both scholarly and policy-related discourse. It has become

normalised in our vocabulary. The term has a history. It is a linguistic invention, and a critical social science requires us to expose its' genealogy. This is not done to undermine the concept of resilience which, arguably, is making an important contribution to contemporary developmental practice, but rather to place the term within a historical perspective, in a way that would allow us to use the term more carefully and with a deeper understanding of its constructed meanings.

A third contribution of the thesis is the way it uses life history to explore the construction of meaning. There are multiple ways in which to investigate the construction of knowledge but what this thesis does is to acknowledge the importance and power of human agency, although it does so in a way that places human agency within a historical and geographical context. As indicated, this thesis explores the evolving idea of resilience through the life work of Holling, the individual widely credited as the author of resilience thinking. The thesis does not provide a bibliography and is limited to his adult years. C.S. Holling is a white male, born in New York in the United States of America (USA) in December 1930, but who became a Canadian citizen and grew up in Canada. These details are undoubtedly significant for understanding his later life and work, but I don't directly address this in the thesis, focusing on the years beginning with his post-graduate research. The thesis is essentially an exploration of how the idea of resilience germinated in Holling's written and spoken work from the early 1950s until the early 1970s, and then evolved and gained widespread credence from then until the present time. But, it is more than this. It is an interpretation of how the spatial context within which Holling lived and worked, subtly or more directly, had a bearing on the ways in which his work evolved.

Beyond Holling, there is a fourth contribution of the thesis in relation to the exploration of the translocation of the idea of resilience into new spatial contexts, and the possible influence of these contexts on the further evolution of the idea. That is to say that the thesis tries to flesh out the various agencies that different spaces had on the evolution of the resilience idea at different stages of

its historical development. As such it illustrates a "new materialist[1]" understanding which holds that: "humans live in a profoundly material world and that any action they take has to account for their relationships with non-human things" (Beauregard (2015:3-4). In this regard, the engagement of resilience within the specific context of South Africa is used both in the above sense and as a way to provoke further reflection on the radical alternative that resilience theory is supposed to introduce into governance because of its holistic and topological modes of thought that undermine positivist and empiricist assumptions (Grove, 2013:1).

Throughout the entire process of germination, evolution and translocation, it is the idea of space that remains central to the argument of the thesis. The difficulty in threading the argument is that the term "space" is itself a highly complex discursive construction. It is understood in a material sense but also in terms of symbolic meaning, of movement and relationships, and even abstractly in terms of the room for discussion, political action, institutional activity, and more. In this thesis I use the term space more or less to mean the *physical* dimension of knowledge production, although the complexity here is still the vastly varying scale, from a scientific laboratory to a forest, a city, or even a country. I also understand that inertness of "space" transforms into "place" through the meaning and definition provided by human actors. When I write of space in this thesis, I am referring to a *sense of* space whose meanings or identifications are to be found within the specific contexts of the variant object of my attention in each given chapter. Besides, knowledge can be understood in relation to the manner that it creates the spaces and conditions of material

1 "[T]he most common name given to a series of movements in several fields that criticise anthropocentrism, rethink subjectivity by playing up the role of inhuman forces within the human, emphasize the self-organizing powers of several nonhuman processes, explore dissonant relations between those processes and cultural practice, rethink the sources of ethics, and commend the need to fold a planetary dimension more actively and regularly into studies of global, interstate and state politics (Connolly, 2013:399)".

experience (Wright, 2005: 917). As such, it is constructed as spatialised narratives of human actions, while artefacts are the material form of these spatialised narratives (Turnbull, 2002).

Now, if considering that some material lasts longer than others, the spatialised narratives of the built environment of a research institution for instance can serve as a relic of struggles over the validation of knowledge that is being produced. In this respect the outcomes of initial struggles over the validation of knowledge are continuously rehearsed or/and actualised in the current production of knowledge because: "social arrangements delegated into non-bodily physical form tend to hold their shape better than those that simply depend on face-to-face interaction" (Law, 2009:148). That is to say that the space where a given research project is undertaken has specific attributes whose function depends on the values of the hosting society (see Hillier, 2008:228). By the means of these very attributes, this space is not only impacting on human affairs when manipulated but retains a form of agency on its own. This view is plausible when we admit that a "society is hiding behind the fetish of technique" (Latour, 1994:53). And that the society that is hiding itself behind a technique epitomised by an artefact such as the built environment of a research institution may not always correspond to the one which coexists with these very artefacts contingently in a given geographical space. In fact, the dynamics of a society's political history may project a reality that is no longer corresponding to large segments of its old yet actual and functional built environment, whereby different social arrangements have been embedded initially in the past. Lefebvre (2009:186) brings us closer to a better understanding of how the complexity of inferences made here in relation to the knowledge that is being produced and the space hosting the activities of its production operate when he says: "[T]he past has left its marks, its inscriptions, but space is always a present space, a current totality, with its links and connections to action. In fact the production and the product are inseparable sides of one process." It follows then that the chapters of this thesis are variant but are connected by an exploration of the

dialectics between knowledge and space. All together they participate in the construction of the main argument stating that the knowledge being produced in a given space somehow retains some features of that space, even when it circulates in very different spaces afterwards.

Chapter 2 puts forward the methodology of this thesis out of a blend of elements of social constructivism, artefactual constructivism, life history and critical discourse analysis. Insights from critical discourse analysis are used as an analytical tool for the examination of the data related to the life history (process and product) of C.S Holling, so as to highlight the multiple connections between spaces and knowledge while looking specifically at the markers of the spatial contexts across distinct historical periods leading to the emergence of the idea of resilience internationally.

Chapter 3 brings together in three sections the threads upon which the main argument of this thesis will unfold gradually in the subsequent chapters. The first section of the chapter is concerned with the malleability of knowledge and some of its implications across societies and locales. The second section tries to make explicit some economic and political stakes resting upon the categorisation of knowledge as "scientific" or otherwise. The third section looks back at the malleability of knowledge in the ways in which both scientific and other forms of knowledge are becoming more and more assets in competitive dynamics. The final section brings the work of C.S. Holling about resilience theory into perspective, along with the prominent role gained by social-ecological research in addressing some of the challenges facing knowledge economy currently.

Chapter 4 examines the potency that the physical environment has in exerting cognitive influence over human beings. In doing so, the first section situates the historical approach that this thesis adopted in its engagement with space along with the question of non-human agency which is a central concern for the "new materialism". The second section explores the origin and meaning of environmental determinism as a way of trying to shed light on the influence it

has had on geographical imagination. While the chapter acknowledges the critique of environmental determinism, it nevertheless argues that it would be a mistake to deny the ways in which non-human agency participates in the production of knowledge.

Drawing from chapters 3 and 4, chapter 5 demonstrates that an analysis in which a laboratory is a focal point is prone to encounter the entanglement between different forms of knowledge and various conceptions and material constructions of space all at once. In doing so, with reference to Holling's research in the 1950s, the chapter suggests that we cannot reduce a space such as a laboratory to a single type or to uniform roles. In fact, from the insect outbreaks in plantations to the construction of a laboratory like the one at Sault Ste Marie, Ontario, the spaces through which a research inquiry acquired its frame bear the hallmarks of the multiple engagements (tacit and explicit) which form the experience of a researcher. That is to say that Holling's initial research is neither the outcome of its sole volition nor can it be reduced only to human related-influences.

Chapter 6 shows that from 1952 to 1964, Holling's research is a formal expression of the Sault Ste Marie laboratory's mission. This mission was embedded in the epistemic culture and social dynamics of the time which included, in the intellectual terrain, the *fondamentalisation* of economic entomology[2]. This chapter explores the ways in which the *fondamentalisation of* economic entomology is revealed in Holling's articulation of the "nature-culture" relationship. It was an articulation which disrupted the binary division between culture and nature and paved the way for a conception of resilience which brought nature and culture together in complex systems.

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2 It is a process that encompasses the changes that happened in the field of economic entomology between 1884 and 1959. It blurs the line between basic and applied research and integrates some elements of ecology, physiology and system analysis to fashion the specificity of economic entomology.

Chapter 7 explores how, in the 1950s, the Sault Ste Marie Laboratory became embedded in C.S. Holling's epistemological imagination and shaped his continued role as a researcher. In two sections, chapter 8 highlights the institutional and conceptual arrangements that precede a wide circulation of the resilience concept internationally starting in the late 1980s, and the extent to which subsequent research on resilience and resilience related policies bear their imprints as well as the traces of Holling's previous experience in Canada. It appears that regardless of the extent of its circulation across geographical spaces and disciplinary spaces, Holling's concept of resilience remains embedded in the epistemic culture which grounded his initial research in Canada from the 1960s to the 1970s.

Finally, chapter 9 points out that the process of introducing the resilience concept in South Africa resulted in the strengthening of some of the knowledge claims made by Holling and his colleagues early in the 1970s. It helped to universalise the resilience concept while proving the relevancy of its fundamental claims in tropical ecosystems which included South Africa. In contrast to that early contribution, the strand of knowledge generated in South Africa or about South Africa on issues related to resilience does not originate solely from C.S. Holling. Yet significant research programmes and policy documents in the country whether on resilience or on "social-ecological systems" justify more than they shaped the political arrangements backing a wider circulation of Hollings idea of resilience internationally, especially since the 1990s.

2. Methodology

Introduction

The role of ideas in the engagement with the materiality of spaces, as well as the input of this materiality into the constitution and circulation of ideas, fall broadly within the scope of constructivism. There are however various definitions of constructivism and different ways of engaging with it in social science literature. Constructivism is seen separately as "meta-theory", "social theory" and "method", but in my work I used all these different aspects in an interrelated way for the conceptualisation and the operationalisation of this thesis. At a meta-theoretical level the entirety of this study is couched in *artefactual* constructivism. According to Demeritt (1998:175), artefactual constructivism "reconciles a recognition of the productive activity of scientists in constructing and representing the facts of science with an appreciation of the role of other, heteregenous agencies, in realising the nature of the world". By leaving room for the heterogenous agencies of the non-human, it allows for an exploration of the agencies of space in its various forms in the production of knowledge. In doing so, it separates itself from strands of social constructivism that fail to give agency to non-human actors. In mainstream explanations of social constructivism, the non-human dimension has no independent agency but is always mediated by human agencies. Adler (1997: 322) writes, for example, of "the view that *the manner in which the material world shapes and is shaped by human action and interaction depends on dynamic normative and epistemic interpretations of the material world*". Artefactual constructivism, however, allows us to acknowledge the agency of physical artefacts (including space) while maintaining an emphasis on the social construction of ideas. In this thesis, I blend elements of artefactual social constructivism with methods such as the use of life history, and critical discourse analysis.

While introducing the "artefactual" into social constructivism may resolve the denial of the agency of non-human elements, there are other possible limitations in the use of social constructivism which must at least be acknowledged. These are evident, for example, in a debate on social constructivism in the disciplinary field of International Relations. In the social constructivist framework, for example, human ideas and norms are fundamental in shaping international relations but Bjorkdahl (2002) insists that *interests* underlie what are considered to be the ideas and norms that shape patterns of behaviour.

These limitations aside, a series of helpful methods and research designs are gathered under the umbrella of social constructivism. This is recognised by Finnemore and Sikkink (2001:396), who argue that social constructivism "opens up a set of issues, and scholars choose the research tools and methods best suited to their particular questions". As indicated, rather than rejecting social constructivism because of its apparent incapacity to grasp adequately the non-human dimension of the influence of ideas, values and norms on the identities and interests of the actors involved, I try to explicitly compensate for this weakness, by using an artefactual constructivism in my use of a critical discourse analysis, and in my reliance on life history as a method (see Bjorkdahl, 2002). It is this blend of artefactual constructivism and various elements originating from life history and critical discourse analysis that enable me to understand as best as possible both human and non-human agencies relevant in this doctoral research. Such a mixed framework helps to examine the questions intersecting with the coming into being of the resilience idea and the role and variety of spaces in the production of knowledge. The rest of this chapter comes in two sections. First, there is a more detailed discussion about the meanings of constructivism and its variants; and how the limitations of social constructivism in particular are reduced though a combination of constructivism with elements of life history and critical discourse analysis. Secondly, it is shown how aspects of life history and critical discourse analysis, blended with artefactual constructivism, inform a relevant method for the entirety of the questions reviewed in this thesis. The last

section speaks about the method in question by way of translating the implications of the previous sections for a scholarly engagement with the questions that this thesis is attempting to answer.

2.1. Social construction of knowledge and construction of social reality

Before delving into the ways in which social constructivism has been tailored for this thesis, it is important to note that constructivism itself should be understood in its *conventional* and *critical variants*, the latter being closely associated with critical social theory (Hopft, 1998:172).Within the context of international relations theory, for example, its' *conventional* form presents an alternative to mainstream international relations theory offering a research programme which deals with the reconceptualisation of balance-of-threat theory, the security dilemma, neoliberal cooperation theory, and democratic peace theory. The research programme retains a focus on issues of identity in world politics and the theorisation of domestic politics and culture in international theory. In fact, Hopft (1998:181) notes that "[T]o the degree that constructivism creates theoretical and epistemological distance between itself and its origins in critical theory, it becomes 'conventional' ". In contrast, he also notes that while sharing many fundamental elements of critical theory, its critical variants resolve some issues by integrating defensible rules-of-thumb, rather than pursuing critical theory all the way up the postmodern critical trajectory. But, according to Price and Reus-Smith (1998: 261), critical international theorists are both modern and postmodern in their forms, sharing at least four common intellectual orientations in relation to epistemology, methodology, ontology and normativity. In terms of epistemology, critical theorists interrogate positivist approaches to knowledge and criticise attempts to formulate objective, empirically testable ideas about the natural and social world. Methodologically, they reject the hegemony of a "single scientific method", promoting pluralism in the approaches

to knowledge production while putting the emphasis on interpretive strategies. In terms of ontology, they challenge the rationalist conceptions of human nature and action by showing the significance of the social construction of actors' identities and the importance of identity in the formation of interests and actions. And normatively, they stand against value neutral theorising by denying its very possibility, and putting forward the necessity to develop theories explicitly committed to the exposure and disintegration of structures of domination.

. In international relations theory for example, Wendt (1992:422) notes that constructivism just like any other social theory does not determine the content of international theorising, but it does structure how questions are asked and answered about world politics. Also "social constructivism" has become very fashionable, a catch-all term which refers to the variety of approaches to nature (Table 1) science, and knowledge (Demeritt, 1998:175).

Table 1. Theories of social construction of "nature". SSK refers to sociology of scientific knowledge. ANT refers to actor-network-theory. Source: Demeritt (2002).

	Philosophical constructivism and Kantian idealism	Social scientists' constructionism as refutation	Social scientists' constructionism-as-philosophical-critique			
			Phenomenological	SSK	Discursive	ANT
What is constructed?	Concepts, linguistic categories, abstract mathematical entities of pure thought	Mistaken ideas and ideologies of nature (i), (ii) and (iii)	Social and environmental problems, nature	Scientific knowledge and natural phenomena	Concepts of nature; in some versions: also material manifestations of nature	Quasi-objects, material-technical semiotic objects
How?	Conceptually through proof or pure thought	Variously, but often through the influence of hegemonic power	Intersubjectively through claims making	Negotiations among scientific actors	Through language and discourse	Through the practical articulation of heterogeneous human and non-human actors
Metaphysics	Maximalist: sceptical about the existence of unobserved or unobservable entities and ontologically real	Support the metaphysical idea of reference and the notion that concepts of nature (i), (ii), and (iii) can be tested empirically by reference to how 'nature' actually is	Agnostic about truth of concepts of nature (i), (ii) and (iii) and about existence of natural phenomena, but realist about society and social actors	Various approaches to truth and reality of nature (i), (ii) and (iii) from phenomenological agnosticism to neo-Kantian ontological idealism. Realist about society and social actors	Various. Generally nominalist: sceptical of absolute ontological distinction between representation and reality, nature and society; critical of metaphysical reference	Critical of metaphysical reference; see 'nature' and 'society' as the outcome of heterogeneous processes, rather than as the starting-point for explaining these processes
Key proponents	Hacking (1999)	Various	Hannigan (1995), Spector and Kitsuse (1987)	Woolgar (1988)	Butler (1993); Escobar (1996); Haraway (1991)	Latour (1999)

Cognisant of the above, the "new materialism" approach in planning mentioned in chapter 1, resonates particularly well with artefactual constructivism, because it does not imply that actual existence depends on the human construction of this existence, although it does acknowledge that ideas about this existence are

constructed. This is hugely important for an argument that the physicality of space can itself exert an influence independent of the ideas about this space.

New materialism and artefactual constructivism are versions of constructionism closely related to actor- network- theory. For Checkel (1998), social constructivism in international relations is mostly concerned with underlying conceptions of how the social and political world operates. According to him, it is not a theory but an approach that questions the material and methodological individualism upon which many strands of IR scholarship (i.e. neoliberalism and neorealism) has been built. This approach is guided by two assumptions: "(1) the environment in which agents/states take action is social as well as material; and (2) this setting can provide agents/states with understanding of their interests (it can "constitute" them) (Checkel, 1998:325). Checkel (1998:326) adds that the first assumption suggests that "material structures, beyond certain biological necessities", are assigned meaning only by the social context from which their interpretations emerge. The second assumption according to his view, stresses the basic nature of human agents and the states in particular in their relations to wider structural environments. Consequently, for Adler (1997:223), social constructivism's significance and its added value to the study of international relations rests first and foremost:

> in its emphasis on the ontological reality of intersubjective knowledge and on the epistemological and methodological implications of this reality. Constructivists believe that International Relations consist primarily of social facts, which are facts only by human agreement. At the same time, constructivists are 'ontological realist'; they believe not only in the existence of the material world, but also that this "material world offers resistance when we act upon it" (Knorr Cetina, 1993:184). Thus constructivism is an attempt, albeit timid, to build a bridge between the widely separated positivist/materialist and idealist/interpretive philosophies of social sciences.

Similarly, in relation to the "double hermeneutics[3]", Guzzini (2000) points out that social constructivism is probably best captured by distinguishing its position on the level of observation, the level of action proper and the relationship between these two levels. As such, he argues that social constructivism is epistemologically about the social construction of knowledge and ontologically about the construction of social reality. No surprise then that research on social constructivism in international relations focus on the role of ideas, norms, knowledge, culture, and arguments in politics shedding a light on the role of collectively held or " intersubjective" ideas and understanding of social life in particular (Finnemore and Sikkink, 2001:392). Thus for Wendt (1995:81), "to analyse the social construction of international politics is to analyse how processes of interaction produce and reproduce the social structures- cooperative or conflictual- that shape actors' identities and interests and the significance of the material contexts". Quickly translated into a methodology, Wendt's observation means to dig into political institutions and practices whose roots are to be found in theories of knowledge (see Dryzek, 1987:656). This explains why social constructivism's distinctiveness is grounded in its theoretical arguments, and not in empirical strategies (Finnemore and Sikkink, 2001:393). Nevertheless Price and Reus-Smit (1998: 276) argue that:

> In their empirical work, constructivists have applied complex historically sensitive frameworks to concrete issues-areas of world politics. In doing so, many such works advance our understanding by specifying how their accounts relate to conventional explanations, whether they displace them, subsume or complement them, or address different questions altogether (Kazenstein, 1996:37).

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3 It suggests a consideration of the two levels of actions imbued in scientific explanation namely, the level of action proper and the level of observation. According to Guzzini (2000:162), in both cases we interpret, at one time making sense within the life-world of the actor, and at another time making sense within the common language of the community of observers.

In effect, cognisant of the fact that interpretation is part of the social construction of international reality, Adler (1997:337) argues that social constructivism should deal with "the question of which interpretations and whose interpretations become social reality". Put succinctly, what Adler (1997:337) means is that research in social constructivism should attempt to answer the question: "why do certain ideas and concepts acquire epistemic, discursive and institutional authority (Kratochwill, 1989; Mearsheimer, 1994/95; Risse Kappen, 1994)?"

Following Adler's (1997) contribution, Finnemore and Sikkink (2001) identify two groups among the constructivists researching on norms in world politics as well as the blind spots, biases, predictability and complementarity of their research outcomes. The first group tries to explain that global social structures exist and have considerable effects. In doing so, this group puts the bulk of its efforts on the adherence with international norms or rules, and neglects the variations in compliance. In other words, Finnemore and Sikkink (2001:397) argue that the researchers among this group "overlook the fact that international norms have to come from somewhere and may not identify feedback effects from local agents onto global structures (Kaufman & Pape, 1997)". The second group goes in the opposite direction since it is precisely interested in the ways in which norms vary locally. Yet it tends to mask or take for granted the finding of the first group regarding the strong overall influence of ideational phenomena. Finnemore and Sikkink (2001:397) see the danger in this second approach to be an exaggerated concern in relation to the details of local variations of norms' compliance and the risk "to lose sight of large overall shifts in the global normative fabric".

Moreover Checkel (1998:341) identifies three main reasons explaining why agency has not been properly considered through a social constructivism framework. The first has to do with constructivist researchers' reliance on sociological institutionalism insights for their thinking about the social world. In

fact those insights lie on a particular strand of organisation theory which overlooks the questions of agency, interest and power. The second, by focusing on shared, intersubjective understandings (norms), social constructivists often show little interest in questions of agency, especially non-human agency. Finally, the influence of Alexander Wendt on the development of social constructivism came along with an understanding in which individual agency is bracketed as a factor to be interrogated by mutual constitution. Nevertheless, more recently, Finnemore and Sikkink (2001:400) observed that a large section of social constructivism research has been addressing the issues around the purposive efforts of individuals and groups which change social understandings. In other words, social constructivists attempted to understand how these groups and individuals operate and identify the conditions that might contribute to their success. But the extent to which those attempts can be considered successful is mitigated and Checkel's observations remain relevant (see Bjorkdahl, 2002). Therefore a use of life history and critical discourse's elements which are informed by artefactual constructivism/new materialism follows the previous efforts to restore the significance of agency within a constructionist framework and the necessity to answer some of the questions which in this thesis intersect with Checkel's observations.

2.2. Inserting layers of artefactual constructivism in life history and critical discourse analysis

Although there is desire to provide a wider understanding of life history (2.2.1) and critical discourse analysis (2.2.2) in this section, only a few elements of both methods are used in combination with insights from artefactual constructivism to complement social constructivism in issues around agencies, ideas and norms.

Life history and the handling of (auto) biographical data

A definition of 'life history' by Watson and Watson-Franke suggests that it refers to any retrospective account by individuals of a fraction or entirety of his/her life

through written or oral form as elicited and induced by someone else (Lewis,2008:560). Such a view of life history approach relies on "participants' interviews in a way that allows their stories to emerge, as well as to explore these stories within the social, political, historical, cultural, familial and psychological context within which they are embedded (Matiss, 2005:83)". So, life history integrates both elements of geography and of history from the vantage points of the individual and a wider collective such as the nation. On the one hand, according to Boulding (1959:122) history and geography scripted in the curricula of national schools give a "perspective" rather than the truth in presenting the world from the vantage point of the nation. On the other hand, Matiss (2005:83) shows that the emphasis on historical change in life history sheds a light on the individual in relation to his/her contexts - because:

> This focus is a dual one, moving between the changing biographical history of the person and the social history of his or her lifespan. Invariably the gathering of a life history will entail the subject moving to and fro between the developments of their own life cycle and the ways in which external crises and situations...have impinged on this (Plummer, 1983:70).

The focus - which is referred as a dual one in the quote above - contains the seeds of the "double hermeneutics" mentioned in the previous section. It enables social constructivism to make a distinction between the level of action proper ("history of the person"), the level of observation ("the social history of his or her lifespan"), and the relationship between the two levels ("moving to and fro between the developments of their own life cycle and the ways in which external crises and situations...have impinged on this") (Matiss, 2005:83). But, in this part of the methodology, social constructivism has already been superseded by artefactual constructivism. For this study, I am adopting a constructivist outlook that recognises that both the human and the non-human aspects of both "context" and "agency". In this thesis the artefactual (or physical) dimensions of

space have a form of agency together with, as well as providing a critical framework for, human agency.

Furthermore, because the "double hermeneutics" differentiates between, but brings together, natural science and social science, and naturalist and interpretivist approaches, it gives access to different sets of data (see Guzzini, 2000). Within the framing of double hermeneutics, a single scholarly paper may have a scientific description of the natural world – of insects and forests, for example – as well as an interpretive view of the culture and agency of human actions. This is especially pertinent to the work of C.S Holling whose thinking evolved from the natural sciences into the social sciences (from natural ecology into social ecology), but who never lost touch with his originating work. In reality, Holling's work on resilience represents only a small portion of his total output, although this is what he is most famous for within the circle of social scientists at least.

Lewis (2008:575) summarises the particular value of life history in three-fold. It: "provides *perspective* in terms of creating a keyhole into institutional context and history; gives a view of a *trajectory* of an individual career path that provides information about individual choice-making and transition; and offers rich *description* in the form of nuance and detail, as well as the emotion of lived identities and experience." But participant interview is not the only way to reach this *perspective*, *trajectory* and *description.* In fact these three features of life history can also be found "in a critical dialogue with research findings from elsewhere, and with [a] global view of the social-economic and cultural environment where the studied lives take place" (Abrahao, 2012: 30)". The information that is left out of the available accounts of a person's experience in life history, as well as the various ways in which life history can be revealed, opens the possibility for a multiplicity of uses of life history (Bertaux and Kohli, 1984:217).

In this thesis, elements of life history are used concomitantly as a process and as a product. In other words, C.S Holling's (auto) biographical data generated along with the process of his own research on resilience are assumed to be framed with the logic of his life history. For Homan (2003:55), the value of autobiographical data[4] lies, amongst other things, in the capacity of a written text (abstracted from the face-to-face contact which is characteristic of much ethnographic fieldwork) to provide a distinctive and potentially different perspective because people may feel less pressurised or worried about giving the "right" answer. Autobiographical data is also arguably hindered by the fact that it can be manipulated to fit the agenda of the subject, or can simply be altered by a faulty memory (Pereira *et al,* 2005; Kennedy, 2012, Clements, 1999:24). Autobiographical accounts are also never only about the self (Mercer, 2007:575). Even though they are written from the perspective of the self, others are implicated and affected.

The use of autobiographical data is very limited in this thesis. While this may be seen as a form of *post facto* rationalisation, it does accord with the recognition by a number of writers of the limitations of an autobiographically centred account of life history. The use of life history in this thesis means an engagement with a variety of available data sources. Kouritzin (2004: 4) refers to such sources:

> (b) interview data used to flesh out and aid in understanding the oral history, (c) any available documents (e.g. diaries, letters, school records, legal papers, news clippings) corroborating or contradicting the narrator's life events, (d) third-party interviews with other persons to provide additional information or alternative explanation, (e) reference and comparison with other research and examples, and analysis and comparison across the different sources.

4 According to Tenni *et al* (2003:1), "autobiographical data is data that '...contains information about the self' (Brewer, 1986)."

With its' constructivist base, this thesis also challenges certain assumptions in both the writing and statements of Holling and of others about the life history of Holling. That is to say that it uses life history to "challenge the fetishness about certainty and objectivity of knowledge and the quest for universal truths"; and moves "from modernism and its assumptions about legitimate knowledge and knowledge production toward broadening what counts as research" (Dhunpath, 2000:543-544; Bullough and Pinnegar, 2001:13). In this respect, Bullough and Pinnegar (2001:15) note that the junction between "biography and history", the highlight of the multiple connections between the issues confronted by the self and the context as well as the ethos of a time, prefigure a move from self-study to research. Thus "[L]ife history is unique in creating the possibilities for going beyond conventional notions of what constitutes useful knowledge, for brushing with the muted subjectivities of those we research, and for revealing the transmutation of unobservable experience" (Kouritzin, 2000:30). A simple example of an apparent certainty in the life of C.S Holling that I at least wish to cast doubt upon is that neat division between the periods before and after 1973. It is arguably *research*, rather than self-reflection or autobiographical comment, which reveals the actual complexity in the evolution of C.S Holling's thinking. Self-reflection is also often very limited as a tool for understanding the influence of context, whether spatial or any other dimension. It is often very difficult for a self-reflecting subject to establish a sufficiently autonomous positionality in relation to his or her own life to disentangle matters of context from personal agency.

2.2.1. Relying on critical discourse analysis

Stevenson and Dryzek (2012:191) insist that any discourse typically consists of "a 'storyline' about how problems came to be (or came to be overcome) and what should therefore be done (or not done)". It has already been noted that in order to respond adequately to a strand of questions at hand in this thesis, social constructivism is replaced by artefactual constructivism/new materialism. This

shift provides a base where both discursive and material power of the various contexts unravelled through the elements of life history can be accessed with the help of texts having inclinations towards both the social sciences and the natural sciences. The centrality of power in this approach justifies the choice of critical discourse analysis (CDA) out of the wide range of discourse analysis methods available in social sciences literature. But this thesis is not committed to a full blown CDA. Rather aspects of CDA are instrumentalised when needed to tackle particular issues and questions.

Van Dijk (2001:52) defines CDA as "a type of discourse analytical research that primarily studies the way abuse, dominance, and inequality are enacted, reproduced, and resisted by text and talk in the social and political context". The adding of the word "critical" to the phrase "discourse analysis" implies abandonment of any restraint on *evaluation* of the texts and talks that are studied (Hammersley, 1997:239). But Mauthner and Doucet (2003:413) argue that even data analysis methods "reflect, and are imbued with theoretical, epistemological, and ontological assumptions-including conceptions of subjects and subjectivities, and understandings of how knowledge is constructed and produced." The evolution of the use of the term "critical" provides a good illustration of Mauthner and Doucet's argument. In this regard, Hammersley (1997:243) recalls that:

> As I noted earlier, the term critical began life as euphemism. And, in an important sense, it still operates as one today. However, it is now needed not because Marxism is taboo but because it has been discredited, not just by actually existing socialism and its collapse, but also by feminist, poststructuralist and postmodernist critiques. So, the term "critical" seems to function as an umbrella for any approach that wishes to portray itself as politically radical without being exclusive in its commitments.

As in the case of social constructivism, the field of CDA is not a homogeneous one. It subsumes a variety of approaches towards the social analysis of discourse which differ in theory, methodology, and the type of research issues they

emphasise (Fairclough, 2004:1). In this regard Wodak and Kandall (2007:3) notes that the term " critical" means " not taking things for granted, opening up complexity, challenging reductionism, dogmatism and dichotomies, being self-reflective in my research, and through these processes making opaque structures of power manifest." According to her, "critical" is not to be understood in the common sense of the word i.e. criticising or being negative. Wodak and Kandall echo the view of Norman Fairclough when they posit that "there is not one critical discourse analysis approach. All [forms of] critical discourse analysis have their own theoretical positions combined with specific methodology and methods". Beside, every theoretical approach in CDA is inherently inter or trans-disciplinary and certainly not to be studied by linguists alone (Wodak and Kandall, 2007:4). Also, Fairclough and Wodak (1997:271-80) recapitulate the main tenets of CDA as follows:

1. CDA addresses social problems
2. Power relations are discursive
3. Discourse constitutes society and culture
4. Discourse does ideological work
5. Discourse is historical
6. The link between text and society is mediated
7. Discourse analysis is interpretative and explanatory
8. Discourse is a form of social action

Wetherell (2001:391) argues that critical discourse analysts prefer keeping theoretical and analytical distinctions between different extra-discursive practices. This difference reflects the influence of Marxism in the development of CDA. She highlights the case of Norman Fairclough (2001) who notices that, in the process of arguing that every social practice has linguistic or discursive elements, tries to make distinctions between the various elements making up a practice. She refers, for example, to diverse practices including manufacturing and child rearing arguing that they include at the same time the productive

activity, the means of production, social relations, social identities, cultural values, forms of consciousness involved, and the making of meaning.

Furthermore, Wetherell (2001) remarks that critical discourse analysts in comparison with other discourse analysts heavily anchored in linguistics, tend to take a more materialist position which indicates that they have an interest in the real material world independent of talk and discourse. If ontological separations are made between different kinds of social practices (discursive and non-discursive), then it is also possible to ask about the determination of one by another. Although there are many perspectives in the study and critique of social inequality, the way CDA approaches these questions and dimensions is by focusing on the role of discourse in the (re)production and challenge of dominance. This (re)production process may involve different "modes" of discourse. CDA wants to understand "what structures strategies or other properties of text, talk verbal interaction or communicative events play a role in these modes of reproduction" (Wetherell, 2001:392). Also CDA pays more attention to top-down relations of dominance than to bottom–up relations of resistance, compliance and acceptance. This does not mean that critical discourse analysts see power as unilaterally imposed on others.

Although an analysis of strategies of resistance and challenge is crucial for our understanding of actual power[5] and dominance[6] relations in society, and whilst such analysis needs to be included in a broader theory of power, resistance and discourse, CDA prefers to focus on the elites and their discursive strategies for

5 Power is understood in this context in relation to "the more or less direct or overt support, enactment, representation, legitimation, denial, mitigation or concealment of dominance among others (van Dijk, 1993:301)."

6 Dominance means "the exercise of social power by elites, institutions or groups that results in social inequality including political, cultural, class, ethnic, racial, and gender inequality (van Dijk, 1993:301)."

the maintenance of inequality (van Dijk, 1993:301). In effect, a central notion in most critical work on discourse is that of power, and more specifically the social power of groups and institutions. Social power in this context is defined in terms of control. Groups have (more or less) power if they are able to control (more or less) the acts and minds of (members of) other groups. This ability presupposes a power base on privileged access to scarce social resources such as force, money, status, fame, knowledge, information, "culture" or indeed various forms of public discourse and communication of the vast literature of power.

There are different types of power depending on the various resources employed to exercise such power, viz. the coercive power of the military and violent means is based on force. The rich man's power, rather than being based on force, will have power because of their money whereas the more or less persuasive power of parents, professors, or journalists may be based on knowledge, information, and authority. Also power is seldom absolute. Groups may more or less control other groups, or only control them in specific situations or social domains. In addition, dominated groups may more or less resist, accept, condone, comply with, or legitimate such power and even find it "natural". The power of the dominant group is integrated in law, rules, norms, habits, and even a quite general consensus, in this sense it is similar to the Gramscian notion of hegemony (van Dijk, 2001:354:355). In many situations, and sometimes paradoxically, power and even power abuse may seem "jointly produced". For example when dominated groups are persuaded by whatever means that dominance is "natural" or otherwise legitimate to be subjugated. But, more specifically in relation to the issues around the coming into being of resilience idea in this thesis, artefactual constructivism/new materialism inverts the top-down bias of CDA into a bottom- up approach. Nevertheless CDAs top-down bias is considered a vantage point vantage to trace the spread of resilience idea internationally and at a local level in South Africa.

CDA operates at both the micro and macro level of analysis. Language use, discourse, verbal interaction and communication belong to the micro level of social order. Power, dominance and inequality between social groups are typically terms that belong to a macro level of analysis. This means that CDA has to theoretically bridge the well-known "gap" between micro and macro approaches. A CDA analysis of the relations between discourse and power therefore finds firstly access to specific forms of discourses i.e. politics, media. Secondly, it examines the way discourse impacts on the mind knowing that action is controlled by our minds. Finally, it looks at those groups which are most influential and have more chances to control the minds and the actions of others. In other words van Dijk (2001) splits the issue of discursive power into two basic questions for CDA:

1. How do (more) powerful groups control public discourse?
2. How does such discourse control mind and action of (less) powerful groups, and what are the social consequences of such control, such as social inequality?

Nonetheless Jones (2007:338) argues that there is nothing specifically critical about critical discourse analysis in comparison to other mundane communicative practices. He points out that the problem with critical discourse analysis is *discourse analysis.* The categories, elements and procedures associated with different forms of "discourse analysis" grounded in conventional linguistics and pragmatics cannot afford any *critical* purchase on communicative processes, and get in the way of a proper appreciation of how communication is done in everyday life. This is so because the underlying beliefs framing various approaches to discourse are rooted in a set of convictions entailing the refusal or the inability to recognise the *integration* of communicative practices into social processes. Consequently the theoretical and analytical construct of discourse analysis tends to be derived from an artificial and arbitrary *segregation* of certain *contingent and contextually conditioned features* of the forms and outcomes of communicative activity from the totality of human conduct.

However a combination of elements of life history and CDA with artefactual constructivism/new materialism is a remedy to this dichotomy and a way to recognise the influences of heterogenous agencies (i.e. the building of a laboratory, insects or a forest) which participate in the formation of discourses and ideas. Still, neither idea nor discourse is the same. In fact, Schmidt (2008:321) argues that:

> Ideas differ in levels of generality: They may be specific to policy, encompass a wider programme, or constitute an underlying philosophy. They also differ in type: Cognitive ideas are constitutive of interests and normative ideas appeal to values. Discourse serves not just to represent ideas but also to exchange them through interactive processes of (a) coordination among policy actors in policy and programme construction and (b) communication between political actors and the public in the presentation, deliberation, and legitimation of those ideas, against a background of overarching philosophies.

While a particular idea may undergo numerous developments throughout history so as to integrate different features of Schmidt's typology of ideas and then morph into a discourse, it is important to notice that discourse analysis or more appropriately in this case critical discourse analysis allows a distinction between norms, ideas and interests. It is not possible to make this qualitative difference under a strict social constructivist framework. Besides, O'Halloran (2005:1947) is of the view that the combination of CDA with a biologically-based paradigm will enable it to detect the mystifying social agent absences from potentially any text-data. The agencies in question can be heterogeneous or autonomous and come from human and non- human sources, or both. That is to say that artefactual constructivism/new materialism contains the insights of this biologically based-paradigm. As such it moves beyond a debate about texts only so as to recognise the agencies of non-human agents and the effects of the material aspects which constitute what is often narrated as "contexts".

2.3. Translation of the overall methodology into a method

The method is primarily based on the germination and then evolution of the idea of resilience in the work of C.S Holling although a critical aspect of this method is providing the context for this process. Fortunately, C.S. Holling and others in a number of writings recount the events which led to the discovery of the resilience idea. These include the following key contributions"

1. *A Journey of Discovery, Global Resilience Requires Novelty-A* speech (Holling, 2006)
2. *Resilience Thinking: Interview with Brian Walker* (Walker, 2007)
3. *Rapporteur's Notes for the Workshop on Hypotheticality, Resilience and Option Foreclosure, Toward a Structural View on Resilience* (Haefele *et al*,1975)
4. *Buzz Holling and the Functional Response* (Holling,1969)
5. *Stability in Ecological and Social Systems* (Holling,1973)

In *Calling Buzz Holling,* and *SDU Interview: 3 questions to Professor Buzz Holling about the Resilience Concept,* Holling (2008) is interviewed in order to explain to academic and non-academic audiences what he means by resilience and the place that such a discovery has in his own life cycle. Besides these elements of autobiographical data, there are also the biographical data contained in academic papers and other publications about his works or about the recognition that his academic contribution gained in the 1960s and 1970s. This type of data typically includes a short description about him; an indication of the institution to which he is affiliated; and, information on collaborators. However, such information is often in fragments. They can be found for example in:

1. *Ecology and Planning, Toward an urban Ecology* (Holling and Orians, 1971)
2. *The Role of Small Mammals as Predators upon Sawfly Population, and The Selection by certain small mammals of dead Parasites and healthy prepupae of the European pine sawfly, neodiprion sertifer (Geoff)* (Holling, 1957)

However, in a *Journey of Discovery*, Holling (2006) provides a historical perspective on the development of his academic career as well as what he and his peers consider as his major contributions to science. This paper is intended to respond to the bulk of the questions regarding how he came up with some of his influential ideas and serves as guidance for (aspiring) researchers. As indicated earlier, there are a few other papers in which he speaks about various stages of his work and a bit about himself in similar fashion. But the *Journey of Discovery* occupies a central position in the framing of this thesis because of the ways in which Holling situates his 1973 paper, "Resilience and Stability of Ecological Systems" along other less recognised aspects of his life and academic contribution. Initially, I used this linear periodisation to structure my own research, but I later came to understand that the 1973 "watershed" is too strongly emphasised. Ideas of resilience are clearly present in Holling's pre-1973 work, while much of the conceptual form of resilience (for example, the ideas of panarchy) evolved after 1973. This periodisation is, nevertheless, a useful *starting point.* For the period before 1973, I drew on a range of sources, including the publications originating from his master thesis, in the 1950s, a copy of his PhD thesis and the scholarly articles drawn from it. I soon realised however that geo-historical contextualisation was critical to provide the perspective that was needed on Holling's evolving work. I shifted from looking only at Holling's work, and the then sparse biographical references, to readings on the geographical context of the 1950s and 60s. I found the spatial focal points in his earlier life (for example, the North American boreal forest, Ontario, and the Sault Ste Marie laboratory) and this helped reduced the arbitrariness of my

original heuristic strategy. After 1973, of course, Holling reflected on his own work and life prior to 1973, and it was important to relate my contextualisation to his own articulation.

The insights gained from the study of the first period culminated into a reconstruction of the epistemic culture in which Holling has been immersed in the 1970s. Following that, I moved to the second period when Holling left Canada for a position at the International Institute for Applied Systems Analysis (IIASA) in Austria. Meanwhile his 1973 paper was already published as a result of his years of research in Canada and an early collaboration that he started with IIASA in 1972. Thus from 1973 until the 1980s, the digitised archives of IIASA regarding the development of resilience into an interdisciplinary concept as well as the intellectual life of Holling's and his colleagues at the institute are passed under review through the examination of various research reports, correspondences, and scholarly publications available online (www.iiasa.ac.at) . During this period the emphasis was placed on how Holling's experience in Canada materialised both physically in terms of the design and the choice of the case studies of his research and conceptually in terms on his inputs in the organisation and operationalisation of IIASA's activities. Also, through secondary accounts on the description of the physical space of the Institute and the accent on computer models' in the methodology of Holling's work and of his colleagues at the Institute, the physicality of his stay in Austria is briefly highlighted. These include, for examples:

1. *From Cold War to Global Warming: A History of IIASA through the decades, narrated with extracts from past Options articles* by IIASA (2007).
2. *On butterflies and nuclear reactors: media and politics of resilience at the IIASA* by Schrickel (2014).

These secondary accounts provide some insight into the ways in which the idea of resilience was adapted at IIASA, and also of some of the conflicts around the idea as revealed in the IIASA archives. This period is closed with a publication from 1986 of:

3. *The resilience of terrestrial ecosystems: local surprise and global change* (Holling, 1986), a chapter in *Sustainable Development of the Biosphere* through which Holling gained a large professional following relatively quickly.

Even if we accept 1973 as a culmination or turning-point of sorts, the post-1973 era is too complex and diverse to be regarded as a single period. I suggest a third period beginning around the early- to mid-1990s. This period is about the recognition and the circulation of the idea of resilience. Until the 1990s, ideas of resilience were still relatively marginal to scholarly and policy discourses, and Holling was not well known outside a limited circle. This changed rapidly and dramatically after that time. Although an ageing Holling has remained influential and active, the rapid expansion in, and diffusion of, the idea of resilience means that the third period has less to do with him than with key players who have spread, elaborated on, or revised, his ideas. For this period I mostly used secondary sources (academic papers) to show the significance of what resilience has become. I tried to surface a little bit more the role of material power in the diffusion of the concept. In doing so, I identified the creation of some pivotal knowledge infrastructures and the trade-offs that came along with them through Holling's life history. In this regard, the role of non-state actors and state actors, as well as networks of individuals, is accessed through analysis of their performance assessment reports, memberships, sources of funding and foreign policy documents (available, for example, at www.stockholmresilience.org and www.resalliance.org, and more broadly through desktop research). Some of these documents are:

4. *Stockholm Mistra Institute (SMI) on Sustainable Governance and Management of Social-Ecological Systems* (SRC *et al*, 2008)
5. *Progress Report 2007-2012* (SRC, 2012)
6. *Norm Entrepreneurs: Scandinavia's Role in World politics* (Ingerbritsen,2002)

I understood, however, the limitations of using secondary material only for exploring knowledge diffusion and uptake. I therefore decided to introduce a particular case study that allowed me to use direct contact and discussion with human agents actively involved in the further construction, or use of, ideas of resilience. I was able to connect Holling's research on resilience with the pioneering works of Brian Walker in systems ecology/ resilience at the University of the Witwatersrand in South Africa in the 1970s through the International Biological Programme (IBP). Some articles have been particularly helpful in this process:

1. *Thinking: Interview with Brian Walker. Questions asked by Tein McDonald* (Walker, 2007),
2. *Representations of Nature mediating between Ecology and Science Policy: The case of the International Biological Programme, Big Science and Big Data in Biology: From the International Geophysical Year through the International Biological Program to the Long Term Ecological Research (LTER) Network, 1957-Present* (Aronova *et al*, 2010)
3. *DSTs forward-looking strategy to address global change* (CSIR, 2009)
4. *Ecology of Tropical Savanna* (Huntley and Walker, 1982)
5. *Aspect of Stability and Resilience of Savanna Ecosystems* (Walker and Noy-Meir, 1982)

Also, conversations with my supervisor, Professor Philip Harrison[7], and exchange of emails with Dr. Debra Roberts[8] and Professor Barend Erasmus[9] provided guidance in terms of the location of information regarding the lineages and points of entry for scholarly engagements with the idea of resilience in South Africa. In my engagement with Dr. Roberts, I had an inclination toward the use of resilience in contemporary scholarly works and planning practices in South Africa. Those conversations assisted mainly in the clarification and verification of some of the connections regarding the transfer of the idea of resilience to and across South Africa which were made in the earlier stages of the research whilst using almost solely textual data. They also gave me a sense of how far I can use conversations/interviews to make claims in my thesis regarding the use of resilience ideas in contemporary academic and planning practices in South Africa. In other words they emphasised the difficulty in locating exactly the ramifications of Holling's idea of resilience in contemporary scholarly and planning practices in South Africa, and cast doubt on the existence of a coherent body of knowledge in resilience in general, or urban resilience in particular, in this country.

In addition, one of the major difficulties in this thesis has been to give a sense of order to the fragments of biographical and autobiographical data collected about C.S. Holling and resist the temptation to extrapolate based on partial information. I hesitated long before trying to contact the 85 year old C.S Holling for direct answers, as much of what he was likely to say already existed in

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7 He is the current Chair at the South African Chair in Spatial Analysis and City Planning at the University of the Witwatersrand.

8 She is the head of Environmental Planning and Climate Protection at the Ethekwini Municipality in Durban and the Chief Resilience Officer in Durban for the Rockefeller Foundation's 100 Resilient Cities Programme.

9 He is the current Director of the Global Change and Sustainability Research Institute (University of the Witwatersrand).

publicly recorded interview, and in his *A Journey of Discovery*. I did not wish to burden him with answering challenging questions on his life. In the end, however, I did try to contact C.S Holling to ask for clarity on specific matters of detail that would help fill in the gaps on his life. In particular, I asked about his involvement with various organisations in the USA and Sweden in the late 1980s and in the course of the 1990s. Unfortunately and understandably he did not reply to my e-mail. For this reason, there are some gaps in detail - for example, the exact period of time that he spent with different organisations – and also some ambiguity in interpretation with a lack of information on some of his personal motivations for research choices and institutional affiliations. While none of this is crucial to the outcomes of the thesis, it may matter in places. Overall, however, there is sufficient of C.S Holling's personal reflections in the public domain to articulate his voice alongside the memories and interpretations of others, and also my own interpretations.

Conclusion

In the first two sections of this chapter, there arose the methodology of this thesis out of a blend of elements of social constructivism, artefactual constructivism, and life history and critical discourse analysis. Insights from critical discourse analysis are used as an analytical tool for the examination of the data related to life history (process and product) of C.S Holling, so as to highlight the multiple connections between spaces and knowledge while looking specifically at resilience ideas and the variety of their configurations' imprinted across distinct historical periods. Social and artefactual constructivism/new materialism - constitute the ground upon which the analytical and empirical strategies associated with elements of critical discourse analysis and life history blossom a method that unfolds the answers to all the questions posed by this thesis. Through an articulation of a method for the overall thesis, the final section engages with the relevance and application of the mixed methodological framework presented in the first two sections of this chapter.

3. Crafting a line on knowledge production in social-ecological research

Introduction

Knowledge is both material and ideational. It is not restricted to materialised ideas (knowledge embedded in physical artefacts or technologies), and includes discourses that frame representations of materiality. In other words, knowledge reflects some "understandings and ways of doing things which highlights the relationship of embodiment as artefacts and embodiment as understandings, meanings and readings of the artefacts" (Henry and Pinch, 2000:203). Dewsbury and Naylor (2002:254) say something similar: "knowledge as practice is set against a backdrop of material agents as much as it is scripted from the intentional agency of the individual researcher; that it is embodied; and the witnessing of knowledge into being is an inherently political act".

A focus on knowledge production flows from a seemingly intractable dilemma. While the objects of our concern may exist in an objective form, our realities – or our "knowledges" are shaped by the subjectivities that form our consciousness and are largely represented through the contingently constructed medium of language. Since knowledge is constitutive of practice, but has no objective relationship to materiality, understanding as best we can the process through which knowledge is constructed remains important to decipher why we act as we do.

Dewsbury (2003:1910-1911) stresses that the most significant outcome of the predominance of representational understanding is that "there is a totalisation of thought in the very artifices through which we present that which we are attempting to understand". However, just as there is no simple correspondence between material truth and representation or knowledge, so there is no direct correspondence between knowledge and practice. The weight of knowledge – or

at least of scientifically derived knowledge – may bear on practice but also has logic which is distinct from the logic ascribed to scientific reasoning (Bourdieu, 1976:53). As such, in understanding practice, we must give consideration to a variety of knowledge forms, and also to the lack of knowledge, the open-endedness of knowledge, and the extent to which power relations are implicated in knowledge production. It is this that brings into focus the very subject of this thesis.

At the end of his 1973 article on "Resilience and stability of ecosystems", C.S. Holling concluded that an approach to the management of resources was grounded in resilience and would put the emphasis on the need to keep options open, the need to view events in a regional rather than local context, and the need to place more attention on heterogeneity. This remark is particularly relevant for this chapter because it does not flow from "the presumption of sufficient knowledge, but the recognition of our ignorance; not the assumption that future events are expected, but that they will be unexpected" (Holling, 1973:21). Consequently, the writings that follow, are neither a comprehensive review of knowledge production nor the presentation of a precise and definitive theoretical lens through which the subject of this thesis will be examined. Rather, they provide a patchwork of some entry points upon which the line of thinking underlying this thesis will gradually be drawn, chapter after chapter.

To put it succinctly, in this chapter, my intention is not to put forward a single argument; instead it is to craft a scaffolding for the argumentation of this entire thesis. In order to infuse some degrees of coherence, clarity and wholeness in the overall act of writing or reading the four sections which constitute this chapter, I identify three key dimensions to the knowledge production process, and I engage with insights originating from different authors in relation to these dimensions, but without any claim to be providing a comprehensive literature review of what is a vast area of study. These three dimensions represent three of the four sections of this chapter : 1) a broad account of the production and

constitution of knowledge; 2) political and economic stakes underlying the distinction between scientific knowledge and other forms of knowledge production; 3) the increasing significance of knowledge in the economy and ways in which the categorisation of knowledge and the production of scientific knowledge have changed in relation to shifting economic interests; 4) in line with the broad themes of this thesis, particular attention is paid to the importance of knowledge production in relation to social-ecological research. In doing so, the overall chapter shows that notwithstanding claims to universality, knowledge production is geographically produced. As such, the popularity of the term resilience both in the academy and policy circles provides some reasons to investigate what the geographical production of knowledge concretely entails and what informs/supports the claims to universality deriving from it.

3.1. Knowledge and its kinds

Any definition of the term "knowledge" is a part of what is intuitively considered as knowledge. Yet, it is not necessarily a by-product of science. Several definitions of this term as well as a range of heterogeneous knowledge systems co-exist. For example Feldman and Kogler (2010: 392) suggest that knowledge is an ethereal concept that is probably best captured through its embodiment in human capital, referring to the individuals who are capable of comprehending, combining, and producing, /creating new knowledge. However, as Demeritt (1996:485) points out, claims to knowledge are also claims to power and this is especially so for claims to scientific knowledge.). According to Demeritt's analysis, debates about science, objectivity and scientific facts are debates about what counts as "real knowledge" and of the legitimacy of the voices to be heard in the struggle to define it. Bourdieu (1989:729) similarly remarks that "[K]nowledge of the social world and more precisely, the categories that make it possible, are at stake, par excellence, of political struggles, the inextricably theoretical and practical struggle for power to conserve or transform the social world by conserving or transforming the categories through which it is

perceived". Bourdieu sees "reflexive knowledge" as a means of enabling the possibilities to go beyond the social reproduction and theoretical reification induced by "practical knowledge" although Lynch (2000: 36) alerts us to be cautious about practices of reflexivity (Shrirato and Webb, 2002). He observes that reflexive analysis is often portrayed as having the potential to reveal forgotten choices, expose hidden alternatives, lay bare epistemological limits, and empower voices misrecognised by objective discourse. Lynch also argues conversely that "what reflexivity does, what it threatens to expose, what it reveals and who it empowers depends upon who does it and how they go about it (Lynch, 2000: 36-42)." In the light of Lynch's argument, there are no guarantees of success and no intrinsic gains to "doing" reflexivity or "being" reflexive. Therefore any project that deconstructs objective claims should be treated no more or less similarly to the claims it seeks to debunk.

Lynch's argument is particularly relevant when trying to grasp what is done under the label of "science studies". So in this paragraph, I will briefly present what science studies is about, in order to align Lynch's argument along with the writings of this chapter, and to highlight the background of the claims made by some authors in the following paragraphs of this section. That is to say that science studies can refer to the plurality of historical, sociological and anthropological approaches to scientific claims and practices (Powell, 2007: 310). It encompasses also a large recent body of literature in the theory of knowledge and social epistemology. This body of work suggests that "research, reflection and writing are not so much pathways into the transcendental, as they are concrete phenomena, forever rooted in the immanence of daily life" (Scott, 2004:480). However, science studies is neither a homogeneous school of thought nor has a history that can be framed in a single story. Barnes (2001:524) follows this line when he distinguishes three sub-traditions: Mertonian institutionalism; the sociology of scientific knowledge (SSK); and, cultural studies of science which

emerged as a reaction against the model of the traditional history of science[10]. Rhoads and Thorns (1994:92) trace the historical formation of three contemporary viewpoints in the philosophy of science as a response to a growing dissatisfaction with logical positivism[11], namely social constructivism, post-positivist empiricism, and scientific realism.

Dimaggio (1979:1461) infers from Bourdieu the idea suggesting that any social science based on the subjective perceptions of participants or on common sense classifications of social problems can only reinforce and confirm the very domination it regards as problematic. Nevertheless, it is worth recalling that the goal of social sciences is not to copy natural sciences by inventing infrastructures but to modify the representation that the public has of itself quickly enough to provoke the greatest number of objections to this representation (Latour, 2000:120). To illustrate this point, Withers (2002:305) shows that for the historian and experimental natural philosopher, the management of the production and categorisation of knowledge in the context of discovery-working in the archive goes hand in hand with a consideration of the reception of knowledge as "public knowledge" in different contexts of justification. In fact, differences exist between them because for knowledge made in the laboratory to circulate successfully depends more upon its replicability elsewhere, whereas knowledge gained in the archive originates often from a unique source. The former rests on calculation and repetition, the latter depends more upon interpretation, implication and trust.

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10 It is often labelled as "presentism" or " whig history" and it refers to the idea that disciplinary change is guided by progressive-working out of some deep-seated, internal principle or idea that comes to fruition at precisely that point of time in which the author of the history is writing (Barnes, 2001:524).

11 It is an attempt to distinguish science from non-science by getting rid of the metaphysical- that is, unobservable theoretical- elements from scientific theories (Rhoads and Thorn, 1994:92).

Chamers (1990:7) notes that the aim of natural science is to find general laws and theories applicable to the world through the most demanding route possible when considering existing techniques. But Friedland (2009:15) recalls that, according to Bourdieu, "[S]cientific reason derives neither from "ideal norms", nor from "technical rules of a scientific methodology", but from struggle to secure dominance and command the profit of the field". Such an understanding is echoed in Law and Urry (2004) view's stating that in social science methods are constitutive of, rather than a reflection of, social reality and any attempt to impose a methodological stance on them is doing injustice to some features of the situation that one wants to investigate. Also, Brown (2009) notes that the contextual explanations of science studies "work best analysing science at the frontier, especially when the effects predicted or measured are obscure and the apparatus and experimental design is complicated and delicate". Indeed Latour (1981: 212-213) acknowledges that once a discipline is mature, it becomes expensive and hard to show that the discipline itself, and the facts on which it rests, are socially constructed.

At this point, it is plausible to consider knowledge production as a social activity and knowledge in its variety as representational, performative[12], historical, contingent and coproduced with society. In effect Turnbull (1997) reports that historian and sociologist are now more ready to admit, on the one hand that the specific form of knowledge production seen within the scope of "modern science" is a relatively recent local activity that was coproduced with industrial

12 "A performative understanding has two aspects. On the one hand knowledges are the product of human movement, actions, practices and protocols. It takes active work to transform the world into knowledges and they are embodied in people, their activities, relationships and their tools, artefacts and all forms of technology especially modes of representation, communication, and mensuration. On the other hand knowledges are not abstract entities they are conjoint practices of groups of people, and shape the world they inhabit. In practicing and making their knowledge of the world, people make themselves, the society and the spaces they inhabit (Sillitoe and Marzano, 2009:3)."

capitalism. Having as a point of entry the claim that modern science emerged principally in one geographical locale, historians of science initially adopted "the wheel" as the metaphor for its international structure, Europe was the centre with the rest of the world revolving. On the other hand, science in the broad sense of systematic knowledge was never uniquely Western its roots include a number of diverse cultures such as Islam, India, China, and Africa (see Lor and Britz, 2005).

Chambers and Gillespie (2000:223) argue that the idea that science holds a European centre and a global periphery sustains a confusing, and ultimately spurious, understanding of the relations of science and place. In effect these scholars observe that then and now, Europe had major centres, minor centres and peripheries; cities like London had central institutions and peripheral institutions. Nonetheless, the explanations of the spread of modern science have been facilitated with the appearance of historian Georges Bassala's well-known model describing the introduction of modern science into non-European nation. Georges Bassala's model amplifies the diffusionist hypothesis already couched in the work of W.W. Rostow. In 1960, Rostow describes the stages of economic growth in his "non-communist manifesto", a seminal work on modernization theory. In Rostow's perspective, science it seems diffuses from Europe and pool where the ground was ready to receive it. Georges Bassala's model provides the details of the phases associated with the spread of Western science from centre to periphery. In his model, in phase 1, expeditions in the periphery simply provide raw material; during phase 2, the derivative and dependent institutions of colonial science arose; and sometimes an independent and national science which is called phase 3, would later develop (Anderson, 2002:648).

The fact that the Bassala's model seemed to prescribe the direct path to national scientific development rendered it initially attractive (Chambers and Gillespie, 2000:224). Though in the 1980s, Bassala's simple evolutionary model of scientific development was to provoke intensive criticism in science studies. Those critical

responses were fuelled in part by the more general challenge of dependency theories and world systems theory to the older diffusionist models of modernisation and development (Anderson, 2002). More recently, Boor *et al* (2014:11) find that the mobile banking industry challenges the assumption that the North (Western countries) is unequivocally the origin of new technology. According to these scholars, high levels of need and flexible platforms, in association with increased access to information and communication technology, provide enough opportunities for novel innovations to originate in developing countries.

3.2. Struggles over knowledge validation

Holling's initial research started in Canada, yet over the years some of its findings began to circulate internationally. It is the case for the concept of resilience. Broadly, the recognition of the localness of scientific knowledge highlights the struggles over the scale at which knowledge claims are represented and legitimised as an element of re-scaling. According to Wright (2005, 904-905), the re-scaling of the ability of what is deemed to be considered as legitimate knowledge from a "local" ,"regional" or "national" activity, to a "global" one is a re-scaling faithful to both changes in knowledge/power relations and to their consolidation and reinforcement. Turnbull (1997: 1199) observes that probably the most significant outcome of the recognition of the localness of scientific knowledge is that it allows parity in the comparison of the production of contemporary "techno-scientific" knowledge with knowledge production in other cultures.

The distinction between contemporary "techno-scientific" knowledge and knowledge in other cultures reflects an analytical separation between what have been portrayed as "western knowledge" and what have been regarded as "indigenous knowledge". On the one hand "western knowledge" through its capacity to make the knower invisible and eradicate place has been traditionally defined as "the knowledge of all places" (Wright, 2005:904). On the other hand,

indigenous knowledge with its intrinsic characteristic as local has often been considered as "a body of knowledge built up by a group of people through generations of living in close contact with nature" (Berkes and Berkes, 2009:7).

Turnbull (1997:1199) recalls that previously the possibility of a truly equitable comparison between scientific knowledge and indigenous knowledge was overshadowed by the assumption that the latter was merely local and was to be evaluated in the light of the scientific characteristics it might display. On this matter, Woolgar (1988:12-17) argues that there is no essential difference between science and other forms of knowledge production. In contrast to the philosophy of science, he suggests that one of the defining characteristics of science studies is the recognition that science cannot be distinguished from non-science by decision or rules. He insists that there is no way we can find these general laws and theories out there. According to him science is not universal at all but the outcome of complex social processes whereby the variations in the form of legitimacy of scientific knowledge claims are gradually eliminated. In the same vein, Law and Mol (2001:609) point out that the universality of science "did not figure as a consequence to add up, make links between, or otherwise relate various localities, but rather as something which transcends them". What is being perceived as "universal" in science" is a set of local practices produced through a process of standardisation of methodologies resulting from the negotiations situated in the networks that have been extended globally (Kuukkanen, 2011:592-598). Even the rationality often coined with science cannot be reduced to a given culture as its particular features namely, universality, objectivity, efficacy and accumulation cease to be the unique characteristics of techno-scientific knowledge so as to become traits attached to the collective work of knowledge producers in a given "knowledge space" (Turnbull, 1997: 553).

Moreover all objects of science are not exclusively produced by scientific practices associated with objectivity (Smith, 2005:17). A constructionist's view on

science proposes that scientific objects are inventions forged in specific historical contexts and shaped by local circumstances (Daston, 2000:3). Although this may be true in general, Lave, *et al* (2010:664) add that science may always have had economic and political dependencies, but knowing specifically what those dependencies mean is extremely important.

Mere Roberts finds that western knowledge and indigenous knowledge share a number of similarities such as empirical observation and the maintenance of extensive data sets, albeit the main distinctions between indigenous and western knowledge appear mostly in areas of cause and effect, and function (Johnson and Murton, 2007:125). But, Agrawal (1995) argues that a classification of knowledge into western and indigenous is bound to fail for a number of reasons. Firstly, the knowledge that constitutes both indigenous and western categories is heterogeneous. Secondly, the separation between western and indigenous is artificial and tends to fix each category in time and space with no respect for the inherent dynamics of life across histories. Bryan (2009:27) adds that the very concepts used to identify certain types of knowledge as indigenous remain rooted in colonial power relations. According to him, the fact that the colonial construction of "indigenous knowledge" is difficult to reveal is not a matter of mere absence; it is "a product of the ways in which modern knowledge is presented simultaneously seamless and objective, making colonialism's characteristic asymmetries of power appear natural or pre-given." In relation to the category of people's closely associated with indigenous knowledge, Bryan (2009:27) points out that:

> The authenticity of claims to indigenous identity lies with their ability to demonstrate a historical continuity with a pre-colonial past shored up through claims of particular relationship with nature. The savage slot thus frames the basis for political action, mobilizing concepts rooted in colonialism as a means to address contemporary political problems.

Claims to be native and rooted hold different implications in different places but some important political recognition of indigenous people and their rights are noticeable (Nash, 2002:227). For example in 2005 UNESCO adopted the Universal Declaration on Cultural Diversity but the United States of America along with Israel refused to endorse the treaty while Australia and others abstained. Also the ways in which scientific knowledge and indigenous knowledge as well as small technological transformations are put into circulation, assembled and enabled to work together have been reconceptualised (Turnbull, 2009 :2). Some scholars argue that these changes reflect the development of a "knowledge economy" and its capacity to absorb indigenous knowledge (Sillitoe and Marzano, 2009:2). Although Hollings is a white male, it is important to insist that a part of Canada's population is made up of indigenous people.

3.3. Economic ramifications and configurations of knowledge

Knowledge plays a pivotal role at the core of increasingly more industrial and innovation processes (Rychen and Zimmermann, 2008:767). Floys and and Jakobsen (2010) note that the liberalisation of trade and financial markets jointly with technological development (particularly in information and communications technology) have reduced geographical and other barriers previously protecting local industries against international trade competition. It is in this context that the creation of new knowledge, new ways of doing things and new products have emerged as central in the improvement of global competitiveness for business sectors, places and regions. As a result, knowledge appears to fall into heterogeneous fragments within the broader remit of the "knowledge economy". For example, Clarke (2001:189) observes that different kinds of knowledge pervade the knowledge economy including "know-what", "know-why", "know-how" and "know-who". Some can be easily packaged as commodities, while others, especially "know-how" and "know-who" are more

difficult to measure. The seminal distinction between codified and tacit knowledge captures the variety of knowledge listed by Clarke (2001).

Drawn from the work of Michael Polanyi, Howells (2002:872) notes that "codified or explicit knowledge refers to know-how that is transmittable in formal, systematic language and does not require direct experience of the knowledge that is being acquired and it can be transferred in such formats as a blueprint or operating manual." Tacit Knowledge, according to him, is the result of direct experience and is not codifiable via artefacts. In fact, it "represents disembodied know-how that is acquired via the informal take-up of learned behaviour and procedures." Codified knowledge can be easily commoditised in comparison to tacit knowledge (Bathelt *et al,* 2004:32). Codification and the development of shared knowledge and tacit knowledge between the members of a community constitute the main aspects of knowledge production (Lazaric *et al,* 2008:840). But Feldman and Kogler (2010:397) stress that the tacit character associated with some kinds of knowledge is questionable because it is actually embodied in human capital. Also the difficulty of disentangling knowledge and competency remains because knowledge travels on the rails laid down by practice (Lazaric *et al,* 2008:848).

Whilst there is not a consensus about what "knowledge economy" really means, it is broadly accepted that the production of knowledge has always been an inherent part of the set of activities captured within the term "economy" (Brinkley, 2006: 5). In this regard, Winden *et al* (2007) identify two main perspectives on knowledge economy. First, the knowledge economy means a separate part of the economy, the one in which (technological) knowledge is created. It comprises advanced activities in science, technology and innovation. It is the top section of the economy with its central actors in the name of corporate research institutions and universities. This perspective is the dominant one in policy circles closely associated with the European Union and the Organisation for Economic Co-operation and Development (OECD). It entails that

government strategies to enhance the knowledge economy seek to increase R&D spending, facilitate patenting and promote technological ideas. The reasoning behind these strategies is that Western Europe will inevitably continue to lose activities to emerging countries in other parts of the world. Therefore Europe's economy should put the emphasis on high level innovative activities. The second perspective is that, the knowledge economy is the one in which knowledge is becoming the more dominant factor throughout the economy. In this respect Powell and Snellman (2004:201) define knowledge economy as:

> [P]roduction and services based on knowledge-intensive activities that contribute to an accelerated pace of technological and scientific advance as well as equally rapid obsolescence. The key components of a knowledge economy include a greater reliance on intellectual capabilities than on physical inputs or natural resources, combined with efforts to integrate improvements in every stage of the production process, from R&D lab to factory floor to the interface with customers.

This second perspective differs essentially from the first because it retains that "not only is the production of new scientific or technological knowledge regarded as a driver of growth, but so is the use and valorisation of knowledge in economic processes and acquisition of skills" (Winden et al, 2007:528).

The emphasis put on the role of knowledge in the economy parallels a transformation in the way scientific knowledge is produced. According to Nowotny *et al* (2003:181-183), it is generally accepted that this transformation can be witnessed through three significant trends among others, (a) the "steering" of research priorities, (b) the commercialisation of research, and (c) the accountability of science. The aforementioned trends inform the argument presented in *The New Production of Knowledge*, a book published in 1994 and authored by Michael Gibbons, Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Scott and Martin Trow. According to Shinn (2002:600), these authors argue that the contemporary function and organisation of scientific

knowledge and technical practices, in industry, education and society at large lies in considerable contrast with relationships in earlier times. A distinction between two modes of knowledge production is to be perceived throughout this argument, "Mode I" and "Mode II". "Mode I" is cognate with a separation between academia and society or no interaction between academia and industry. In this mode of knowledge production, "academia revolves around an autonomous university, self-defined and self-sustained along with scientific disciplines and specialities, and the determination by scientific peers of what does and does not constitute science and truth." "Mode II" emerges out of a "context of application by the so called "transdisciplinary collaborations". This mode of knowledge production "perceives the weakening or collapse of the modern university, the disappearance of scientific disciplines and atrophy of peer control over the direction and content of research programmes". In "Mode II", science is depicted as having the characteristic of trans-disciplinarity, by fluent circulation of short-term, 'task-force' teams of experts to problem domains, and by the emphasis of social and economic problems in forming what spheres of knowledge should be enhanced. Nevertheless "Mode II" supplements rather than replaces "Mode I".

Furthermore Hessels and Lente (2008:755) reports seven objections in the literature raised by the claims of Mode II. Firstly, the lack of empirical evidence for the significance of the attributes of Mode II. Secondly, the incorrect long term historical perspective viewing Mode I as the original type of knowledge production. Thirdly, the universality of the claim is not justified. Fourthly, the coherence of the concept is problematic because several multi-disciplinary researches do not show organisational diversity or quality control. Fifthly, a lack of theoretical roots and reference to sociological theory, the proponents of Mode II support the observed trends. Finally, the book presenting Mode II lacks a proper future outlook. Similarly, reflecting on the debate that flourished after the release of *The New Production of Knowledge*, Nowotny *et al* (2003:189) recapitulates several positions criticising the argument presented in the book.

> To some, it amounted to little more than the legitimization of malignant trends- in particular, the subordination of research to market and political agendas on the mistaken assumption that scientific breakthroughs could be predicted and therefore planned. To others, the argument was not underpinned by adequate evidence; critics argued that the characteristics of knowledge production summed up by the "Mode 2" label were neither as significant nor as novel as we had suggested. Other critics pointed out that, although we made much of the wider social distribution of knowledge and, therefore, of the more intense engagement between science and society, no real attempt was made to discuss the dynamics of society, which were treated as an unproblematic given. Some accepted the accuracy of our account, but insisted that it described social and political epiphenomena; the core of science remained inviolate. Finally, others saw *The New Production of Knowledge* as offering a postmodern vision of research.

Re-thinking Science: Knowledge and the Public in an Age of Uncertainty, a book published in 2001 and authored by Helga Nowotny, Peter Scott and Michael Gibbons attempted to respond to the critics of *The New Production of Knowledge.* Yet the authors of this work point out that they are not merely trying to address the points raised by the critics. Rather, they seek to consider two main critiques, and engage them in order to offer a more theoretical version of the argument put forward in *The New Production of Knowledge* (Nowotny *et al,* 2003:190). In the light of the authors' views, their first book was an attempt to flesh out the dialectical relationships between science and society while their second book tried to identify the main changes taking place in society. Shinn (2002:608) shed a different light when contrasting these books:

> The 1994 book hints at a new epistemology: the latest book develops the theme and identifies it as a mainstay of Mode 2. Like the 1994 volume, the latest book is silent when it comes to giving evidence, or for suggesting directions for research. The book appears to be mainly a product of introspection and a basis for future research.

A decade after its introduction in academic literature, the notion of "Mode II" of knowledge production has been referred to in over 1000 scholarly articles and seems to have played a significant role in shaping science, technology and innovation policies (Hessels and Lente, 2008:741). Notwithstanding its influence, the "Mode II" account of knowledge production is contested and not unique. After a review of the alternative account of Modes II and criticisms, Hessels and Lente (2008:755-760) add that Modes II diagnosis of the contemporary dynamic of scientific practice contains both adequate and doubtful claims. They argue that important differences in aim and scope exist between the various assessments of the changes in science systems (Table 2). The difference in their balance between descriptive and normative content is one of them. For example, an approach such as "post-normal science" displays a clear normative inclination, others primarily limit themselves to reporting observations. Another major difference is between heterogeneous research programmes (such as Triple Helix and innovation systems) and well-defined analyses (for example New Production of Knowledge and Academic Capitalism).

Table 2. The various diagnoses put emphasis on different characteristics of knowledge production. Source: Hessel and Lente (2008)

The various diagnoses put emphasis on different characteristics of scientific knowledge production

Levels	Characteristics	NPK	Post-normal science	Triple Helix	Post-academic science	Academic Capitalism	Strategic science/research	Innovation systems	Finalisation science
Cognitive	Choice of research agenda (research content)	X	X	X	X	X	X	X	X
	Methods (teamwork, transdisciplinarity)	X	X						
	Epistemology (socially robust knowledge)	X[a]	X						
Organisational	Map of disciplines (transdisciplinarity)	X		X					
	Values/labour ethic of scientists (reflexivity)	X			X				
	Norms of quality control (extended peers)	X	X		X		X		
External relations	Interaction with other societal 'spheres' (industry, government)	X		X	X	X	X	X	X
	Incorporation of non-scientific expertise (participation)		X						

[a] NPK is unclear on this point. The follow-up book '*Re-Thinking Science*' (Nowotny et al., 2001), however, does claim that an epistemological transformation is taking place.

In reality the Triple Helix is also prominent among the diagnoses on the transformation in scientific practices. It emerges out of a study of the renewal of the Boston economy, through a university-industry-government collaboration for firm formation from academic research in the 1930s. Amir and Nugroho (2013:119) report that it is a reaction to the problem of empirical validity coined with the *New Production of Knowledge*. According to them, while the proponents of the Triple Helix suggest that " Mode II" is not new, their analysis tries to model the complex system of innovation and investigate the relations between the most significant three actors in science and technology, which are, the university, government and industry.

Furthermore Arnkil *et al* (2010:13) note that the Triple Helix has slightly changed through three developmental phases. In the Triple Helix 1, they note that the three helixes are defined institutionally. In regard to the Triple Helix II the emphasis is put on the communication within the system and to a variety of knowledge systems. Finally, they report that in the triple helix III the focus is on the hybrid organisations of academic, government and industry. Despite the evolution of the Triple Helix, Shinn (2002:609) points out that "the novelty of the Triple Helix metaphor discreetly recedes. The disturbing dislocations of the Triple Helix are being supplanted by evolutionary, transitional and incremental adjustments within academia!" (see Viale and Pozzali, 2010). Accordingly, Amir and Nugroho (2013:121) still find a gap in this approach which they summarise in two points. First, the Triple Helix model does not address enough the questions of locality in which the model is applied, particularly in instances when research results are scaled up and commercialised. Second, in the light of an account of the classical sociological perspective[13] of social forces in society, it is rather

13 In the context of South Africa, Cooper (2011) engages with this remark by highlighting the changing structure of research organisations, the significance of the developmental mission of a university and the participation of civil society in the production of scientific knowledge

unfortunate that the Triple Helix model does not include the role of the citizen or third sector as their role in system innovation is more than just being intermediaries. In contrast, for instance, the individualised and secret aspects of "indigenous knowledge" is at the heart of debates over intellectual property (Wright, 2005:904). In fact, debates over "indigenous knowledge" are often tied to its potential for commercial appropriation and application even though the 'citizen' or the 'third sector' is often treated lightly in a Triple Helix model (Bryan, 2009:30).

Moreover Gertler (2003:76) insists that the production, acquisition, absorption, reproduction, and dissemination of knowledge is seen by many as the fundamental feature of contemporary competitive dynamics. For Olssen and Peters (2005:330), the most significant material change that characterises neoliberalism[14] in the twenty-first century is the rise of the significance of knowledge as capital. Yet, when it is apprehended as a capital, the meaning and actuality of knowledge leads to confusion in the application of economic theory because it is the only resource which increases with use rather than diminishing (Clarke, 2001:190; Adler, 2001:216).

3.4. Significance of social-ecological research in knowledge economy

After a worrisome portrayal of the ways in upon which the Earth is being degraded and its resources depleted by current economic practices, Moberg and Simonsen (2014: 9) argue that "we are the first generation with the knowledge of how our activities influence the whole Earth Systems". If continuing business

14According to Olssen and Peters (2005:314) "neoliberalism" refers to "a politically imposed discourse, which is to say that constitutes the hegemonic discourses of Western nation states".

as usual seems not sustainable as they suggest, they also point out that "[I]t is a fascinating paradox that the same innovative capacity that has put us in the current environmental predicament is actually what can be used to push us out of it (Moberg and Simonsen, 2014 : 13)." In relation to this, Aditya *et al* (2010:4) notice an increasing popularity of the term "resilience" within policies, programming and thinking around climate change adaptation and disaster risk reduction. According to these authors the popularity of this term within development, climate change and disaster communities is possibly connected to its semantic ability to represent a readily identifiable concept. Indeed, such a use of the term resilience resonates with the concept and practice of adaptive management[15] developed by C.S. Holling "in response to his own frustrations as scientist and frequent participant in interdisciplinary environmental impact assessment (EIA) teams in the 1970s initially focused in Canada (Karkkainen, 2005:59)." But a genealogy of this term, or its place in the body of work of Holling, is often referred to his contribution to ecology's literature published in 1973 under the title, "Resilience and stability of ecosystems".

In 1971, two years before engaging the concept of resilience in his 1973 paper, C.S Holling and M. A. Goldberg co-authored a paper which intended to demonstrate some "remarkable similarities" between the characteristics of ecologies and cities. In so doing, they tried to demonstrate the ways in which

15 Karkkainen (2005:70) observed that: "A common theme in the scientific literature on adaptive management is the distinction between its "passive" and "active" forms. Carl Walters, a noted fisheries biologist, adaptive management theorist and practitioner, and frequent collaborator with Buzz Holling, defines "active" adaptive management as "deliberate probing for information" through a multistep process involving integrative ecological modelling, conscious generation of testable scientific hypotheses, and field experimentation through carefully tailored management interventions designed to test specific hypotheses. "Active" adaptive management is, then as much about harnessing management interventions in the pursuit of science as it is about harnessing advancing knowledge in the interest of sound management".

cities function as "interdependent systems as well as their dependence on a succession of historical events along with their spatial linkages and their non-linear structures" (Wilkinson, 2011:159). Using city and ecosystems, the paper attempted to prove that society and nature are interwoven. In this regard this early study of C.S Holling's and his colleague already positioned him at the start of the growing dialogue between war, economy and nature, which has helped to produce the contemporary socio-ecological understanding of life since the wake of World War II. In this effect, Duffield (2011:11) remarks that:

> Techniques of imaginative enactment pioneered in civil defence and importantly, expertise gained through gaming the survivability of nuclear attack not only vectored into an all hazard emergency capacity, they overlapped with the discoveries of complexity, emergence and resilience within nature (Holling 1973). In the performative gaming of surviving nuclear attack, the origins of resilience as an approach to future uncertainty can be traced in the mobilisation for war. In the co-evolution of science and society (Rose, 2010), resilience first emerges as a politico-economic calculus for surviving the probabilities of societal extinction which, itself, is grounded and made expansive in the observable characteristics of predator/prey behavior in the natural world.

In fact, Gunderson *et al* (2002:530), argue that resilience has been defined in two different manners in the ecological literature. One meaning puts the emphasis on efficiency, constancy and predictability as seen in the attributes of engineers' desire for fail-safe design. The other meaning refers to persistence, change and unpredictability. These attributes are embraced and celebrated by evolutionary biologists and by those who search for fail-safe design. The first meaning is often termed "engineering resilience", and it is referred as "the ability to return to a stable steady state following a perturbation". The second meaning insists on "the conditions far from any stable steady state, where instabilities can flip a system

into another regime of behaviors". But Walker (2010) acknowledges that ecologists have come to the realisation that understanding just the resilience of ecosystems is not enough to contribute solutions to the problem of resources and sustainability. For that reason, he connects both social and ecological systems in a definition of resilience encompassing: "the capacity of a system to absorb disturbance and to reorganise while undergoing change so as to still retain essentially the same function, structure, feedbacks and therefore identity" (Walker, 2010: i).

"Resilience" has evolved into an approach, a way of thinking, a perspective that guides and organises thoughts for the analysis of social-ecological systems (Folke, 2006:260). In summary, resilience thinking focuses on social-ecological systems (SES) at three levels: resilience as persistence, adaptability and transformability. Adaptability viewed as part of resilience refers to "the capacity of SES to adjust its responses to changing external drivers and internal processes and thereby allows for development within the current stability domains, along the current trajectory" (Folke *et al,* 2010:6). Transformability in resilience thinking is understood as "the capacity to create new stability domains for development, a new stability landscape, and cross thresholds into a new development trajectory" (Folke *et al,* 2010:6). Nonetheless Stokols *et al* (2013:2) argue that an important challenge facing analyses of resilience alongside of sustainability as dynamic features of social-ecological systems lies the fact that these constructs are sometimes construed so widely and generically that they end up distorting meaning. Similarly, Turner (2013:4) writes:

> For resilience thinkers, the organizational scale of inquiry is the system. Unless captured in a system's structure, differences among entities that constitute a system are of less concern. As a result, resilience adherents, when reaching out to the social sciences to study socio-ecological systems, are attracted to approaches such as ecological economics and rational choice theory. These provide clear

> testable rules of factors governing human behavior, and do not wallow in the complex webs of interest, power, and the multiplicities of social identity that concern political ecologists and other social scientists. Analogies between ecological dynamics and the dynamic of financial and commodity markets are commonly invoked with social science lessons coming from welfare economics, collective actions, social capital, and organizational theory (Scheffer et al., 2002).

Furthermore, measuring the resilience of ecosystems or social-ecological systems requires an important amount of knowledge of the system in question and it is unlikely that scientists have all the necessary instruments (Holling, 1973:20). Notwithstanding those limitations of resilience thinking, for Wilkinson (2011:149) the most significant contribution of social-ecological resilience for planning is to be found in "its role as a different and useful frame for both problem-setting and problem-solving." According to Hornborg (2013:119), several steps need to be taken in order to discuss the resilience of a "social-ecological system." This means that it would be necessary to define its geographical boundaries, its physical constitution (such as population, resource, metabolism, etc), its social, cultural organisation, the relevant physical and social parameters and their acceptable ranges of variability, the vulnerability of these parameters to disturbance, and so on. But he insists that in spite of the voluminous rhetoric on resilience of social-ecological systems, he is not aware of any case study in which all these aspects have been competently treated. Thus, for Mackinnon and Derickson (2012:261), the thinking behind resilience is epitomised by a certain scalar imprecision, treating different scale such as cities, region and local communities similarly as the platform for fostering local adaptation in the face of global threats. They insist that the question whether the spatial unit in question can be usefully or accurately understood as a self –organising entity modeled after an ecosystem is not properly addressed. In fact according to them, viewing

cities and regions as self-organising units is a misplaced assumption that serves to divorce cities from wider processes of capital accumulation and state regulation. These wider processes of accumulation become more apparent when Slater (2014:2) observes that:

> It is not a new development that scholarly priorities are regrettably shaped by policy priorities (and by strategies of big business and worries of mainstream media) and therefore it is no coincidence that an entire cottage industry on "resilient cities" has emerged at a time of global austerity (needless and wicked political and corporate assault on the poor that needs to be captured as a crisis per se, rather than as response to an economic crisis). The insidious work of urban resilience lies in the obvious and, austerity [environment catastrophe] and everything will be fine in the end.

While sharing the above perspective on "urban resilience" research, Hendrik Ernston (2014, 1-3) from the African Centre for Cities at the University of Cape Town, nevertheless praises resilience theory for the work done in connecting society and ecology. In this regard he points out that:

> Indeed, those who have followed my writing know that I have used resilience theory as an analytical perspective before, or rather social-ecological systems theory, but that I have moved far away from it...Tom Slater's piece brings up some of the reasons for my shift as it foregrounds how socio-ecological analytical perspective (heavily reliant on systems theory) has transformed into a normative language of policy about almost anything...Thus, Tom Slater is doing the right thing-he helps us to focus on where the intellectual battle lies now. He is critiquing, and rightfully so, a quite sinister maturation of "resilience thinking" that has travelled from (and with) the hands of ecologists (and the study of shallow lakes in Canada), over ecological economist workshops in the archipelago of Stockholm, mixed with Santa Fe style complex adaptive systems theory, to

> become a well-polished research/policy language that asks for resilience, while keeping intact the relations of power (in the city).

As a result, Folke *et al* (2010:2) acknowledge that to understand the dynamics of interrelated social-ecological systems other concepts are needed. But Davoudi and Porter (2012:329) recall that:

> Being open to new concepts has engendered planners' attention to innovation and their predilection for challenging the status quo. However, it has also given rise to uncritical acceptance of terms and concepts that are often unhinged from their philosophical or disciplinary lineages and used in slippery ways in both policy-speak and theory-invention.

Nevertheless the concept of space itself becomes of a particular interest in discussions around the resilience concept for a couple of reasons. First, because space is actively constructed through the practices and associations made through our own research as well as the research of the scientists we seek to study (Greenhough, 2005:234). But, also for its specific significance in the manner in which Davoudi (2012:304) conceives the notion of resilience in planning (evolutionary resilience[16]):

> Evolutionary resilience promotes the understanding of places not as units of analysis or neutral containers, but as complex, interconnected socio-spatial systems with extensive and unpredictable feedback processes which operate at multiple scales and timeframes. This resonates strongly with the relational understanding of spatiality which, according to Massey, is defined by "simultaneity of multiple trajectories" (Massey, 2005, p. 61).

I return to each of the above points broadly in chapter 4 and more specifically in chapter V. Meanwhile what stands as a challenge for social and ecological

16 This form of resilience resists the idea of equilibrium and holds for a fact that the very nature of a system may change over time with or without an external disturbance.

systems to be effective is to build knowledge, incentives, and learning capabilities into institutions and organisations that can manage local, regional and global ecosystems (Folke, 2006:262). This "new" knowledge, incentives and learning capabilities, as in Ernstson *et al's* traditions (2010:539), should respond to the necessity to nurture an overall cultural criticism of policies and knowledge production that disconnect nature from society. The later works of Hollings and his colleagues on *Panarchy* (2002) is particularly relevant on this matter because as Ruhl (2012:31) notes:

> The central thesis of *Panarchy* is that policy responses to declines in environmental quality and the growing scale of human activities have often been "flawed because the theories of change underlying them are inadequate," and that as a result, "the ultimate pathology of...traditional resources exploitation and management...is to create less resilient ecosystems, more rigid institutions, deeper social dependencies" (Gunderson and Holling 2002: xxi-xxii). Improving theories of change in natural and social systems to improve design of policy responses is thus one of the motivating forces of the book.

However Ebbesson (2010:421) argues that an analysis of legal structures, concepts and institutions is different from an analysis of social and ecological facts. In other words it is not possible to deduce a factual situation from a legal framework; whether the focus is on how institutions function or how ecological systems respond. For this author, "normative texts and structures cannot be taken as a pretext that the practice and human conduct 'is' or as it 'ought to be'. Still legal structures and concepts significantly affect the works of institutions in practice, also with respect to managing common resources (Ebbesson, 2014:421)". But for Holling (2012:37), in a system's anticipating transformation (in a flip from one state to another as he puts it) law is of little help. But Ruhl (2012:32) is of the view that:

> In short, no new theory of how to do things in environmental and natural resources management, particularly one that challenges entrenched ways of doing things and interests aligned around them, is likely to gain traction in practice if it cannot gain traction in the form of endorsement and implementation through specific laws and regulation.

Based on a close reading of 74 published items (not an exhaustive literature review) authored by legal scholars engaging with resilience theory, Humby (2014:128-129) finds that the focus of their interdisciplinary works has been on the United States of America and they did not put any attention on "urban resilience". Still, the ways in which the resilience idea evolved over the years and across spaces since Holling's publication of "Resilience and Stability of Ecosystems" in 1973 and the attempts to endorse it or simply co-opt it, surface some entry points able to enhance our understanding on how legal structures, concepts and institutions constrain or enable actions both internationally and locally.

Conclusion

The dynamic of knowledge production is in many instances due to both the formation of new ideas from interactions within local ecosystems, and the local/global linkages between creative processes and creative actors (Bathelt and Cohendet, 2014:870). This chapter is not intending to capture this entire dynamic or mirror it in a comprehensive way because it is virtually impossible to manage such a task within the scope of this thesis. Instead, it attempts to bring together in three sections the threads upon which the main argument of this thesis will unfold gradually, chapter after chapter in the light of the salience of the case-in-point presented in the final section. In this regard, the first section is concerned with how knowledge is produced and constituted and some implications of this across societies and locales. The second section tries to explicit some economic

and political stakes resting upon the categorisation of knowledge as scientific or otherwise. The third section looks back at how knowledge is produced and constituted in relation to the ways in which both scientific and other forms of knowledge are behaving more and more like assets in competitive dynamics. Since knowledge can also be understood in relation to the manner in which it creates spaces and conditions of material experience as understood by Wright (2005: 917), the work of C.S. Holling on resilience theory is finally brought into perspective in the light of the prominence gained by social-ecological research in addressing some of the challenges facing knowledge economies. Moreover the construction of knowledge as spatialised narratives of human actions, and artefacts as material form of those spatialised narratives, suggests the existence of links between space, knowledge, human and artefacts (see Turnbull, 2002). The positions of those links are not all static or always dynamic. So, from a diachronic perspective, the relationships they entail are not necessarily pre-determinate or open to (re)negotiations. Knowledge, space, human and artefact can contain one another without losing their elemental specificity in the web of their interactions. For the following chapters, the multiplicity of configurations that is possible to originate out of these kinds of interactions are salient as well as the specific combinations they take when focusing on a case-in-point such as the "discovery" of resilience by C. S. Holling and its circulation across spaces.

4. Space in the construction of knowledge

Introduction

The relationship between knowledge and space is intricate. For the sake of analytical clarity, the previous chapter dealt with how knowledge comes into being and the importance of social-ecological research. That task was accomplished by assembling a number of threads deriving from the literature on knowledge production. It was, as explained, not a comprehensive review of the vast literature on knowledge production but rather a selective account of specific dimensions of knowledge production to help frame the investigations in this thesis. The previous chapter did not explicitly address the spatiality of knowledge production. Rather it introduced the theme only in relation to the critique of the universality of scientific knowledge. Here, I intend to focus explicitly on space as an enabler of knowledge formation, and on knowledge as a spatialised narrative. As a result, this chapter questions what constitutes space and what bearing it might have on the knowledge emerging from it.

"Space" is not an invariant term and its references are often materially heterogeneous. The idea of difference remains at the heart of the very notion of "space": "that is, a set of distinct and coexisting positions which are exterior to one another and which are defined in relation to one another through relations of proximity, vicinity, or distance, as well as through order relations, such as above, below, and between..." (Bourdieu, 1996:11). As a key word, Harvey (2006:12) argues that "space" often elicits modifications, complications and sometimes emerges from the modifications rather than from any complexity of its notional aspect. That is to say that: " When, for example we write of 'material', 'metaphorical ', 'liminal', 'social' or 'psychic' space (just to take few examples) we indicate a variety of contexts that so inflect matters as to render the meaning of space contingent upon the context."

Up until now, I have been using a set of texts to reflect on knowledge and space. But any search for space in literary texts poses the problem of "finding it everywhere and in every guise" (Lefebvre, 1991:15). In this respect, while recalling that the knowledge underlying people's mental representations of space come from heterogeneous sources namely from looking, from hearing, from touching, from imagining, and from language, Tversky (2003), insists that the mental representations people form from their interactions with their environment differs from the external representations of space, of geometry, physics or maps. For geometry, physics and cartography, space is absolute; it is typically metric, uniform and unitary. Thus things can then be measured and located in space. Tversky insists that in the embodied conceptions of space, the things in space are fundamental, and the qualitative spatial relations among them with respect to a reference frame constitute scaffolding for mental spaces. Lefebvre (2009:196-204) note that such a qualitative aspect of space is one of its main paradoxes. This is because space seems to be "the milieu par excellence of quantification that is the most efficient instrument of quantification, while in reality and the truth it conveys (practical) qualities, places, sites, and situations, 'topias' and the relations between these elements".

Furthermore, regardless of the fact that they are located somewhere between models originating from the scientific disciplines and everyday life and language, spatial metaphors seem to supplant constructs and metaphors closely associated with positivistic and systemic theoretical trends now out of fashion (Silber, 1995:348). They also pinpoint the current distrust of any kind of encompassing, totalistic image or paradigm. In the subsequent parts of this chapter, some of these positivistic and systemic theoretical trends are revisited and their bearings on the view that there is potency in the physical environment to exert cognitive influence over human beings are examined. In doing so, the first section situates

the historical approach that this thesis adopted through an engagement with space along the question of non-human agency which is a central concern for the "new materialism" as shown in Chapter 2. The second section insists on the origin and meaning of environmental determinism by way of trying to shed a light on the influence it has on geographical imagination and clarify an aspect of the argument of this thesis claiming that non-humans agency participate in the production of knowledge.

4.1. Human and non-human agencies in relation to space

During the 1900s, the advent of modernity in Europe was seen in material terms as a form of knowledge and capacity to transform nature[17] for the sake of progress[18] (Hobsbawm, 1987). On the one hand, "nature" provided the "raw material" from which different spaces were produced (see Lefebvre, 1991: 84). On the other hand, according to Hobsbawm (1987:26), "progress was measured by the ever rising curve of whatever could be measured, or what men choose to measure." In this context modernity was understood as an experience capturing a myriad of sensibilities which reflected the specific and changing meanings of three basic features of human existence namely, 'space', 'time' and 'being' (Soja, 1989:25). Moreover, the twentieth century was characterised by a transition from ontological to symbolical interpretations of mathematical entities. This transition entailed the creation of new units of analysis, while the real computation was still done in terms of numbers (Feldhay, 2000:55). The skills in

17 David Demeritt (2002) provides some interesting clarifications on the social construction of nature and its physical underpinnings. I elaborated on this point in chapter 2.

abstract thinking gained from this transition, while found in non-numerical ordered societies in forms of games or music, remained largely associated with an unequal distribution of the general use of writing and formal schooling, a byproduct of the mass education of the twentieth century and European domination of the rest of the world (Crump, 1990:4-8; Hosbawm, 1987:22). Nowadays similar skills are a required for computerised ways of engaging with existing spaces and creating or discovering new spaces.

Whilst Tuan (1971:184) observes that "all people" display the tendency to organise the world around themselves, this thesis articulates its perspective mostly out of the existing works in western academic research. I do recognise however parallel development in conceptual organisation – for example, in Confucian China. In this respect, Couclelis (1999: 30) traces the roots of the systematic thinking about space in four traditional disciplines namely mathematics, physics, philosophy, and geography. These disciplines bring forth respectively, the formal, theoretical, conceptual and empirical perspectives on the subject. Each of these includes many different fields and views. For instance, mathematics is said to comprise geometry, topology, and trigonometry; philosophy encompasses epistemology and the philosophy of science; theoretical physics includes classical and relativistic mechanics and quantum theory; and geography is subdivided into human and physical. All these fields and some others have contributed to the development of their own perspectives on space and time. However a plurality of overlaps among these four disciplines and the distinct fields and subfields within them have opened a terrain to additional insights and ways of thinking as illustrated by Couclelis in Figure 1 below.

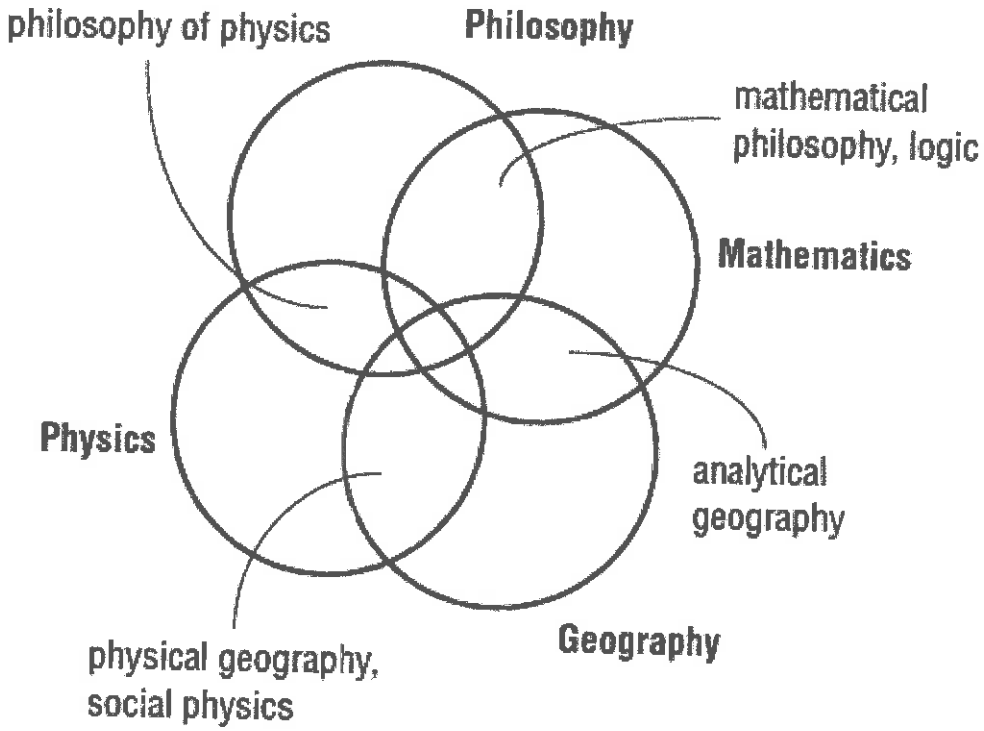


Figure 1. Historical roots of spatio-temporal perspectives. Source: Couclelis (1999).

In effect, the geographical way of looking at the world is the oldest of the four disciplines in which systematic thinking about space finds its origins. It became part of the spatiality paradigm of 20th century scientific approaches to the question of society and space (Urry, 1995). These approaches held in common that space is the by-product of social processes[19]; as a result it has no existence independent of human agency. This spatiality paradigm correlates with the fact

19 It is important to note that the meaning of the word "social" is not given. The use of the word "social" by different authors in relation to space may suggest a form of unity (paradigm) among them, when in practice, they may enact different versions of the "social". In *Reassembling the Social*, Bruno Latour is concerned with similar problematics. Its approach seeks to track "the social not as a special domain, a specific realm, or a particular sort of thing, but only as a very peculiar movement of re-association and reassembling" (Oppenheim, 2007:474).

that space as a concept was overshadowed by "time" in critical social theory. In relation to that, Soja (1989:34-35) argues that the instrumentality of space was increasingly lost from political and practical discourses. It is noted that during the late twentieth century, the politics and ideology entangled in the social construction of human geographies and the crucially important role the manipulation of these geographies played in the late nineteenth-century restructuring and early twentieth-century expansion of capitalism seemed to be rendered invisible or mystified by the spectra of the socio-political sphere. Along this line of thought, Hakli (2001:410) reflects:

> [I]t seems that a lot of useful research exists on the relationship between social science discourse and the states' agency and projects. Yet, neither the early sociology of knowledge nor the more recent studies of social sciences have given the role of territoriality in social knowledge production the attention one might expect. Reasons for the latter are hard to pin down, but echoing Soja's (1989) notion of the subordination of space in social sciences, Agnew (1993:251-252) has pointed out the failure within mainstream social science research to deal with space and spatiality in anything but national or structural terms. Both national and structural accounts of space are hidden geographies in the sense that they are usually not the result of conscious reflection on how space and society are related, and thus, how society is spatially constituted (Simonsen, 1996: 494). Taylor (1996) comes to the same conclusion, but in terms of inert treatment of space as a platform within mainstream social science research that has taken state territoriality as the given spatiality of society (see also Wallerstein *et al,* 1996).

Alongside the above historical developments, the significance of "academic geography" in scientific practices decreased over the years (Naylor, 2005).

However, for many geographers during the imperial era, including those who were shaping a distinctively American geographical tradition such as Ellsworth

Huntington and Ellen Churchill Semple, Heffernan (2008) notes that the dominance that certain peoples exerted over others was regarded as being either divinely preordained or the by-products of environmentally conditioned racial characteristics. Such views had implications for the ways in which the relationships between knowledge and space in scientific practices were articulated in the early phases of modernity. In fact Heffernan (2008:12) notes that the early representatives of "academic geography" notably Mackinder at Oxford and Friedrich Ratzel in Leipzig had the twin tasks of explaining the human and natural features of the world as well as justifying the existence of European empires.

Stemming from Enlightenment ideas about the environmentally determined nature of different peoples, "environmental determinism" seemed to emerge as the base upon which early twentieth century geographers built a scientific foundation for theories by which it was possible to understand how people lived and acted in a changing world (Frenkel, 1992). In other words, through the prism of "environmental determinism", linkages of climatic conditions and other aspects of the physical environment to virtually everything, from culture, regional character, and political organisation to the rise of civilisation were established. Some of the claims put forward by this approach such as northern Europeans being "energetic, provident, serious, thoughtful rather than emotional, cautious rather than impulsive", or the capacity to predict the destiny of any society or economy by mapping isotherms and humidity, assumed scientific authority up until the mid-1920s in academic circles (Frenkel, 1992:144). However Powell (2014:2) suggests that the general input of "environmental determinism" is still seductive and it is constantly re-packaged across a number of fields of inquiry, albeit it is more prevalent now in paleoanthropology and some forms of environmental history. For example, Driver (2004:3) recalls that in the course of the last 50 years, the discourse on

'tropicality' has been spread widely under the influence of decolonisation, development, global tourism and commodity advertising and environmental politics. In fact this discourse, he notes, is drawn from images of the "tropics" which have long been the site for European fantasies, projects of cultural imperialism, and the politics of human and environmental salvage. In the post-colonial world, these fantasies have, if anything turned out to be more pervasive, if distinctly less enchanting.

Robinson (2003:275) notes that the universalism of many theoretical claims within the discipline of geography often developed in ignorance of a variety of social contexts to which they are supposed to apply, is the hallmark of much "Western geographical writings". This insidious trend is not about to end as many of the textbooks introducing students to the basic concepts of human geography or to its sub-fields, still convey the impression that the only experiences that are a matter of concern are those had by the six per cent of the world's population who happen to live in white and English language dominated societies (Bonnett, 2003:55). This is not to overlook the fact that many localised, taken for granted, material sites in which geographical knowledge has been previously constituted are still unexamined and the impact that they might have on the resulting knowledge is not clear yet (Lorimer, 2003:201).

Daniels (2010:1983) distinguishes within some main strands of work on geographical imagination, three types of positioning that need further attention: firstly, the place of imagination in fields of inquiry; secondly, the historical-geographical imagination; and thirdly, the physical sites and spaces where the geographical imagination is produced and disseminated. These standpoints equate respectively to the 'conceptual', 'topical', and 'material'; and correspond to a move from abstract to concrete in Daniels' review. Accordingly there is neither a single unified discipline of geography today nor a single history of "geography" (Heffernan, 2008:3). In fact Barnett (1995:417) notes that:

> The historiography of geography has become a vibrant and significant field in ways in which it has not been before. But perhaps we need the history of geography not because of the unquestionable requirement to understand geography's past as it necessarily still bears on the present situation but because that past can easily be made to serve as a convenient arena in which we get to practice with different sorts of difficult theory. This is quite evident if one observes which bits of geography are being favored by new contextual and critical histories of geography-there is an overwhelming, although not exclusive, fascination with geography's historical involvements with empire.

Also, part of the story of the submergence of space in early twentieth century social theory is often related to the explicit theoretical rejection of environmental causality and all physical or external explanations of social processes and the formation of human consciousness (Soja, 1989). For example Hillier (2008:223) argues that for some authors like Edward Soja among others, the refusal to attribute any agency to the physical space independent to social processes goes hand in hand with their rejection of the "quantitative revolution" of the 1960s meaning the quantification of spatial patterns as part of the move towards a universal scientific geography based on mathematical foundations. Nevertheless some studies suggest that this type of position should be examined again (Livingstone, 2003; Harvey, 2010; Kitchin and Blades, 2002). Without suggesting a return to environmental determinism, they do suggest a reconsideration of the agency of space, including the physical dimensions of space. These writers offer a non-deterministic view of the agency of space which can help to understand further the significance of space in knowledge production.

Furthermore, Gieryn (2002:113) recalls that:

> All scientific knowledge claims have a provenance: they originate at some place, and come from there. However, as they become truth,

> these claims shed the contingent circumstances of their making, and so become transcendent (presumably true everywhere, supposedly from nowhere in particular). Turning the argument around: scientific claims are diminished in their credibility as they are situated somewhere, as if their truthfulness depended upon conditions located only there.

But according to Tuin and Dolphijn (2010:159), "[T]he strength of new materialism is precisely to be found in its ability to show that agential, or the *non-innocent* nature of all matter, seems to have escaped both modernist (positivist) and postmodernist humanist epistemologies (Roberts, 2012:2513). Below, Schultze and Boland (2000:1980) trace the origin of this problem in relation to the modernist view and Gieryn's statement above:

> Modernity, beginning with Enlightenment and industrialization, breaks away from the locality, tradition and cyclical time associated with place (Sack, 1992). It fosters a time-space configuration of space (Casey, 1993), an abstraction that divorces space from time through the "lifting" of social life above the here and now (Giddens, 1991), and the dissolution of ties that hold local practices in their place. Giddens (1990) refers to this as "time-space distanciation", which results in the homogenization of the social world.

While Gieryn (2002) and Tuin and Dolphijn (2010) have made clear arguments around the apparent disappearance of space in universalised knowledge, and yet its persisting hidden power, Lefebvre (2009) offers another, more complex, argument. For Lefebvre, space itself is actively produced and so knowledge about space is implicated in the actual creation of space. Space is not the container within which knowledge is produced but the construction of space and the construction of knowledge are co-implicated. In effect, according to Lefebvre the passage from the production in space to production of space happened because of the growth of productive forces themselves and because of the direct intervention of knowledge in material production. He adds that this knowledge

eventually becomes knowledge about space and information on the totality of space. Beauregard (2015:59-60) adds in relation to work on planning that "[R]ecognised by planning theorists, the material world is then relegated to being merely a context for or a consequence of social action. Space and things passively await manipulation. In rational model approaches to practice, that world is relevant only because it is the object of planning expertise (Black, 1990)." Beauregard's view echoes that of Lefebvre. Space is not only the context but is actively produced by human action *at the same time* that knowledge about space is being constructed. The production of space and the production of knowledge can therefore hardly be separated although, empirically, it is difficult to show how the two relate as process of interaction are diffuse, multiple, implicit and largely hidden.

4.2. Non-determinacy in the influence of space over humans

The physical space displays cognitive attributes (4.2.1) able to influence human activities (4.2.2).

4.2.1. Cognition and proximity

The one way in which space impacts on knowledge creation is through the processes in which relations and networks of proximity impact on cognition. Much of this literature has to do with the construction of knowledge through the proximities established between actors in government, the private sector and academia (e.g. the now well-known Triple Helix model). Drawn from the work of the French School of Proximity Dynamics, Boschma (2005:63) disentangle five dimensions of proximity, i.e. 'cognitive', 'organisational', 'social', 'institutional' and 'geographical'. Purely for analytical reasons cognitive proximity is separated from organisational proximity. Whereas organisational proximity refers to the

extent to which relations are shared in an organisational apparatus, either between or within organisations; cognitive proximity facilitates the communication between economic actors which are subject to bounded rationality (although too much cognitive proximity may actually be an obstacle to learning and innovation). Social proximity is defined in relations to socially embedded relations-relations involving trust based on friendship, kinship and experience- between agents, while institutional proximity originated with the institutional framework at the macro-level. Geographical proximity refers to the spatial or physical distance between economic actors both in absolute and relative terms. On this final point, Rychen and Zimmermann (2008:773) report that as much as local relationships are essential for the knowledge economy, permanent geographical proximity is not the most unique way to achieve them. Temporary proximity is an alternative. In this respect, Torre (2008:870) adds that the need for geographical proximity has neither died nor become negligible. In fact in Torre's view, it now impacts mostly on certain stages of the process of production, research or development and does not necessarily require the co-location of the actors involved in this interactive process.

While insisting that non-economic actors have been often neglected by most of the traditional approaches in the literature on the localised character of knowledge production, Cohendet *et al* (2014:933) argue that the complex dynamics explaining how these agents' deviant ideas eventually turn out to be radical innovations and can therefore contribute to generating significant externalities both at a local and global scale have not been fully explained by the existing literature. Not much is said on the ways in which various dimensions of proximity may complement or substitute each other, and thus participate dynamically in the effervescence of the collective process of knowledge production (D'Este and Guy, 2013:541). This stems at least partly from the demography and geographical distribution of the production and use of

prominent theories on knowledge production by scholars around the world. For instance the geographic distribution of the Triple Helix audience is very broad and includes a large group from Latin America, Asia and Africa. By contrast the "Mode II" is concentrated in Western Europe, the United States and Canada. Based on the institutional affiliations of citing authors, over 90 per cent of the audience of the "Mode II" is concentrated in Western Europe, the United States and Canada, as against about 65 per cent of the Triple Helix (The latter count is based on participation in conferences) (Shinn, 2002:603). As a result both the geographic distribution of the "Mode II" and the Triple Helix, reinforce at least partly, the relevancy of knowledge-based theory of spatial clustering and disseminate its narrow understanding of proximity. Such an understanding of proximity surfaces in the following outline:

> Innovation, knowledge creation and learning are best understood if seen as a result of interactive processes where actors possessing different types of knowledge and competencies come together and exchange information with the aim to solve-technical, organizational, commercial or intellectual problems. Such exchange and interactions can be organized in different ways. The main argument regarding the spatial aspects of this has been that –on the one hand- the more codified the knowledge involved, the less space-sensitive should these processes tend to be. If- on the other hand – the knowledge involved is diffuse and tacit, the argument is that such interaction and exchange is dependent on spatial proximity between the actors involved. Only by being in the same local environment, and by meeting repeatedly in person, can and will such more subtle forms of information be exchanged (Bathelt *et al,* 2004:32).

In reality economists have studied and identified four kinds of institutions where new knowledge and technique is produced, non-profit institutions like universities and government agencies, firms, individual inventors and "collective invention" (Allen, 1983; Cowan and Jonard, 2003). In spite of the diversification

of actors in the production of knowledge, the results of an analysis of the components of the knowledge systems in Canada, that is between universities, industries, government laboratories and hospital, show that universities remain at the core of the system and all other actors rely heavily on their expertise (Godin and Gingras, 2000:277). Also, even though the data of this research are limited to Canada, the authors add that this trend should be similar in others countries as well. Conversely, Howells (2002:880) reports that knowledge spillover studies have confirmed that knowledge transfer is spatially constrained, yet they show little, if any, understanding of the mechanism of knowledge transfer and sharing. According to him, what is striking here is that, while many of the studies only used "codified knowledge" as measure in the knowledge spillover process, they still show a considerable distance-decay effect in knowledge transfer. That is to say that the assumption that codifying knowledge somehow frees it from its geographical limitations needs reinterpretation.

In their analysis of 1021 Research and Development (R&D) units , each distinguished by its main orientation towards either research or development work, Zedtwitz and Gassmann (2002:569-573) find that research is concentrated in only five regions worldwide while development is mostly dispersed. The regions in question are the triad regions of Europe, United States of America, Japan as well as a major centre in South Korea, Singapore and others emerging economies along the Pacific Rim. In addition this research suggests that a number of the most extreme cases of industries agglomeration are mainly caused by natural advantages (i.e. proximity to water), while a high degree of heterogeneity is noticeable among the causes that lead to spatial clustering in most remaining industries (Feldman and Kogler, 2010:385). Yet Audretsch (2004:2723) insists that the geographic account of knowledge production is limited because there is no understanding of the way in which spillovers occur and are realised at the geographical level. In his view, the pre-existing pattern of

technology related activities render it difficult to distinguish spill-overs from the correlation of variables at the geographical level. Hence Rychen and Zimmermann (2008:769) argue that spatial analysis cannot be adequately addressed if it is not directly linked with the process enabling the creation and use of "networks", where individual "ego-networks" are the outcome of individual and bilateral decisions to create ties that take into account the whole existing or expected network. It is in this manner that, David Livingstone (2003) brought back the focus on the importance of Geography for scientific inquiry in his book, *Putting Science in its Place: Geographies of Scientific Knowledge.* As such, Naylor (2005: 1) notes that: "Geography then is an intellectual pursuit that is historically and geographically situated, understood differently according to place and time. This is the argument that Livingstone applies to science more generally, the geographical discipline included". This thesis expands Livingstone's argument so as to interrogate why it is that situated knowledge differs or is maintained from place to place and from time to time. In doing so, highlights of the agency of space emerge out of the diversity of its physical dimension, and their bearings on human cognition are addressed. In contrast the bulk of examples cited above on the work done and the research that needs to be undertaken on proximity and spatial clustering are often biased in favor of human agency. Nevertheless all together, they reinforce the fact that an understanding of space through social processes is only part of human experience as it gives priority to the acknowledgement of how cognition affects how human beings perceive and remember space over how space may affect human beings cognitively (Harvey, 2010).

4.2.2. Different spaces and agencies

The literature on proximity in relation to the knowledge economy shows the significance that the environment itself might have on what is being put in the process of knowing without deciphering what its influence might be exactly

about. In *Putting Science in Its Place*, David Livingstone (2003) engages with a diversity of space and the heterogeneous influences they have on the ways in which scientific knowledge is often produced. That is to say that:

> *Putting Science in its Place* establishes the fundamental importance of geography in both the generation and consumption of scientific knowledge, using historical examples of many places where science has been practiced Livingstone first turns his attention to some of the specific sites where science has been made -the laboratory, museum, and botanical garden, to name some of the more conventional locales, but also places like the coffeehouse and cathedral, ship's deck and asylum, even the human body itself. In each case, he reveals just how the space of inquiry has conditioned the investigations carried out there. He then describes how on a regional scale, provincial cultures have shaped scientific endeavor and how, in turn, scientific practices have been instrumental in forming local identities. Widening his inquiry, Livingstone points gently to the fundamental instability of scientific meaning, based on case studies of how scientific theories have been received in different locales. Putting Science in its Place powerfully concludes by examining the remarkable mobility of science and the seemingly effortless way it moves around the globe (University of Chicago, n.d.:1).

In fact, for Livingstone (2003:4) scientific theories do not spread uniformly from their point of discovery. According to Livingstone, in the process of their circulation, they are modified and transformed. As a result, he notes that the meaning of scientific theories is not stable, rather it is mobile and varies from place to place. The examples of space that Livingstone (2003) uses to make his point have a strong inclination toward human agency. Whether it's the botanical garden or the coffeehouse, it appears that space in Livingstone's view is still heavily controlled by humans. In contrast this thesis illustrates the view that there is a significant influence that space has (whether it is a forest or a

laboratory for examples) over human cognition which escapes human control or is not reduced to human understanding. For instance there are a number of studies investigating the cognitive maps[1] of rooms, buildings, college campuses, neighborhoods, cities, amongst others. Some of these spaces (built environment) have been chosen for specific reasons, yet it is rare for researchers to justify the choice of any given space they have used (Flyvbjerg, 2006:233). In this context, Kitchin and Blades (2002:6) suggest that:

> There is certainly a great deal of research into college campuses. If researchers believe that the processes which contribute to the development of maps are common to all environments then the choice of the environment may not be of great importance, because is one related to the processing of environmental knowledge, whatever the specific components of that knowledge. However some theories of cognitive mapping conflate cognitive processes with the environment itself (for example by discussing landmark knowledge) and the type of landmark offered by one environment might be different from the type available in another environment.

In an interview with the residents of three main cities in which Lynch (1960) categorised the spatial elements as landmark, nodes, path, edge, and districts according to the roles they play in their cognitive maps, inferences are made that error in cognitive maps is frequently metrical and rarely topological (Kuipers,1978:130). This example puts the emphasis on the significance of the qualitative aspect of space over the quantitative aspect in relation to how human beings remember space and how it depicts on the canvas of their memories; versions of the idea of difference central to the very notion of space.

However geographical spaces such as maps serving as outcomes of the work of cartographers, are versions of spatiality that have become so important that it is an obligatory point of passage for many (Law, 2003). This is still relevant in the field of technology-innovation and management (TIM). For example, Beyhan and

Cetindamar (2010:112) contrast Livingstone's argument about the circulation of scientific theories with the view that geographical spaces became an obligatory point of passage for many in this manner:

> The contribution of developing countries to the international TIM literature has been growing substantially in the last decade (2).Our analysis shows that in 2007 nearly one fourth of the articles published in the ten specialised journals in TIM under study are written with the contribution of at least one author affiliated to developing country institutions. Although (1) and (2) provide evidence that the TM literature generated in developing countries differs from its counterparts generated in developed countries in terms of themes and concepts that are focused on, these studies do not present a detailed analysis of knowledge sources and intellectual pillars that developing countries studies are based on...One likely avenue for future research is the investigation of the observed convergence of theories. Our study shows that developing country researchers utilise theories created in developed countries to understand even issues specific to developing countries, however our study does not pass any judgment on reasons/mechanisms behind it.

The findings of Beyhan and Cetindamar (2010) emphasise the observation pointing out that while fieldwork is at the core of any understanding of the relationship between travel, science and the making of geographical knowledge, little attention has been paid to its history in comparison with the considerable research on geographical ideas and institutions (Driver, 1998:22).

Notwithstanding the prominence of geographical spaces as exemplars of spatiality, scholars in the field of science studies argue that there are alternative kinds of material relations and alternative kinds of space which exist alongside them (Law, 2003: 10). In relation to the stance that understandings of space, maybe influenced by experiences with spaces, material or otherwise, Mol and Law (1994:643) note that even the activity of "mapping" itself differs from place

to place. Through the use of topology in social theory, these scholars extend the possibilities of mathematics far beyond its initial Euclidean restrictions by articulating other spaces. In so doing, they argue that:

> "The social" doesn't exist as a single spatial type. Rather, it performs several kinds of space in which different "operations" take place. First, there are regions in which objects are clustered. Second, there are networks in which distance is a function of the relations between the elements and difference a matter of relational variety. These are the two topologies with which social theory is familiar. The first is old and secure, while the second, being newer, is still proud of its stability to cross boundaries. However they are other kinds of space too, and in this paper we touch one of these. Sometimes, we suggest, neither boundaries nor relations mark the difference between one place and another. Instead, sometimes boundaries come and go, allow leakage or disappear altogether, while relations transform themselves without fracture. Sometimes, then, social space behave like a fluid.

The aforementioned understanding of space as a fluid resonates alongside Henry Lefebvre's notion of "abstract space" and draws attention to the role of power in knowledge production. In fact the notion of "abstract space" roughly sheds a light on how the diversity of space is overlooked and its possible influences neglected when power tends to homogenise human understanding. That is to say that according to Lefebvre (2009:187-189), the abstract space is a product of capitalism and its derivatives. Thus, it reflects the world of business, the power of money, the *politique* of the state both at the international and national level. It depends on networks of banks, business, great centers of production, highways, airports, and information networks. It enacts the logic of homogeneity and a strategy of the repetitive. This logic of homogeneity and the strategy of the repetitive in Lefebvre's "abstract space" erodes the analytical and phenomenal boundaries which sustain the uniqueness of "place" as a distinct space (spot) in

relation to others (see Gieryn, 2000). But David Harvey notes that the collapse of many spatial boundaries does not equate to the reduction of the importance of space (Urry, 1995:23). In effect according to him, as spatial barriers diminish so does the increase in the awareness of what different places in the world actually or appear to contain. Harvey's argument is reinforced by Gieryn (2000:463) when he suggests that regardless of the fact that places seem to lose their distinctiveness, technological revolutions in transportation and communication have all but annihilated the effects once imposed by location and distance on human interaction and on the flow of goods, capital, or information. Likewise Gould (1991: 5) insists that: "No matter how the connections, structures and geometry of geographical space are altered, no matter how much geographic space is shrunk by cost, or "collapse" by time, it always forms the underlying platform, the backcloth, upon which things of the human world exist and move."

Conclusion

The argument in this chapter is twofold. On the one hand, it suggests that there is potency in the physical environment to exert cognitive influence over human beings. But it was not the ambition of this chapter to grasp either this potency or the heterogeneity of the physical space in their entirety as they could be experienced in the real world. On the other hand, the work done here has been to go beyond the limitations which might prevent understanding of the formation of pre-cognitive and embodied knowledge within a positivistic or/and mere social constructivist framework. An examination of the historical development of systematic thinking about space and the significance of "academic geography" in scientific practices helped to achieve this goal while putting the emphasis on the non-human agency of space. Still, some levels of indeterminacy of such a cognitive influence remain reinforced by the idea of difference at the core of the notion of space.

The character of a dialectical human-nature relationship can be moulded along the articulation of the analytical ends of a researcher without having the impact of the physical environment totally annihilated in the process. Knowing exactly the characteristics of what could be the impact of the physical environment in a given situation is both a matter of empiricism and idiosyncrasy. But the extent to which empiricism and idiosyncracy matter in this thesis is contained in the first strand of the argument of this chapter. Whilst the second strand will be fleshed out gradually in the unfolding of the following chapters around the case-in-point which is the concept of resilience. In this regard, following the critique of the universality of scientific knowledge provided in Chapter 3, here, it can be added that different manifestations of knowledge hold the potential to maintain or disrupt the existing variety of spaces. The extent to which novelty is allowed in the production of knowledge is likely to be in contention with given spaces (including their human and non-human components) if it does not conform to their structural continuities and/or their incremental fashioning. As such knowledge (re)production carries the hallmarks of the kinds of engagement we have with given spaces, and the kinds of society we design, live in, disrupt or maintain. Planning is an epitome of these kinds of engagement. But in most parts of the world, change within planning systems is incremental and planning practices are often reformist in character.

According to Harrison *et al* (2008:3) "[A]s the demands of context change, as new development pressures emerge, and as existing planning systems increasingly appear to be out of step with reality, so adjustments are made which usually take the form of modifications to what has gone before." From this perspective, the possibility of radical change is confined to rare instances of cataclysmic change, after war, revolution, and to some extent in the transitions from socialism in Eastern Europe, China, Tanzania and Ethiopia, or the transition from Apartheid in South Africa. So within planning, the pursuit of radical change

initially associated with the emergence of the concept of resilience appears almost *unthinkable*. That is to say that the (epistemic) culture (s) within planning "sets up an opposition between the thinkable and the unthinkable, between what is a worthy subject and what is unmentionable, what is interesting *per se* and what is uninteresting *per se*" (Kenneth,1973:241). For example, while planners work with property maps, desktop computers or cellular telephones, the rule of humans is unquestioned because these nonhuman things are almost absent from the way practice is theorised (Beauregard, 2015:1). The same fate is reserved to the non-human agency of some spaces which are part of planning practices. Yet a consideration of the complexity of the roles of spaces in knowledge production as highlighted throughout the subsequent chapters of this thesis may assist planning theory in making the connections between theoretical knowledge and planning practice in the "real world". Thus the next chapter highlights the political dimension embedded in the production of knowledge while erecting a stage upon which the argument put forward in this chapter will be further elaborated and contextualised. The stage in question reconstructs the configuration of relations linking the North American boreal forest, Sault Ste Marie Laboratory in Ontario, Canada, and Crawford Stanley Holling so as to ignite the discovery or rather the invention of resilience.

5. Sault Ste. Marie laboratory in Ontario, C. S. Holling and the North American boreal forest

Introduction

In the previous chapters I have argued that knowledge (re)production carries the hallmarks of the multiple engagements we have with space at its various scales; with the places we design, live in, disrupt, or maintain. Canada is not an exception to this; quite the contrary. In fact, Bocking (2007: 868) reports that in Canada, "science" distinguished itself as an effective instrument in the projection of authority over "space" by: "asserting the material basis for transcontinental aspirations, redefining insect outbreaks as national phenomena-thereby justifying federal initiatives, or extending managerial control over the forests and rivers of British Columbia". But, in as much as we shape our environment, it shapes us in turn too (MacEachchern, 2008: xii). So here the relationships between the North American boreal forest, Sault Ste Marie Laboratory in Ontario, Canada, and C.S Holling, are used to illustrate how human beings, and the natural and the built environments, interact dialectically in the ways in which scientific knowledge is produced.

Discursive processes are the result of an entangled set of influences political, economic, discursive, spatial, and more whose causal effects in the formation of human subjects and their ideas are frequently non-linear and mainly extremely complex. I am very cognisant of this as I use a story to elaborate the argument introduced in Chapter 4. As such, the articulation of this argument is not strictly linear but creative because of ways in which it recruits unconscious thoughts and finds new combinations and permutations of ideas for the sake of reconstructing the stage upon which the plot unfolds (see Kandel, 2013:549). But the plot itself

which is how Holling's evolving thinking eventually coalesced into ideas of resilience is only examined substantially in chapters 6, 7 and 8.

In this chapter the attention is given to the relations linking the main human and non-human characters of the story, namely, Sault Ste Marie Laboratory, the province of Ontario, C.S. Holling and the North American boreal forest. Holling is a "a rigorous rational thinker, but he is also a deeply intuitive visionary who follows his hunches, leaping far beyond the bounds of rational justifications to explore worlds of possibility that are inaccessible until he opens them up by leaping" (Gass, n.d.: 4). Sault Ste Marie Laboratory is the place where Holling conducted part of his experiments during his graduate studies and job as an employee of the Canadian Minister of Agriculture. Ontario is the City which gave birth to Sault Ste Marie Laboratory and it is also the place where Holling conducted part of the fieldwork required for his initial research projects. The North American boreal forest, in its relationships both with humans and insects, gave birth to the laboratory and to Holling's early scientific works.

Two elements add both specificity and generality to this story. The specificity is Holling's human experience in Sault Ste Marie in Ontario, and the individuality it somehow entails, because: "some of us are brought up in somewhat different environments, are exposed to different combinations of stimuli, and are likely to exercise our motor and perceptual skills in different ways, the architecture of each brain will be modified in a unique way (Kandel and Mack, 2003:272)". The generality relates to Holling's analytic and artistic abilities which mimic the technique of a manager or sculptor to arrange objects (which may or may not have been specially created for the purpose) in space for the sake of reaching a purpose (Holling, 2006; Gass, n.d; Sims and Doyle, 1995). These elements will unfold in the two sections that constitute this chapter. The first section introduces the reader to how the Sault Ste Marie Laboratory came into being and how it entangled with the North American boreal forest and Holling's

academic pursuit. The second section is a translation of the first section into a synthesis calibrating the theoretical discussion of chapter 3 and 4 in the light of the case-in-point. In so doing, the spatial heterogeneity of the Sault Ste Marie Laboratory and its role in the production of Holling's scientific research in the 1950s and 1960s is put into perspective.

5.1. The construction of Sault Ste. Marie Laboratory in Ontario and C.S. Holling graduate studies

The laboratory is contextually situated within a particular history, and a particular set of nested spaces. The laboratory must be related to aspects of Canada's history and specifically to the emergence of Ontario as a city in central Canada (5.1.1) but also to the ways in which it connects with C.S. Holling's life history (5.1.2).

5.1.1. The city the forest and the laboratory

The history of knowledge and practices and the influence of scientists on how to protect or exploit the planet are included in the history of humanity's relationship with nature (Bocking, 2008:294). This is particularly evident when looking both at the economic and environmental aspects of this relationship. In Canada, the economy starts with the hunting, farming and trading societies of First Nations (Aboriginal people). With the arrival of Europeans in the 16th Century, the economy has been through many important transformations illustrated by the early Atlantic fishery, the transcontinental fur trade, and then rapid urbanisation, industrialisation and technological change. Whilst different industries have appeared and disappeared, Canada's reliance on natural resources from fur to timber to minerals to oil to forest, and export markets for these commodities, mainly the United States has shaped much of the economy through the centuries and is continuing to underpin many regions of the country

today (Drummond,2006 :1). The reliance on natural resources reshaped Canada's surrounding environment as well. For example, Castonguay and Saint-Laurent (2008:273) argue that environmental changes to the Canadian forest followed its economic history. That is to say that, when the colonial economy began the exploitation of merchantable timber at the end of 18th century, large stands of white pine in New Brunswick, Quebec and Ontario were cleared. By the end of the 19th century, the prominence of the sawmill industry and the rise of the pulp and paper industry re-energised the deforestation process by cutting forest species (such as spruce and fir) initially viewed as not profitable.

Canada's economy is tainted with the racial element underpinning the relationships between First Nations and European descendants. Historically, colonial injustices against the First Nations are embedded in Canada's social fabric because of slavery and the country's connection into the global slave trade. Yet, according to Debbane and Keil (2004:218), the country's perception of itself as a "multicultural" society is reinforced by the fact that: "the markedly different urban settlement structure of Canadian cities, as compared with the US, has created the impression that the non-existence of large-scale and extreme segregation in Canadian urban areas has avoided the problems of a spatialised racist landscape that characterise US cities." Eventually, there is no trace of these injustices in the following account of the emergence of Canadian cities by Drummond (2006: 5):

> By 1867 the great cities of central Canada were Montreal and Toronto. The former began as a port and commercial centre. By mid-19th century, it was a place of industry, and by 1900 it was producing large amounts of clothing and textile products, electrical equipment, railway rolling stock and many light industrial products. It was also an important financial centre. Toronto after a slow beginning, developed after 1897 on similar lines, much of its early prosperity being based on Great Lakes shipping. By 1900 both cities had

> energetic banks and insurance companies and active stock exchanges. Both cities had begun to attract immigrants from central Europe and Italy. But it was largely natural increase and migration from Britain that built the cities of central Canada between Confederation and 1939.

Within this optic, Di Matteo *et al* (2014:6-7) argue that Ontario's economy was ignited during the early twentieth century by two major factors that energised its manufacturing sector's growth and ensured that Toronto would supplant Montreal to become the leading financial centre of Canada. The first was the Prairie settlements that saw hundreds of thousands of European settlers flock to the prairies and form a market for consumer goods produced by central Canadian Industry. The second was the forestry and mining resource boom of Ontario's northern border which generated inputs into southern Ontario industry, and fashioned Toronto's role as a financial hub as expertise was acquired from financing new resource ventures. Through enormous resources from rent and royalties, the Ontario government increased its spending on infrastructure in the late nineteenth and early twentieth centuries.

McGugan (2012:5) notes that during the 1800s most of Southern Ontario was surveyed and made ready for "development". Settlers who were primarily English, Irish and Scots cleared land primarily for agriculture. At that stage of "development", the forest in the territories of Ontario was thought to be inexhaustible. Because of that, forestry in Ontario as in many other forested countries of the world began with a century of crude exploitation informed by a policy of immediate reward and short term expediencies. Having as a point of entry the recent disputes between Canada and the United States, and disputes between provincial governments and First Nations over natural resources ownership, Armson (2002) traces the ways in which property rights in the forest have been allocated in Canada throughout history. In Armson's view a practice relying on licenses to allocate timber on public (or "crown") land originated

before the Confederation with the Crown Timber Act of 1849. Across half of century this licensing process remained almost the same. Throughout the 19th century and at the peak of white and red pine logging in eastern Canada, governments often auctioned off timber rights for very short periods. But these systems changed along with the growing pulp and paper industries in the early 1900s. Long term commitment became a necessity if the required financial investment were to be made, because pulp and paper were more expensive than sawmills. So, Armson (2002: 39-40) notes that "[F]or the most part, provincial governments used timber licences as a tool to encourage such investments, which usually led to the growth of town and revenues."

In the 19th century, with the expectation to gain some economic returns, the Canadian federal and provincial governments started their support to scientific activities in a number of disciplines, including botany, geology and meteorology. As for entomology, the outbreak of insects in the dawn of the 1870s, and the availability of insecticides such as the Paris green, was one factor that led the government to find ways to advise farmers on the use of pesticides through the formation of new institutions, namely the experimental farms system and the Ontario Agricultural College (Bocking, 1998:3).

The federal government assisted farmers and promoted agriculture through a program called "The Dominion Experimental Farms". This programme was created in 1884 following the appointment of a select committee of the House of Commons to inquire into the best means of enhancing and developing Canadian agriculture (Minister of Agriculture, 1925:3). As a result, Dr. William Saunders of London, Ontario, a chemist by training and the first director of the Experimental Farms Branch, was instructed late in 1885 to visit experimental stations in the United States and European countries with a view to formulating policy for Canada. In the light of the report that he produced after his trip, the then Minister of Agriculture, Sir John Carling, passed an Act for the establishment of

an Experimental Farm for the provinces of Ontario and Quebec jointly (Central Farm), one for the Maritimes Provinces, one for the province of Manitoba, one for the Northwest Territories, and one for British Columbia. The Act in question defined the kind of inquiry to be pursued. These included livestock breeding, dairying, the testing of cereals and other field crops, grasses and forage plants, fruits, vegetables, trees, and plants; the study of seeds, fertilizers, plant diseases and insect pests, the investigation of diseases of domestic animals, and such other experiments or researches as might benefit agriculture. The Central Farm at Ottawa and the Farms at Nappan, Nova Scotia; Brandon, Manitoba; Indian Head, Northwest Territories; and Agassiz, British Columbia were in practical operation within two years of the passing of the Act (Minister of Agriculture, 1925).

Before the end of the World War II, there had been only a few attempts to regenerate forest on a sustainable basis and the exploitation of public timber under license was the norm. Armson (2002) recounts that Abitibi Paper Company at Iroquois Falls and Paper Company at Sault Ste Marie both began major forest regeneration in the 1920s in Ontario. But, along with the post-World War II economic boom, McGugan (2012:7) reports that there seemed to be an inclination to develop a land ethic and moral obligation to do the "right thing" with respect to the management of natural resources in Ontario. It became evident that forestry could no longer be only exploitation. So, effective management of the forest on a sustained yield basis and a forest inventory, appeared as the key to develop new a forest management process. In this respect, Castonguay and Saint-Laurent (2008) identify both ecological dynamics and industrial and governmental policies as the causes of environmental change (reforestation).

In an examination of the evolution of northern Ontario's tree planting and labour force since the commencement of the forest regeneration programmes following

World War II, Sweeney (2009:51) identifies four crucial periods: pre-1962, 1962-1979, 1980-1994, and 1994-present. According to him each period differentiates itself through important changes to the political economy of the forest products industry and legislation impacting on land tenure, licensing, funding, and service delivery in Ontario's forest. For instance he points out that:

> In the decade and a half following World War II, the nature of the forest products industry in Ontario, and Canada for that matter, changed dramatically. In order to meet growing North American demand, Ontario's pulp and paper capacity grew by 49 per cent between 1950 and 1959. This prompted a new system of legislation that commodified Ontario's forests by guaranteeing large corporations access to timber in exchange for investment. Large scale manufacturing projects and growth in timber harvests required significant changes to forest tenure, an increase in forest management, and the organisation of work in the wood (Sweeney, 2009:51).

But earlier in the 1930s, the European spruce sawfly *Diprion Herciniae* (Htg.) outbreak caused important losses to the Canadian paper and pulp industry (Figures 2 & 3) which in turn responded by supporting the biological pest control work of the federal entomological service (Castonguay, 2001). In so doing, they pressed the federal government to increase its financial contribution and its involvement in forest protection and conservation. Following another cycle of destruction initiated by the spruce budworm (*Choristoneura fumiferana Clem*) in Manitoba and its spread eastward, the Canadian government created the Forest Insects Control Board in September 1945 to appease the industry[20]. Although the

20 Historically, Canada has invested significant amounts in biological pest control, probably more so than most countries (Smith, 1993:60).

potentialities of pathogens as control agents were glimpsed in the early years of biological control work in Canada, it was not until 1940 that intensive research on a virus disease of the European spruce sawfly *Diprion Herciniae* (Htg.) was launched (Glen, 1961:x). The findings of the study in question re-invigorated the interest of American and Canadian entomologists and at the same time led to the end of the European spruce sawfly *Diprion Herciniae* (Htg.) outbreak which had devastated the forests of Quebec and New Brunswick throughout the 1930s.

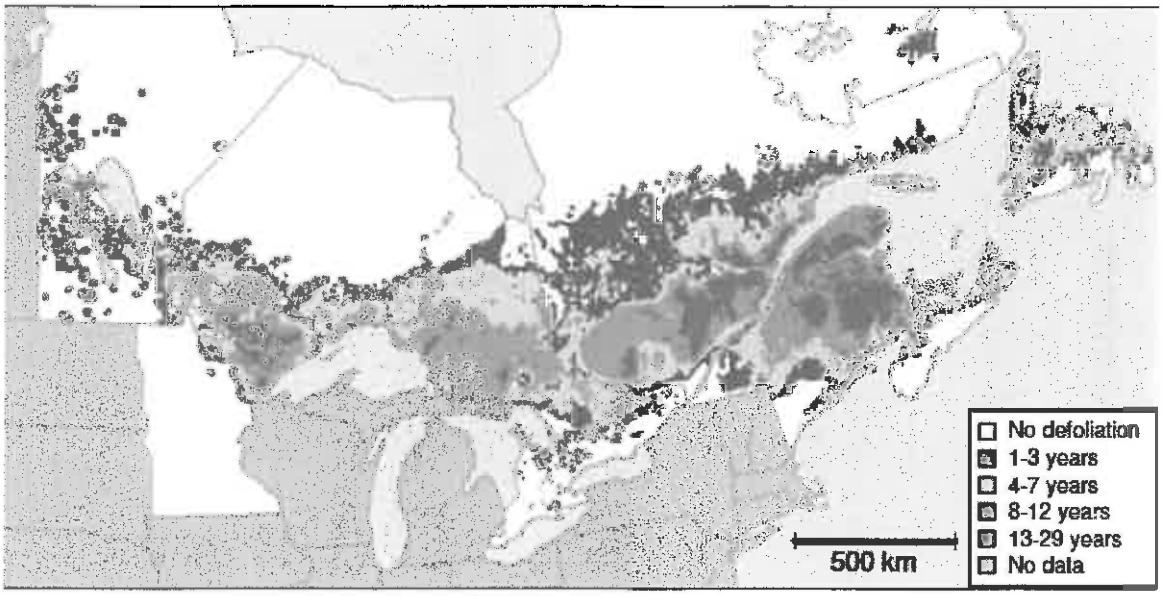


Figure 2. Frequency of defoliation by eastern spruce budworm from 1954 to 1988 in North American forest. Source: William and Birdsay (2003).

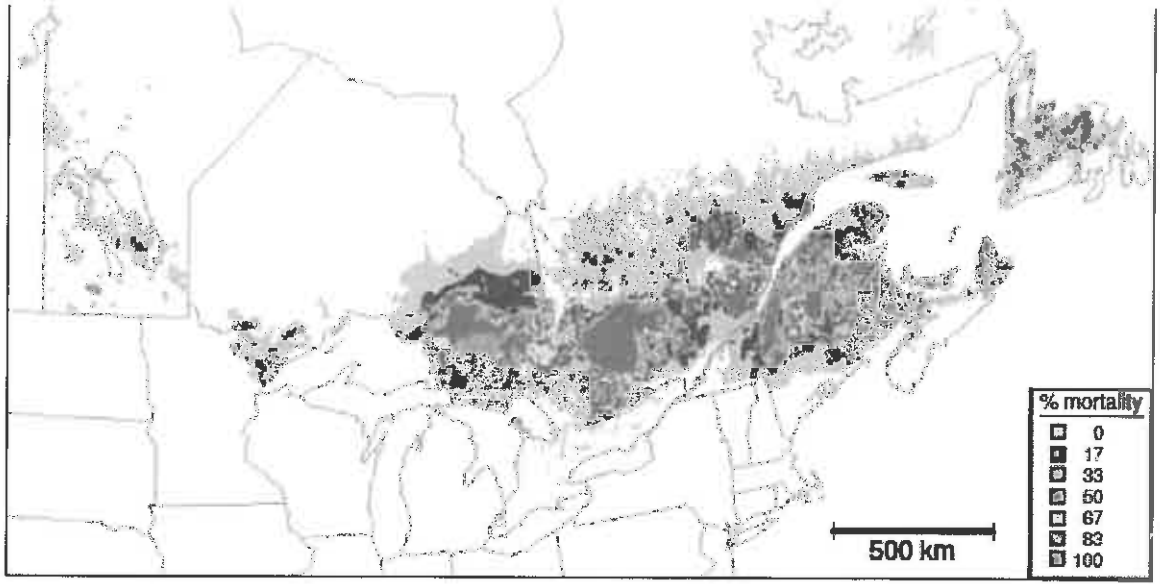


Figure 3. Expected mortality of susceptible forest resulting from eastern spruce budworm in North American forest from 1966 to 1988. Source: William and Birdsay (2003).

In 1950, the infestations of the spruce budworm kept diminishing throughout the eastern and north-eastern Ontario and in the lakehead region (Prebble, 1950). Castonguay (2001) reports that between 1940 and 1960, the Entomology Division of the federal Department of Agriculture stopped assisting farmers and foresters in the field with the aim to put its focus more fully to research activities. Castonguay avers that, this change of priority meant more autonomy for entomologists in the definition of research projects which were supposed to match with their interests as well as the demands of the Department of Agriculture and its patrons. Rather than seeking only to identify the most suitable control methods, entomologists investigated outbreak causes, as well as the modes of action. This change also went hand in hand with the funding of a program of work for developing pathology designed by John J. de Gryse, the Chief of the Forest Insect Unit and the creation of new research facilities as Castonguay (2001:23-24) adds:

> The Forest Insects Control Board readily agreed to finance the program of work defined by DeGryse. First, it funded the construction of a laboratory entirely dedicated to the study and propagation of pathogenic organisms for insect control. Second, it authorized a search for an organism lethally specific to the spruce budworm insect. When domestic surveys failed to locate such an organism, two Canadian entomologists left for Europe where German and Czechoslovakian entomological services collaborated in the identification and collection of natural enemies of *Choristoneura murinana and C. histrionana*, two species closely related to the spruce budworm (*C. fumiferana*). In the same year, 1946, the federal government provided the Department of Agriculture with $150, 000 to construct an insect pathology laboratory at Sault Sainte Marie in Ontario. The Entomology Division had recently established its headquarters there in the forest Insects Laboratory.

In 1959, the Department of Agriculture united the experimental farms systems and its scientific service in a move to create a research directorate. At a regional level, experimental farms and laboratories were integrated into regional stations, and at national level, some laboratories such as Sault Ste Laboratory became research institute (Castonguay, 1998:84).

The construction of the laboratory at Sault Ste Marie in Ontario was completed in 1950 and became known as the Insect Pathology Research Institute, Forest Entomology and Pathology Branch, Canada Department of Forestry (Glen, 1961: x). According to Prebble (1950), although considerable adjustment of air conditioning and other equipment was ongoing after the building was put in operation, the laboratory of insect pathology became operational in June 1950. Concretely, it meant taking over the Forest Insect Ranger building from contractors in the autumn and the use of the office-garage-workshop facilities during the winter months while greatly easing the pressure on the facilities of the forest Insect laboratory. The construction of the greenhouse-headerhouse

began during the winter of 1950-51, but these facilities were not operational before the end of the fiscal year. Granted with such facilities and a few others acquired gradually, the Institute was "an early containment laboratory, where entomology research branched out into applied bacteriology and engineered the use of viral pathogens for insect control, bringing about a new level in the restructuring and control of nature" (Hammond, 2005: 623). Castonguay (2001) observes that between 1950 and 1959, the researchers recruited at the Institute were registered in the departments of bacteriology, parasitology or botany at different Canadian universities to pursue advanced studies and undertake graduate projects. Those projects reinforced the research agenda of the Institute and influenced the development of research pathology in Canadian universities. According to this scholar, "[I]f academic departments had taken up the various aspects of insect pathology, none of them individually could have offered the array of approaches related to the field. The Sault Sainte Marie Laboratory had the instruments and experimental data, as well as the collaborators (national and international), to tackle research problems and contribute to the development of different branches of insect pathology" (Castonguay, 2001:26-27).This is evidenced by some elements of C. S. Holling's life history.

5.1.2. Encountering C.S. Holling and situating its initial scientific research

Libby (2014:93) argues that life histories are being used to brand a form of territoriality which is different from nationalism in the ways in which "well known heroes enable global recognition: they give particular scientific groups a niche in the highly competitive market for scientific authority and research funding." In relation to C.S. Holling, this scholar adds that:

> Resilience science provides a rather different example of branding a discipline through a scientific "father". In this case its Canadian progenitor, C.S. (Buzz) Holling, is still actively engaged with this new

> integrated science of ecology and society. The concept of resilience is defined in the foundational paper in 1973. This has subsequently been used by practitioners of resilience science to stake out territory within a broader field of environmental management (Libby, 2014: 98).

But, *how would you explain resilience to a ten year-old*, the following is Holling's answer:

> If I was a ten year old I would understand resilience more than if I was 50 years old. The essence of resilience has to do with ebullient surprises that occur or you encounter. And what are surprises? They are the things that are not explained by theory that you contain at the moment or the paradigm, they are the unexpected events that nature shows you, that you're learning. A learning human can classically be imagined as ten year old because his world has matured to a certain point and much is unknown. Resilience is more of a metaphor for a 10 year old than a 50 year old. Less and less of a 50 year old's world is one of surprise particularly compared to a ten year old. Resilience is for the ever youthful (Holling, 2008:7).

In effect, Holling was born on December 6, 1930 to Canadian parents at Theresa, New York, (Larkin, 2008). He grew up in Ontario and became a member of the Royal Ontario Museum's Toronto Junior Field Naturalists. As part of the answer to the question where ideas come from, Holling (2006:23) describes himself in these terms:

> I am prodigiously curious about nature, and that triggers initial ideas. I am also terribly persistent and stubborn about developing and testing an idea that grabs me; at those times I am totally and narrowly focused, driven by the potential. That is what eventually makes an idea useful. So I conclude that nature creates the idea; stubbornness makes it useful! But I have had to learn how to see nature. It is curiosity, anecdote, funny correlations, jokes and metaphors that have done that.

Holling learned how to "see" nature, completed his Bachelors degree in 1952 at the University of Toronto and his Masters at the University of Toronto in 1954. His graduate studies included both vertebrate zoology and forest entomology. Primitive Art was also part of Holling's studies as well as sculpting, an activity that he has been undertaking alongside his research:

> I love the nascent ideas, the sudden explosion of new ideas, the connections of the new ideas with others. And I love the development and testing of the idea till it gets to the point it is convincing. That needs persistence to the level of stubbornness and I happily invest in that persistence. I guess I fit somewhat into the artist type, less the technical type and still less into an efficient consolidator. As part of that kind of scientist, I have tried to develop senses that help me listen to intriguing voices that are hidden amongst the noise. Owlish ways to hear the rustle of the mouse. The simplest example of what I mean is in sculpting, another pleasure I have. I start with a number of hazy ideas and then I discover the image caught and hidden in the swirls of the wood's grain. I listen to the voice of the wood (Holling, 2006:23-24).

In the above quotation, Holling establishes a connection between science and art in an attempt to convey the fullness of his experience. This narration captures the origin of cognitive sculpting in art, and mirrors the development of Hollings' career both as a scientist and as a manager (Table 3). Cognitive sculpting is a technique similar to modelling that managers use to express the complexity of what they are doing. Through that way of doing things, management appears both as a science and as an art. As such, Sims and Doyle (1995:123) argue that "cognitive sculpting is a way of capturing implicit views that managers have about how they practise their management art." Both the origin of this technique and its use are transparent in the ways in which Holling conveys some of his ideas. For instance regarding some manta sculptures created by Holling (Buzz), Gass (n.d.: 9) recounts that:

For a long time, Buzz has been interested in the organization and dynamics of flocks, herds, schools, and other aggregations of animals. Sometimes, his interest has become intense. In the early '90s, he developed a composite wooden sculpture based on a complex model of the schooling behaviour of manta rays. The basis of the model was a set of assumptions about the angular relationships individuals would maintain as they swam in lazy spirals upward and outward from starting. He carved the individual mantas in wood, painted them then mounted them precisely in position in a Plexiglas box with nearly-invisible monofilament line.

On one of his trips to Vancouver, Buzz brought the wooden mantas with him and we constructed 3D computer models of some of them. It was an old, slow computer and an early version of the software, and I was still in my infancy as a modeller.

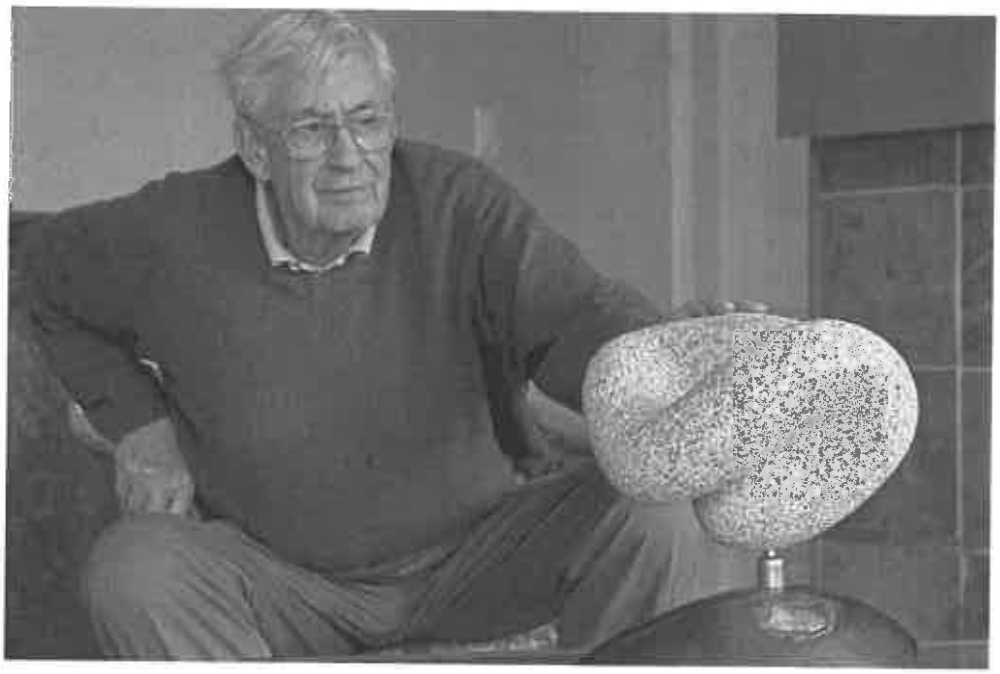


Figure 4. Picture of C. S. Holling. Source: Gass (n.d.)

This form of complementarity between art and science is somehow acknowledged in Holling's acceptance speech for an Honorary Doctorate by

Simon Fraser University: "Sixty years ago I was where you graduates are now, but graduating from the University of Toronto. By the time I got my PhD a few years later, I was launched on a goal to understand population processes. It was the unknown that beckoned me and simple curiosity that motivated me" (Ramalingam, 2011:1).

Table 3. Selected events in Holling's life between 1952 and 2002

Years	*Studies*	*Position*	*Relevant publications*
1952	Bachelors degree, University of Toronto	Researcher at the Canada Department of Forestry/ Sault Sainte Marie	
1954	Masters degree, University of Toronto	Researcher at the Canada Department of Forestry/ Sault Sainte Marie	Holling, C.S. 1955. "The Selection by certain small mammals of dead. Parasite, and healthy prepupae of the European pine sawfly, *neodiprion sertifer* (Geoff.), in *Canadian Journal of Zoology*,33(6) : 404-419
1957-63	PhD, University of British Columbia	Researcher at the Canada Department of Forestry/ Sault Sainte Marie	Holling, C.S.1957. The Role of Small Mammals as Predators upon Sawfly Population. Ph.D. University of British Columbia. Holling, C.S. 1958. "Sensory stimuli involved in the location and selection of sawfly cocoons by small mammals", in *Canadian Journal of Zoology*, 36:633-653. Holling, C.S. 1959. "The components of predation as revealed by a study of small mammal predation of European sawfly", *in Canadian Entomologist*, 91 (5):293-320. Holling, C.S. 1959. "Some characteristics of simple types of predation and parasitism", in In *Canadian Entomologist*, 91(5): 385-398. Holling, C.S. 1961. "Principles of Insect Predation" in *Annual Review of Entomology*, 6:163-182.
1964		Researcher at the Canada Department of Forestry/ Sault Sainte Marie	
1965-67		Researcher at the Canada Department of Forestry/ Victoria	Holling, C.S.1965. "The Functional response of predators to prey density and its role in mimicry and population regulation" in *Memoir of Entomological Society of Canada, 45:1-60.*

			Holling, C.S. 1966. The strategy of building Models of Complex Ecological Systems. In: Watt, K.E.F. (ed.) *Systems Analysis in Ecology*. Academic Press: New York and London.
1967-68		Professor at University of British Columbia	Holling, C.S., 1968. The tactics of a predator. In *Insect Abundance. Symposia Royal Entomological Society, London* (pp. 47-58).
1969-73		Director of the Institute of the Animal Resource Ecology	Holling, C.S. 1969. Stability in Ecological and Social Systems. In: Woodwell, G.M. and Smith, H.H. (Eds) *Diversity and stability in ecological systems: Brookhaven symposia in biology*: May 26-28, 1969. Brookhaven: Brookhaven National Library.128-141. Holling, C.S. and Golberg, M.A. 1971. "Ecology and Planning" in *Journal of the American Institute of Planners*, 37 (4): 221-230. Holling, C.S. and Orians, g. 1971. "Toward an Urban Ecology" in *Bulletin of Ecological Society of America*, 52 (2):2-6. Holling, C.S. 1973. "Resilience and Stability of Ecological Systems" in *Annual Reviews*, 1-23.

1974-84		Researcher at International Institute of Applied Systems Analysis (IIASA)	Fiering, M. and Holling, C.s.1974. "Management and standards for perturbed ecosystems" in *Agro-Ecosystem*, 1: 301-312. Clark, W.C., Holling, C.S. and Jones, D.D. 1975. "Toward a structural view of resilience" [Online] Available at: < http://www.iiasa.ac.at/publication/more_WP-75-096.php > [Viewed on 15 August] Holling, C.S and Walters, C. 1976. Introduction and Overview. In: International Institute of Applied Systems Analysis, The IIASA Ecology Project: A Status Report. Laxenburg, Austria, July 1975 [Online]. Available at: < http://www.iiasa.ac.at/publication/more_RR-76-002.php> [Viewed on 16 August 2015] Holling, C.S. Dantzig, G.B., and Baskerville, C. 1975. "A case Study of Forest Ecosystems/Pest Management" [Online]. Available at: < http://www.iiasa.ac.at/publication/more_WP-75-060.php> [viewed on 15 August 2015]. Holling, C.S and Walters, C. 1976. Introduction and Overview. In: International Institute of Applied Systems Analysis, The IIASA Ecology Project: A Status Report. Laxenburg, Austria, July 1975 [Online]. Available at: < http://www.iiasa.ac.at/publication/more_RR-76-002.php> [Viewed on 16 August 2015]. Clark, W.C., Dixon, D. J. and Holling, C.S. 1979. "Lessons for Ecological Policy Design: A case Study of Ecosystem Management" in Ecological Modelling, 7: 1-53.
1981-84		Director of IIASA	Walker, B.H., Ludwig, D.; Holling, C.S., Peterman, R.M. 1981. Stability of Semi-arid Savanna Grazing Systems. Journal of Ecology, 69:473-498.
1985-87		Researcher at International Institute of Applied Systems Analysis (IIASA) and at the University of British Columbia	Holling, C.S., 1985. Perceiving and managing the complexity of ecological systems. *The Science and Praxis of Complexity*, pp.217-227. Holling, C.S. 1986. The resilience of terrestrial ecosystems: local surprise and global change. In: Clark, W.C. and Munn, R.E. (eds) Sustainable Development of the Biosphere. London, New York, New Rochelle, Melbourne and Sydney: Cambridge University press, 288-317. Holling, C.S., 1987. Simplifying the complex: the paradigms of ecological function and

			structure. *European Journal of Operational Research*, *30*(2), pp.139-146.
1988-89		Institute of Resource Ecology, University of British Columbia	Holling, C.S., 1988. Temperate forest insect outbreaks, tropical deforestation and migratory birds. *Memoirs of the Entomological Society of Canada*, *120*(S146), pp.21-32. Holling, C.S., 1989. Integrating science for sustainable development. *Journal of Business Administration*, *19*(1), pp.73-83.
1990-2000		University of Florida/Resilience Network/Resilience Alliance	Walters, C.J. and Holling, C.S., 1990. Large-scale management experiments and learning by doing. *Ecology*, *71*(6), pp.2060-2068. Holling, C.S. 1996. "Surprise for Science, Resilience for Ecosystems, and incentives for people" in *Ecological Applications*, 6 (3):733-735. Holling, C.S. 1998. "Two Cultures of Ecology" Conservation Ecology, [Online]. Available at < http://www.ecologyandsociety.org/vol2/iss2/art4/> [Viewed on 18 August 2015]
2001		Eminent Scholar, Arthur R. Marshall Jr. Chair in Ecological Sciences, University of Florida	Gunderson, L. and Holling, C.S.eds.2001.*Panarchy: Understanding transformations in human and natural systems*. Washington DC: Island Press. Holling, C.S.2001.Understanding the Complexity of Economic, Ecological, and social Systems. Ecosystems, 4: 390-40.
2002		Retired from the University of Florida	

Indeed Holling has been a researcher in the Sault Ste Marie Laboratory while undertaking his graduate studies subsequently at the University of Toronto and at the University of British Columbia from 1952 till 1964. In 1955, he published a paper deriving from his Masters thesis in the *Canadian Journal of Zoology*. The paper was titled "The Selection by Certain Small Mammals of Dead, Parasitized, and Healthy Prepupae of the European Pine Sawfly, *Neodiprion Sertifer* (Geoff.)"; and it emerged from an inquiry on the effect of small mammal predation in

controlling populations of the European pine sawfly *Neodiprion Sertifer* (Geoff). This sawfly attacks scots, jack, red pines, and reached epidemic proportions in the scots pine plantations of southwestern Ontario (Holling, 1955) The study attempted to understand the selective ability of certain mammals in relation to cocoons containing healthy, diseased and parasitised prepupae of the European pine sawfly *Neodiprion Sertifer*. It fell within the scope of investigation of Sault Ste Laboratory. In this regard, it highlighted the relevance of biological pest control for an economy depending on forest products such as red pine, scots or jack. Consequently the forests of Ontario, the laboratory and the pulp and paper industry appear to have participated in the making of this research both at conceptual and operational levels. The acknowledgement section of the paper illustrates it well:

> The suggestions and criticisms of my supervisor, Dr. K. C. Fisher, university of Toronto, have been invaluable. Part of this study was conducted while I was in the employ of the Department of Agriculture. Dr. M. L. Prebble, Chief, division of Forest Biology, Department of Agriculture, kindly allowed me to use this information. Considerable aid was given by Dr. R. M. Belyea, Officer in- charge, Forest Insect Laboratory, Sault Ste. Marie, Ontario, in providing the facilities of the laboratory and in criticizing the manuscript. This study was partially financed by a portion of a grant to Prof. J. R. Dymond, Head, Department of Zoology, University of Toronto, from the Research Council of Ontario and by a scholarship from the National Research Council of Canada (Holling, 1955: 418).

The Doctor of Philosophy degree completed by Holling in the Department of Zoology of the University of British Colombia in 1957 followed the trail of the work that he undertook during his Masters degree. His dissertation was titled, "The Role of Small Mammals as Predators upon Sawfly Populations" and its

purpose was twofold. First, the thesis sought mainly to understand the basic components and subsidiary factors at the core of the behaviour leading to predation and second to suggest the role predation plays in controlling the number of animals. The overall assumption grounding this purpose is the belief that predation - does not differ wherever it occurs or whoever the predator is that is, whether the predator is a wolf and the prey a deer or the predator is a shrew and the prey an insect the form of predation is the same. In order to introduce his second purpose which was to assess the role small mammals' play as predator of an economically important insect, Holling (1957:1) provided a preview of the context of his research:

> The data of this analysis were obtained from a study of predation by small mammals of the European pine sawfly, *Neodiprion Sertifer* (Geoff.) in southwestern Ontario. This sawfly is a serious defoliator of pines and was first reported in North America in 1925 (Craighead, 1950). It spread rapidly, and in 1939 was observed in Ontario near Windsor (op. cit.). It later reached such high numbers in the pine plantations of southwestern Ontario that by 1951 the insect caused 70 to 100 per cent defoliation of Scots, jack and red pines.

Moreover, in the acknowledgement section of his dissertation, Holling remarked that part of the data used for his study was obtained while working for the Division of Forest Biology, Department of Agriculture. He thanked Dr. M. L. Prebble, chief of the division, for allowing him to use this information but also for criticising the manuscript. In the same vein, he acknowledged Dr. R. M. Belyea, Officer-in-Charge in the Forest Biology Laboratory at Sault Ste Marie for the criticisms and suggestions offered. Both the purpose of Holling's dissertation and his acknowledgements suggest how the expertise of Sault Ste Marie laboratory contributed to the exploration of solutions related to the exploitation of forest

products. It also points out the active role that humans played in the re-composition of Ontario's forests.

However, to have a grasp on the influence of the forest in this research, it is important to recall that the first report of the European pine sawfly *Neodiprion Sertifer* (Geoff) in North America, and the release of a book closely associated with this insect under the authority of the Hon. W. R. Motherwell, the then Minister of Agriculture, happened in 1925. This shows that the field of biological pest control in which Holling's dissertation is grounded was tuned to the population dynamics of insects in the forest. It also highlights that the capacity to understand and control the population dynamics of some insects was crucial for economic activities such as agriculture or forestry before the advent of Holling's research. In this regard the publication associated with the first report of the European pine sawfly *Neodiprion Sertifer* - is titled "The Dominion of Experimental Farms" and its subtitle reads: "[A] system of experimental stations operated by the Federal Government which investigates agricultural problems and is capable of giving continuous services to Canadian farmers". In its section dealing with international plant disease legislation, it is noted that:

> Not only is it the aim of the plant pathological service to aid in the control of plant diseases already within the country, but the botanical service jointly with the Entomological Branch of the Department of Agriculture is also devoting considerable time and attention to the more international aspects of plant pathology, viz., through the prevention, by legislation and supervision under the Destructive Insect and Pest Act, of the importation of diseased vegetation from any country abroad (Minister of agriculture, 1925:32).

In the light of the above, Holling's graduate research while being contained within the scope of inquiry of Sault Ste Laboratory, participates alongside other institutions of the Canadian federal and provincial governments in the fixation of

belief[21] regarding humanity's relationship with nature. This was made possible because the Department of Agriculture harnessed the technical manpower which could be found in insect control, and instituted a new division of labour with the provinces so as to position itself as the centre of entomological expertise in Canada (Castonguay, 2004:3). In fact, the *Destructive Insect and Pest Act* (which received royal assent on 4 May 1910) through the Department of Agriculture, sought to prevent the threat that the population dynamics of some insects in the North American boreal forest might represent for the Canadian economy.

5.2. Sault Ste Marie Laboratory: a component of Ontario's knowledge Infrastructure

To define what a laboratory means is to confine it to one or two of its aspects but engaging with those different aspects of its definitions helps to reconstruct what informs their meanings (5.2.1).Yet the lab is not only a concept; it is also an artefact whose influence on material experience can be cognitive (5.2.2).

5.2.1. Defining a laboratory

Since its inception in 1950, Sault Ste Marie laboratory was co-operating with various scientific services at the regional, national and international levels (Table 4). In the 1960s, when Ontario's government began a long term-strategy of investing in its post-secondary education systems, Sault Ste Marie laboratory became a component of a network of 17 universities and 22 colleges of Applied Arts which formed the backbone of Ontario's economic development policy (Wolfe and Gertler, 1999:17). But, as a laboratory, the Insect Pathology Research

21 It is a consensus formation in science which refers to a process whereby paradigms or theoretical hypotheses become accepted as fact in community of specialists (Amann and Cetina, 1988:133).

Institute was not limited to its physical address at Sault Ste Marie, Ontario, because the laboratory is "the place where scientists work", if we have to borrow the terminology of Latour (1987: 64). This proves to be true in the light of the diversification of actors - (universities, industries, government laboratories and hospitals) undertaking scientific research in Canada and the increasing significance of inter-sectorial collaborations among them (Godin and Gingras, 2000). Latour's terminology seeks also to encourage the analyst to go beyond the perimeter set by the laboratory's physical address in order to dive "inside laboratories walls, because laboratories are the place where inside/outside relations are reversed" (Latour, 1983:160). Nevertheless, to distinguish one laboratory from another, it is equally important to understand the laboratory as a part of the built environment. Indeed a laboratory is contained within an architectural construction so as to mean "the result of procedure that separates an outside, an environment that is considered negligible for some epistemic claim or technological invention and an inside, a (partly) controlled environment that is considered relevant for this claim or invention" (Guggenheim, 2012:101). Hine (2007:663) disagrees with this kind of analytical approach. For this reason, he argues that:

> By studying differences between laboratories we once more assume that laboratories are distinct sites, and that sites contain culturally significant wholes. The upshot of the contemporary anthropological thinking suffusing the more imaginative developments in ethnography is that these bounded cultural entities rarely exist, and it is a distraction to assume in advance that they can usefully define our studies. Rather than going to identified places to study science, the spatiality of science becomes a topic of exploration in itself (Law and Mol, 2001).

Some reservations can be held regarding Hine's argument because he seems to neglect the fact that both the scientists and the social scientists (in science studies) undertake at least part of their work in the physical space of the

laboratory; and that most laboratory-placed studies have been undertaken in North America and Northern Europe where the physical spaces of the studied laboratories belong to almost the same architectural genre[22] (Martin *et al*, 2012: 3; See Lawhon and Murphy, 2012:362). Besides regarding the colonial encounters during the 1900s, Hobsbawm (1987:31) notes that " the failure or refusal of most of the inhabitants of the world to live up to the example set by the western bourgeoisies was rather more striking than the success of the attempts to imitate it". In this way, Hobsbawm touches the issues of mimetism and appreciation of difference in post-colonial societies. Therefore it is not surprising if the differences between laboratories were not culturally or physically significant or perceived as such. Finally, the point Hine raises concerning the upshot of contemporary anthropological thinking does not hold much water, especially if we take into consideration the new development of anthropology in Latin America regarding the question of, modernity, coloniality, culture and ontology for details see Mario Blaser (2009).

Moreover, Latour (1983:165) confers a form of agency on to the laboratory, similar to the ways in which the construction of Sault Ste Marie Laboratory in Ontario has appeared to influence the framing of C.S Holling's scientific research since 1952:

> The specificity of science is not to be found in cognitive, social or psychological qualities, but in the special construction of laboratories in a manner which reverses the scale of phenomena so as to make things readable, and then accelerates the frequency of trials, allowing many mistakes to be made and registered.

22 I draw part of this reservation from Baydar (2004:22) when he states that "until colonial encounters Western architectural history and theory did not have to attend to cultural particularity as a sign of cultural difference."

Whereas Latour seems to deny any special quality of cognition to the scientist working in the laboratory and to the laboratory itself, we can infer from Harvey (2010:199) that the conception of the physical space[23] deriving from his insight is rather incomplete as it favors "examinations of how cognition affects how we perceive and remember space over how space may affect us cognitively". Harvey's argument is reinforced by the very fact, that while not being settled about spatiality in its theoretical propositions, social studies of science emerged only after scholars like Bruno Latour, Karin Knorr Cetina, Michael Lynch among others decided to conduct their research in laboratories (that is in physical entities) (see, Law and Mol, 2001:610). In addition Garforth (2011:4) notes that: "Just as natural scientists act with scripts, material, methods, and machines so does the ethnographic researcher act on and with her assembled researcher subjects, inscription devices and traces, in the laboratory." But saying such a thing could be also turning upside down one of the main contributions of science studies because it implies that if there is no special form of cognition for the scientist and social scientist, it is the physical space of the laboratory which seems to embody this feature instead. This possibility is not to be excluded rather it should at least be explored further.

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23 Law and Mol (2001:612) fathom two interfering spatial systems in Latour's Actor-Network-Theory, namely the network and the Euclidian spaces. The network-space is a syntactical or semiotic space where some elements composing it are static in relation to each other, and able to be mobile in relation to Euclidian space that is defined by a set of three dimensional coordinates. In addition these scholars suggest to *think* about space through the metaphor of fire and fluidity. While the arguments of these scholars (Latour, Mol, Law) infer *de facto* a socio-material agency (actant) to technological artifacts (for example computer, building, etc...) , the materiality of the space in their theoretical framework is not completely defined though always socially mediated, and still opened to scholarly imagination (Sorensen, 2007:2, Law: 2003:10:11).

Table 4. A brief resume of conferences and annual meetings attended by various members of the staff of Sault Saint Marie and of special assignments undertaken in co-operation with other scientific services in 1950 and 1951.Source : Prebble (1950). This table helps to grasp what is Saint Sault Marie laboratory beyond its physical address, meaning " a place where scientists work".

Conference on virus diseases,
Ottawa, April, 1950 - G. H. Bergold
F. T. Bird
J. M. Cameron

Federation of American Society of Experimental Biology,
Biochemical Section, Atlantic City,
April, 1950 - E. F. Wellington

Research Council of Ontario, Committee on Forestry Research,
Toronto, April, 1950 - M. L. Prebble
Cornwall, September, 1950 - D. A. Fraser

Consultation on Chemical Control Methods with United States
Authorities, Washington, D. C., Beltsville, Md.,
and New Haven, Conn. April, 1950 - J. J. Fettes

Royal Society of Canada,
Kingston, Ont., June, 1950 - G. H. Bergold
S. G. Smith

International Conference of Microbiologists,
Rio de Janeiro, Brazil, August, 1950 - G. H. Bergold

Electron Microscope Society,
Detroit, Michigan, September, 1950 - F. T. Bird

Northeastern Forest Disease and Pest Control Committee,
Warrensburg, N. Y., September, 1950 - M. L. Prebble
Boston, Mass., February, 1951 - M. L. Prebble
F. T. Bird

Canadian Society of Forest Engineers,
Sault Ste. Marie, Ont., October, 1950 -
R. M. Belyea
J. R. Blais
W. E. Cawthray
J. J. Fettes
D. A. Fraser
M. L. Prebble

Conference on Radioisotopes in Biological Research,
Ottawa, February, 1951 - G. H. Bergold
J. M. Cameron
D. A. Fraser

Conference, Division of Forest Biology,
Ottawa, March, 1951 - J. M. Cameron
B. M. McGugan
M. L. Prebble
W. G. Wellington

Society of American Foresters, Wisconsin -
Upper Michigan Section, Escanaba, Mich.,
March, 1951 - J. R. Blais
M. L. Prebble

Survey of budworm damage in Kabonga district of
Northwestern Quebec, October, 1950 - R. M. Belyea

Entomological Society of Ontario,
Guelph, November, 1950 - J. M. Cameron
J. J. Fettes

American Association for the Advancement of Science,
Cleveland, Ohio, December, 1950 - D. A. Fraser

5.2.2. Cognition of the laboratory

In effect, despite the variability of the imprints of the locale, science exists and maintains a form of coherence because of infrastructure (Harvey, 2000). Edwards (2006:239) notes that the term "infrastructure" refers to technological and institutional systems. According to Edwards, infrastructure reflects the invisibility gained by systems as they become embedded in ordinary life and as reliance is placed on them by whole societies. He adds that "knowledge infrastructure comprises robust networks of people, artefacts, and institutions that generate, share, and maintain specific knowledge about the human and natural worlds"

Nevertheless, he continues in saying that the space syntax approach still finds it difficult to address the process of building. He calls for a theoretical approach encompassing both the object and the process. Regarding the process of construction, Graff (2009) suggests that the way in which the built environment is produced is in relation to the social characteristic of a distinctive period of time. Graff suggests that, these practices are in turn affected by the global development in philosophical thinking associated with power structures, either aligned with or merely representing a resistance to power. Although the field of the built environment is trying to emancipate itself from the modern rationality which excludes from the realm of analysis what could not be quantified or measured, this particular way of understanding has nonetheless entailed the impoverishment of both the building product and process (Rabeneck, 2008:272). This point adds more strength to the reservations held earlier in this section in relation to the irrelevance of the study of the physical space of the laboratory (Hine, 2007). As a result, the way that the laboratory has been operational or understood as capable of blurring the line between the inside and outside seems to be more the outcome of the mobility of scientists and/or the disposability of the object of scientific knowledge.

The physical settings of the laboratory influence scientific practices; through the disposition of equipment and other accoutrements, restriction and promotion of certain form of interactions, the human behaviors are regulated (Livingstone, 2003:18). The physical delimitations of the laboratory distinguish what is socially constructed and discovered from what preceded the social and human discovery. It follows then that the variations arising from the circulation of scientific theories and measurements from one locale to another, while reflecting the heterogeneity of the object of scientific knowledge, are precisely what science aims to erase by erecting the regularity of its objects above ordinary objects of common experiences (Daston, 2000:1-6). In this regard, Daston (2000) remarks

that phenomena that are indisputably real in the colloquial sense that they exist may become more or less real depending to the extent of their integration into scientific thought and practices. In relation to the change of status from experiential knowledge to scientific knowledge, Porter (1995: 29) argues that there is a preference for precise and standardisable measures rather than highly accurate ones. As such, he emphasises that frequently accuracy is meaningless if the same operation and measurements cannot be performed at other sites. Thus data processing as understood by Maunder (1992:75), the handling of data until they are in a form ready to be used for specific goals, seems to be what renders the laboratory operational and alters the effect of the irregular in the formation of scientific knowledge.

All types of knowledge contain a certain amount of tacit rules which may be impossible to formulate in principle, yet the irregular (localised, non-ubiquitous and context specific) is what makes tacit knowledge different from scientific knowledge (Collins, 1974:167). In fact Michael Polanyi's original conception of tacit knowledge is experiential and cognitive (Gertler, 2003:89). It is experiential in the sense that it is seen as an acquisition of "know how" through experience. It is cognitive because it is not easy to articulate consciously and we may not be aware of it or the way it influences our behavior. Nevertheless Gertler (2003: 95) stresses that Polanyi's conception of tacit knowledge does not devote sufficient attention to the role of origins and social context. According to him, we need to consider more carefully how tacit knowledge and context is produced before we can say anything intelligent about the conditions under which tacit knowledge can readily be shared. Edwards (2010:19) follows Gertler's insight when he states that:

> Get rid of the infrastructure and you are left with claims that you can't back up, facts you can't verify, comprehension that you can't

> share and data you can't trust. Without infrastructure knowledge can decay or even disappear. Build up a knowledge infrastructure, maintain it well, and you get stable, reliable, widely shared understanding.

As a result, tacit knowledge in places where there is weak or no infrastructures, may end up being seen as mere claims. But it is generally held that tacit knowledge can only be shared by two or more people having in common the same social context, namely share values, language and culture (Gertler, 2003:78). Since a "claim" is devoid of proof, only some part of the regime of "claims" can be seen as a manifestation of tacit knowledge among people living in a given locality because of being outside the reach of infrastructure, or other forms of societal influences given that they share values, culture, or language to name but a few things. Therefore tacit knowledge being cognitive, the inherent heterogeneity of the natural environment could be seen as a relatively "stable" base from which it emerges.

Considering the natural or the built environment as a heterogeneous source of knowledge is somehow acknowledging a pre-modern or space syntax conception of the world and departing from a version of a constructionist framework which celebrates human beings as the only meaning maker (Crist, 2004:9; Kitchin and Blades, 2002:6;). For example, Brown (2009: 220-228) notes that if human beings were pure minds living in a non-physical world with no discrete objects, it would be probably impossible to discover or invent any mathematics. For this author, some perspectives in science studies failed to account for the universality of mathematics by not being able to provide a system or a body of theorem in the discipline that we now regard as totally false. Brown's viewpoint in relation to the making of mathematical knowledge is reinforced by Feldhay (2000:53) through his analysis the *Dissertatio Physico-mathematica de motu terrae of* Paulus Guldin, in which he argues that Guldin's techniques contain a conceptual

framework that implies new options for interpreting mathematical entities and their relation to physical reality.

The relationship between the physical world and mathematics reflect the assumption that there is an isomorphism between the two (Crump, 1990:8). This isomorphism does not confer on mathematics a form of universality regarded as a uniformity of processes of discovery and invention but as similarities in resulting conclusions. What eventuates from these similarities is what is common in the natural environment, what it has as different (both in terms of content and properties) dependent heavily on infrastructure and differentiated processes of invention and discovery. The relationship between classical mathematics and intuitionism epitomises the above inference. In fact the goal of intuitionism has been so far to rebuild mathematics from the ground up while avoiding what is considered as an illegitimate method and assumptions. It only rejects classical theorems if they cannot be proven in its own framework. What can be proven in an intuitionist framework, can also be proven in more orthodox mathematics, but the reverse is not true. Nelson (2012:18) notes that intuitionism is an extension of classical mathematics, meaning that to explain it in terms of logical constants it is not viable. Consequently intuitionists negate the fact that the physical environment is endowed with a form of cognition and just like constructionists they give a priority to human mind as the only meaning maker (Snapper, 1979:210-211). The narrow explanatory power of intuitionism denotes a crisis of trust in the field of mathematics and suggests that mathematics itself is not deterministic but the priority which is given to certain technique over another is likely to be. Nevertheless intuitionism is particularly appreciated in the design of algorithm and computer programs whose significance in the research of C.S. Holling became increasingly visible in the 1970s.

Conclusion

The projection of the authority of the Canadian federal government over its territory relied on scientific expertise and enhanced the development of some scientific disciplines having the forest or some of its components (insects or trees) as objects of their studies along the way. For instance, Perry (1998:438) argues that despite some shortcomings on the part of both foresters and the public, forestry took root in North America following World War II, and by the 1950s was firmly grounded on both industrial and public lands. Of particular relevance in Ontario, was the rise of concerted studies in forest resources inventory and productivity (Uhlig, 2012:10).

Over the years, with the continual effort of a variety of institutions and people such as the Sault Ste Marie Laboratory, the Canadian Minister of Agriculture or the pulp and paper industry, Canada established itself as a world leader in the biological control of forest insect pests using parasitoids (Smith, 1993: 52). While these kinds of achievements are often credited to humans only, a closer look at Holling's research in the 1950s suggests at first glance that the spaces where they originate are not reduced to a single type and their roles are not uniform. In fact from the insect outbreaks in plantations to the construction of laboratories like the one at Sault Ste Marie, Ontario, the spaces through which a research inquiry acquired its frame bear the hallmarks of the multiple engagements (tacit and explicit) which form the experience of a researcher. That is to say that Holling's initial research is neither the outcome of its sole volition nor it is reduced to human related-influences. Rather the North American boreal forest participates dialectically in the ways in which Holling's research is constituted through the availability of its knowledge object (European pine sawfly, *Neodiprion Sertifer*), the fieldwork (southwestern Ontario), the laboratory's experiments and data (at Sault Ste Marie), or the federal government's policies (The *Destructive Pest Act*). In a nutshell this is what the first part of this chapter

of individuals, discourses and artefacts; and the different kind of carriers of knowledge are never equally distributed in space.

6. The epistemic culture grounding of C.S Hollings' research from 1960s to 1970s

Introduction

In the preceding chapter, the meanings of the terms "nature" and "culture" as well as the relationships between them, have been problematised around the notion of laboratory, salient in Holling's graduate studies and career as a researcher in Canada. With a PhD in forest entomology in 1957, and years of work experience for the Canadian Department of Forestry from 1952 till 1967, Holling's research is engrained in the tradition of economic entomology- the science of insect pest control in agriculture and forestry set by the Canadian federal Department of Agriculture. In effect Glen (1961: ix) remarks that biological control work was initiated in Canada by pioneering amateur entomologists such as Dr. William Saunders, the first director of the Dominion Experimental Farms who imported *Trichogramma mimilltm* Riley from New York State for liberation in Ontario gardens against the imported currantworm, *Nermatus ribesiss* (Scop.); and James Fletcher, a parliamentary clerk and the first Dominion Entomologist who made a considerable number of introductions of parasites and disease organisms during his stewardship from 1884 to 1908. So, according to Glen, the basic concepts and the tradition of biological control were well established before the arrival of C.G. Hewitt, the second Dominion Entomologist who supported the method fervently and created Canada's first professional entomological service in 1909.

The contribution of Hewitt in the development of economic entomology is particularly important, to make sense of the ways in which Holling's thinking

evolved so as to extend its disciplinary space[25] between the 1960s and 1970s. In effect, following Hewitt's leadership, the entomological service, which was focused previously on the mere dissemination of knowledge, modified its mission dramatically. Through the *Destructive Pest Act*, Hewitt increased the number of researchers and created twelve regional laboratories to conduct research on biological, chemical and cultural methods of insect pest control (Castonguay, 2004:18-25). These changes are part of what Castonguay (2004) calls the *fondamentalisation of* economic entomology which happened between 1884 and 1959. Such a *fondamentalisation* blurs the line between basic and applied research and integrates some elements of ecology, physiology and system analysis to fashion the specificity of "economic entomology". Concretely, it is a process which entails that:

> Les chercheurs élargissent et systématisent la base cognitive d'une science appliquée pour guider l'application de leurs connaissances et, à terme, atteindre les visées pratiques de leur domaine. En entomologie économique, la protection des cultures et de la forêt demeure le principal objectif de la recherche, mais plutôt que d'atteindre cet objectif uniquement par la mise à l'essai de differentes mesures de contrôle, les entomologistes s'engagent dans une recherche fondée sur la physiologie et l'écologie expérimentales pour comprendre les phénomènes régissant les populations d'insectes et affectant l'éfficacité des interventions pour controler les infestations (Castonguay, 2004:17).

25 According to Bocking (2007:86), a disciplinary space is "the territory in which the concepts and methods particular to a discipline are considered authoritative and relevant. Just as the dissemination of a scientific theory or method from its point of origin is not simply the consequence of its inherent virtues, a disciplinary space must be asserted. It is thus the physical manifestation of scientists' efforts to convince others-other scientists, or those in position to apply their results that the methods and conclusions of their discipline are locally reliable."

> Researchers expand systematize the cognitive basis of an applied science to guide the application of their knowledge and eventually, reach the practical aims of their field. Economic entomology, crop and forest protection remains the main objective of the research, but rather than achieve this only by the testing of various control measures, entomologists engage in experimental physiology and ecology-based research to understand the phenomena regulating insect populations and affecting the effectiveness of interventions for controlling infestations (Castonguay, 2004:17).

This chapter provides an account of the interplays between the development of economic entomology, nature and society in North America. It anticipates also what the *fondamentalisation* of economic entomology entailed for Holling to become one of the first ecologists to recognise the connection between ecological and social systems (University of Vancouver Island, 2015). So, in two sections below, the epistemic culture[26] upon which the research of Holling was grounded from 1960s to 1970s is explored although the research itself is substantially examined in the next chapter. In this respect, it is firstly shown how the "modern environmental consciousness" in New Brunswick emerged along the line of the increasing importance of environmental concerns in North American cities due to the environmental costs of industrialisation, and how the earlier discourse around forest regeneration in Toronto was carried forward into the North American cities movement of the 1960s. Secondly, the implications of such social dynamics for the development of scientific research are illustrated through the importance of systems analysis during that era, and its place in the then emerging field of urban studies. The ways in which it intersected with the disciplinary lineage of ecology and biology are briefly reviewed.

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26 According to Cetina (2007:363), the epistemic culture "refers to those sets of practices, arrangements and mechanisms bound together by necessity, affinity and historical coincidence which, in a given area of professional expertise, make up how we know what we know."

6.1. The spread of environmental concerns in North America

The forest regeneration programs in New Brunswick came after the realisation that forests are not an inexhaustible resource. The spread of environmental concerns that followed such a realisation shows clearly that neither the development of a scientific discipline is insulated from social dynamics (6.1.1) nor are the forests and the urban context entirely separated (6.1.2).

6.1.1. The rise of "environmental consciousness" in New Brunswick

The emergence of economic entomology in Canada benefited from scientific cooperation with the United States and a number of European countries. The experiences of those countries in relation to the scientific disciplines supporting or denouncing the exploitation of forests are a vantage point to understand the rise of "environmental consciousness" in New Brunswick. For example the constitution of forestry highlights the tensions between the rhetorical and material productions of spaces and their social, economic, political and ecological consequences. In fact, forestry as a scientific discipline has its origin linked with the response to the execrable condition of Europe's remaining forests and impending wood scarcity during the latter eighteenth and early nineteenth centuries (Perry, 1998:437). In the North American boreal forest, economic activities depending on forest products and the responses to the spruce budworm "outbreak", had a profound impact on the development of the discipline. For example, Langston (2000:32) reports that:

> When Euro-Americans first came to the Blue Mountains of eastern Oregon and Washington in the early 19th century, they found a land of open forests with ponderosa pines 5 feet in diameter. These forests were so promising that people thought they had stumbled into paradise (Langston 1995). But a century later, that paradise was

> irrevocably lost. The stately ponderosa pines were gone, and in their place were thickets of fir and lodgepole. The ponderosa pines had resisted most insect attacks, but the trees that replaced them were the favored hosts for defoliating insects, such as spruce budworm and Douglas-fir tussocks moth. As firs invaded, insect epidemics swept the dry western forests.

The above story is not restricted to the Blue Mountains of eastern Oregon and Washington. In fact, over the years, the spruce budworm became the most thoroughly examined insects that defoliate trees in North American boreal forest throughout the United States and Canada (Rauchfuss and Ziegler, 2011). Depending on how it is considered, it has both a symbiotic relationship with the forest and a conflicted one with humans. If it is acknowledged that its relationship to the forest is older than the one that characterised the human-forest relationship in Europe during the latter eighteenth and early nineteenth centuries, the spruce budworm nonetheless competes with humans with regard to the economic benefits that the forest can provide (Holling *et al,* 1975. Figure 5). For example, Holling et al (1975:1) reports that in any one "outbreak cycle" a huge quantity of softwood in contaminated area can perish, with important consequences to the economy and employment of regions like New Brunswick, which is highly dependent of the forest industry. Retrospectively, Rauchfuss and Ziegler (2011:564) provide a more balanced account of this kind of event:

> Spruce budworm often is referred to as a pest, and from a human and economic vantage point that description is appropriate. Berryman (1987, 3) defined an outbreak of a pest species as "an increase in the population of an organism that has a deleterious influence on human survival and well-being." From an ecological perspective, however, spruce budworm might benefit the ecosystem by keeping primary production at an optimal level (Mattson and Addy 1975). An outbreak observed from this ecological view point

can be defined as 'an explosive increase in the abundance of particular species that occur over a relatively short period of time" [Berryman (1987, 3)]. Forest composition seldom changes after an outbreak of spruce budworm even if the outbreak kills the trees (Blais 1985; James et al. 2010; Nealis and Regnière 2004), and carbon is stored in the regenerating spruce-fir forest.

The composition of the forest had been also affected by economic activities engaging the forest to the extent that they create favourable conditions for the occurrence of spruce budworm outbreak. New Brunswick epitomises this course of events.

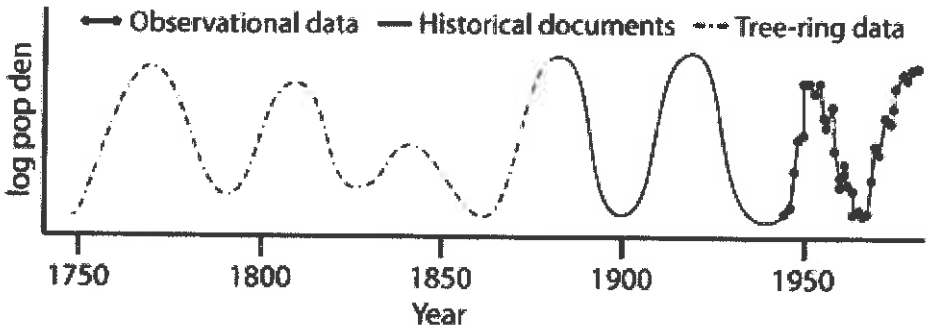


Figure 5. Multiple data sources can be combined to extend the spruce budworm outbreak reconstruction back in time. In this example, the log of the population density (log pop den on the y-axis) of observational data since 1945, historical records since 1878, and tree-ring data since 1750 are combined to make one 250-year reconstruction of spruce budworm for northern New Brunswick. (Redrawn from Royama 1984). Reproduced from Ecological Monographs with the permission of the ECOLOGICAL SOCIETY OF AMERICA). Source: Rauchfuss and Ziegler (2011).

New Brunswick played a precursor role in the development of industrial forest methodology in Canada (see Sandberg and Clancy, 2002:167). This role stems from an economic transition and forests recomposition. In the aftermath of the collapse of its lumber industry in the 1920s and the short depression in 1921, this

staples-dependent hinterland of Canada attempted to compensate its loss by investing massively in the pulp and paper industry (Rashid, 2003). These investments included the facilitation of companies to crown land and providing them water concessions. This government assistance arrived at a moment when the poor condition of the forest already presented some opportunity for the pulp and paper industry. Since the forests of New Brunswick were already depleted of quality timber, the lack of large trees put the lumber industry at a disadvantage and the remaining small trees were just adequate for the pulp and paper industry to survive because its productivity was based less on the size of the trees than it was in relying on wholesale volume (Rashid, 2003). The overexploitation of the spruce in the dawn of the twentieth century led to a disproportionate colonisation of the vacuum left in the forest by basalm fir. The beginning of the 1920s saw the emergence of the basalm fir as a profitable species for the economy following a major spruce budworm outbreak. By the 1930s, the pulp and paper industry had depleted the black spruce in the forest and the economic value of basalm fir rose accordingly. The increasing amount of basalm fir in the forest converged with the symbiotic relationship between the spruce budworm and the forest, increased the likelihood of another outbreak while the deepening of the dependence of the pulp and wood industry on this species reinforced this concern (Rashid, 2003). For instance, Rauchfuss and Ziegler (2011:567) reports that:

> Sanders (1991) and others have suggested that spruce budworm has co-evolved with its main host species as shown by evidence from, for example, studies of foliar chemistry (Mattson et al. 1983) and spruce remains in the soils (Simard et al, 2002). Balsam fir "sacrifices" older trees so that the resistant younger trees regenerate. Older spruce trees, on the other hand, survive because they provide more foliage than the spruce budworms need (Matton 1985) or because their budbreak is later (Fleming et al. 2002).

There is a parallel between the distinct manner in which both the pulp and paper industry and the spruce budworm co-evolved with the recomposition of forest which is further elaborated in chapter VII in the light of the refinement of the resilience concept. Due to its critical dependence on the "main host species" of the budworm, the industry justified the intense management of the population of this insect along with a depiction of the budworm as a competitor or as an enemy of this important sector of the New Brunswick economy (Rashid, 2003). This management took the form of a spraying program of the spruce budworm which started in 1952 as a short-term containment strategy and became over the years a necessity for the survival of the industry. Sandberg and Clancy (2002:167) note that the spraying program became an annual fixture:

> At full stretch, between 1952 and 1984, the annual coverage ranged from one million to almost 4 million hectares (APEC, 1993), with an all-time peak in 1976 when 3,880,000 hectares were treated. This declined sharply, to the point that only 250,000 hectares were sprayed in 1992 and 90,000 in 1993. This decline was due less to a change in management policy than to the decline in the incidences of spruce budworm in the province.

Consequently, the spraying program became enmeshed in intense debates about what counts as science, the role of science and values in the management of forests (Rashid, 2003; Langston, 2000; Sandberg and Clancy, 2002). For McLaughlin (2011:2), this so called "Battle of the Budworm", one of the largest and longest aerial insecticide programmes in the world was the primary cause of the emergence of modern environmentalism in New Brunswick. According to this author, the sportsmen's organisations were the first groups to protest and their main concern was the conservation of their most valuable game fish (the Atlantic salmon). With the contribution of ecological science into the debates, New

Brunswickers' discomfort about the spraying program grew in the late 1950s and 1960s to incorporate concerns about the effects of the spray on general forest and water ecologies. For McLaughlin (2011), similarly to other regions, the "environmental consciousness" in this province rose partly because of the effort of members' of New Brunswick's scientific and technical community such as scientists associated with the Fisheries Research Board of Canada marine research station in St. Andrews as well as a number of Scientists affiliated with the University of New Brunswick. However Demeritt (1998:185) observes that: "[F]oresters struggling with insect infestations have learned from long experience that they are not free to behave towards the forest in any way they choose. Other actors matter too. This realisation was crucial in the recent development of new forestry and its concerns..." Besides the protests against the spraying program in New Brunswick was a major factor in the establishment of the Conservation Council of New Brunswick in October 1969, the first environmental organisation in the province and one of the first such in Canada (McLaughlin,2011).

6.1.2. Forest regeneration and the "Spadina controversy" in Ontario

Radford (2011:1) writes: [I]f you choose one text by one person as the cornerstone of the conservation movement, the signal for politically savvy environmental activism, and beacon of the worldwide lay awareness of ecological systems, *Silent Spring* would be most people's choice." In fact, *Silent Spring* by Rachel Carson, a hallmark study on pesticides and their impact on the environment published on June 4, 1963, included a section on the spraying program in New Brunswick (Sandberg and Clancy, 2002). In that piece of work, Carson argues that pesticides, especially DDT, are not only killing bugs but target the food chain, threaten birds and fish populations, and could eventually sicken children (Griswold, 2012:1). Rashid (2003) amplifies Carson' argument about the spraying program in New Brunswick. Yet as it appears in Carson's work, the

"modern environmental consciousness" was stretched out beyond this province of Canada in the 1960s.

Mclaughin (2011) argues that in the years following World War II, "modern environmental consciousness" emerged out the confluence of three factors. The first concerns the legacy of the ideologies of conservation and preservation in their capacity to set a fertile ground for the development of environmentalism in the post-war period. While these two ideologies established themselves as intellectual movements in the late 19th and 20th centuries, they remain different in their approach to the human-nature relationship. The utilitarian understanding of conservationists prioritised a wise use of natural resources to facilitate their continued sustainable use by forthcoming generations.

Preservationists were guarding the "wilderness" and any other natural areas less influenced by humans, as such they believed that mental and spiritual wellbeing depended on regular connection between individuals and those protected areas. The second factor suggests a growing attention at the local, national, and global levels on issues related to "wartime technologies that became Cold War era dangers", such as chemical poisoning, radioactive fallout from atomic weapons; or problems that were connected to North America's post war industrial boom such as deforestation and water pollution (Mclaughin,2011:2). Finally, there was the impact of the post-war scientific and technical community, especially the gradual prominence of ecology as a distinct scientific discipline from the 1950s and 1970s. Among these three factors, Carson's *Silent Spring* is widely recognised for igniting the global environmental movement but the extent to which it did that is still a matter of debate. Accordingly, Lorus and Milne (1962:3) argue that "Silent Spring is so one-sided that it encourages argument, although little can be done to refute Miss Carson's carefully documented statements. Valiant attempts will certainly be made to defend the motives and methods of biocide users". However, for Griswold (2012:5) it remains that "Carson's was one of several

moral calls to arms published at the start of 60s." Among such voices, there was Jane Jacobs who participated as a "concerned citizen" and through her book *Death and Life of American Cities*, in the articulation of an alternative vision for cities in North America and in Ontario in particular (Barc, 2010).

Hartman (1999:177-180) argues that the concept of "Fordist urbanisation[27]" illustrate adequately the economic and spatial transformation that took place in the Toronto area just after the World War II. With the support of the Canadian state at all levels of government, this process entailed change in the landscape of Metropolitan Toronto as wetlands, forest, meadows, agricultural lands, and small towns were becoming new urban spaces organised to enhance the Fordist-style of mass production and mass consumption. By the 1970s and 1980s, many aspects of this Fordist-style of suburbanisation went hand in hand with ecological degradation as land surrounding Metro Toronto underwent development (Hartman, 1999). For example, Marshall (2009:1) argues that the construction of highways and expressways (and the non-construction of planned expressways) influenced land use significantly. In this regard, she notes that:

> There have been roughly three stages in the construction of expressways in Toronto area: the first, lasting from the 1930s to the early 1950s saw the construction of inter-city provincial expressways which terminated well short of downtown Toronto. A second stage lasting from the early 1950s to the 1970s, was a rapid growth of urban expressways, built by the province, and the new Metropolitan Toronto government with plans for many expressways that died (thankfully!) on the drawing board in the 1960s and 1970s. The third

27 Hartman (1999:177) notes that: "The major feature of a Fordist city "is a profound transformation in transportation systems and the use of space" (Filion, 1995:48). Production facilities moved out of the cities to new spaces which allowed the development of large assembly-line facilities. Workers wanting to be closer to their jobs moved out of these new suburban locations and lived in new suburban housing".

> stage, lasting from mid 1970s to the present, is the construction of suburban and bypass freeways in Southern Ontario, primarily by the province. All but one of the Metropolitan Toronto expressway projects left either their ghost or scaled-down versions of the full plan.

The construction of highways and expressways denotes also the growth of the automobile industry in Ontario. In effect, with the changes regarding a gradual economic liberalisation in international trade and an increasing North American economic integration especially in the manufacturing sector, Ontario benefited from the Canada-United States Automotive Products Agreement ("Auto Pact") (Di Matteo, 2014:7). This agreement reorganised Ontario's automobile industry on a continental basis in the late 1960s by removing tariffs on motor vehicles as well as automotive parts between the two countries and at the same time boosting its manufacturing sector (Wolfe and Gertler, 1999:10). However these changes were neither limited to Ontario nor to the sole economic aspect of Canadian society. Thus Drummond (2006: 5) notes that:

> In Quebec and in Ontario, as elsewhere in Canada, urbanization and industrialization were assisted by the thrift and diligence of the population, whose members were also willing to borrow funds and skills from abroad and, at least until the 1970s, to receive immigrants during times of prosperity. Educational arrangements helped, first by providing for general literacy; next, by arranging for higher liberal and professional education; and then, starting in the 1970s, by offering various sorts of specialized secondary and tertiary technological studies in, for example engineering and agriculture.

Sweeney (2009:56) stresses that in 1962, the *Crown Timber Act* was revised, and the Ontario Departments of Lands and Forests was put in charge of the regeneration of forests on Crown lands, whereas forest product firms maintained responsibility for management and planning. According to this author, stumpages revenues served as a source of funding for regeneration while the

rationale for this split sought to enable logging to develop along economic lines and forest regeneration along biological ones. This way of proceeding provided immediate results when, in 1964, over forty million trees were planted on Crown land, a huge success at the time. The forest generation, in public hands between1962-1979, was also marked by the mechanisation of forest products firms. By the end of 1960s, OMNR policy attempted explicitly to recruit local women, post-secondary students, and First Nations employees as a way to expand tree planting programs. Sweeney captures the profile of this workforce and the underlying tensions pertaining to its formation:

> Post-secondary student tree planters were common in 1960s, and became the dominant labour pool in the late 1970s, when private contractors emerged. The use of students created two more axes of difference between tree planters and permanent residents of northern Ontario. First, post-secondary students were most often from affluent middle-class backgrounds, as opposed to the working-class background of residents in regions dependent on resource-based industries. Second, and possibly more importantly, student tree planters hailed from southern Ontario, and are perceived as "other" by northern Ontarians and readily accepted as equals. Additionally, the tensions between the formal level of education held by student tree planters and the sentiments of anti-intellectualism that abound in the occupational communities of permanent forestry workers exacerbated stigmatization and marginalization. However, student tree planters are marginalized in a manner far different than the local women, First Nations, and prisoners previously used in Ontario, or the migrant Latinos used throughout the United States (Sweeney, 2009:58).

Moreover, Ackoff and Gharajedaghi (1996) argue that the "children of the post-World War II workforce" constituted a permissive generation subject to be treated as nothing more than "purposeful entities". According to these scholars, the fact that they mistakenly expected their interests to be protected by their

employers led to them being alienated from work and diminished their productivity. So by the end of the 1960s , it became evident that the West was going through both a rapid rate of change because of technological developments and increasing complexity caused by an explosion of interconnections resulting from continuously improving transportation and communication. Consequently, the socio-economic climate started experiencing significant perturbations, predictability of the future decreased considerably, and the only equilibrium that could be obtained was dynamic. In this context Ackoff and Gharajedaghi add that employees could perform theirs tasks better than their employers, but only on condition that they were granted the freedom to do so. As a result "the mechanistic and organismic concept of management as command and control, or even softer supervision, became less and less appropriate" (Ackoff and Gharajedaghi, 1996:20). These changes are well illustrated by the unfolding of events marking "the most contentious urban development disputes in Canadian history" which ended in the decision of Ontario's Premier Bill Davids's to cancel the Spadina Express-way in June 1971 (Robinson, 2011:296).

The Spadina Expressway was part of the second stage of a series of planned highway routes which according to Barc (2010) was supposed to include the Highway 400 extension, Scarborough, and the Crosstown, all of them culminating in the inner city. The construction of the Spadina Expressway would have meant also the demolition of nearly a thousand houses and the construction of parking lots in replacement (Barc, 2010). Eventually, what was at stake in the construction of this Expressway unfolded into the so called "Spadina controversy". According to Robinson (2011), the Spadina controversy was submerged into a broader movement that affected American and Canadian Cities in the 1960s and 1970s. Through this movement, urban dwellers objected to the postwar "auto-centric planning" that was seeking to support and promote

economic growth; and they articulated an alternative vision for cities having as paramount objectives, safeguarding the urban environment by preserving communities, preventing environmental degradation, and encouraging public transit. Of particular note in Ontario was the increasing number of people who started questioning their political representatives and who no longer considered the expertise of planners as impartial. Robinson (2011) notes that among these people, many were university-educated "baby boomers" shaped by the rise of student radicalism that participated in the definition of the institutional culture of that era. And the main sources of funding of prominent organisations such as "Stop Spadina Save Our City" were coming from "concerned middle" class people including academics, professionals, ratepayers, teachers, etc... and "very generous students" (Robinson, 2011: 296).

The financial support provided by students organisations to the city movement against the Spadina express-way correlates with the fact that from being a marginal segment of the workforce at the beginning of the forest regeneration program, students became a significant portion of tree planters by the 1970s and onward. Besides, the profile of the students' workforce in forest regeneration matches well with the "concerned middle class people" promoting an alternative vision for cities. These correlations become more than mere coincidences when Robinson locates (2011:313) the overall Spadina controversy within the broader debate about what constitutes progress in a city where the automobile industry was on the rise and the forest was being significantly damaged:

> The expressway debates were not about fighting for or against progress; rather, they were over what constituted progress. Pro-Spadina advocates, such as Businessmen's Leagues against Spadina Termination (BLAST) member R.M. Wilcox, argued that transportation systems must promote urban and suburban growth. In his view, the Spadina region needed a makeover to enable modern high-rise apartments and office buildings to replace out-dated and

> run-down stores and homes. Anti-expressway protestors vehemently rejected the notion that expressways were progressive, instead insisting corporate-driven auto-centric growth" destroy[ed] the majority for the betterment (short term only) of the wealthy, powerful minority. Politicians meanwhile were as divided as their constituents

However this broader debate on progress benefited from certain developments in ecological classifications. Both the debate on progress and the developments in ecology fall within a Triple Helix model of knowledge production encompassing a university-government-industry collaboration. In effect Uhlig (2012:12) observed that right at the start of the 1970s, there was a rapid development of regionally focused ecosystem classifications, beginning in the Clay Belt portions of northeastern Ontario and progressing across northwestern, northcentral and central Ontario. According to him the very significant thirst for sound ecological information to enhance forest management practices, wetland and wildlife habitat interpretations, and protect important systems such as old growth, expanded beyond the initial domain of forests and also extended to the investigation of wetlands. These new developments in ecology enhanced the growing influence of the "new environmental movement" whose several successes were attributed to *Silent Spring*, range from the Clean Air and Water Acts to the establishment of Earth Day to President Nixon's founding of the Environmental Protection Agency in 1970 (Griswold, 2012:9). As a result, both the management of forests in particular, and the practice of management in general, became subject to debates and adjustment:

> The functions of management became one of enabling and motivating subordinates to do as well as they know how, to develop them so they can do better in the future than the best they can do now, to manage the interactions, not actions, and managed with other internal and external organizations. This can only be done with a social systemic model in mind (Ackoff and Gharajedaghi, 1996:20)

The published work of Holling in the 1960s and 1970s is informed by this necessity to move away from a management approach based on control and command to another more attuned to practical challenges in science and policy primarily related to North American boreal forest-(which I discuss further in chapter 7). Meanwhile I suggest that such a view is crystalised in "Resilience and Stability of Ecosystems", when Holling (1973:21) writes that:

> The resilience and stability viewpoints of the behavior of ecological systems can yield very different approaches to the management of resources. The stability view emphasizes the equilibrium, the maintenance of a predictable world, and the harvesting of nature's excess production with as little fluctuation as possible. The resilience view emphasizes domains of attraction and the need for persistence. But extinction is not purely a random event; it results from the interaction of random events with those deterministic forces that define the shape, size, and characteristics of the domain of attraction. The very approach, therefore, that assures a stable maximun sustained yield of a renewable resource might so change these deterministic conditions that the resilience is lost or reduced so that a chance and rare event that previously could be absorbed can trigger a sudden dramatic change and loss of structural integrity of the system.

The above issues around ecology and society in Canada show that Holling's research at least from 1960s and 1970s was initially situated within a Triple Helix model of knowledge production. In fact from 1952 to 1964, Holling's research is a formal expression of Sault Sainte Marie laboratory's mission because he and some other researchers recruited in the laboratory between 1950 and 1959, were trained to identify research problems, interpret results, and diffuse knowledge from within an international scientific community (Castonguay, 2001: 40). This mission- as indicated further in chapter 7 reflected the fondamentalisation of economic entomology and the broader social dynamics surrounding the articulation of Holling's thinking between 1960s and 1970s.

6.2. Expansion of disciplinary space of economic entomology into urban studies and ecology.

The *fondamentalisation* of economic entomology materialised the possibility to expand its disciplinary space by adding up elements originating from different disciplines. In the light of the emergence of "Urban Studies", and the empiricism which is part of this process, shows how a system approach provides the methods to construct its extended disciplinary space (6.2.1). Besides a common disciplinary lineage between ecology and biology illustrates well how their pre-existing links allowed or facilitated this kind of expansion (6.2.2).

6.2.1. Reliance on system analysis and the rise of urban studies

The *pensée empirique* (logic of practice) at the core of the *fondamentalisation* of economic entomology is systemic because "[O]bserved phenomena in the natural and human-made universe do not come in neat disciplinary packages labeled scientific, humanistic, and transcendental" (see Barthélemy, 2005; Laszlo and Krippner, 1998:4). But to figure out the extent to which it can be so, requires a general knowledge of what system analysis is about. To evaluate the modern "systems approach", Bertalanffly (1972:407) suggests that, it is advisable to consider that the systems idea is not an ephemeral trend or recent technique, but a way of thinking as old as European philosophy. Bertalanffly's philosophy and its descendant, science, came into being when the early Greeks learned to grasp or examine in the experienced world, an order or "komos" which was intelligible and, therefore controllable by thought and rational action. A version of this cosmic order appears in Aristotle's statement: "[T]he whole is more than the sum of its parts." In fact Aristotle made the distinction between two types of

causes, meaning efficient and final (Rapoport, 1968:452). According to Rapoport, metaphorically speaking, efficient causes can be seen as a "push from behind" whereas final causes are considered as a "beckon from ahead". That is to say that, an efficient cause of an event B is considered to be an event A, which comes before B. That is, B happens because A occurred. B is conceived as final cause of A if A happens with the purpose to trigger the occurrence of B. From this interpretation, B is regarded as a goal "pursued" by some agency, and A as a way to reach that goal (make it happen). Therefore, Rapoport adds that "final" causes imply goals, and these, in turn, are usually associated with actions of sentient beings. But Aristotelian teleology was suppressed from the later development of Western science while the basic system problems in his statement such as the order and goal-directness of living systems were negated and by-passed, rather than solved. Hence Bertalanffly (1972:408) argues that the basic system was still relevant and he insisted that:

> The problems with which we are nowadays concerned under the term "systems" were not born yesterday" out of current questions of mathematics, science, and technology. Rather, they are contemporary expressions of perennial problems which have been recognized for centuries and discussed in the language available at the time.

For instance, Quade (1963:1-7) argued that systems analysis seeks to suggest a course of action by systematically examining- the objectives, cost, effectiveness, and risks of alternative policies or strategies- and designing additional ones if those examined are found wanting. It is also a way of addressing complex problems of choice under uncertainty. While it was initially developed to address long-range military problems, it was also used extensively by managers and engineers of large corporations such as telephone companies and manufacturers of electric power. Quade noted that the name of this analysis is not derived from the systematic approach underlying it, rather it is associated with the subject

matter at the time of its inception. In fact the first post-World War II "militaries studies" were mostly concerned with weapons systems. As such, assessments to allow a decision maker to choose among systems to find out whether a particular system could reach the desired objectives or set up a framework within which tests of the system could be prepared was eventually called "systems analysis". It follows then that the objectives of systems analysis as well as the analysis of operations research attempted to primarily recommend policy or provide some form of guidance, rather than merely understand and predict. Therefore Quade points out that systems analysis appear to be nearer "engineering" rather than "science".

However systems analysis as it has been initiated in "military studies" in post-World War II followed "general systems theory". Ludwig Von Bertalanffly's (1901-1972) theory, was the first to formulate the notion of general systems orally in the 1930s and in various publications in post- World War II (Bertalanffly, 1972). In fact, general systems theory took its shape in interwar studies. Then, it went on to find a friendly reception in the Anglo-American hemisphere, where there was some debate with partly, independent, partly, overlapping, and developments in operations research, engineering science, management science and cybernetics, all of which had some ties with the United States think tank, the Rand Corporation (Davidson 1983, Hammond, 2003). Yet, for Bertalanffly, the roots of general systems theory are to be found in the research undertaken before him in the field of (mathematical) biology:

> The proposal of general systems theory had precursors as well as independent simultaneous promoters. Mohler came near to generalizing gestalt theory into general system theory. Lokta did not use the term "general systems theory", his discussion of systems of simultaneous differential equations remained basic for subsequent "dynamical" systems theory. Volterra's equations, originally developed for the competition of species, are applicable to

> generalized kinetics and dynamics. Ashy, in his early work, independently used the same systems equations as von Bertalanffy employed, although deriving different sequences (Bertalanffly, 1972:411).

The term "general systems theory" resonates with Bertalanffly's criticism of the teleological approach to biological phenomena. This approach was epitomised by a school of thought associated with the so called "vitalists" (Rapoport, 1968). Vitalists put the emphasis on "final" causes in their explanatory framework of biological processes. In contrast, Bertalanffy argued that, the principle of equifinality associated with teleology "was manifested in a class of systems more general than biological ones namely, "open systems" (Rapoport, 1968:463). That is to say, equifinality characterises the behavior of biological systems because they are open rather than because they are living beings "pursuing goals" characteristic of their type." In fact, Bertalanffy tried to fill the gap between the controversial theoretical approaches to biology in his time; that is mechanism and vitalism. Mechanism was the method that tried to limit life phenomena within the explanatory context suggested by physics, while vitalism was informed by the belief that that which transcends being is rendered intelligible by physics was something metaphysical i.e. formulated laws of organisation ruling biota as well as ordered entities. In doing so, he tried to bring together insightful aspects of both views in a third perspective called "organismic". This perspective inherited the notion of wholeness from vitalism by fundamentally admitting the relative autonomy of the living world. Therefore, it objected to the neo-positivist notion of a mechanistic generation of form in organisms and the possibility of a total reduction of life to physic-chemical processes. Besides the organismic perspective defended a mechanistic critique toward vitalism's notion of super-material, transcendent entelechy (Bertalanffly, 1972).

For Rapoport (1968) general systems theory is a theme in the philosophy of science dealing with the recognition of parallel approaches or methods in different disciplines, which are not widely accepted as related because of the growing specialised jargons. Rapoport's definition of general systems theory equates to what Boulding (1956) sees as its objective. According to Boulding, general systems theory is a name which serves to describe a level of theoretical model-building which lies somewhere between the highly generalised constructions of pure mathematics and the particular theories of the specialised disciplines. In this sense, "[M]athematics attempts to organise highly general relationships into a coherent system, a system however which does not have any necessary connections with the "real" world around us. It studies all thinkable relationships abstracted from any concrete situation or body of knowledge" Boulding (1956:129).

In addition, Arckoff (1971:661) notes that the concept "system" played a critical role in the post- World War II scientific developments and both its definitions and applications are varied. Nevertheless in a move toward the systematisation of systems concepts, this scholar puts forward that:

> The systems approach to problems focuses on systems taken as a whole not their parts taken separately. Such an approach is concerned with total-system performance even when change in only one or a few of its parts is contemplated because there are some properties of systems that can only be treated adequately from a holistic point of view. These properties derive from the *relationships* between parts of the systems: how the parts interact and fit together.

Ackoff and Gharajedaghi (1996:14-17) recognised that there are different systems as well as different manners of representing (modelling) them. For the sake of investigating the consequences of mismatching systems and their models, they classify three basic systems and models, and a meta-system

encompassing the rest, according to their *purpose* (purpose being a matter of choice). The first one is deterministic which means that neither the parts nor the whole are purposeful (for example automobile). The second one is animated which is to say that the whole is purposeful and the parts are not (for example animals including human beings but not plants). The third one is ecological, it contains the interplay of mechanistic, organismic and social systems, but in contrast to social systems have no purpose of their own. The meta-system is social because both the parts and the whole are purposeful (for example universities or corporations).

Sterman (2002:513) observes that "[T] he most important assumptions of a model are not in the equations, but what's not in them, not in the documentation, but unstated; not in the variables on the computer screen, but in the blank spaces around them." Indeed the "blank space" around the increasing reliance on systems analysis and models in the 1960s and 1970s was at least partly filled with the broader movement that affected American and Canadian Cities in the 1960s and 1970s and saw the rise of the Spadina controversy in Toronto. Richardson and Kurt and Midgley (2007) recall that there were a lot of large scale modelling projects in North American cities in the 1950s and 1960s. According to these authors, the one that seemed to be the most controversial and typical example in the literature were the giant models built especially around California, where council offices recruited consultants to build models of entire cities with no specific purpose in mind. The immense complexity emerging out of those models led to meaningless and unreliable results, and what followed in the 1960s was the extinction of the super model. In fact, according to Richardson et al (2007) , stakeholders began to realise the limits of total rational planning. To illustrate this point, the authors mention a relevant example in operational research (OR) in the UK, which was the planning of Stansted airport in the 1970s. Here, millions of pounds were spent commission

an analysis investigating the best option for constructing a new London airport. But this project ended up being restructured in a way that encompassed the alternative vision of the cities as noted earlier in the case of Toronto:

> They narrowed it down to three options and then said, "This is the one based on all social impact and what you have." Politicians promptly went and said, "Well, that's no good. It doesn't take into account the politics of marginal constituencies, and we'll choose this one instead.|" And this one's regarded in the OR community as being the example of the death of rational planning, which resulting in rational planning coming into disrepute (Kurt and Midgley, 2007:165).

Even so, planning together with urban sociology, geography, economics, governance, environmental studies and housing and neighbourhood development are the seven main subfields of "Urban Studies" in the light of the Bowen *et al* (2010) survey and assessment. In effect the field of Urban Studies took off in the 1960s, amidst the huge economic wealth and prosperity of a growing post-World War II United States' economy juxtaposed against the racial turmoil and social protest which was prevalent in American cities at the time (Bowen *et al,* 2010:201). Its objective was informed by problems such as the Spadina express controversy because it distinguishes itself from traditional academic discipline through a commitment to deal in a straight forward, two-way interplay with the complex realities that shape and determine the urban context. Also, by trying to resist long term trends toward a greater specialisation and compartmentalisation of scientific knowledge, it espouses the goal of general systems theory (see Bowen *et al,* 2010).

According to Gieryn (2006:6), knowledge-claims in Urban Studies like in some other scientific specialities, "gain legitimacy by preserving and drawing on simultaneously and in a complementary way the assumed distinctive virtues of both lab and field". As a result he adds that:

> The city becomes, at once, the object and venue of study-scholars in urban studies who constitute the city both as empirical referent of analysis and the physical site where investigation takes place. For this reason, urban studies a becomes propitious case for exploring the emplacement of scientific claims, and (in particular) the relationships between the place where knowledge comes from and its bid for credibility (Gieryn, 2006:6).

Any meaning of the term "city" suggests some invariant semantic boundaries. But if the city is considered as an empirical referent (semiotic space), then those boundaries become subject to negotiation within the ways in which scholars experience the physicality of what they refer in their narrative. The physicality of city through the endurance of buildings over long periods of time constrains the ways in which investigations take place (see Harris and Smith, 2011). So what is physical about a city is less negotiable than what it may mean. In circumstances where an intent is embedded in the physicality of the city, then urban scholars are more likely to be influenced by that intent than they can shape the city's physicality through their contingent investigations alone. Also the physical site where investigation takes place is not invariant as the endurance of the term city may suggest.

In fact in the material world, there is not only one city, they are cities. So, Ramadier (2004:435) notes that each city is unique due to its own history, distinct natural resources, distinct geography, distinct inhabitants and buildings, to such an extent that one can even postulate that each city is probably a unique society in itself. He adds that cities are objects pertaining to many realities, and because of that, a number of disciplines have focused on city as an object of analysis. This multiplicity of reality is associated with the available quantity of city in the material world since each of them is unique. But as an empirical referent for analysis, the city tends to be standardised regardless of the heterogeneity of its physicality. Such heterogeneity can be responsible for the multiplicity of

reality even in a single city. Thus, what seems to be unique about city in Ramadier's account are in fact the particularities emerging out of the narration of the details of the venue where the investigation takes place.

If each city was truly unique, then the possibility to consider the term city as an empirical referent of analysis could not exist. Since this possibility exists, Ramadier can identify two approaches out of the many interdisciplinary bridges (geography borrowing a number of its models from physics and anthropology, semiology drawing from anthropology and sociology, architecture inspired by biology and psychology etc..) erected to grasp city's phenomena. The first one is grounded on the assumption that the city and its development depend on natural laws, as for instance the gravity models of urban geography. The second one assumes a cultural vision of development. Both approaches seem to belong to contradictory theoretical schools of thought and reify the traditional division between culture and nature, according to Ramadier. In contrast Holling and some of his colleagues close this gap between nature and culture in his articulation of the links between society and ecology in the 1960s with "Stability in Ecological and Social Systems" and 1970s with "Ecology and Planning" and "Toward an Urban Ecology"- in the next chapter, the contents of these papers are examined along a discussion encompassing the strength and weakness of the use of systems analysis in Holling's work.

Published in the mid-1990s, Ackoff and Gharajedaghi (1996:17) observation regarding the application[28] of the various systems (mentioned earlier in this

28 Vayda and McCay (1975:299) argue that even before the advent of systems analysis in ecology, natural historians were already looking at natural communities as engaged in lawful processes tending to reach a "climax" community with "superior" social organisation. As such ecosystems came to be regarded "as self-regulating and self-determining systems with goals such as maximising energetic efficiency or productivity, the efficiency of nutrient cycling, biomass, or,

section) as a means of scientific inquiry contain the seed of a critique of the resilience theory articulated by Holling and his colleagues around the same time: "[W]e are not aware of anyone trying to model organisms or mechanical systems as social systems, but clearly, social systems have often been modelled organismically (e.g., Stafford Beer, 1972) and even mechanically (e.g., social physicists and Jay Forrester, 1961, 1971)." In other words, whereas Holling and his colleagues are not the only ones to see the value in using an organismic perspective to understand social systems, the connections that they make between society and nature are criticised for not addressing the relationships of power in society and to serve as a means to maintain the status quo through policies designed with the help of systems analysis. So, the influence of systems analysis in their research outputs is treated with suspicion and its genealogy in European philosophy is used as evidence against the claims of universality of resilience theory.

6.2.2. System analysis and overlaps between the field of ecology and biology

The term *oecology* was fathered by the German Darwinist Ernst Haekel in 1866, in reference to a study of "nature's economy". According to Zebrowski (2013:161-162), the phrase stems from Linnaeus' 1749 The *Oeconomy of Nature*: an inquiry on the divine order visible within nature's design. In late eighteenth century the notion of *oeconomy* still referred to household management as per the original sense from which its prefixe *oikos* derives, meaning home or habitation. Therefore Linnaeus' 1749, The *Oeconomy of Nature* suggests a divine order of nature instead of a connection to "political economy" in the

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through an increase in species diversity and food web complexity, maximising organisation ("information" content) and stability".

contemporary definition. As a result pioneering studies of nature's economy wondered at the balance and harmony in which the divine design couples ends with means up until the infinitely small detail. Though this attention to detail was also a source of problems in regard to their intelligibility and human's capacity to govern them. While man could aspire to this level of management, it was only God with his omniscience who could achieve such perfection in design. So, in the late eighteenth and early nineteenth centuries, Zebrowski (2013) notes the emergence of Ecology as a field of study.

During the 1950s and 1960s, three schools of ecology were emergent, namely, "ecosystem ecology", "theoretical ecology" and "systems ecology" (Palladino, 1991). But contemporary ecology is constituted with a variety of sub-disciplines including population ecology, conservation ecology, spatial ecology, landscape ecology, physiology ecology, evolutionary ecology, functional ecology, and behavioral ecology having in common the following assumptions:

> (i) different biota interact in ways that can be described with sufficient precision and generality to permit their scientific study; and (ii) ecological interactions set the stage for evolution to occur primarily because they provide the external component of an entity's fitness. The latter aspect makes ecology a central part of biology (Sahotra, 2014:2).

The central place that ecology occupies in biology is made explicit in the ways in which the objective of population ecology is encompassed within the goals of biology. In fact biology has two goals according to Young (1988). On the one hand it investigates the various forms of species over time or along different environmental characteristics. On the other hand it seeks to understand the survivability of different species so as to reach conclusions about their

prevalence in an environment under conditions of competition. Young adds that population ecology claims to be mostly concerned with the survivability of species of organisation, but the empirical research are shaped within the limit of a more restrictive goal. That is the study of fluctuation which a species undergoes over time under different environmental conditions. As such classical population ecology was limited to the investigation of state based models primarily because of the requirement that models be tractable, in order to allow prediction and explanation (Sahotra, 2014:4). One of these models is Predator Prey Population Cycles by Volterra[29]. So, it is not a hazard if the golden years (1920-1940) of theoretical population ecology coincided with the emergence of general systems ecology in biology. Indeed, ecological theory is rooted in evolutionary biology and was likely to be separated historically from application (Holling, 1973:2).

In the dawn of the nineteenth century, Sharon Kingsland noticed that within the path of the development of theoretical population ecology, many biologists tried to formalise their ideas in relation to natural resources and natural history just as in many branches of biology, these "ecologists" sought to develop theories of general validity, and to articulate them in mathematical language (Palladino, 1991: 225). In fact, debates and development both in the field of ecology and biology overlapped, that is true at least regarding the reliance on general systems analysis in both fields. For example Graham and Dayton (2002: 1486) report that in the early years ecology was sustained by a relatively small number of journals, focusing primarily on broad natural patterns. From 1900 to 1940, the

29 A scholar whose work in mathematical biology had been cited by Bertalanffly (1972) as a precursor to the general systems theory but also by Holling in research on predator and prey in 1966.

quantity of journals increased dramatically as biologists started to align themselves according to both organism and function, in other words they became more specialised. Furthermore, the 1950s, 1970s, and 1990s were marked by the rise of habitat-oriented and conservation journals. As a result these scholars point out that ecologists working in the early 1900s used individual journals which were much more general than ecologists see today. Holling was well aware of the historical development of ecology as a discipline and its lineage in evolutionary biology. In this regard in writing the "The two cultures of ecology", an editorial meant to shape the focus of the then newly created *Conservation Ecology*, he attempted to revive the sense of generality enjoyed by ecologists in the 1900s and enhance interdisciplinary work around resilience theory:

> Ecological science is in transition. Previously separate schools of ecology are being linked across scales - from physiological to landscape. Policy and practice are being integrated in ways that demonstrate that science benefits as much as does practice. Biological ecology is being combined with the environmental sciences and with social and economic understanding. It is a transition made possible by a maturing body of theory, methods, and examples. And it comes at a time when the policies needed to harmonize the interaction between people and nature occurs at unfamiliar scales from regional to global. It is this transition in ecology that provides the focus for *Conservation Ecology* (Holling, 1998:1).

Still it is worth noting that economic concerns were at the core of ecology since its inception (Krebs,2006).

Conclusion

The two sections of this chapter anticipate that the *fondamentalisation of* economic entomology is manifest in the events, methods and theories couched in the tapestry of Holling's articulation of "nature-culture" relationship. And that

such a "nature-culture relationship" which disrupted the ontological division between culture and nature, was materially constituted in what formed the epistemic culture in question. In other words, the "nature-culture relationship" in Hollings' evolving thinking from the 1960s to the 1970s implies that it is the outcome of "the construction, through material interventions and interactions, of artefacts and other phenomena of the laboratory" (Demeritt, 1998:176). Also, it acknowledges that "[T]he parameters of the laboratory and other spaces of science may be socially and materially structured, but they are far from being fixed" (Greenhough, 2005:225). Indeed the *fondamentalisation of* economic entomology provided a vast array of methods for pest control whether it was biological or chemical. It was also subject to the implications that these methods might have on an economy dependent on agriculture/forest products and to the broader society and nature. So, what follows "is not just about how people make knowledge in the world, but how they physically and socially make the world through the ways they move and mobilise people, objects, information and ideas" (Buscher and Urry, 2009: 112).

7. Social-ecological links and the incorporation of the resilience idea in Hollings' evolving thinking from the 1950s to 1980s

Introduction

I have argued in the previous chapters that space plays a constitutive role in the formation of "scientific" knowledge, but this role is often obscured or even invisible. To put it differently, the spaces in which knowledge is construed, built,

revised or experienced has an influence on the substance of the knowledge that is produced, and yet there is minimal, if any, reflection on the dialectical nature of this influence. This chapter moves beyond this argument to explore in a concrete setting the interplay between the materiality of space and the gradual emergence of a discursive construction. As explained in the introduction, I am using the concept of "resilience" as the case-in-point, and am exploring how the hidden influences of spaces in the evolving thinking of C.S Holling which eventually made a connection between social and ecological systems, which included cities, and then cohered within the concept of "social-ecological system". In doing so, I situate Holling's 1973 paper "Resilience and stability of ecological systems" within the context of the evolution of his own research since the 1950s, and against the backdrop of the epistemic culture of 1960s and 1970s as elaborated in chapter 6.

However, this chapter is not directly concerned with the importance that the 1973 paper acquired many years after its publication. Rather it tries to identify which spaces participated in its constitution, and to unravel their entanglement in the ways in which Holling narrated what the paper is about. That is to say, that the links between the 1973 paper and Hollings' previous work (and workspaces) are established as well as the factors which have implications for the proposition of this paper. The following sections unfold along these logical lines of the reconstruction of events and discursive construction. Drawing from the research outputs of Hollings' dissertation, the first section pinpoints how its subsequent research moves from the disciplinary base of economic entomology to an analytical framework extending its reach in ecology and relying increasingly on systems analysis. Secondly, the imprints of the epistemic culture of the 1960s and 1970s are highlighted in Holing's attempts to connect social and ecological systems as well as the traces of resilience idea in his narrative. Thirdly, the factors enabling the expansion of the disciplinary space of Holling's research are

examined in the light of the coming into being of the 1973 paper and the re-articulation of resilience concept. The last section explores the scientific contribution of the 1973 paper to IIASAs research program. It reports on the debates and controversies that underpin the extension of its disciplinary space and geographical spaces of its origin in the light of the establishment of a new field of study and practice called adaptive management.

7.1. The reach of the fondamentalisation and systems analysis in Holling's initial research

Economic entomology is the disciplinary base from which the work of Hollings in the 1950s gradually changed its disciplinary character (7.1.1) into an interdisplinary one relying more on systems analysis (7.1.2) in the 1960s.

7.1.1. Entering the stability-diversity-complexity debate

One of the practical objectives of Holling's graduate research on *predator and prey* was to find a suitable method for biological pest control in Ontario's plantations. But as the findings of his dissertation suggest, the contribution of his research surpasses largely this kind of practical objective and depicts a conceptual work seeking to universalise local research activities and outputs. For example, Holling's dissertation argues that the simplest type of predation is caused by only two variables; "prey" and "prey density". In the specific example used for his study, the basic components are responses to change in prey density. The increase in the number of prey consumed per predator, as prey density rises, it is called *functional response*. The increase in the density of predators, as a result of increase in prey density, is called *numerical response*. These functional and numerical responses as basic components of predation can also be affected by a number of subsidiary components such as prey characteristics, the number and variety of alternate foods, and the predilections

of the predators. The use of a hypothetical predator-prey model has served to reach these conclusions which, according to the study can be applied to all types of predation and all types of parasitism as well (Holling, 1957: 135).

There are three notable articles written about these findings. The first one was published in 1958 in the *Canadian Journal of Zoology*, and titled "Sensory stimuli involved in the Location and Selection of Sawfly Cocoons by Mammals". In this study the objective was to "describe the searching technique and to identify the senses involved in the location and selection of cocoons of the European pine Sawfly by three important predators: *Sorex cinerereus Kerr*, *Blarina Brevicauda talpoides Gapper*, and *Peromyscus maniculatus bairdii* Hoy and Kenicott" (Holling, 1958: 633). This very paper puts in perspective the subsidiary components of predation as mentioned earlier in Holling's dissertation. The second article was published in *The Canadian Entomologist* in 1959, and titled "Some Characteristics of Simple Types of Predation and Parasitism". This study was concerned with the basic components of predation. In this regard, he developed a conceptual model using blindfolded human subjects (the predator) and 4-cm sandpaper discs (the "prey"). The third paper was published in *The Canadian Entomologist* in 1959, and titled "The components of Predation as revealed by a study of Small- Mammal Predation of the European Pine Sawfly". This paper summarises the study undertaken during Holling's PhD degree while connecting the first and second papers.

The dissemination of the results of Holling's dissertation right after the completion of his PhD degree and later through some other studies deriving from it, left a profound impact beyond economic entomology so as to reinforce the *fondamentalisation* of this field of enquiry. In this respect, Denny (2014: 200) points out that:

> Holling's work struck a deep chord among ecologists. Over the 55 years since it was proposed, his classification of functional responses

> has been woven into the fabric of ecology, where it has acquired the aura of received knowledge. Now designated by roman numerals, Holling's functional responses appear in every introductory ecology text, usually with illustrative examples (e.g., filter feeders are Type I; insects and parasitoids, Type II; vertebrates, Type III), and his classification is commonly employed by theoretical ecologists when incorporating predation into models of population and community dynamics. Holling's classic papers have been cited nearly 4000 times, 222 times in 2012 alone.

It follows then that during the 1960s, Holling's research entered the stability-diversity-complexity (SDC) debate which has persisted as a main focus on theoretical ecology for half a century.

In effect Justus (2008:321) argues that SDC is about the fundamental and simple question of whether there is a relationship between the complexity and/or diversity of a biological community and its stability. According to Zebrowski (2013: 163), in 1935, Arthur Stanley provided a classification of systems grounded in the value of 'stability". Stability appeared to be defined in terms of the ability of a system to keep its composure over time. It was in that research that the concept of "ecosystems" appeared for the first time in a distinction between the biotic communities" and " complex organism" present in the holistic theories of Clements and Smuts, in order to define a relatively unstable system given the range of factors both external and internal which could pertubate the equilibrium. Yet Zebrowski adds that the assumption concerning the natural return of a system to equilibrium was internalised and almost never questioned.

However the main philosophical questions in the field of ecology continued to address the relevant notions of ecological diversity and stability and the relationship between diversity and stability (Sahotra, 2014). It is along those lines

that the SDC debate followed its development. Justus (2008) observes that from 1955, when Robert MacArthur initiated the debate, to the dawn of the 1970s, the orthodox view among ecologists was that diversity and complexity was significant if not the main causes of community stability. Robert May, a physicist turned mathematical ecologist, criticised this approach with analyses of mathematical models of communities that seemed to prove the opposite. The good reception of May's research was due to its mathematical rigour. And the criticisms it received for its apparent biological irrelevance led the SDC debate into the ecological limelight but subsequent inquiries did not resolve it. In fact, different investigations seemed to justify conflicting claims and showed an underlying lack of conceptual clarity regarding ecological stability, diversity, and complexity, argues, Justus (2008). So, it is in a context of fragmentation of research outputs that systems ecology emerged in the 1960s.

7.1.2. Pioneering work of Holling in systems ecology

Dale notes that if the benefits of using systems analysis as it was becoming common to do in other scientific disciplines in the 1960s were evident, pioneering works such as Olson (1963), Patten (1965), Holling (1966), and Watt (1968) hardly explain: "what systems analysis is, what it does, what restrictions it imposes, nor how the variety of ecology (or more precisely ecological methodology) can be attached to this framework". Still, Lindseth (2011:2) reports that systems ecology had been known for mixing an inclusive, holistic approach with a comparatively intensive reliance on mathematics and the use of computers to model ecosystems dynamics in all their complexity." For instance, Watt (1966: 6-9) identifies four steps in a systems research in ecology, namely "measurement", "analysis", "description", "description and simulation and optimisation". The first step seeks to provide a compelling inventory of the variables and causal pathways that seem of potential significance in the formation of the system. The second step is an evaluation of the relative

significance of the variables which have been provisionally considered important in the first step. The third step structures the model on the basis of the relevant variables selected in the second step. Finally once a model has been created which accurately mimics the behavior of a complex system, then it can be utilised in simulation studies to show how the system can be manipulated in real life in order to maximise its benefits for man.

In the 1960s, Holling's growing quest for generality started mirroring the objective of general systems theory and his research outputs gave him a place of choice in the nascent field of systems ecology yet simultaneously decreased the visibility of their epistemic connections with both the field of its initial research in Ontario and the Sault Ste Marie laboratory. He made the first step of the systems research program as defined by Watt (1966) in a paper published in the *Annual Review of Entomology* in 1961, and titled "Principles of Insect Predation". This move was done by way of reviewing the literature on predation while translating it into a verbal and mathematical language which is both sensitive to the generality of its modus operandi and the specificities which might have occurred from case to case. On the one hand, he started the paper with an acknowledgement that the state of knowledge on predation under his review is hardly precise yet aims to provide a clear picture of the effects of predation on insects. On the other hand, he concluded by reflecting on the fitness of the method that he chose to conduct his review in this manner:

> But is it feasible to express a complete explanation of predation in mathematical language in view of the complexities that can arise? Any such attempt might well be a very rough approximation with limited details application and, once proposed, might stifle further understanding in the face of an apparently inviolate mathematical explanation that provides a specific explanation of an event that is actually only generally understood. It is however, perfectly feasible and practical to explain accurately and specifically the components of simple types of predation and, hence, to present the explanation of such situations in mathematical form. Since

these simple components operate in even complex processes and, at least, provide a means to direct effort toward the unknown (Holling, 1961: 1960).

In 1965, Holling published another article in *Memoirs of the Entomological Society of Canada,* titled "The Functional Response of Predator to Prey Density and its Role in Mimicry and Regulation of Population Density". In this paper, he insisted on the contribution that systems analysis can bring in relation to the analysis of complex biological phenomena, and remarked that the subject under his study represented the latest step he had taken in the development of an integrated analysis and synthesis of components of predation. What informed Hollings' position was the understanding that as much as the analysis of the parts of a complex system may be a daunting task, their significance remains limited in the absence of an underlying framework able to make sense of all the interactions of the relevant fragments of the whole. Denny (2014: 200-201) notes that three lessons emerge from this article. Two of them are particularly relevant here. Firstly, the categories that Holling used throughout these papers show the importance of a mechanistic approach in ecology. Secondly, regardless of its stature in ecology, the division of functional responses into three different categories is not very practical. This second lesson sounds a bit unfair in the light of Holling's insistence in this paper to ground his analysis on "realism". For instance, he notes that the approach that he used for his inquiry "assumes an intimate union between theory and experiment, with experiment dictating theory and theory suggesting experiments in many successive steps." Nevertheless this second lesson highlighted the level of abstraction of a systems research program in ecology as well as Holling's manipulation of both the lab and the field in the conceptualisation of his research outputs.

The manipulation of the lab and the field in Holling's research is well illustrated in another paper published in 1966 in *Memoirs of the Entomological Society of Canada*, and titled, "The Functional Response of Invertebrate Predators to Prey

Density". In the introduction of that paper, Holling (1966:5) observes that between 1923 and 1935 considerable effort had been undertaken to develop a mathematical model of animal populations (Lokta 1923, Thompson 1924, Volterra 1931, Gause 1934, Nicholson and Bailey 1935). According to Holling, apparently, these models, for the very first time provided the population biologist the same tools that proved to be successful in analysing processes in physics. Indeed these models were good at representing with accuracy the action and interaction of several processes that affected the quantity of animals and at inferring generalisations related to the gross behavior of populations. Yet Holling argues that if the main criterion of evaluation of a method depends on the capacity of the resulting theory to manipulate events, then these early mathematical models were not notably valid. Indeed these models could not address the complexity of animal population that is why, he went on to say:

> By accepting this language, the biologist is forced to adapt the image of the process to the severe limitations imposed by the language. If the process is fairly simple in structure then this can be done with great profit. But if the process is as complex as population processes are, the simple approach can be only applied by sacrificing reality.
>
> It would therefore be an entertaining and potentially profitable undertaking to analyze the various processes that affect animals numbers-e.g. predation, competition, and parasitism- by initially ignoring the limitations imposed by the restrictions of traditional models and emphasizing the need for realistic explanation. Once the analysis is complete it might be possible to express the explanation in a precise mathematical form without sacrificing reality (Holling, 1966:5).

The 1965 and 1966 papers were published while Holling was based at the Forest Insect Laboratory, Sault Ste. Marie, Ontario. The 1966 paper contributed to the SDC debate by addressing the complexity of animal population through a systems analysis approach.

Moreover in 1966, Holling was awarded the Mercer Award, given to the young scientist in recognition of "an outstanding paper" in ecology using a systems analysis approach. Holling's "outstanding paper" was titled: "The Strategy of Building Models of Complex Ecological Systems". It had been included in a 1966 book edited by Kenneth E. F. Watt under the title, *Systems Analysis in Ecology.* The 1966 book was in a way a rallying cry for the nascent field of systems ecology (Lindseth, 2011:3). In chapter 8, Holling (1966:200) explains in detail how the five distinctive features of ecosystems (space, historical effects, threshold, limits and continuities) can be handled by computer and the language used to program them. In doing so, he noticed that even if a similar model of large systems can emulate the general and realistic model of predation that he had been developing, an analytical problem concerning the gathering of data remained.

The problem concerning the data was to avoid that the particular bearings of the initial fieldwork put too much weight on the system being built so that it coloured completely the model's generality with its unique features. At this stage, it was possible to see exactly that Denny's second lesson on the abstraction of Holling's 1965 paper was relevant. In effect, this "outstanding paper" was published when Holling was working for the Canadian Department of Forestry, Victoria, British Columbia. But his intent regarding the handling of data in order to achieve generality, purposely altered the significance that his initial research such as the one in southwestern Ontario and at Sault Ste Marie laboratory might bring to bear on its contribution to the development of systems ecology. In contrast, the recognition attributed to his own agency as a scientist is well acknowledged as Watt (1966: 13) points out at the introductory chapter of the 1966 book:

> The ideas of Holling will speed up research, by helping ecologists in different institutions to pool their efforts in an organized way, the organization stemming from a common interest in fleshing out the

> broad conceptual models that will gradually be developed to explain the broad general phenomena of ecology: predation, parasitism, episodic waves, the effects of climate on population stability, dispersal and so on.

This portrayal of the ownership of an idea is not totally accurate. In fact Holling presents a different perspective that integrates the agency of the laboratory in the production of knowledge in the light of his own experience:

> For many of the ideas I have published on using ecological or economic information and data, the initial idea came from the experience I had in research organizations. They go through the process of an initial pioneering state of innovation and invention and novelty, through a slow process of accumulating a reputation and papers and results, to the point where more and more groups depend upon that organization continuing as it was, so they become embedded in a particular way of doing things. The novel ideas that continually appear often move to some other organization that is an early phase of development. The organization that generated those ideas, or the environment for those ideas continues, but in a less productive way (Ross, 2010:2).

In this way, Holling's contribution emulates the pioneering works of the Dominion Experimental Farms and highlights the ways in which the Canadian Ministry of Agriculture set the base for the epistemological imagination in the field of economic entomology. In so doing, he reinforced the significance of governmental laboratories such as the Sault Ste Marie laboratory and the *Destructive Pest Act* in the development of new fields of scientific inquiry (Castonguay, 2001).

7.2. Disruption of the nature – culture divide

The epistemic culture in which Holling found himself studying and working in, left its marks in the narration of his research outputs (7.2.1) and his effort to re-

articulate humanity's relationship with nature (7.2.2) until the beginning of 1970s.

7.2.1. Connecting social and ecological systems and tracing of the resilience idea

The concerns of the North American cities movement of the 1960s are echoed in Holling's "outstanding paper". In fact at the introduction of this paper, he wrote in very general terms about particular issues related to the depleting forest resources in Ontario and the Spadina controversy[30], the meaning of progress, and made use of the word "resilient":

> Man has been attempting to manage his resources ever since he planted his first seed and petted his first dog. He has been surprisingly successful. Modern agricultural practices could, in theory, provide sufficient food to feed the present world's population adequately. It can be argued, however, that this success is the product of man's insight and wisdom, nor that it will continue. Although the threat of world overpopulation is becoming increasingly apparent, the million or so years of man's immediate history have not been long enough to enable him to exhaust completely the non-renewable energy and material resources of his world. Nor have his remarkable engineering feats of levelling forests, filling swamps diverting rivers been quite extensive enough or indiscriminate enough to cause major catastrophe. In the face of such an onslaught nature has proved to be remarkably resilient. Nature clearly is not in a state of delicate balance but can, in fact, withstand brutal changes without disastrous consequences (Holling, 1966:195).

[30] The spadina controversy in Toronto was part of a movement in American cities having as paramount objectives, safeguarding the urban environment by preserving communities, preventing environmental degradation, and encouraging public transit.

The above quotation is a problematique[31]. It does not belong solely to the object of inquiry of a given scientific discipline as such. Rather it suggests that the complexity of the problem at hand be addressed through the integration of scientific disciplines in a methodological approach. This kind of approach has been supported by general systems theory, and Holling's use of systems analysis in ecology is the continuum of this way of undertaking scientific research. Also, in proceeding that way, the researcher is placed in a vulnerable position where he has to constantly learn new things in order to straddle more easily across the gaps separating disciplines; and reach a better appreciation of the wholeness of the system that he seeks to validate through his analysis. In a nutshell, that is what Holling attempted to do at the symposium on Diversity and Stability in Ecological Systems held in 1969 at Upton Brookhaven National Laboratory. Whereas the symposium reflected a shift in the recent development on the problem of "species diversity", Smith (1969:212) observed that:

> The organizers obtained a wide spectrum of participants despite their disclaimer that a number of important people were absent. The list of authors is a fair Who's Who in population biology, which in some ways is unfortunate. Almost all the material presented has been published before, and the banter that follows each paper, though amusing in some cases, does not contribute very much. The same people who gave the papers also made the comments. I wonder where the hungry graduate students were?

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31 "A problematique is a structural model, a graphical device for enhancing human understanding and facilitating the development of action plans for correcting undesirable situations. It is comprised of brief statements representing problems and a pattern of interaction among them. The relationship portrayed is typically one of aggravation rather than causality since modern societal issues are not readily reduced to simple cause and effect relationships. The problematique is one component of a larger system for exploring and managing complexity (Warfield and Perino Jr, 1999:221)."

The title of Holling's paper was "Stability in Social and Ecological Systems". He introduced himself both as an "ecologist" and a self-proclaimed "amateur sociologist". In this way, he attempted to contribute to the fragmented SDC debate through a discussion on "the relevance of knowledge of ecological stability to understand the stability of industrial man's society." In doing so, he engaged with a simulation model of land acquisition by man and compared it with another model simulating population interactions between predator and prey. This led him to conclude his presentation with a discussion on social stability. Prior to moving to the substance of his paper, he made a declaration which captures more the connections in the problems that he tried to address than his status and expertise as a scientist:

> In choosing this focus on social stability, I recognize my presumption. By so doing, I am treading the dangerous path of the amateur-an amateur sociologist, and by accepting this status, being something of an anathema to the specialist. I do so largely because of the profound similarities between ecological systems and sociological ones (Holling, 1969, 128-129).

Indeed, Holling identified that there is a fundamental and basic similarity between ecological and social systems because the features that determine their complexity are identical. There are essentially four properties namely, diversity of interactions, history, space, and structural properties. In the section of the paper dealing with social stability, Holling broadly brushed a picture of a world on the edge of a global environmental crisis. A world in which human institutions which served well their purpose regarding technological and industrial advancements have become hostile to any meaningful change. He went on to say that, when both the population and the environment capacity are increasing by some sort of law, it is possible to demonstrate that the "signal" sent by the environment limit to the population may be very weak. On this latter point a

short exchange having to do more with sociology than ecology, occurred between Holling and two commentators at the conference.

> Coliveaux: You [Holling] are basing your last remarks on the people you think most likely to detect the signal first. I think that there may indeed be the young and the poor, but, much more important, I think they will be the people of small islands like Britain or Japan. In the long-term history of our species, the type of industrial half-life of 10 years which you gave us is rather irrelevant because the first detection will be on such island communities as Japan; an overpopulated archipelago which can already no longer get the raw materials of industry and which must even import fish. This sort of thing will happen to all island communities before it happens to continents. They must be tempted by the classic solution to their problem, the answer which Germany tried in Lebensraum, to take from the continents by force what they would no longer be given. A likely future, perhaps even an ecologically desirable one, is a nuclear war started by an island community against a continent, a war started because these things will happen to island communities before the continents suffer. There is an interesting secondary nuclear implication here, of course. An island is an excellent place from which to start a nuclear war because it is more defensible against nuclear retaliation. Antiballistic missiles make no sense to a continent but they do make a lot of sense to an archipelago.
>
> Holling: O.K. I will change it to half-life of 5 years (Holling, 1969:141).

Coliveaux points out both the limits of Holling's knowledge in sociology, but most probably the limits of the application of his experience in North American cities. The people (young and poor) upon which Holling based his remarks were the tree planters in the forest regeneration program in Ontario. The world that concerned Holling was mostly Western (North American cities) and the significance that he gave to that topic, seemed mostly guided by his own concerns as a citizen. His concerns and profile at that time were similar to those

of the urban residents who supported an alternative vision of cities during the "Spadina controversy" in Ontario (see Robinson, 2011). Consequently the point that he made is well received and even emphasised by the second discussant.

> Watt: The problem is probably even more serious than Dr. Holling has pointed out because not only is the signal very weak but the population in this country, certainly, and in many other countries has been very carefully programmed by mass media for several years now not to respond to the relevant signals and to respond to a whole set of pseudosignals which are really noise. Specifically, try to think through why you are programmed, if you are women, to buy lipstick or why if you are man you are programmed to buy a car. In fact almost every response that most human beings have now to the information in the external world is so strongly conditioned by these attempts to condition us to respond to the wrong things that it is very difficult for the system to detect any signals at all.
>
> Holling: These are examples of the sort of social inertia and lags that I talked about (Holling, 1969:141).

In a concluding note, Smith (1969:313) argues that the overall symposium provided several ideas on which new investigations may be grounded. It calls for a disregard of universality because one theory won't be able to explain the contradictory phenomena encountered in the field. According to him, this symposium epitomises: "a broad and perhaps classic review of a field that may be going stagnant; nothing much new, but some things said very well and provocatively." And among the things well said, Smith refers to Lewontin's (1969) paper which attempted a rigorous definition of stability in mathematical terms.

For Justus (2008:331), the 1969 paper of Lewontin is the only one which profoundly addressed the task of examining the meaning of stability and

diversity, and impacted the following development of the SDC debates. Justus captures the importance of Lewontin's paper in the following words:

> Lewontin drew an important distinction between stability as a perturbation- based concept, which resistance, resilience and tolerance are, and non-perturbation-based concepts, such as constancy. Constancy, Lewontin (1969, p.21) suggested, "is a property of the actual system of state variables. If the point representing the systems is a fixed position, the system is constant. Stability, on the other hand, is a property of the dynamical space in which the system is evolving." The two concepts are therefore different and not necessarily coextensive.

In contrast during the same symposium, in a paper supported by considerable empirical evidence, Preston (1969:7) argues that: "whatever stability there is in the ecological world, it is not a static equilibrium, but a fluctuating or dynamic one, and normally a highly fluctuating one. Stability lies in the ability to bounce back, not in the ability to hold tenaciously to ground once taken or numbers once achieved."

The conclusions reached at the end of the symposium correspond to the assessment of the field presented by Holling right at the beginning of his paper. While he sought to find a solutions to the fragmentation of research outputs through the use of systems analysis, its discussion on stability through degree of sensitivity of population raised more questions than it provided entirely convincing answers.

> Scott: You [Holling] defined an unstable population as one which is highly oscillating. I don't think that is unstable, necessarily.
>
> Holling: No. I was trying to suggest that instability occurred in the instances when the oscillations increased in amplitude, that is, on an open spiral.

> Scott: They have to increase in amplitude until something happens, which one can define as the point of instability-we kill each other, or something like that. Do you think that the world is going to become unstable, not oscillating but with oscillations of increasing amplitude?
>
> Holling: I see something of the kind that Hoyle, the astronomer, discussed in which he imagined wild oscillations and profound drop-offs. I certainly don't expect elimination of the human species, but do expect some drastic socioeconomic collapse triggered by nuclear holocaust or social erosion of some kind (Holling, 1969:141).

During his presentation at the symposium, Holling used the term stability but also the word resilience in correspondence to specific meanings. But in the above exchange with Scott, Holling associated instability with a geometrical figure (open spiral) in order to make sense of social processes at hand (Figure 6). In contrast, resilience in the light of his presentation seems to be equated to the absorptive capacities of the environment in circumstances of an ever increasing human pressure on ecological systems. For him, resilience is "what has allowed man- and the ecologist- to avoid facing the depth of his ignorance (Holling, 1969:128)". Eventually, the epistemological limits of scientific methods of knowing do not encompass all that is possible to be known. Thus, for Holling, the environment sends signals to the human population. These signals can be rendered intelligible or not, can be answered or ignored. But what remains certain is that the environment has a form of cognition. Besides in 1966 in Holling's "outstanding paper", he already provides a definition of resilience tied to animals' abilities to respond to environmental signals:

> This resilience is the inevitable outcome of the evolutionary process. Those organisms, those communities that lacked the mechanisms necessary to permit adaptation to major changes could not survive the many short-and long term dislocations of the environment that occurred long before man appeared. These mechanisms are homeostatic or feedback processes that tend to resist change and

> promote stability. Any departure from a norm tends to be opposed, and opposed with increasing vigor as the departure become greater and greater (Holling, 1966:195-196).

Holling's evolutionary view of resilience is reinforced by Eric Kandel and Sarah Mack's understanding of both animal and human abilities to adapt to their environment. In effect Kandel and Mack (2003:272) argue that biological evolution and learning are the only two major kinds of mechanisms available to animals and humans for adapting to their environment. While the biological one is slow and needs thousands of years in higher organisms, learning is rather quick and happens repeatedly during the short life span of an individual.

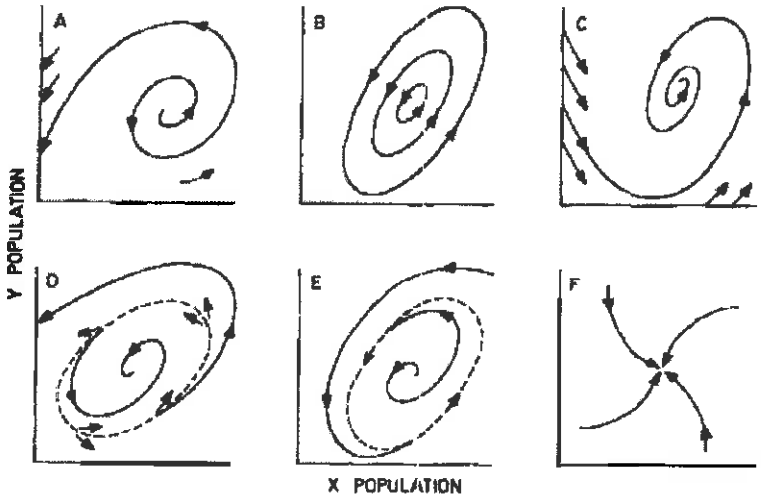


Figure 6. Although there is no such a representation in Holling's paper at the Brookhaven symposium, the "open spiral" that he refers to during his exchange with Scott will appear in the figure 2 in his 1973 paper on resilience and stability. As such the "open spiral" is one of the possible behaviors of a system according to the predator-prey model. Source: Holling (1973).

7.2.2. Expanding the disciplinary space in Holling's evolving thinking

In the aftermath of the symposium, in 1971, Holling and Gordon Orians, Department of Zoology, University of Washington, authored a report called "Toward an urban ecology" in *The Bulletin of Ecological Society of America* . The

content of the report draws extensively on Holling's presentation during the symposium. It suggests an engagement with the city not merely as an empirical referent of analysis, but also as a venue where investigation take place and relationships between nature and society are articulated. Though the two scholars remark that during the symposium on "Diversity and Stability in Ecological Systems" held in 1969 at Upton Brookhaven national laboratory "scarcely a word was said connecting the two" (Holling and Orians, 1971: 2). Instead their assurance to make such a connection has been diminished. So, driven by their own "ignorance" as they claim, they advocate for a new area of studies that is underpinned by the social significance of urban studies with an exaggerated sense of their ignorance rather than an excessive view of their knowledge. This ecological approach to urban systems was meant to be grounded in the recognition of both the similarities and differences of urban and ecological systems. The similarities are in relation to four properties namely, historical quality, spatial interlocking, systems property, and structural properties. The differences are related in part to the recent history of cities and in part to the specific features of man as an organism. The reason why they chose urban studies reflects more a desire to influence the relationships between nature and society than a quest for generality in science because: "[U]rban studies is an area that inevitably generates policy and action. It is not a protective cocoon for exploring abstract niceties that are never put to the test (Holling and Orians, 1971:2)." Even more interesting is the practical dimension of the report which in the words of the authors read as follows: "[T]his report resulted from an Ad Hoc Committee on Urban Ecology appointed by President Bormann. Following Council in March 1971 certain actions have been taken to implement the recommendations (Holling and Orians, 1971: 3)."

Whereas it is apparent that Holling followed his idea linking ecological and social systems after the symposium, it is equally important to point out that he started

building a system suitable for this kind of ideas. Edwards *et al* (2007:8) note that successful systems building always includes organisational, financial, legal, and marketing elements. In fact at the time when he presented his paper at the symposium, he was based at the Resource Science Centre, University of British Columbia, and Vancouver. The acknowledgement section of "Toward an urban ecology" states that he organised a workshop on a land simulation model through which contributions from a group of faculty and students from the Ecology, Economics, Forestry and Planning Groups at the University of British Columbia helped him improve his research. In the same vein but with the aim of bringing generality and applicability in science rather than to affect policy as such, in 1971, A.D. Chambers, a resource scientist and science adviser based at the Science Council of Canada, and Holling, then Director of the Institute of Resource Ecology at the University of British Columbia, made this remark:

> Our analytical tools and training emphasize rigor at the expense of holism. We can therefore, do an admirable job of learning more and more about less and less. There are, as consequence, serious gaps within research activities themselves, with hypothesis and theory often having rare and sporadic contacts with empirical testing and reality. Just as there are gaps between methodologies, so also between disciplines. Environmental problems have economic, social, ecological and physical dimensions, and no one discipline can possibly encompass all the necessary concepts and techniques. (Holling and Chambers, 1971:13).

The above informs a series of "Resource Science Workshops" seeking to close some of these gaps.

In 1973, Holling and M.A. Goldberg; Associate Professor of Commerce at the University of British Columbia, published a paper titled "Ecology and Planning" in *Journal of American Institute of Planners*. The paper tried to make the similarities between planner and ecologist more obvious while it emphasises the shared

properties between urban and ecological systems. But there is not a substantive difference between "Stability in Social and Ecological Systems", "Toward an Urban ecology" and "Ecology and Planning". The initial line of Holling's theoretical argument remains the same, while illustrations and contingent incremental adjustments are found to fit the disciplinary merger which is to be achieved together with each respective co-author. "Ecology and Planning" and "Toward an urban ecology" are ways to close gaps between scientific disciplines as well as bridge helping Holling's ideas to circulate across scientific institutions and cities across North America. In this respect his short biography in the "Ecology and Planning" paper suggests that in 1971, his ideas had already started affecting urban policy and that he identified himself as a systems ecologist rather than an economic entomologist:

> C.S. Holling is the Director of the Institute of Animal Resource Ecology at the University of British Columbia. He is a systems ecologist by training and has developed computer simulation models of predator-prey interactions in ecological systems. He has extended many of these functional relationships to successfully simulate recreational and speculation models in the Gulf Islands near Vancouver (Holling and Goldberg, 1971:122)"

The perceived status of economic entomology, a field of inquiry led by governmental research institutions, had less prestige than a discipline firmly rooted in academic institutions and at the forefront of an environmental movement such as systems ecology. But the fact that Holling presented himself as a systems ecologist rather than an economic entomologist is not only justifying the position of choice that he occupied in the then emerging field of systems ecology. Rather it also points out how the *fondamentalisation* of economic entomology helped him to embrace new territories of expertise and engage with epistemic, economic, social and political challenges all at once. In the same vein, the position that he occupied as a manager of a research

organisation facilitated the materialisation of his ideas. In effect, in a paper titled "Making a Marriage, an Institute, or a society", he outlines a way to convey new ideas inspired by his account on China's self-sufficiency[32]:

> True strategic failure occurs when solutions lie in other, isolated hands. That is the route which leads to systems analysis as the panacea of the world's ills-glue for the unglued. The successful strategy then makes possible the easy exploration of alternate tactics. One important set are the tactics of initiating a fresh concept and direction within a system which by definition resists change. And these tactics must dance between the extremes of dictatorial fiat and subtle deviousness, both of which are seeds for disaster (Holling, 1973: 5).

Similarly, Dale (1970:13) suggests that what is needed for the ecologist who uses systems analysis, is not to be fluent in all of the variety of its methods, but a certain capacity to communicate between them. Thus building knowledge infrastructures supports materially the circulation of Holling's ideas while systems analysis helps to expand the disciplinary space of his research. The following sections demonstrate this point in the light of Holling's re-articulation of the concept of resilience at the International Institute of Applied Systems Analysis (IIASA).

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32 In this paper Holling (1973:2) points out China's self-sufficiency in these terms: "China seems to be one country which has carefully crafted a strategy. One facet of this strategy is self-sufficiency, but it is not expressed directly in terms of the nation. That would be mildly interesting, but the key wrinkle is that this goal is proposed for social units on small spatial areas. So it is a goal of self-sufficiency for the village (the production brigade) or for the communes which are collections of contiguous villages. From this specific addition to the goal flow the most social consequences".

7.3. The International Institute for Applied Systems Analysis and the Re-articulation of the resilience concept.

Through the collaboration that Holling started with the International Institute for Applied Systems Analysis (IIASA) in 1972, the methods of inquiry and the conceptual work that he has been experimenting with since the 1960s will be refined and universalised (7.3.1). The re-articulation of the resilience concept integrates these developments (7.3.2).

7.3.1. IIASAs ecology project and the "new light" on resilience

IIASA is an international scientific institution that undertakes policy-oriented research into problems that are too large or too complex to be addressed solely by one country or academic discipline. Climate change is one such problem. This institute deals also with problems that many countries hold in common and which need to be solved both at national and international level, this is the case for energy security, population aging, and sustainable development. Over 300 mathematicians, social scientists, natural scientist, economists, and engineers from over 45 countries conduct research funded by scientific institutions in the Americas, Europe, Asia, Oceania, and Africa (IIASA, 2015). IIASA portrays itself as independent and unconstrained by political or national self-interest, yet a brief look at its history suggests that such a depiction is not entirely accurate.

The idea for the creation IIASA was initially proposed by Lyndon Johnson in 1966 as part of the many "bridge building" initiatives between the United States and the Soviet bloc (McDonald, 1998:55). The objective was to bring together researchers from different countries and disciplines to examine a number of problems affecting advanced economies- pollution, health care delivery, traffic congestion, and the management of large enterprises in general. On the 3-4

October, 1972 in the Offices of the Royal Society in London, IIASA was created under the principle that global problems required global solutions and with Vienna (Laxenburg) as its venue. The quest for global solutions intended to overlook the geopolitical divide of the Cold War by bringing together the best scientists from both West and East (IIASA, 2007:3). In fact McDonald (1998) argues that it is primarily the enthusiasm of people around the world for systems analysis and the talent of the people from the field involved in the process of negotiations which led to the success of the negotiations surrounding the creation of the institute. According to McDonald the bridge between the West and the East was not enough to foster the creation of the institute alone. But the promise of an exciting environment for research supplemented the aim to bring the West and the East closer. This view resonates in an address by IIASAs founding Director, Howard Raiffa in May 1980:

> We have something precious here; something vastly different from other institutions. My fervent hope is that we will not lose perspective that we will continue to nurture IIASA, despite the troubling time in the world. IIASA, being nongovernmental, being multi-national, should remain a fixed point within a turbulent sea. IIASA has a mission: to continue to be; to continue to look ahead and anticipate the problems of the future; to identify what the real problems of the globe are, and not to get caught up in the hopefully ephemeral disputes of superpowers (IIASA, 2007 : 7).

So, right at the start, the main task of the founding director of IIASA was to recruit high-quality researchers who would work together to fulfill this mission. Holling was among the first group of Westerners to be recruited to the institute along with people like George Dantzig[33], Mike Fiering[34] and Tjalling Koopmans[35].

33 He was awarded degrees from Maryland (1936) and the University of Michigan before completing his doctorate from the University of California, Berkeley, in 1946. While at Berkeley, he made an immediate impact. He worked for the US Bureau of Labor Statistics, served as Chief

The new recruits at the institute brought with them their best young students and colleagues to work on IIASAs newly established research program (McDonald, 1998:66). It was in July 1973, when together with his crew of Bill Clark, Dixon Jones, their wives and a programmer, Zafar Rashid, he arrived at IIASA. But it did not take long before Howard Raiffa reminded him to schedule the first organisational meeting of the Ecology Project for a few weeks ahead (Holling, 2014). As a result the Ecology Project's task on spruce budworm infestations in eastern and Central America was the framework of IIASA's initial

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of the Combat Analysis Branch for USAF Headquarters Statistical Control and as Mathematical Advisor for USAF Headquarters, Research Mathematician for RAND Corporation, and Professor of Operations Research and Chairman of the Operations Research Center at the University of California, Berkeley. He became a professor of operations research at Berkeley. He moved to Stanford in 1966 and continued to teach and publish into the 1990s as a Professor of Operations Research and Computer Science, Co-Director of the Systems Optimization Laboratory, and Director of the PILOT Energy-Economic Model Project. Professor Dantzig's seminal contribution has laid the foundation for much of the field of systems engineering and is widely used in network design and component design in computer, mechanical, and electrical engineering. He died in May 5, 2005 (Informs,2015)

34 He was a Gordon McKay Professor of Engineering and Applied Mathematics at Harvard University. A leading authority on water resources systems design, he was appointed Gordon McKay Professor of Engineering and Applied Mathematics in 1969. Born in New York City, Professor Fiering graduated with an A.B. from Harvard in 1955, and a Ph.D. from Harvard in 1960. He died on October 28, 1992, at the age of 58 (Havard Gazette, 1996).

35 He was a Dutch-born American economist who earned his degrees in mathematics and physics at the universities of Utrecht and Leiden. He obtained his Ph.D. in economics at Leiden in 1936. His seminal contribution on the methodology of economic analysis has been widely read. In 1975, Koopmans shared the Nobel Prize for Economics with Leonid Kantorovich from the Soviet Union in recognition of their work on a rational method (activity analysis) for allocating resources in order to reach a given economic objective at a lower cost. He died in February 26, 1985 (Encyclopedia Britannica, 2015).

research program. Under Holling's supervision, this project would become one of IIASAs early successes.

The Ecology Project commenced work in 1973 so as to erect a platform where IIASAs mission could be articulated fully after its completion. The initial objective of the project was to find out how far it is possible to develop a coherent science of ecological management i.e. concepts, methodology, and case studies. As a result the project sought its focus in opting "to analyse in detail specific regional case studies, choosing problems that had universal character, adequate but incomplete data, outside collaborators, a troubled management history, and that intersected the interests of other IIASA scientists" (Holling and Walters, 1976:1). While the cases studies were put under the banner of, forest/spruce budworm management, Pacific salmon and water management, and human impact on high mountain regions, Holling and Waters (1976) insist that the reason why they were chosen had nothing to do with their transcendent and global importance. Rather, according to these two scholars, it was because of the fact that "each of the specific examples has all the ingredients of a large class of problems that together comprise the global problem of resource management for food, fiber, and cultural need of societies."

The Ecology Project combined both the empirical elements of the research on predator and prey that Holling started in the 1950s and some of his research outputs on systems ecology in the 1960s. For instance in an IIASA working paper titled, "Program for Ecology and Environment", he summarises what the program tried to achieve in these words: "The overall goal of the project is to demonstrate the practical and theoretical value of combining good ecology, good modeling and good policy analysis in the resolution of resource and environmental problems" (Holling, 1973:1). It is important to point out here that Holling's environmental concerns were shaped by his experience in Canada and also through the North American cities movement of the 1960s.This has been

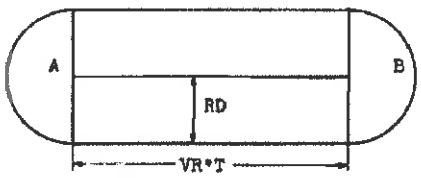
examined in the previous chapter. With this in mind, his concerns appear to be grounded in the common problems facing advanced economies as well as in IIASA's mission. As a result by virtue of being a lead researcher at IIASA, Holling's environmental concerns and research interests became a matter of global solutions to global problems. The importance that Holling credits to his stay at IIASA provides some details in what such a process of re-articulation entails:

> For me, the International Institute of Applied Systems Analysis provided an astonishing place, in its early years around 1972, to work with some of the best in different fields-Georges Dantzig in optimization, Howard Raiffa in decision theory, Tchalling Koopmans in economics, Mike Fiering in water/stochastic modeling, and Alex Basykin in mathematics. We all learned from each other as we tested the usefullness of novel methods for novel systems. Bill Clark and Dixon Jones were my partners in this and each has made huge contributions to related fields.
>
> That experience became the opportunity for us to identify and then test the value of methods developed in other fields-particularly economics, operations research and decision theory. Our conclusions were presented in Clark *et al* (1979). It was a huge step in understanding the strengths and limitations of familiar methods and new methods from other fields. That effort and experience at IIASA shaped our research and education activities for the next decade at least (Holling, 2006:19).

In a research memorandum, titled "Development and Use of Ecological Modules in Resource Development Simulation", Holling (1973, 1-8) reviews the approaches developed at IIASA to address the complexity of ecological systems and show how they integrate within simulation models of resource and environmental problems having economic, social and physical aspects in addition to ecological aspects. The reviewed approaches were to be fleshed out by connecting them to three models, a recreational land use model of a portion of

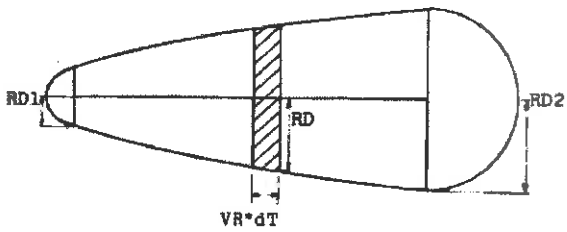
British Columbia, a land use model of a large hydroelectric power development in Northern Canada and an ecological model of predator-prey interplay. Those three models were part of the research undertaken by Holling in Canada from early the 1950s until the early 1970s. Besides the types of work contained in this memorandum, practical steps were undertaken towards the materialisation of the new area of studies that he anticipated earlier in his paper titled "Toward an urban Ecology". But here, the emphasis is on practicing a rigorous science. Eventually such a science borrowed intensively from systems analysis to put forward its knowledge-claims. For example in another research memorandum, "Description of Predation Model: Predator-Prey Functional Response", scarcely a word related to the geographical space is to be found. The research is mostly in mathematical and computerised language so also is the representation of space (Figure 7).

To derive a general expression for the search time TS, consider a predator moving from A to B searching for prey. If we assume a constant hunger level, the area swept out by the search will be of this form:



AREA = KA*HONP*(L + EYE)*(H - HTP) (14)

Thus in the general case, AREA, and hence also RD in our original equation (11), change with hunger. The search area swept out by the predator will have a form more like this:



The above equation for TS must be changed to reflect the change in RD

Figure 7. Kind of representations of space (AB, AREA, RD) which are a part of the equations that Holling used to model the predator-prey functional response. Source: Holling (1973).

The elaboration of this kind of model with the help of computers suggests the emergence of a virtual form of laboratory allowing deductions and experimentations which could not be performed without it (see, Holling, 1966; Rashid, 2003). Also, a footnote to this research memorandum suggests that Holling was affiliated both at the Institute of Animal Resource Ecology, University of British Columbia, Canada and at the International Institute for Applied Systems Analysis, Laxenburg, Austria, from 1973 to 1974. Even the renovations effected on the baroque palace which became the venue for IIASA in Laxenburg, integrated the significance, but also the function that computers will eventually play in the development of this new research institute. For example the baroque origins remained in the sequence of simple rooms located along seemingly endless corridors in the wings of the building, as well as high windows and ceilings from which hung heavy crystal chandeliers (Schrickel, 2014:6). But the blackboards, projectors and the built forms of a data center connecting a network of computers which came along with the renovation of the building materialised some aspects of how research's activities would be organised at IIASAs venue.

The findings reported in "Development and use of ecological modules in resource development simulation" shows some intersections between the Ecology Project, the SDC debate and the discussions at the Upton Brookhaven national laboratory Symposium in 1969. In this regard, following the realisation that the behaviors of the models under his study presented "more than one domain of stability or attraction around equilibrium points, trajectories or limit cycles, with at least one domain bounded by an unstable limit cycle", Holling adds:

> From an equilibrium-oriented viewpoint, then, these systems can appear rather weakly damped and quite sensitive to disturbance. But from the viewpoint of the boundary, they are immensely stable with a high degree of persistence. In essence this is what ecologists have always been saying that what is important is not the efficiency of such systems but the probability of their persistence. This orientation switches attention away from events near the equilibria to events near the boundary of stability, and it is this switch that for us is placing so much of our understanding in a very new light (Holling, 1973:8).

The "very new light" that Holling is referring to is in fact an articulation of the concept of resilience according to the observed behaviors of the models under his examination. Such articulation translates the perturbation of the systems into a description of the "shocks and trauma" that natural systems experienced over the period of their existence on the one hand, and the abilities of the (natural systems) that have survived while absorbing these changes on the other hand (Holling, 1973: 9). Whereas Holling (1973) saw that the application of such an understanding of resilience held the potential to fuel "some interesting consequences" in policy and planning process, a closer look at his earlier work suggests that his attention was focused on that "new light" since the 1960s at least. For instance, in his "outstanding paper" of 1966, his evolutionary view on the concept of resilience encompassed already the conclusions that his research at IIASA led him to draw. The mathematical language that he used to articulate the behavior of the systems under his examination is similar to the language used by Lewontin to present his well-received definition of stability at the Upton Brookhaven National laboratory Symposium:

> Lewontin (1969.p.16) argued that local stability inadequately defines ecological stability because it only describes systems behavior arbitrarily close to a particular point in *H*. Strictly speaking, therefore, local stability only describes systems behavior for infinitesimal

> displacements from Xq. Real-world perturbations, however, are obviously not of infinitesimal magnitude (Justus, 2008:331).

Also, the main tenets of his findings on stability at IIASA were already present in Preston's (1969:7) following observations on stability at the Upton Brookhaven national laboratory symposium: "Whatever stability there is in the ecological world it is not a static equilibrium, but a fluctuating or dynamic one, and normally a highly fluctuating one. Stability lies in the ability to bounce back, not in the ability to hold tenaciously to ground once taken or numbers once achieved."

7.3.2. The writing of "Resilience and Stability" paper and the re-articulation of the resilience concept

At the beginning of the 1970s, Holling was invited to write a review article for the Annual Review of Ecology and Systematics. He chose to write a review about two different ways of conceiving stability as well as the consequences that entails for theory and practice (Holling, 2006:6). In the following statement, he describes how he moved from the conclusions that he drew at IIASAs Ecology Project to his paper titled "Resilience and Stability of Ecological Systems" published in 1973:

> That paper came from a series of earlier experimental studies and papers analyzing a particular process, predation. The goal was to see how far one could go by being precise, realistic, general and integrative. These are goals that normally are dealt with independently, in at least partial isolation from each other in order to achieve useful and usable simplification. (The key, classic references are Holling, C.S. 1965. The functional response of predators to prey density and its role in mimicry and population regulation. Mem. Ent. Soc. Can. 45:1-60 and Holling, C.S. 1966. The functional response of invertebrate predators to prey density. Mem. Ent. Soc. Can. 48:1-86)...

> ...I was invited to write a 1973 review article for the Annual Review of Ecology and Systematics. I therefore decided to turn it into a review of the two different ways of perceiving stability and in so doing highlight the significance for theory and for practice. That required finding additional rare data in the literature that demonstrated flips of populations from one level or state to another, as well as describing the recently discovered known non-linearities in the processes that caused or inhibited the phenomenon (Holling, 2006:6).

In order to find the rare data needed to make its case on the two ways of approaching stability, Holling relocates the findings of the Ecology Project at IIASA within the broader SDC debate. As such, Lewontin (1969) together with other prominent figures within the SDC debate like Hutchinson (1970) May (1971, 1972), Slobokin (1964) and MacArthur (1971) are put into conversation throughout the paper. Besides, he makes the difference between systems ecology and the then ecology by highlighting the specific contribution that this new discipline can add to the existing knowledge in the field. In doing so, he uses a systems analysis approach to interrogate the very notion of stability in ecology and at the same time the epistemological limits of this discipline. This ended up in a discussion about the methods used in traditions of analysis in theoretical and empirical ecology, and to a decisive distinction between stability and resilience. His discussion on the methods is similar to traditional debates on the relevancy of a quantitative or qualitative approach in science. However he manages to show very well how any of such understandings in ecology affects what is conceived as equilibrium, and how the empirical reality of ecosystems shows that equilibrium is not something merely static. From there the confusion of the then notion of stability came into question with its roots both in mathematical analysis suggesting conditions very near equilibrium points, and its extension in system's behaviors related to persistence and probability of extinction. All the above is put forward while holding tight to the fact that in the natural

environment, systems are likely to be continually in a transient state that does not change even under the influence of man. Thus to bring more clarity to the overall subject, Holling distinguishes stability and resilience in this manner:

> Resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persisting. In this definition resilience is the property of systems and persistence or probability of extinction is the result. Stability, on the other hand, is the ability of systems to return to an equilibrium state after disturbance. The more rapidly it returns, and with the least fluctuation, the more stable it is. In this definition stability is the property of the system and the degree of fluctuation around specific states the result (Holling, 1973:17).

It is important to note that most of the leading minds on the SDC debate were rooted in population ecology, and the distinction that Holling makes in this paper between systems ecology and the then ecology is also a way to demarcate himself and the emerging school of thought (systems ecology) to which he belongs from the former group and their school of thought (population ecology). In this regard, a use of systems analysis and computer models to articulate his knowledge-claims marks some of the main differences between these two traditions in their approaches to the concepts of stability and resilience. For example in trying to recapitulate the history of the SDC debate in theoretical ecology over a century (before and after Holling s 1973 paper), Justus (2008:340) mentions all the SDCs scholars referenced in Holling's 1973 paper but also Holling's own contribution to the debate. While he acknowledges the fact that SDCs debate had been unsettled in its understanding of ecological stability to the point of causing confusion such as the ones experienced by Holling after the Brookhaven Symposium in 1969 or acknowledged in this 1973 paper (my emphasis), Justus nonetheless classifies the resulting SDC debate in a way that

makes it difficult to distinguish its substance from what Holling's 1973 paper proposes without bringing systems analysis and computer models into play (Figure 6 & Table 5).

Table 5. Different concepts of ecological stability. *R* designates a reference state or dynamic. P_v designates perturbations to system variables; P_p designates perturbations to parameters; and P_{vp} designates perturbations that affect both variables and parameters. Source: Justus (2008:340).

	Type	Definition	Properties
Perturbation-based stability types	Resilience	Rate a system returns to *R* following P_v, P_p, or P_{vp}	Comparative concept
	Resistance	Inverse of the magnitude a system changes relative to *R* following P_v P_p, or P_{vp}	Comparative concept
	Tolerance	Range of P_v, P_p, or P_{vp} a system can sustain and still return to *R*	Comparative concept
	Local asymptotic stability	A system returns to *R* following "small" P_v	(i) Dichotomous concept (ii) Special case of tolerance to *Pv*

	Type	Definition	Properties
	Global asymptotic stability	A system returns to *R* following any P_v	(i) Dichotomous concept
			(ii) Special case of tolerance to *Pv*
Perturbation-independent stability types	Constancy	Inverse of the variability of a system	Comparative concept

Furthermore Holling uses his own work on predation published in 1961 and 1965 and the findings of some scholars leading a strand of the debate on pest management in North American boreal forest, such as Baskerville (1971) or Morris (1963). These scholars belong to a network of a cadre of foresters and forest scientists based in industry, the provincial government, the maritime regional office of the Canadian Forestry Service, the forestry faculty of the University of New Brunswick (UNB), and the local (Maritime) section of the Canadian Institute of Foresters. These various organisations were under the umbrella of the Forest Protection Limited[36] (FLP), an institutional catalyst for a generation of forest-management thinking that advocates and legitimises the chemical spray approach to forest protection (Sandberg and Clancy, 2002:170). In effect Holling (1973:3) is of the view that:

> [B]anning D.D.T. may seem admirable, but advocating such narrow solutions can lead the ecologist to join the group of apparent villains (I emphasize apparent) who planned our freeways and designed our dams. That is a good way to destroy the myth of ecologist's moral

36 FLP is a hybrid enterprise, established jointly by the New Brunswick government and by the major pulp and paper companies, to plan and deliver an aerial spray program of unprecedented magnitude. It was created after World War II with the objective of expanding considerably pulp and paper manufacturing at a time when a new spruce budworm was erupting (Sandberg and Clancy, 2002).

> rectitude but hardly a way to be responsive to significant social needs.

Besides Holling's career in the Canadian Department of forestry and Canadian research institutions shared a number of similarities with the career of Gordon Baskerville[37] whose views were critical for the FPLs agenda:

> When the respected forester Gordon Baskerville characterized the New Brunswick "forestry problem," he concurred that the economic agenda set by the government in the 1940s necessitated the spray program (Baskerville, 1995: 37, 45-7). In one sense, Baskerville spent his formative professional years in Flieger's shadow [influential forester and forest entomologist, and first manager of the FPL]. After gaining his forestry degree for UNB Forestry in 1955, Baskerville worked for several decades in the maritime Branch of the Canadian Forestry Service. He then served stints as Professor and Dean at the UNB Forestry Faculty and later as assistant deputy minister of the New Brunswick Department of Natural Resources from 1979 to 1982 (Sandberg and Clancy, 2002:170).

Gordon Baskerville just like Holling and a few others were researching on "Forest ecosystem/Pest Management", a case study of the Ecology Project at IIASA. In that case study, IIASA was cooperating with scientists coming from the Institute of Resource Ecology, University of British Columbia, and from the Maritimes Forest Research Centre, Department of the Environment (Environment Canada). And some plans were designed for the study to be implemented in New Brunswick with the formal agreement of officials of Environment Canada from the Deputy Minister to regional authorities in New Brunswick (Holling and Walters, 1975:2). In the light of this cooperation, it was apparent that the FPL network had ties with IIASA. Though the "institutional networking" around the

37 He is the key individual for the implementation in New Brunswick of policies related to the Ecology Project's task on the budworm case study (Clark *et al,* 1979:44).

Ecology project suggests that IIASA was actually building its own network taking some of its inspiration and relevancy from FPL (Figure 7).

This institutional networking demonstrates IIASAs involvement in *science politics* a clash of scientific ideas and paradigms according to Sandberg and Clancy (2002:166). Hence Holling and Walters (1975:12) argue that: "[N]one of the above is science. But in a naïve way, it is a suggestion that IIASA can develop a new art, the art of scientific diplomacy that will require the best of scientific projects at IIASA, provided there is something to feed upon. The central goal is the art itself." It follows then that Holling's suggestion in the concluding section of the 1973 paper was to apply his concept of resilience in the field of management which was to be understood within the framework of this "scientific diplomacy". Because his 1973 paper would challenge the command and control approaches to ecosystem management advocated by systems ecologists, a school of thought which shared the methods of inquiry used to make his case (see Zebrowski, 1973:1965).

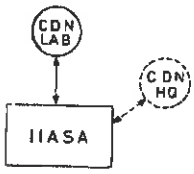


Figure 1. Networking - Step 1 1973-1974.

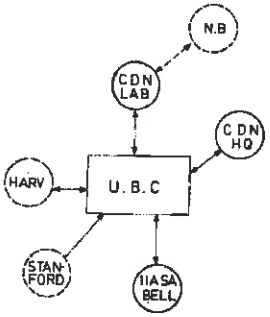


Figure 2. Networking - Step 2 1974-1975.

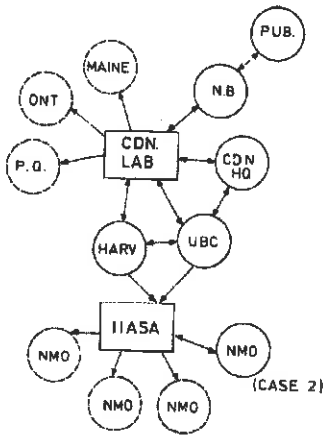


Figure 3. Networking - Step 3 1975-1976.

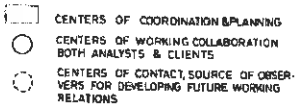


Figure 8. Institutional networking in IIASAs Ecology project. Source: Holling and Walters (1975)

However a management approach informed by Holling's resilience concept and therefore based "not from the presumption of sufficient knowledge, but the recognition of our ignorance" was not totally new in the 1970s (Holling, 1973:21). For instance, in the case of the Blue Mountains of the in land West, Langston (2000:34) argues that:

> Nearly a century ago, Frederick Ames (1910) warned that before foresters could begin to manage the Western forests, they needed to recognize that they did not understand the forest well enough to predict its response to management. Nevertheless, they had to manage; even doing nothing at all was a form of management. What they should do, therefore, was treat "all of sales as a vast experiment"

Similarly, Hollings made a number of experiments handling a vast amount of data using computer models and systems analysis in order to start formulating an approach of management based on the resilience concept. But he did not make any reference to Frederick Ames in his 1973 paper. While Frederick Ames suggested that foresters should pay more attention to both the forest and the effects of the human action on the forest as the case study of Forest Ecosystem/ Pest Management did, his ideas proved unworkable. Because no one knew what to do with the increasing amount of data that he required foresters to gather (Langston, 2000).This points again to the significance of computer models and the use of systems analysis in the way Holling re-articulated the concept of resilience and inferred a different approach to the management of forests during his stay at IIASA.

7.4. Connecting ecology with society: C.S. Holling at IIASA

Throughout the processes of establishing a science of ecological management, Holling and his colleagues at IIASA, revisited the 1973 paper and interrogated the assumptions in their respective contributions (7.4.1). The resulting debates and achievement of the goal of IIASAs Ecology Project refined and expanded the concept of resilience while showing the marks left on its propositions by its disciplinary origin, the geographical spaces of its inception and initial application in Canada and North America (7.4.2).

7.4.1. Achieving the goal of IIASA's ecology project

In the light of "Resilience and Stability of Ecological Systems" published in 1973, the resilience concept was already stressing three characteristics of change that occur in an ecosystem over time (Gunderson *et al,* XV). Firstly, a depiction of the "persistence of relationships within systems" and the "ability of systems to absorb changes of state variables, driving variables and parameters, and still persist." Secondly, it acknowledged the existence of alternative and multiple states contrary to the assumption of single equilibrium and global stability. Thirdly, it suggested the surprising and non-linearity nature of change. Additionally, the works that led to its refinement at IIASA were aware both of the significance and shortcomings of these three aspects of resilience. In this respect, Clark (1973:1-2) argued that:

> Much of our present work on "resilience" has concerned analysis of systems with alternative, non-zero, attractor domains or equilibrium states, the characteristics of boundary conditions separating those domains. This emphasis may provide useful and novel insight of sorts, but it should not be mistakenly taken as major interest. For, in fact, what we really ultimately want to do this year is:

1. Characterize in empirical detail the systems behaviour we term resilient;
2. Identify the structural (organizational) attributes of the system which result in the observed resilient behaviour;
3. Synthesize a predictive theory of the evolution (development) of our sorts of systems under specified patterns of history.

The above outlook regarding the research on resilience at IIASA reminds us that it was a body of work undertaken collectively by Holling and his colleagues. It was not isolated from the rest of IIASA's research projects. Rather, the fact that the resilience concept was at the core of IIASA's initial project (Ecology Project) allowed it to be thoroughly interrogated from different disciplinary vantage points and integrated or simply aligned with the research outputs of other emerging IIASA research projects. This view is reinforced by Clark *et al* (1979:46) when they note that:

> Major portions of the budworm case study took place while we were at the International Institute for Applied Systems Analysis. At the same time, various groups at that institute were engaged in studies of other resource development problems. This provided the opportunity to identify elements common to a wide range of problems. The projects chosen for the comparison included the forest pest problem described here, a study of national and international aspects of Pacific salmon management perspective-global versus regional, ecological and social versus physical and economic, national versus international. But they proved to share a perception of the primary issue (hypotheticality and coping with the unknown) and the central organizing concept (resilience topology). Surprisingly, and significantly, they also exhibited a similar structure of analytical steps (Fig.21.).

As for the articulation of the concept of ecological resilience in the 1973 paper, it was not finalised. Yet in "Systems Resilience and its Policy Consequences", a paper written in the early days of his collaboration with IIASA while still based at the Institute of Ecology Resource, Holling (1973:3) anticipated already what its application might necessitate:

> We are now, therefore, at a point where an intriguing concept has emerged, a set of models are available to explore the concept, and a policy framework is hazily emerging that emphasizes resilience and the maintaining of future open options. We are close to completing a significant study of systems Resilience and its policy consequences, and plan to use the year with IIASA to bring it to fruition.

In fact Holling (1973:6) situated the policy consequences of the resilience concept within the possibility of catalysing a "new science of ecological management/engineering". He summarises his views on the subject in the following lines:

> The point I wish to make is that the traditional view of stability, as presently practised, concerns responses to small perturbations and considers stable systems as those which fluctuate least and damp most rapidly. But an equally valid view concentrates on the responses to large perturbations and reveals that highly fluctuating systems can be immensely "stable" in that they can persist in the face of major disturbance.
>
> This view leads to a strategy of management that can attempt to work with the natural dynamic rhythm of eco-systems- that attempts not to eliminate fluctuations but to transfer them into directions less in conflict with man's desire; that attempts to design systems which are not so much fail-safe but safe in the inevitable event of their failure (remember Hurricane Agnes).

On July, 7th, 1975, a "workshop on hypotheticality, resilience and option foreclosure" was organised at IIASA. The objective of the workshop was to investigate common themes and consequences pertinent to the concepts of hypotheticality, resilience and option foreclosure. These three concepts relevant to systems designs and evaluation emerged from applied studies conducted at IIASA since 1972. Each of them was mainly concerned with understanding the nature and implications of the unknown (as distinct from the merely uncertain) in various aspects of applied systems analysis (Haefele *et al,* 1975:1). In spite of that, each of these concepts had its own genealogy. For instance, hypotheticality, was initially addressed as an engineering question dealing with "how do we best proceed with the development of new technologies or programs where traditional trial-and error approaches to design and evaluation are not possible." Resilience originated from "consideration of ecosystem behaviour whereby persistent natural systems were found to exhibit a variety of mechanisms enabling them to absorb stress, adapt to changes in their environments, and often survive in case of surprise. And the idea of policy option foreclosure was the outcome of studies of resource development programs grounded in the observation suggesting that "existing approaches to planning and development systematically and predictably lock society into inflexible and nonadaptive situations to which the only response is too often the preservation of an undesired status quo (Haefele *et al,* 1975:1)."

While the genealogies of the concepts to be discussed during the workshop intersected, their specific disciplinary lineages caused some disagreements. In this regard, confronted with the mechanistic views of some contributors to the workshop, especially the engineers, Holling clarified the rationale of his own work and what he expected from his collaboration with others at IIASA:

> As a modest minimum, he [Holling] wanted understanding, in dictionary form, of what each of the various actors meant when they used terms like hypotheticality, option foreclosure, resilience, risk, uncertainty, and probability both objective and sub. He [Holling] also hoped to deepen his understanding of the potential roles of the various methodological tools, especially catastrophe theory, control theory, and stability theory. His reason for doing so, in fact the fundamental goal toward which all his work was oriented, was to design " a world without hypotheticality" not to design yet more coping strategies that dug us all in deeper, but to prescribe approaches which would make the consideration of hypotheticality irrelevant altogether. In this sense he saw the work of many engineers, even (and perhaps especially) the most visionary, as antithetical to his own goals (Swain, 1975:8).

In retrospect, the resilience based approach to management articulated in a paper which he co-authored with Myron B.Fiering in 1974 was part of Holling's goals. The paper was titled "Management and standards for perturbed ecosystems" and published in *Agro-Ecosystems*. Both authors were affiliated with IIASA at the time of publication, while Holling was based at the same time at the Institute of Resource Ecology and Fiering was the Gordon Mckay Professor of Engineering and Applied Mathematics, Harvard University. With this in mind, it is noticeable that Holling's actions to design "a world without hypotheticality" preceded the discussions at the workshop:

> Our objective is not merely to preserve ecosystems (whatever that means) because it is fashionable to do so, but rather to encourage the systems to work with us. Therefore we are concerned principally with ecosystem policy: its definition (s) and scope, its scientific and socio-economic consequences, its implementation of environmental standards. We hold that the implementation of environmental standards and the encouragement of ecosystem resilience are, or can readily be different manifestations of the same: to live more or less

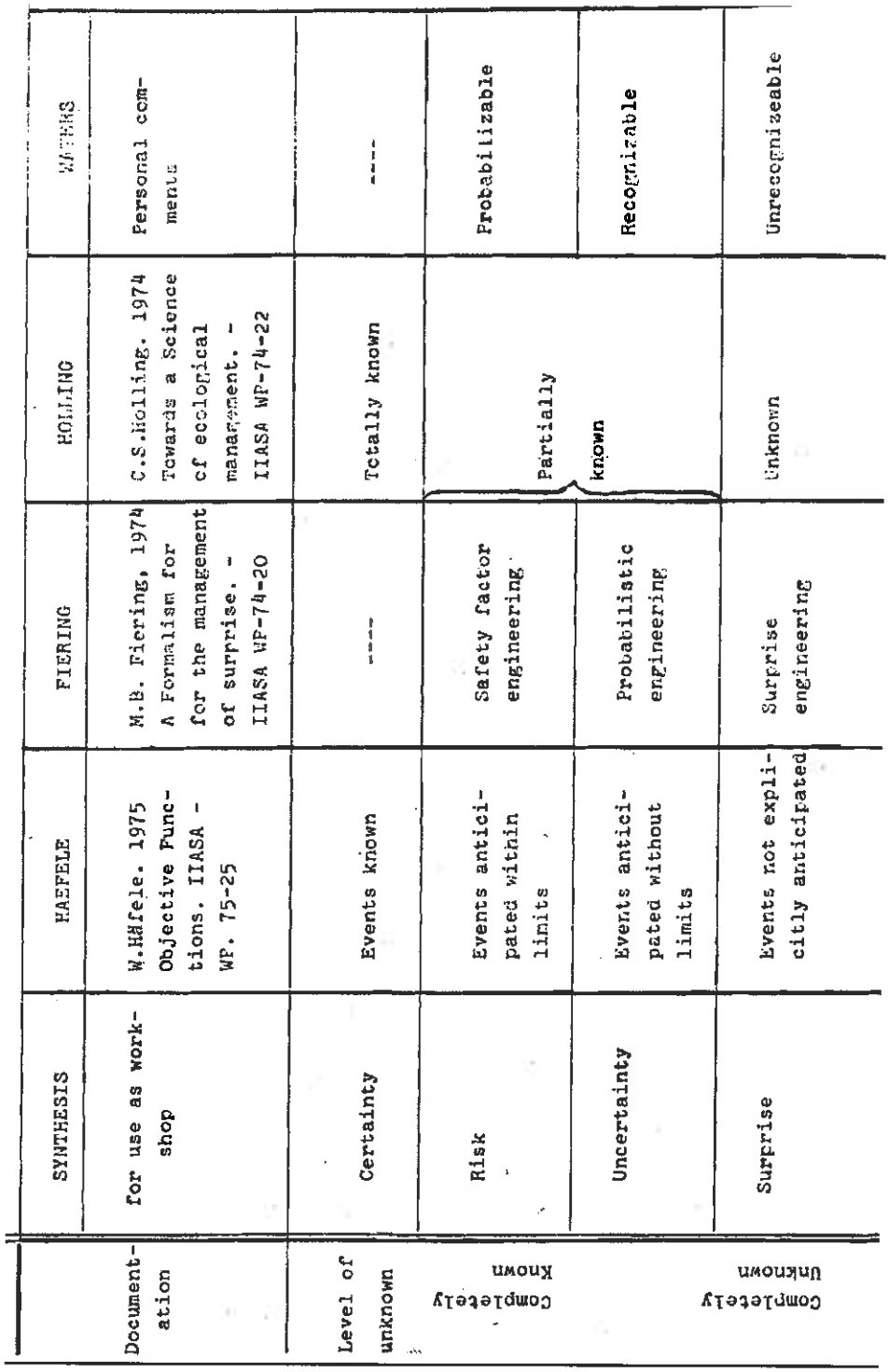
> harmoniously, with and within the ecosphere (Fiering and Holling, 1974:302).

It follows then that Holling objected also to the presumption of sufficient (existing) knowledge informing the views of his colleagues in relation to the concept of option foreclosure:

> Walters then repeated the main conclusions of his option foreclosure paper. We should try to think systematically about the consequences of decisions, not just the systems consequences, he said, confusing Raiffa no end. Using education as an analogy, we should evaluate present decisions in terms of the size and attractiveness of the array of new decisions that are then opened in future time periods. Clark and Swain both noted the analogy with military history and tactics and suggested, sub rosa, that IIASA hire a General or two as consultants. Holling broke in to say that all these suggestions were retrograde essentially back in the "engineering for safety" paradigm. What about (he asked rhetorically) all those folk who value, indeed live off, a series of mini-disasters? Fishermen, entrepreneurs, and Howard Raiffa's hiring policies were all built around the deliberate planning of serendipity. He denounced us all, and decisions theorists in particular, for wanting to take the fun out of life (Swain, 1975:12).

It should be recalled that the discussions at the workshop were primarily based on the works undertaken by Haefele, Fiering, Walters and Holling at IIASA. All these contributors were concerned with approaches engaging with the unknown in applied systems analysis and design. But in Table 6, it is clear that Holling, just like Haefele and Fiering has been involved more or less independently, in "classifying" the various levels of "unknown-ness" which may be particular to given aspects of a problem (Clark, 1975:27).

Table 6. Version of taxonomy. Source: (Clark, 1975)



Document-ation	SYNTHESIS	HAEFELE	FIERING	HOLLING	WATERS
	for use as work-shop	W.Häfele. 1975 Objective Func-tions. IIASA - WP. 75-25	M.B. Fiering, 1974 A Formalism for for the management of surprise. - IIASA WP-74-20	C.S.Holling. 1974 Towards a Science of ecological management. - IIASA WP-74-22	Personal com-ments
Level of unknown	Certainty	Events known	----	Totally known	----
Completely known	Risk	Events antici-pated within limits	Safety factor engineering	Partially known	Probabilizable
	Uncertainty	Events antici-pated without limits	Probabilistic engineering		Recognizable
Completely unknown	Surprise	Events not expli-citly anticipated	Surprise engineering	Unknown	Unrecognizeable

Although it has been written in a tentative way, the notes on "Toward a structural view of resilience" which also served as background material for the

"IIASA Workshop on Hypotheticality, Resilience and Option Foreclosure" are of particular interest to understand how the meaning and applicability of the resilience concept was refined and expanded after the 1973 paper. In effect three components of resilience are identified in these notes, Class I, Class II, and Class III (Clark *et al,* 1975: 3-4). The Class I or Boundary Component encompasses the elements which in systems provide the means of recovery after perturbation, without any involvement from its non-perturbed areas. Negative feedback management rules or control mechanisms, or state-dependent often illustrate well this property. Class II or the Restorative Component refers to (a) the existence of unperturbed parts of the system, and (b) the capacity of those unperturbed parts to participate in the recovery of the perturbed parts. Class III or the Contingency Component take into consideration the level of dependence of a system's resilient properties on facets of the environment beyond its immediate reach. In this case, mechanisms dealing with the provision of a variety of sources for necessary resources, and with decreasing sensitivity to single factors or elements of the systems are considered. These properties of resilience sought to be applied in the vast array of fields connecting the ecology and the "urban". However before getting to the substance of the aforementioned refinement and expansion of the resilience concept, Clark *et al* (1975:8) reflect first on the 1973 paper and point out the rationale behind this subsequent work:

> In particular, at the stage of our research summarized in Holling (1973), we felt that we had good quantitative handles on resilience only for the simple case of a closed, homogenous, deterministic system. The importance of "open" system effects, of spatial and temporal heterogeneity, and of random or irregular events was recognized, but understood only hazily and at a most uncomfortably qualitative level. Yet our review of the literature on "stability" properties of disturbed ecosystems made it clear that these latter

> factors would have to deal with explicitly any really satisfactory conceptual framework.

Still if the policy consequences and the application of the resilience concept appeared evident for Holling since the 1973 paper, the difficulty to grasp some aspects of this concept remained for some of his colleagues, at least up until the IIASA Workshop on Hypotheticality, Resilience and Option Foreclosure". Thereafter, in the "Notes on Holling's Resilience Measures Presentation IIASA, 11 July, 1975", Clark (1975:1-6) stresses four points which still needed to be dealt with before processing a final document on the subject. First, - contrary to Holling's view that, the prey-predator model upon which the resilience concept is based is "the simplest possible case" developed by IIASA researchers mostly for pedagogic and learning purposes, he notes that such a 2-dimensional state space re-presentation (prey-predator) is not the simplest case; the single dimension ("prey") case is. Almost every point made in the presentation could have been done more clearly on a one dimensional axis... ". Second, drawing from works on the typology of hazards, he sketches a way to measure the resilience of a system through a consideration of its components as structures and little or nothing on its detailed character. Third, for the sake of generality, he insists on the use of dimensionless measures. Finally, he remarks that the use of terminology has been unnecessarily sloppy and prone to great confusion because: "One difficulty hangs on the uncritical use of the word "system". Which systems? That defined by the perturbation? That including Restorative Components?" These four points and Holling's rejection of the mechanistic views of engineers and decision theorists during the discussion at the "IIASA Workshop on Hypotheticality, Resilience and Option Foreclosure" fall within the broader remit of a reflection pertaining to the practice and utilisation of applied systems analysis (ASA) which had been put forward by Clark (1975:5) a few months after the workshop:

> IIASA is explicitly in the business of developing and promoting ASA as a vehicle for increasing the impact of knowledge-more precisely the impact of rationality-on the decision making process. Were ASA a traditional technological innovation rather than a subtle conceptual one, we already would have noted its potential social impact with no little alarm, and subjected its internal workings to no mean scrutiny. In fact, however, we have been kept from undertaking such a serious analysis of our own affairs by an aversion to self-examination which is as understandable as it is unjustifiable. This regrettable history notwithstanding, there can remain little question that ASA or if preferred, "knowledge systems" presently constitute a proper and even urgent subject for study at IIASA and elsewhere.

As already demonstrated in the preceding chapters, the use of systems analysis as well as the formation of Holling's environmental consciousness was part of his experience in different parts of Canada (and to a large extent North America) between the 1960s and the 1970s. In effect, there has been a form of empathy in Holling's representation of the North American boreal forest as a traumatised nature under the wrath of man's influence. This empathy sheds a light on the reasons why he had been anthropomorphising "nature" in some of his writings. Whilst it is clear that his concerns about the environment are persistent, the interests calibrating them have been evolving at least since his presentation at the Brookhaven Symposium in 1969. There, Holling was criticising the fact that economic interests and industrialisation impede man to make sense of the signal sent by a traumatised environment (Holling, 1969). In doing so, he was forecasting apocalyptic events on earth. In 1973, Holling, then Director of the Institute of Resource Ecology, University of British Columbia co-authored a paper titled "Resource Science: Nurture of an Infant". His position regarding environmental problems in that paper is not detached from the concerns that he held at the Brookhaven Symposium, yet it is particularly pragmatic and solutions-driven as the following lines show:

> Now Mother Nature is not in a delicate state of balance- community wisdom to the contrary. Natural systems have evolved over a very long time and have experienced traumas and shocks long before man came on the scene. Unexpected catastrophies are part of the natural order and selection operates so that that those organisms, populations, and communities that survive are explicitly those that are able to take unexpected trauma in their stride. They have developed an internal resilience to absorb punishment, and it is this resilience that has absorbed the consequences of man's intrusions. But the resilience is not infinite; we now face the consequences of stretching the bounds of resilience of ecological and social systems (Holling and Chambers, 1973:13).

In the above quotation, social issues are naturalised in the moment of linking both ecological and social systems through the concept of resilience. This has some implications in the ways in which an approach of management based on resilience is to be implemented, yet simultaneously sends us back to the confluence between *science politics* and the *politics of science*[38] which can find an illustration in the rise of environmental consciousness in New Brunswick. With respect to this, Fiering and Holling (1974:302) state that:

> We hold, further, that environmental standards must reflect not only our current perceptions on what is "good" or " bad" about a particular combination of ecosystem states variables, but also how the elements of that array will respond in time to natural interactions and to man's intervention. These must be made in concert.

38 It means that "the science underpinning resource management is constrained by societal forces, and scientific thinking is influenced by powerful political and economic interests. Any management methods that work against such interests may be challenged marginalised or discredited (Sandberg and Clancy, 2002:1965)."

The above quotation clarifies the fact that Holling's view of a resilience based approach to management is informed by the philosophy of conservation that underpinned a strand of the "modern environmental consciousness" in North America, and more specifically in New Brunswick in the 1960s (see Chapter 6, p. 123-128). It also shows that in this approach of management, social and ecological systems are connected. Although the language used to speak about "what is "good" or "bad" about a particular combination of ecosystems state variable" is seemingly scientific, what it entails actually is mostly a matter of *politics of science*. Thus, cognisant of the fact that in this kind of management approach, issues pertaining to the "sciences of man" are also dealt with, then it becomes pivotal to put more attention on the idea that:

> [W]hat looks superficially like the most scientific procedure is often the most unscientific, and beyond this, that in these fields there are definite limits to what we can expect science to achieve. This means that to entrust to science-or to deliberate control according to scientific principles-more than scientific method can achieve may have deplorable effects (Hayek, 1989:6).

The conservative philosophy supporting the approach of management based on Holling's concept of resilience, suggests that his interventions both in *science politics* and in the *politics of science* captures the practice of what Berejikian and Dryzek (2000: 205) call an "intelligent actor". In effect, these scholars argue that if actions constitute situations, then intelligent actors should reason constitutively as well as instrumentally, such that constitutive concerns should often override instrumental concerns. In this context, they note that "instrumental rationality is the capacity to devise, select and affect good means to clarified and consistent ends." Conversely in constitutive reasoning, an actor does not ask the following instrumental question, "Does action X help achieve goal Y?" instead, the actor asks, "Does action X help to constitute a world I find attractive? As a result, the foundation of a new field of study in 1975, Adaptive

Ecosystem Policy and Management at IIASA based on the findings of a research relating forest conditions to pest propagation with implications for forest management policy across North America and Scandinavia, attests effectively that Holling is an "intelligent actor" (IIASA, 2007).

7.4.2. Re-scaling of the resilience concept and New Brunswick's imprints on adaptive management

The establishment of Adaptive Ecosystem Policy and Management at IIASA meant that the main goal of the Ecology Project was achieved. While this new field of study had the resilience concept at its core, the expansion and refinement of this concept derived from an exploration made through a case study whose specific focus was the management problems associated with the competition between man and insect (the spruce budworm, *Choristoneura fumiferana*) for utilisation of coniferous forests in the Canadian Province of New Brunswick. According to Clark *et al* (1979:1), the study in question was framed by a commitment to transfer the various models and policy design capabilities from their initial academic setting to the desks and minds of practicing managers and politicians. A number of workshops, model gaming sessions, and non-traditional communication tools were developed and tested in order to reach this objective.

Furthermore the three components of resilience suggested in "Toward a structural view of resilience"- a paper serving as background material for the "workshop on hypotheticality, resilience and option foreclosure" was a mimicry of the development of theory on the population dynamics of the budworm and practice of pest management in North American boreal forest. This mimicry was made possible by the *fondamentalisation* of economic entomology. As such, Class I or the Boundary Component stems from the *sivicultural hypothesis* in the way it puts the emphasis on maximum sustained yield to restore the forest's "natural" equilibrium. Class II or the Restorative Component and Class III or the

Contingency Component are drawn from the *Double Equilibrium hypothesis* firstly articulated by Morris (1963). This hypothesis proposes two states of equilibria: endemic and epidemic (Rauchfuss and Ziegler, 2011:572). The endemic phase is when the budworm populations are low and are regulated by parasites and predators. The epidemic state occurs when favourable weather or when many moths move to the area in such a way that the budworm population increases dramatically. An important corollary of the *Double Equilibrium hypothesis* was that the frequency of outbreak is not predictable and man's use of spraying is inevitable to deal with the outbreak (Ireland *et al,* 1988:5).

Historically, the management of forests throughout Canada had been subject to changes. For instance, in contrast to the long standing position in New Brunswick advocating for insecticides as the only option for forest management in the short term, in Nova Scotia most scientists sought the causes of budworm outbreak in human action or in commercial terms before World War II until the 1950s. During that period, the approach to the management of forests in Nova Scotia was informed by the *sivicultural hypothesis.* This hypothesis posits that the damage caused by past forestry practices rendered the forest increasingly vulnerable to budworm outbreak. This meant concretely that in order to restore past ("natural") forest composition, pure stands of fire ought to be cut and reproduction of spruce and pine enhanced by sowing seeds of spruce and pine after every cutting activity where fir constitutes the majority of trees (Rashid, 2003). Up to late 1940 a management approach informed by the *sivicultural hypothesis* was not implemented regardless of the fact that ecologists and foresters agreed on its practical value. Still the strength of the *sivicultural hypothesis* was that alternative management was the solution to diminish the likelihood of budworm outkreak. Such a solution was often associated with biological control- a method mostly advocated by entomologists in Nova Scotia. Both biological control and *sivicultural hypothesis* shares the fact that their

implementation required a long-term outlook and a relatively extensive period of time to take effect.

However since its inception in 1922 the *sivicultural hypothesis* had never superseded the spraying of insecticide as the dominant approach to the management of forest in New Brunswick (Rashid, 2003). Instead from the late 1970s onward, the practices of forestry in Nova Scotia and New Brunswick started converging toward the research outputs of IIASA's Ecology Project as more and more politicians began endorsing them (see Sandberg and Clancy, 2002). This shift was not to be attributed alone to the "science" of the Ecology Project. Because its inclination toward entomology rather than forestry in its methods meant figuratively a decrease in the use of pesticides and increase in biological control. It also meant important economic losses for the pulp and wood industry in the short term at least. Therefore it was unlikely to be accepted in New Brunswick. In addition, the task force working on the case study engaging with the competition between man and insect in the utilisation of coniferous forests in New Brunswick relied heavily on the *Double Equilibrium hypothesis.* But T. Royama, who supported this hypothesis at least up until 1977, put forward *the regular oscillatory trend hypothesis* after a careful examination of the same data (Green River Project in New Brunswick) which supported its propositions (Royama, 1984:458). Royama's contribution introduced a new interpretation because:

> Instead of populations shifting rather abruptly from a low equilibrium to a high one, and the reverse, Royama sees in the data a regular, gradual oscillatory trend in numbers, with the period between peaks and valleys at about 35 years. Modelling by Royama and by Regniere (1984) suggests that oscillation of this type is probably driven by density dependent mortality factor (or factors) having a delayed response to changes in budworm numbers. Both have suggested a

> disease as a likely mechanism, and Regniere's study has simulated a 35-years oscillation using hypothetical, vertically-transmitted disease (from parent through egg to next generation) as key mortality agent (Ireland, 1988:6).

At the time of the publication of their hypothesis, both Morris (1963) and Royama (1984) were connected to the FPL network respectively through its Forest Entomology and Pathology Branch, Department of Forestry, Ottawa, Canada; and the Maritimes Forest Research Centre, Canadian Forestry Service.

To summarise what has already been stated, Class I, II and III properties of resilience integrate the symbiotic relationship between the budworm and the forest with the dependence of New Brunswick's economy on forest products. As such the resilience concept captures initially the parallelism between the developments of population dynamics of the budworm on the one hand, and the changes in pest management in New Brunswick on the other hand. Thus adaptive management distinguishes itself by supporting the belief that: "the implementation of environmental standards and the encouragement of ecosystem resilience are, or can readily be different manifestations of the same: to live more or less harmoniously, with and within the ecosphere" (Fiering and Holling, 1974:302).

Moreover Cetina (1991:107) is of the view that an understanding that treats "context", "society", or "culture" at the margin of science/knowledge, and interrogates their "affect" on scientifically rational procedure is surprisingly self-limitative in that it overlooks how these domains are always part of science. This explains why the implementation of the adaptive management in New Brunswick found some obstacles even though the Ecology Project at IIASA was seemingly widely shaped by expectations originating from Canada. In effect, the mismatch

between the search for generality at the core of the Ecology Project and the intersection between the scientific and socio-economic factors in the management of forest in New Brunswick led to mixed reactions. Holling and Walters (1975:4) address part of this concern in the following section ("What We Didn't Do") of a research report at IIASA:

> Our initial objective of putting something in place as quickly as possible had a price attached to it. Superb interaction evolved between Ecology and other IIASA projects Methodology, Energy, and, in particular Urban. Cross-cultural and international interactions within IIASA lies. This was made all the worse because the perception has developed that the work was done by Canadians on purely Canadian problems. In reality, the scientists from the project have come from the FRG, Italy, Japan, USSR and the USA as well as from Canada. We are deeply involved in a water quality study of the Rhine River, and a cross-comparison of regional energy systems in France, the GDR and the USA. During the next few years we must concentrate from a regional base on more global problems, with emphasis switched to international linking and cooperation; this will require persons of the highest skills in scientific diplomacy.

In the above quotation, contrary to what its title suggests, the bulk of the writing with the exception of a few words in the disclaimer regarding the heavy Canadian coloration of the project is about what the project did well and what is to be done to amplify this gain. Paradoxically, the only thing that the authors try to dismiss is the issue on which the section seems to owe its title while its content had a minimal amount of words to elaborate on it. Whereas the "highest skills in scientific diplomacy" needed for the expansion of the scientific achievements celebrated in this section are certainly designed to facilitate the creation of a truly international network of scientists, what they managed so far to achieve since the inception of the Ecology Project at IIASA seem not to have

changed the epistemic culture grounding it. Therefore, the fact that a "perception has developed that the work was done by Canadians on purely Canadian problems" was not entirely misguided. Rather, at least part of it originates from the confluence of the *politics of science* and *science politics* which warranted even the *de facto* participation of scientists whose perception on the overall development of the Ecology Project reminds us of the inclination of Holling's initial research since its first years at the Sault Ste Marie Laboratory. Yet simultaneously, it (*de facto* participation of scientists) also confirmed the success of the project in diffusing what it holds as "science" across the knowledge infrastructure legitimising it. But the sceptical reception of the findings of IIASA's Ecology project in New Brunswick highlight the disciplinary lineage of Holling's initial research at the Sault Ste Laboratory, the subsequent evolution of his way of thinking with the help of computer modelling and systems analysis as well as their place in the local scientific community in Canada. In other words, forest managers in New Brunswick found that the inner workings of the proposed models was difficult to understand and induced a lack of confidence in the results. They also thought that the population dynamics models were prone to have more an entomological than a forestry inclination (Ireland *et al,* 1988:10). Still the growing influence of the "modern environmental consciousness" over the years meant some degrees of change in the balance of power of the politics of science in North America. So, by the 1980s, Holling started realising that the problems affecting the practice of management in eastern Canada and in the west coast of North America "was transient and could be broken by a spasmodic readjustment, an adaptive lurch of learning that created new opportunity" (Holling,1996:59).

In 1982, Holling, then Director of IIASA, asked W.C. Clark, then at Oak Ridge Associated Universities (USA), to start an assessment of what additional work beyond that already underway would most help to achieve the potential for an

enhanced management of interactions between development and environment (Clark, 1986: 5-6). The resulting international program, *Ecologically Sustainable Development of the Biosphere,* was based at IIASA and involved a collaborative network of historians, engineers, geographers, environmental scientists, economists, managers and policy practitioners from around the world. The first phase of this program led to the publication of a book (*Sustainable Development of the Biosphere*) edited by W.C. Clark and R.E. Munn and published in 1986. This ground-breaking work was one of the 'pioneers' to build and synthesise understanding around themes of sustainability and global environmental change, years before global climate change became a fashionable research topic or undertaken by large international research institutions (Allen *et al,* 2010:7). Hollings's chapter in this volume is titled "The resilience of terrestrial ecosystems: local surprise and global change".

This contribution built on the works on resilience at IIASA which followed the 1973 paper, and asks four key questions. How do the Earth's land, sea, and atmosphere interact through biological, chemical, and physical processes? How do ecosystems function and behave to absorb, buffer, or produce change? How does the development of man's economic activities, especially in industry and agriculture, disrupt the global system? How do people whether as individuals, institutions or societies, adapt to change at different scales? The second question is responded to in this chapter by way of exploring how ecosystems function and behave but the other three are kept in mind. This response relies heavily on the distinction between resilience and stability while its conceptual framework is constituted as follows:

> [F]irst the relationships between ecosystems and two other key aspects of the global puzzle must be established namely, with global biogeophysical events, and with societal perception and management. In the former case, some image is needed of the way the global systems in the atmosphere, oceans, and land interact. That image is provided by the Gaia hypothesis [6]. And to relate our understanding of the behaviour of local ecosystems to the way societies perceive and manage those systems the concept of surprise is needed: Gaia and surprise (Holling, 1986:294).

The essence of resilience is surprise according to Holling, and surprise is part of the taxonomy of the unknown which served as a background material "workshop on hypotheticality, resilience and option foreclosure" (Table 6). But Gaia and surprise are not the only concepts mobilised in this analysis, ecosystem scales[39] and adaptive cycle[40] are also introduced. This chapter provides also a qualitative understanding which helps to place attention on the connections between ecosystems and other systems present in societies. It does that in order to define a research agenda able to provide an empirical base for the analogies presented in the Table 7.

In the 1990s, the function and typology in the above table will be further developed by Holling and his colleagues around the concept of panarchy, namely "the way living systems both persist and yet innovate (Holling, 2003:1). I examine these developments in the next chapter.

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39 According to Holling (1986:297), they are "communities of organisms in which internal interactions between the organisms determine behaviour more than do external biological events".

40 It is "a general heuristic of ecological dynamics over time, which is a prototheory of nonlinear dynamics in complex systems of people and ecosystems" (Gunderson and Allen,2010:XXI).

Table 7. Possible analogies between ecosystem function and functions or typologies proposed for other systems. Source: Holling (1986).

Subject	*Function or typology*			
Ecosystem	Exploitation (r)	Conservation (K)	Creative destruction	Renewal
Economics [e.g., 70]	Innovation, Market, Entrepreneur	Monopolism, Hierarchy, Saturation, Social rigidity	Creative destruction	Invention
Technology [e.g., Brooks 87]	Innovation	Technological monoculture, Technological stalemate	Participatory paralysis	Expert knowledge
Institutions [e.g., 88, 89]	Entrepreneurial market	Caste, Bureaucracy	Sect	Ineffectual
Psychology [e.g., Jung as in 90]	Sensation	Thinking	Intuition	Feeling

Conclusion

In the 1950s, the Sault Ste Marie Laboratory enframed initially C.S. Holling's epistemological imagination and shaped his purposes as a researcher. However, it was not only specific, physically marked, spaces such as Sault Sainte, that shaped his work, but also categories of space such as 'the city' which captured a series of similar and separate experiences. Between the 1960s and the 1970s, 'the city' became central in his work at three levels. Firstly, the concerns of the North American cities movement in the 1960s resonated in the articulation of introductory and concluding sections of some of his papers. Secondly, the city became a truth-spot in which both the lab (and urban/culture) and the field (and forest/nature) interacted in order to legitimise his knowledge-claims. Thirdly, the city became incorporated into the urban system which became connected to the ecological systems in Holling's evolving thinking. In contrast, the use of computer models and systems analysis while enabling the re-articulation of resilience, hid the bearings that Holling's multiple engagements with spaces left on the formation of his research outputs. That is not surprising because the expansion

of the disciplinary space of Holling's research went hand in hand with the *fondamentalisation* of economic entomology. His 1973 paper epitomises well these developments both within the context of a disciplinary space and the epistemic culture of the era.

Finally, this chapter firstly shows what the expansion of the disciplinary space of the concept of resilience entails after the publication of the 1973 paper. The publication of "Resilience and Stability of Ecosystems" by C.S. Holling in 1973 did not close the debate on what resilience meant in the field of ecology and beyond at that time. Instead the possibilities that the concept of ecological resilience opened for its application led to further research on the ways in which the theoretical construct that it refers to, manifests in different fields of studies and practices. That is to say that more research has been conducted within IIASA for a better understanding of what counted as properties of resilience in the structure of systems which concern active designers, engineers, managers or responsible policy advisors. But the recognition of this effort did not happen overnight. Hollings emphasises such a course of events when he says: "[u]sually in the work that I have done, the part that I see as innovative has typically taken 25 to 30 years before getting through the cloud of skepticism to be embraced as an integral part of existing knowledge (Holling , 2010:3)".

8. Re-scaling and spread of Holling's idea of resilience internationally from the late 1980s onwards

Introduction

The preceding chapter traces the evolution of Holling's thinking while putting the emphasis on the connections that he gradually made between ecology and society so as to set the ground for the coming into being of his 1973 paper, "Resilience and Stability of Ecological Systems". In doing so, the changes in his conceptualisation of space and narration of research outputs throughout the process of his movement across spaces have been examined in order to explore the influences they might have had on the ways in which his thinking had been evolving. If the previous chapter put the emphasis on the 1973 paper, this chapter does not follow up with the assumption that: "[B]uzz Holling's seminal paper revolutionised the theory of management of environmental systems, emphasising forces that confer resilience in the face of disturbance" or that "[R]esilience theory has matured into a movement involving the best minds in ecological and economic theory and fundamentally influencing management" (Levin, 2010). It posits that "[A] scientific paper, for example, provides a distorted view of how science is actually done, capturing little or nothing of the hesitations, mistakes, and dead ends that are a normal part of any research. And as always, it is necessary to consider the intentions of the author, as well as her intended audience" (Bocking, 2008:302). Besides several developments characterise the concept of resilience after the publications of the 1973 paper. These developments concern mostly the transition from refinement at the International Institute of Applied Systems Analysis (IIASA) by Holling and his

colleagues up until 1986 to the consensus building-work initiated in the 1990s, as well as the key institutions that led to his wide circulation internationally.

The remainder of the chapter is organised as follows. The first section shows how the work undertaken at IIASA by Holling and his colleagues fostered the relevance of the resilience concept along with the rising interest on issues related to climate change and sustainability in the 1980s. It also unpacks the effects of the consensus-building work (in the 1990s and mostly in regard to Sweden) upon which lies the establishment of a set of knowledge infrastructures whose role in the popularisation of the 1973 paper in particular and social-ecological systems research in general is essential. The second section attempts to grasp the expansion and various uses of the work of Holling and his colleagues on "resilience theory" and the extent to which his human experience and the multiple adjustments which characterised the trajectory of his resilience idea and which surface in subsequent resilience related research across disciplines and in different policy circles.

8.1. Re-scaling the concept of resilience

The connection made between the resilience concept and issues around climate change and sustainability at IIASA in the 1980s (8.1.1) led to relatively quick and positive responses out of which a consensus and tailored knowledge infrastructures emerged, then started bolstering research related to resilience and social-ecological systems in return (8.1.2).

8.1.1. Expansion of the institutional and conceptual grounding for the idea of resilience

In the mid-1980s, the U.S. withdrew the support it was providing to IIASA through its mission to build international bridges. According to McDonald (1998:70-71) the Ronald Reagan administration justified this withdrawal with a

claim that the Soviet Union was abusing the institute and was not interested in reciprocity. But the withdrawal of the US support was not the termination of U.S. membership because IIASA was a nongovernmental organisation. McDonald (1998: 72) reports that in order to make sure of the continuity of U.S. involvement, an independent IIASA-U.S. Planning Group was created. Besides, he notes that the U.S withdrawal had an impact on several other national member organisations (NMOs), yet only one (the Royal Society) followed the steps of the U.S. So by the time Holling became the 3rd director of IIASA in 1981 up until 1984, the institute was going through a crisis in relation to its mission and sources of funding. In relation to this, in his capacity as director, Holling restructured IIASAs research programmes that were largely influenced by dominant NMOs rather than the potential contribution of each given scientist working at the institute (IIASA, 2013). He also re-energised IIASAs climate change activities and deepened and strengthened the overall "methodology" of the entire institute (IIASA, 2013). In 1986, the publication of *Sustainable Development of the Biosphere* edited by W.C. Clark and R.E. Munn was a direct outcome of these new developments at IIASA under Holling's leadership.

The additional attention that characterised IIASAs climate change activities in the early 1980s followed the efforts of many environmental organisations which had been struggling to put environmental issues on to the political agenda since the 1960s and 1970s. These efforts gained more intensity and diversity in their *modus operandi* in the course of the 1980s until the beginning of the 1990s. In this regard Breitmeier and Rittberger (1998:7) observe that:

> Although NGOs have been quite successful in challenging states in international political processes dealing with environmental issues since the first UN Conference on the Human Environment held in Stockholm in 1972, it is by no means certain that the frequency and strength of NGO activities have already led to a power shift in favor of civil society anywhere. On the contrary, states began negotiating

> environmental problems at the international level long before NGOs articulated their demands. Apart from the work of experts and technical assessments and monitoring of environmental hazards, states were first to seek collective action at the international level, and it was not before the mid-1980s when the number of nongovernmental participants in international political processes increased commensurately with the frequency of intergovernmental negotiations on environmental issues.

With a range of supporting evidence such as the growth of environmental activities internationally (Figure 9), Meyer *et al* (1997:626) argue that the overall growth of environmental organisations went hand in hand with the expansion of a worldwide scientific culture and the setting up of a large world organisational structure, and that the character of the environmental regime changed over time from informal international discourse and association to more official intergovernmental activity and organisation. For instance, in 1989 after the collapse of the Soviet Union, McDonald (1998:73) mentions three factors which led the George Bush presidency to renew its support to IIASA. The first had to do with the U.S. initiative to create three international centres for cooperative research on global climate change. The second was the considerable impact of lobbying by the American Academy's U.S. Committee for IIASA and others. Finally there was the reduction of U.S. security concerns' after the end of the Cold War. Also, in the course of the 1980s, enough evidence was accumulated to persuade that climate change was one part of a much broader phenomenon, global change (IGBP, 2015:1). Thus it was under the umbrella of this large phenomenon that IIASA adapted its mission after the collapse of the Soviet Union. To put it simply, in 1994 "a Ministerial Conference renewed the mandate for the institute to conduct independent, scientific research with a global perspective; since then members from Asia, the Americas, Oceania, and Africa have joined" (IIASA,

2015:3). Table 9 provides an historical view on the broader policy context in which the idea of resilience germinated in the 1990s.

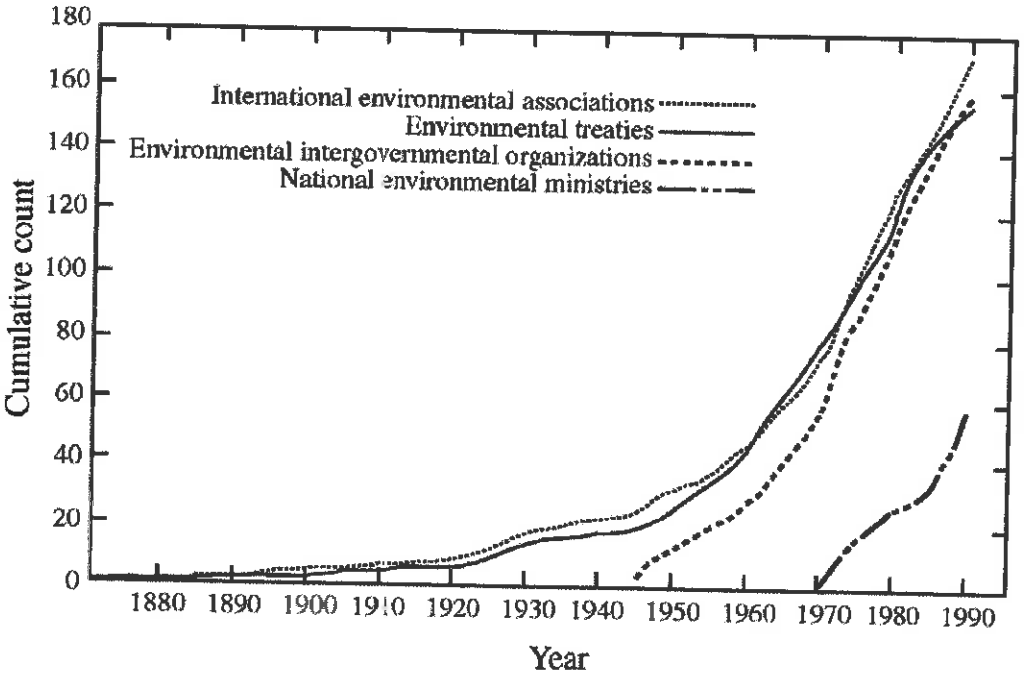


Figure 9. Smoothed hazard rates for initiation of international environmental activities, 1870-1990. Source: Meyer *et al* (1997).

The interest in global change which arose in the 1980s was well articulated in "The resilience of terrestrial ecosystems: local surprise and global change" which is a chapter in *Sustainable Development of the Biosphere*. In that paper, Holling (1986) outlined a research program aiming to establish an empirical base for the analogies that he found between social and natural ecosystems as well as the ways in which living systems respond to change. In doing so, Holling's resilience research found a place in the midst of environmental and global change issues. Therefore it is no surprise that with his 1986 paper, Holling earned relatively quickly a large professional following (Walker and Cooper, 2011:147). For

example, in 1991 the newly recognised Beijer International Institute[41] (BI) in Stockholm started a programme on the ecology and economics of biodiversity loss at a time when contributions from ecosystem ecologists on aspects of biodiversity in ecosystems function and redundancy and development began to rise (Folke, 2006:258). During that period, Holling got involved in the Science Boards of this new institute, the Santa Fe Institute[42] and an aspect of Beijer's biodiversity programme (Holling, 2006:13). As part of Beijer's research programme, Holling and his colleagues developed an ecological synthesis on the role of biodiversity in the functioning of ecosystems putting forward the idea that only a set of species and physical process are essential in the formation of the structure and overall behaviour of ecosystems (Folke, 2006:258).

In the mid-1990s, Holling got a grant from the MacArthur Foundation[43] for his own "Resilience Project". That is to say that, together with Karl-Goran Maler and Carl Folke at the BI, Holling launched his own "Resilience Project" that led in five years to more than 100 papers written from a wide spectrum of disciplinary vantage points and published in specialist and interdisciplinary journals (Holling, 2006:13). Holling's own "Resilience Project" was situated in the continuum of

41 Whilst this institute was established in 1977 under the auspices of the Royal Swedish Academy, it was reorganised in 1991 with ecological economics as its focal point. The core funding of this institute came from the Kjell and Märta Beijer Foundation (Beijer Institute, 2015).

42 It is a private, not-for-profit, independent research and education centre created in 1984 so as to get leading scientists to grapple with some of the most compelling, complex and contemporary problems.

43 It is one of the largest private philanthropies based in the United States. It supports creative people and effective institutions devoted to make the world more just, verdant and peaceful. In addition, the foundation promotes human rights, global conservation and security, enhances the betterment of life in the cities, and seeks to understand the impact of technology on society and technology (MacArthur Foundation, 2015).

IIASA's Ecology Project and his work during his stay at IIASA both in terms of its objectives and its implementation. As such the "Resilience Project" was a collaboration of an international group of ecologists, economists, social scientists, and mathematicians searching: "for an integrative theory and integrative examples of practices. Its goal was to develop and test the elements of an integrative theory that had the degree of simplicity necessary for understanding but also the complexity required to develop policy for sustainability (Holling, 2001:391)." Yet this "Resilience Project" crystallised the position that Holling held against the mechanistic views of the world defended by some of his colleagues at IIASA during the "IIASA workshop on hypotheticality, resilience, and option foreclosure" in 1975. Some aspects of the conflicting views on resilience which appeared during that IIASA workshop surfaced again in the course of the "Resilience Project" (Schickel, 2014). For example Allen *et al* (2010:5) observe that:

> By the early 1990s, many authors of ecological literature (O'Neill *et al.* 1986, Pimm 1984, Tilman and Downing 1994) had applied the word resilience as speed or time of return of an ecological system to an equilibrium following a disturbance. This was part of an ecological system to an equilibrium following a disturbance. This was part of a multifaceted definition outlined by Holling in 1973, but it is a narrow definition and ignores the presence of alternative states. In response, Holling (1996) explicitly contrasts and compares two primary definitions of resilience, which he describes as *engineering resilience* and *ecological resilience*. Ecological systems differ from engineering ones in that change is not continuous but, rather, discontinuous; ecological change is characteried by surprising events (such as hurricanes, fires, or pest outbreaks) that open windows of opportunities for establishing new combinations of species and ecological processes (Allen and Holling, 2008).

In the same vein, following consensus-building work with leading orthodox economists, Holling and fellow ecologists established the Resilience Alliance and agreed to expand the insights of the then research on resilience beyond ecology (Walker and Cooper, 2011:147). Among the group of scholars involved in this consensus-building work there were, Kenneth Arrow from the Department of economics, Stanford University; Bert Bolin from the Department of Meteorology, University of Stockholm; Robert Costanza from the Maryland International Institute for Ecological Economics, University of Maryland; Partha Dasgupta from the Faculty of Economics, Cambridge University; Carl Folke, Beijer International Institute of Ecological Economics, Royal Swedish Academy of Science; Bengt-Owe Jansson, Department of Systems Ecology, University of Stockholm; Simon Levin from the Department of Ecology and Evolutionary Biology; Karl-Goran Maler from Beijer International Institute of Ecological Economics; Charles Perrings from the Department of Environmental Economics and Environmental Management, and David Pimentel from the Department of Entomology and Section of Ecology and Systematics, Cornell University. These scholars were based in higher learning institutions in the United States, United Kingdom, and Sweden at the time when they wrote "Economic growth, carrying capacity, and the environment". In that article, they agreed on the fact that the environmental resources upon which the totality of economic activity depends are finite, and careless use of these resources may irreversibly lead to a reduction in the capacity to generate material production. To put it simply, they argue that there are limits to the carrying capacities of the planet, and these capacities in nature are not fixed, static, or made of simple relations. As a result, they put forward the concept of resilience as "a more useful index of environmental sustainability" (Arrow *et al,* 1995:92).

Along the development of this consensus, the BI became initially a host for a forthcoming institute (Resilience Alliance) aiming to identify a possible

connection between the work of C.S. Holling in ecological modelling and social science, especially ecological economics (Cote and Nightingale, 2012:476). In effect, the Resilience Alliance (RA) originated from the combination of two experiments, the journal of *Conservation Ecology* and the "Resilience Project". Both experiments were developed at the same time and followed somehow the research undertaken at IIASA by Holling and some of his colleagues. According to Holling (1998:1), *Conservation Ecology* started in 1996 as "a very traditional journal designed to publish peer-reviewed science and applications dealing with understanding the foundations for sustainable futures; interdisciplinary and integrative." The low cost of the journal was due to the fact that it relied both on a combination between the internet, the world-wide-web, and the long traditions of volunteer science and a distinguished board. As a result, *Conservation Ecology* was designed:

> [T]o develop and explore the novel theories, methods, research, and policies that are needed to underpin the conservation, restoration, and maintenance of the natural heritage that sustains life and human opportunity. This focus requires some research in what might be called applicable science a mix of theory, basic research, and illuminating applied examples (Holling, 1998:1).

The attention put on "novel theories, methods, research and policy' reminds one of Holling's emphasis on "methodology" when he was the IIASA director. Also, some of the findings which resulted from the design of *Conservation Ecology* were similar to the motivations justifying IIASAs exploration of a science of adaptive management after the publication of Holling's 1973 paper. Indeed the main conclusion of the "Resilience Project" stated that the era of ecosystems management through incremental increases in efficiency was over (Holling, 2001:404).

In 1999, *Conservation Ecology and* the "Resilience Project" merged into a "sustaining, international institute-without-walls" called "RA" and was funded initially by fifteen groups in North America, Europe, Asia and Africa (Holling, 2001:2). This newly established institute continued the publication of *Conservation Ecology,* together with *the Ecological Society of America.* For Parker and Hackett (2012:23), it is the members of RA- a well-known interdisciplinary coherent group of natural and social scientists- who "coined the term resilience theory, a systems perspective that blends ideas from complexity theory, ecosystems ecology, and social sciences to understand dynamics of transformation in socio-ecological systems". From there, Parker and Hackett (2012:23) adds that resilience research began to be performed through the integration of "natural and social science methods, including deductive theory, mathematical models, network analyses, experiments, surveys, ethnography, interviews, and archaeological techniques."

8.1.2. Resilience thinking and the impact of the consensus-building work of the 1990s

Although Holling's definition of resilience in his 1973 paper became the foundation from which resilience theory developed, neither the idea that ecosystems exhibit multiple states nor the resilience concept formulated in Holling's 1973 paper gained immediate traction (Allen *et al,* 2010:10). In fact the development of resilience theory includes the insights gleaned out of Holling's 1986 paper during the course of the "Resilience Project", especially a theoretical framework that could support an understanding of systems of people and nature (Carpenter and Turner, 2001:389). The idea of panarchy as a combination of the concept of space/time hierarchies with a concept of adaptive cycles came to epitomise these new developments. For instance, the members of Resilience Alliance use the term "panarchy" to describe a concept providing an explanation for the evolving nature of complex adaptive systems. As such it refers to:

> [T]he hierarchical structure in which systems of nature (for example, forests, grasslands, lakes, rivers, and seas), and humans (- for example structures of governance, settlements, cultures), as well as combined human-nature systems (- for example, agencies that control natural resources use) (Gunderson and others 1995) and socio-ecological systems (for instance, co-evolved systems of management) (Folke and others 1998), are interlinked in a never-ending adaptive cycle of growth, accumulation, restructuring, and renewal (Holling, 2001:392).

In Figure 10 below, the idea of panarchy actualises the place that the concept of resilience occupied in what illustrates some significant aspects of the theory of resilience proposed by the Resilience Alliance. This figure appeared originally in a book edited by Holling and Lance Gunderson in 2001 under the following title, *Panarchy: understanding transformations in human and natural systems.* In this respect, Holling (2003:1) recounts that:

> The multi-authored book describing the integrative nature of Panarchy (Gunderson and Holling 2001) is partly a culmination of 50 years of my own research work, together with that of a fine group of friends and colleagues in the Resilience Project. During that project, my ideas expanded and grew as they interacted with the ideas of others-other ecologists, economists, social scientists and mathematicians- all co-authors of Panarchy. It was a process of mutual, creative discovery that then turned personal for each of us.

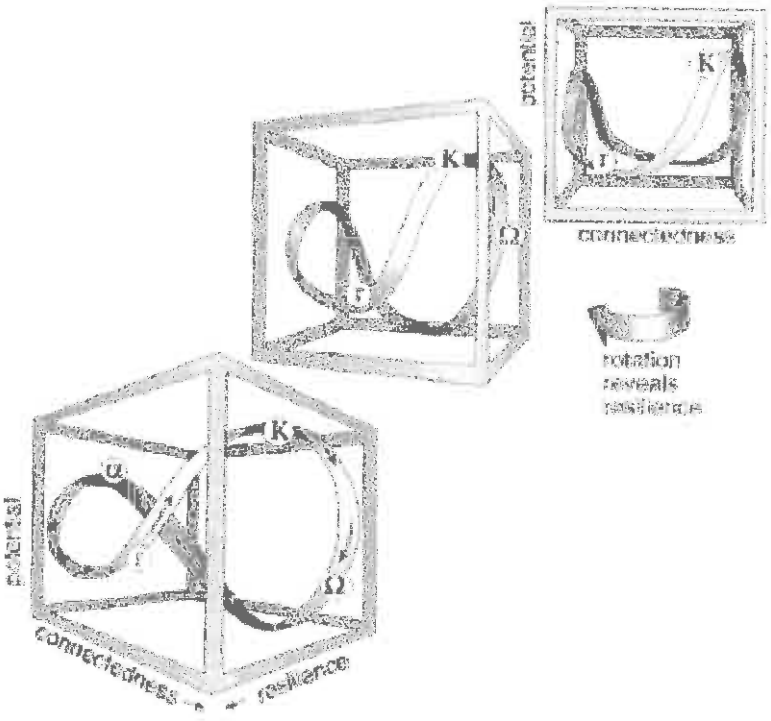


Figure 10. Resilience seen as another dimension of the adaptive cycle. This third dimension (resilience) of the adaptive cycle illustrates how resilience expands and contracts throughout the cycle. K, r Ω and α refer to the four representations of ecosystems' functions. K means conservation, r is exploitation, α is reorganisation and Ω means release. Resilience shrinks as the cycle moves towards K, where the system becomes more brittle. It expands as the cycle shifts quickly into a back loop to reorganise accumulated resources for a new beginning of the cycle. Source: Gunderson and Holling (2001).

Though it is only throughout the years that the concept of resilience reached a point where practitioners used a 1973 paper "to stake out territory within a broader field of environmental management", guard the borders of their acquired territory and control their membership (Libby, 2014:18). That point in time is identified in the conclusions drawn out of the examination of the growth and timing of resilience research through a graph of the number of environmental science articles where "resilience" appears, citations to C.S. Holling's research, and citations to Holling's 1973 paper. That analysis by Parker

and Hackett (2012:33) which is supported by bibliometric data (*Thomson Reuters*) shows that all of the three metrics describe an exponential growth curve whose acceleration increased with the creation of the RA (Figure 11). According to these scholars, articles about resilience were scarce until 1995, after which they grew considerably to a high of 654 in 2009. Before 1995, Holling received less than 2 percent of his citations, at which point citations to his research also increased exponentially. Similar patterns and coincident timing are striking in the case of the 1973 paper. Following a relatively small interest, citations wane until 1995, at which point they increase considerably. Also, these authors point out that Holling received his greatest percentage of citations in 2008 after being retired in 2002 from the University of Florida; and "Resilience and Stability of Ecological Systems" received the greatest percentage of citations in 2009, 35 years after its publication.

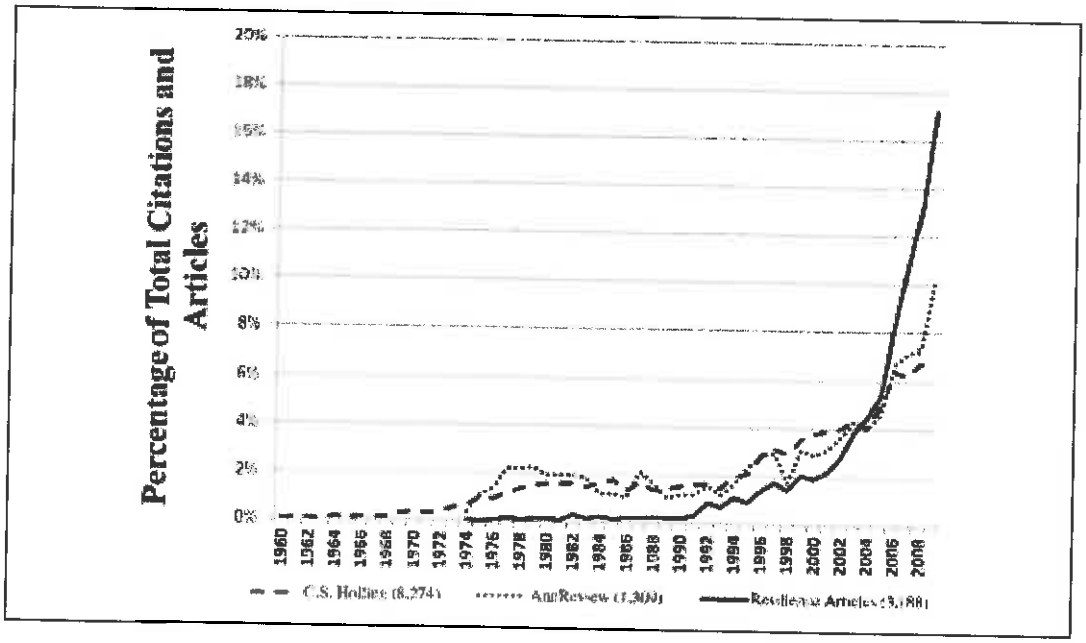


Figure 11. Citations to C.S. Holling, Annual Review of Ecology and Systematics, and "Resilience" Articles. ***Note:*** **Growth in citations of C.S. Holling's research, Resilience and Stability of Ecological Systems (1973), and growth in percentage of articles published in**

Thomson Reuters Web of Science subject area " Environmental Sciences and Ecology" (1974 to 2009) where the term "resilience appears in topic. Total numbers of citations or articles are included in parentheses (Parker and Hackett, 2012).

Parker and Hackett's conclusions are reinforced in Xu and Marinova's (2013:915) findings. Through an analysis of annual numbers of cited research publications using the data from Web of Science and resilience publication in Scopus, Google Scholar and Web of Science from 1973 to 2011, these scholars interpreted the Figure 12 in the following terms :

> The dramatic increase since 1999 in the number of cited publications has partly benefited from the establishment of the Resilience Alliance network with its academic journal Ecology and Society (Janssen *et al.* 2006) as well as from the increased interest in global environmental changes during the 1990s. Activities on the global political arena since 2005, the Stern Review in 2006, the Intergovernmental Panel on Climate Change (IPCC)'s 4th Assessment Report in 2007, as well as the continuing regular climate change meetings and negotiations, all stimulated researcher interest in resilience (Xu and Marinova, 2013: 915).

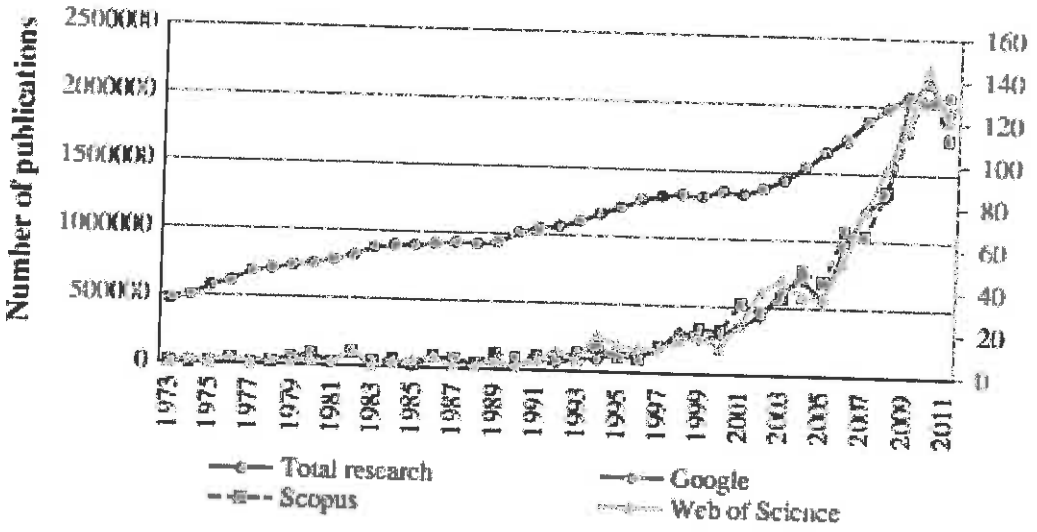


Figure 12. Annual number of cited research publications in Web of Science and resilience publications in Scopus, Google Scholar and Web of Science, 1973-2011 (Xu and Marinova, (2013).

Similarly, Manyena (2006:443) notes that the formation of the Resilience Alliance and the adoption of the term by the United Nations International Strategy for Disasters Reduction in its strategy for 2005-15 show the importance of the resilience concept in modern times. In 2013, *Time* magazine designated *resilience* as the environmental buzzword of the year (Walsh, 2013). In Figure 13, Janssen *et al* (2006) illustrate the prominent position of the 1973 paper as well as the dominance of scholars related to the Beijer International Institute of Ecological Economics and the Resilience Alliance in the knowledge domain resilience.

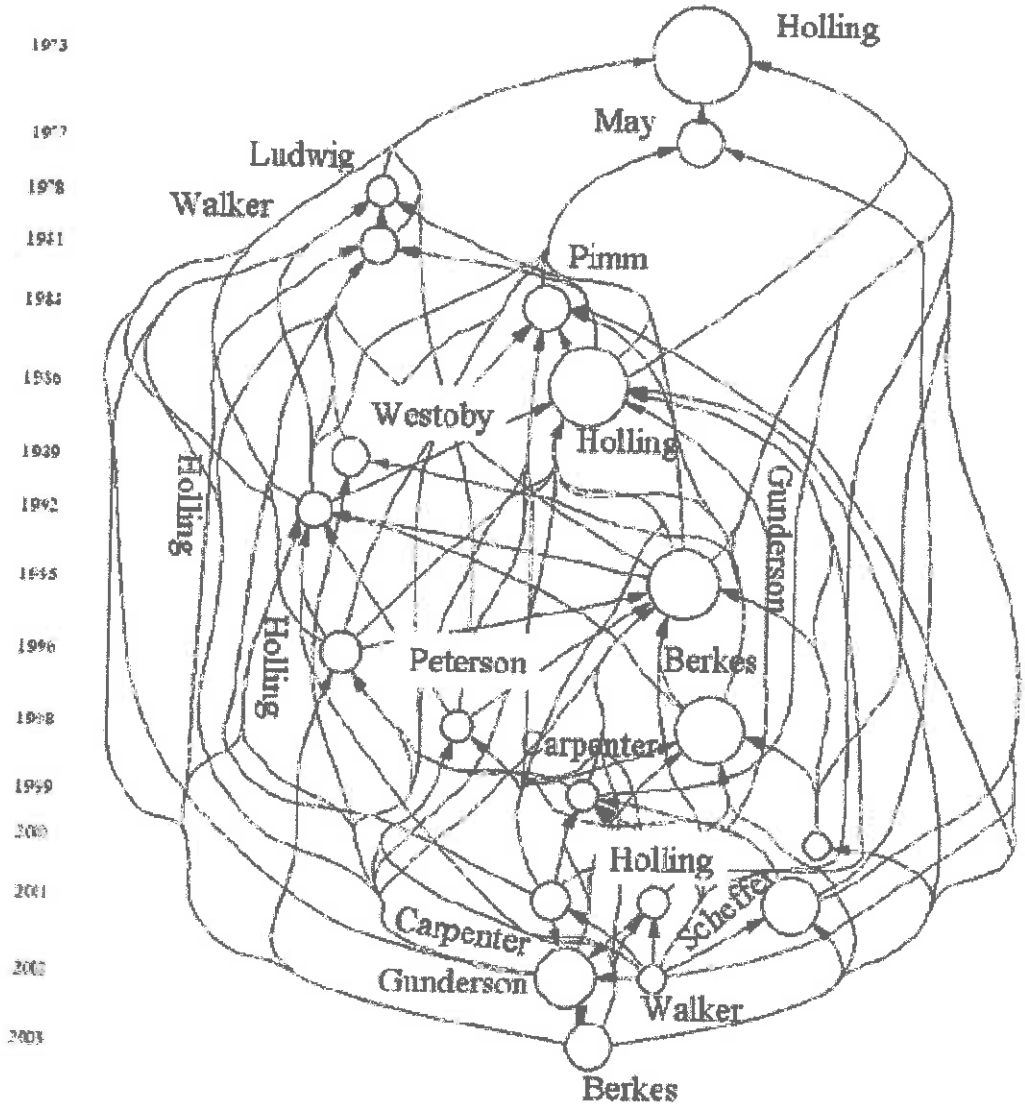


Figure 13. Paper citation network of the most highly cited papers within the knowledge domain resilience (threshold 20 citations within dataset). The node size denotes the number of citations; the arrows refer to citations (Carpenter *et al.*, 2001; Holling, 1992; Peterson *et al.*, 1998). Source: Janssen *et al.*, (2006).

It is important to return again to what the RA is about or more precisely what it became over the years following its establishment in 1999. According to Parker and Hackett (2012: 26-27), the RA can be considered as a ranges of concentric

rings extending from its most prominent members out to peripheral researchers. The core is made up of founding scientists who nurtured the group's guiding ideas and played an instrumental role in its transition from a Network to an Alliance. This kernel of seven scientists stayed relatively stable since 1996. One is female, six are male, and all are from North America, Western Europe or Australia. Two started their careers in the 1960s, three in the early to mid-1970s, and two in the mid-1980s.

In 1999, when the RA was founded, their ages ranged from the 30s to the 60s. Five are experts in ecosystems ecology, and the other two are respectively, an ecological economist, and a sociologist specialised in organisational innovation. While the influences of several other figures in the early years of the RA can be acknowledged, those scholars ended up moving to the periphery of the group or simply excited the network. Also, Parker and Hackett (2012) observe that expanding outward from the core are a number (23) of scholars. Eight became involved as graduate students or postdoctoral fellows in the course of the transition from the Resilience Network to the Resilience Alliance. Trained in ecosystems and applied mathematics, they are the most active and influential group of scholars outside the core set. Among this group, there are two women and six men, all but one (a South African) are from North America and Western Europe. This ring consists also of 15 additional scientists whose close affiliation to the network varies across time some for decades or more and whose works on resilience research have been the most highly cited. These scholars are from Europe and North America, and their scientific expertise ranges from resources management to social vulnerabilities studies, ecological economics, applied mathematics, political science, and ecosystems ecology. Finally, Parker and Hackett (2012:27) identify a third ring, more diffuse in its character and which consists of 20 scientists who joined recently, often by invitation of the core

scientists. This is a more international group with a larger proportion of social scientists.

In short, all the RA members are based at research institutions in twelve countries, and a considerable number among them served in leadership positions on various international projects (e.g., International Panel on Climate Change, Millenium Ecosystems, Program on Ecosystem Change and Society and Divertas). And the overall body of knowledge generated by the Resilience Alliance members includes thousands of peer-reviewed articles and many books (RA, 2015).Throughout the work of this organisation, Holling's contribution is being relayed and expanded by a significant number of authors. For instance Carl Folke, one of the co-founders of the RA is the leading figure in the co-author network of the most productive and best connected authors with the strongest co-authorship relations (Figure 14).

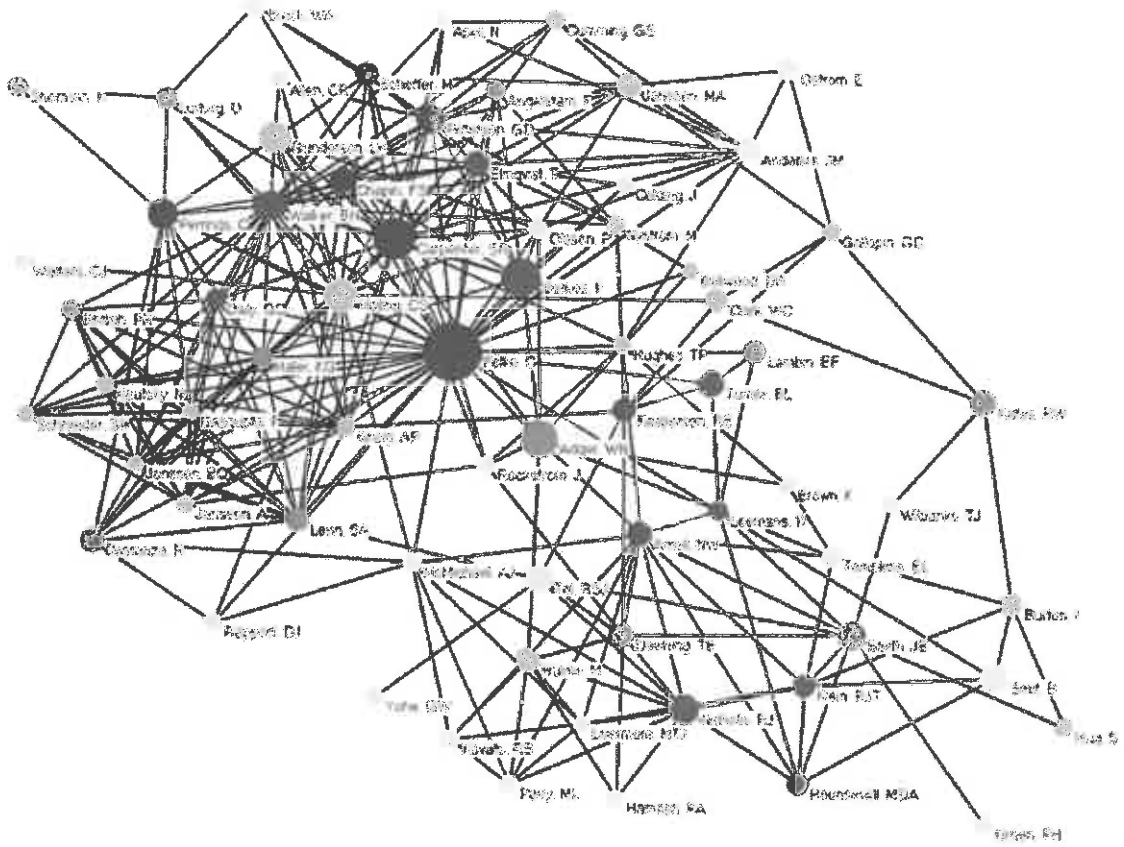


Figure 14. Co-author network of the most productive and best connected authors with the strongest co-authorship relations. Circles denote author's nodes and are labelled by the author's last name and initials. Legend: Node-author. Node area size # of publications: Node area colour # of unique co-authors. Source: Janssen *et al* (2007).

Carl Folke was the Deputy Director of the BI 1991-1996 and Director of Stockholm University's Centre for Transdisciplinary Environmental Research (CTM) 1999-2006. Folke is currently the Director of the Stockholm Resilience Centre (SRC) and Director of the BI. His research in Stockholm is concerned "with the role that systems at different scales play in social and economic development and how to govern and manage for resilience integrated social-ecosystems"

(SRC, 2015:1). He played an instrumental role in the joint effort (Beijer Institute, CTM and University of Stockholm) which resulted in the creation of the SRC. His work has been a part of the RAs research outputs upon which the successful proposal leading to the establishment of the SRC found a scientific grounding and policy relevance (Stockholm University, Beijer Institute and Stockholm Environmental Institute, 2006:6). Besides, Johansson *et al* (2013:4) note that since its establishment in 2007, the SRC has become a world leading research centre putting forward interdisciplinary research on the dynamics of inter-connected social-ecological systems. They also report that the establishment of "resilience thinking" as an integrating umbrella concept brought enormous value to the SRCs research focus on understanding social-ecological relationships and interactions from the local to the global-level issues significant for the future of the earth's ecosystems and human wellbeing.

8.2. The circulation of the resilience idea across spaces

Despite the multiple adjustments it underwent along the various path of its circulation (8.2.1) since the 1970s, the concept of resilience still carries Holling's human experience across spaces (8.2.2). But this has become increasingly confined by the consensus-building work of the 1990s (8.2.3).

8.2.1. The normalisation of the resilience idea through science and policy

In the articulation of the theory of panarchy, Holling and his colleagues highlighted three features that are unique to human systems namely, foresight and intentionality, communication, and technology (Holling, 2001:401). But apparently doing that was not enough to convince everyone that resilience theory could be applied to social and ecological systems, or simply put both to

human and non-human systems. Whereas the human and non-human system appeared to be connected with the concept of 'social-ecological systems", understandings of the meaning of theory differ when respectively applied to natural or social sciences. That is to say that the main function[44] of scientific theories in natural sciences is explanation and prediction, while in social sciences the focus is on a search for understanding rather than explanation and prediction (Koskela, 2008:37; Allmendinger, 2009:12). As a result adopting the term resilience from ecological sciences and applying it to social systems with the assumption that there is no major difference in behavior and structure between socialised institutions and ecological systems opens room for contestations especially from a social science perspective (Adger, 2000). Still Gaddis (1992-1993:53-54) recall that the end of the Cold War went hand in hand with a tendency in social sciences to search for objectivity, legitimacy and predictability through the adoption of traditional methods of physical and natural sciences. He adds that such a shift occurred at a time when physicists, biologists, and mathematicians, concerned about the mismatch between their theories and the reality they were designed to characterise, were replacing old methods with new ones that integrated indeterminacy, irregularity, and unpredictability- the very qualities the social sciences were trying to abandon.

Although the body of knowledge of the RA and the SRC claim to be integrative in its character just like the approaches increasingly adopted by natural scientists at the end of the Cold War, Davoudi (2012:305-306) mentions four critical issues pertaining to the translation of resilience thinking from the natural sciences to the social sciences. The first has to do with the intentionality of human actions;

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44 Regardless of the fact that this kind of argument does not address properly the interdisciplinary aspects of the evolving works of Holling and his colleagues on resilience, it remains explicit or tacit in the way resilience theory is criticised from the vantage point of the social sciences.

the second poses the question resilience to what ends? The third deals with the question of defining a system's boundary, in a particular ecosystem ("resilience of what to what"). The fourth addresses the issues of power over the question of what is a desired outcome and for whom? Regardless of the relevance of these critical issues in relation to the body of knowledge resulting from Holling's idea of resilience, it should be remembered that they have been raised at least partially, earlier in the course of the refinement and expansion of the resilience concept. For example during the "workshop on hypotheticality, resilience and option foreclosure" or when Clark (1975) questioned the use of applied systems analysis as a method of research promoted by IIASA, and issues of intentionality and power are somehow addressed in *Panarchy: understanding transformations in human and natural systems* (2001). In contrast the issues of power around the consensus-building work that Holling developed in the 1990s, the subsequent creation of the RA and the SRC and their links to Sweden have not been unpacked yet.

Sweden has been instrumental in the consensus-building work through which the concept of resilience acquired an important role in the novel ways to understand and manage environmental resources globally. Just like other Scandinavian countries, Sweden's dependence on natural resources for economic survival resulted in the adoption by the state of pragmatic development philosophies as a matter of necessity (Ingebritsen, 2002:13). In other words, the Swedish government adopted early an array of social regulations to sustain the economy. In doing so, its late industrialisation attempted to avoid the ecological downside of rapid growth and urbanisation typical of similar experiences elsewhere in Europe. This kind of effort went beyond the national and regional level. In fact the United Nations Environment Programme (UNEP) was formed after the 1972 Conference on the Human Environment held in Stockholm (attended by 114 governmental representatives

and a significant number of representatives of nongovernmental organisations) (Meyer, 1997:624). The UNEP became an important referent in the IIASA network and a relay in the strategy that Holling's IIASA "Ecology Project" used to gain more legitimacy and influence policies. For example, in 1979, the publication of *Expected the Unexpected-An Adaptive Approach to Environmental Management*, an IIASA Executive Report turned into a book edited by C.S. Holling, was supported by UNEP.

Sweden's involvement with environmental issues at the domestic and international level resonates well with the stand that it took regarding its foreign policy. For instance, Ingebritsen (2002:16) reports the words delivered by the Prime Minister of Sweden to Parliament on 6 October 1996 in this manner:

> Sweden will show the way in the transition to sustainable development. The work of protecting the environment, stimulating local initiative and encouraging the ecocycle approach will continue. An Agenda 21 for the Baltic Sea region will be coordinated in preparation for EU enlargement. (Swedish Ministry of foreign Affairs, 1998:4).

Moreover the creation of the SRC in Stockholm is part of Sweden foreign policy. The invitation for the pre-proposals which led to the creation of this Centre was issued by the Swedish Foundation for Strategic Environmental Research (MISTRA). MISTRA is a public foundation with the aim of enhancing the burgeoning of robust research environments of the highest international class that will have a positive influence on Sweden's future competiveness. Such research should put the emphasis on solving environmental problems and developing a sustainable society (The Swedish Foundation for strategic Research, 2013:15). In doing so, MISTRA invests in the type of research that helps to bring about sustainable development through bridge-building "among academic disciplines, as well as between research, on the one hand, and companies, public

agencies and other stakeholders on the other" (MISTRA, 2013: 1). As a result it provides the material means and creates the skills necessary for the materialisation of at least part of the Swedish foreign policy dealing with the environment and economic survival. No wonder then that in the invitation for the pre-proposal, a section reads:

> Mistra has to date invested about SEK 1.9 billion in some thirty research programmes aimed at solving major environmental problems. The endeavours of these programmes are to develop new products and services for an environmental market, or provide scientific data for international environmental negotiations, or provide new knowledge for sustainable management of ecosystems and renewable natural resources. The last category includes programmes on management of drainage basins, coastal zones, mountainous areas, semi-natural grasslands, sustainable forestry, etc. All together more than SEK 600 million has been invested in programmes aimed at ecosystem management. Several of these programmes involve both social and natural sciences (MISTRA, 2005:3).

Nevertheless MISTRA's goals intersect with Holling's research on resilience and his concerns to connect science and policy. It also captures well the interdisciplinary character of his research and surfaces the stakes of the consensus-building work that he and a number of scholars of the RA undertook in the mid-1990s. But MISTRA is a byproduct of Swedish society and Holling's research on resilience has been initially shaped by his experience in Canada. Sweden and Canada somehow depend on their natural resources to sustain their economic survival. Coming back to the consensus-building work around resilience in the 1990s, it is crucial to remark that it is not challenging fundamentally the market economy. Broadly, it insists that the limit of the availability of natural resources and the ecological damage of industrialisation should be taken seriously in economic practices. This consensus is therefore

articulated within the parameters of climate discourses closer to "mainstream sustainability". According to Stevenson and Dryzek (2011:1868) mainstream sustainability is the first class of climate discourses (Table 8). It is politically conservative and economically reformist. That is to say that it holds for fact that competition and profit motive are embedded in human relations, yet sustainability and material growth can remain compatible. It follows then that with the consensus-building work of the 1990s, the resilience concept became well integrated in the language of this politically conservative and economically reformist traditional middle-power's engagements in international relations.

Table 8. Classifying climate discourses. Source: Stevenson and Dryzek (2011)

Political Orientation	Economic Orientation: Reformist	Economic Orientation: Radical
Conservative	Mainstream Sustainability	Limits
Progressive	Expansive Sustainability	Green Radicalism

Indeed whether it is Sweden or Canada both are considered to be middle power among a list often including all of the Scandinavian countries, Australia, Netherlands, New Zealand to name but a few (Schoeman, 2000:47). However Chapnik (1999:73) identifies three approaches to middle power in the literature, namely the functional, the behavioral, and the hierarchical. But before engaging with the particularities of each of these approaches, he suggests that:

> To develop an objective understanding of middle power, one must begin with the most basic of analyses. A middle power is a state. The use of the term assumes a state-centric conception of the international community in which "powers" are defined as geographically delineated entities. The word "middle", meaning, "equidistant from extreme," implies at least two other types of powers-traditionally referred to as great and small. A middle power, in its most basic form, is a state which is neither a great power nor a small power. "Middle power" is therefore a relative term. To find the middle, one must be able to identify the extreme (Chapnik, 1999:73).

Having the above in mind, Chapnik (1999) continues in saying that both functional and behavioral approaches are politically motivated. While the functional model tries to normalise the status of states when their power is momentarily overestimated, the behavioral approach is circular in its reasoning because it identifies middle power behavior out of the actions of states it has previously considered as middle powers. For the hierarchical explanation, states should be organised according to their international standing. Thus the hierarchical approach can be understood as having three stages: "the middle power before and outside of the negotiations for the creation of the UN, the middle power as negotiator of the UN Charter, and the middle power post creation of the UN" (Chapnik, 1999:74).

For the purpose of this dissertation, I omit a broader discussion on which states truly qualify as a middle power or not in today's world as Chapnik (1999) would have suggested. I embrace a conception of middle power which emerged out of the consensus-building work around the concept of resilience in the 1990s. Such a conception is part of a social contructivist understanding in which ideas and

norms rather than material power[45] *per se* shape the "world order" (Gilley, 2008:248). But these ideas and norms influence the "world order" in a politically conservative and economically reformist manner. As such, middle powers can be "viewed as little more than status-seekers: they are powers that do not qualify for a place in the ranks of great powers, but that are unwilling to be classified with the 'mediocre rest' and seek alternative roles to exercise leadership" (Flemes, 2007:10). In the case of Sweden, like its Scandinavian counterparts, this alternative role and leadership ranges "from the institutionalisation of norms of sustainable development's in global environmental policy, to the creation of common security institutions (the Conference on Security Cooperation in Europe, CSCE or OSCE), to providing a model of generous and consistent aid to the poor" (Igebritsen, 2002:11). Since the SRC is an institution - a relatively stable set or "structure" of identities and interests embedded in formal rules and norms whose motivational forces are only the result of actors' socialisation and engagements in collective knowledge- in the sense of Alexander Wendt (1992), then its very establishment means:

> one of internalizing new understandings of self and other, of acquiring new role identities, not just creating external constraints on the behaviors of exogenously constituted actors. Even if not intended as such, in other words, the process by which egoist learn to cooperate is at the same time a process of reconstructing their interests in terms of shared commitments to social norms. Over time, this will tend to transform a positive interdependence of *outcomes* into a positive interdependence of *utilities* or collective interest organized around the norms in question. These norms will resist change because they are tied to actors' commitments to their

45 Understood in this sense, power refers to relative capabilities (physical and material) which help to classify states in three categories namely, great power, middle power and small powers (Hamill and Lee, 2001:34).

> identities and interests, not merely because of transactions (Wendt, 1992:417).

In relation to what became the concept of resilience after the consensus-building work of the 1990s, the significance of the notion of "ecosystems service" coupled with "resilience thinking" and both placed at the core of the SRCs aim, suggests a resistance to political and economic change unless understood within the following parameters set by MISTRA (2005:4) :

> It is of particular importance to develop the concept of ecosystem services. Natural and social science must together provide a more qualified understanding of how man benefits from functions, products, structures, interactions and other features that are coupled to ecosystems in different geographical settings. Better understanding is needed on functions of ecosystems that can be transformed into services that can be marketed and thus generate streams of income and investment for upholding the generative characteristics of ecosystems. At the same time, it is also important to understand where the limits of these market-based policy options lie and where other non-market based policies have to take over and develop. What are the options of governance of those functions that cannot be turned into marketable services?

Therefore the resilience concept after the consensus-building work of the 1990s or "resilience thinking" as integrated in the research activities of the SRC became part of mainstream sustainability. Whilst Holling's resilience idea has been initially concerned about matters of radical change in relation to ecosystems dynamics, the politics around the epistemic authority that it gained across disciplines and its influence on policies since its early days in Canada is at best reformist. That is to say that over the years, Holling's resilience concept has acquired a mythical dimension just like Canada's middle power status whose history "uncovers a tradition of Canadian rhetoric crafted to justify the attainment of disproportionate influence in international affairs" (Chapnick,

2000:188). This rupture regarding the level of change that should be concretely expected with the use of the resilience concept (in mainstream sustainability) marks also the limits of the impact of the locales where it has been initially enacted (Canada) and subsequently coopted (Sweden), and a shift in the sense (bottom-up) of the sources of influences attached to what has become Holling's idea of resilience:

> The bottom-up view, however, describes the environmental domain poorly. Widespread and mobilized world concern about the environment is heavily dependent on universalistic and scientific ideologies and principles. These have tended to arise and achieve codification in world discourse before, not after they became local and national issues in most nation-states. In fact, the rise of the world environmental domain clearly precedes and causes the formation of generalized national structures that formalize and manage the issues involved (Meyer et al, 1997:638).

In contrast, through a bottom–up approach, Welsh (2012:16) recalls that resilience is a metaphor that draws the ability of something to rebound or resume its original shape following exposure to a stressor. He shows that in the 1970s, the term was associated with two distinct epistemic communities investigating separately the natural world and the inner world of a traumatised child. It follows then that within a range of disciplines, each with their particular methodological traditions, two main parallel discourses developed that may be associated with "psycho-social resilience" and "socio-ecological resilience". Another discourse overlapping with the other two emerged as well, and puts the emphasis on the governance of risk and threat to the social body while hewing closely to political and public discourse on resilience as "robustness". The "socio-ecological resilience" theories originate from C.S. Holling's articulation of "ecological resilience" in 1973 while the governance of risks and threat to the social body is often captured within the scope of "urban resilience".

8.2.2. Systems ecology and the contribution of Brian Walker: the early connections to South Africa

Since the early days of his career, Holling relied largely on systems ecology to frame and articulate his research. The recognition gained from the works he undertook in Canada in the 1960s and 1970s is not separate from the rise of systems ecology in North America. The prominence achieved by both Holling's work and systems ecology more widely arguably relates to the connections that were made with the so-called "practical problems". For example, the International Biological Programme (IBP) legitimated their work before a committee of the U.S. Congress in terms of the on-going "environmental crisis" (Palladino, 1991: 242). This link with "practical problems" was also an explanation given for the success of the IBP International in securing an unprecedented level of funding for its research projects, and in fundamentally changing the funding structure of the study of ecology for years afterwards (Palladino, 1991; Kwa, 1987:413). As I will explain later, this approach of the IBP was to be emulated in South Africa. Before doing so, it is necessary to give some background to the IBP.

The idea of an IBP was initially voiced in Europe in the late 1950s, was endorsed by the international scientific associations of biologists and officially established in 1961 in Amsterdam (Kwa, 1987). Under the leadership of its first president, the biologist Conrad Waddington, the IBP gained rapidly a momentum and within a few years scientific committees were created in many countries (including South Africa) in order to organise projects under its' banner (Kwa, 1987:415). It is clear, that from its beginning the IBP was intended to relate scientific research to human problems.

The IBP was set up under the auspices of the International Council of Scientific Unions (ICSU) and entitled "The Biological Basis of Productivity and Human

Welfare" (Burgis, 2012: 311). It drew its inspiration from the success of the International Geophysical Year (IGY) (1957-1958). There were two key strands of research in the IBP. The first involved studying organic production on land, in freshwater, and in the oceans, with a focus on the potential use of land and aquatic resources. The second was on human adaptability to changing conditions which linked directly to emergent ideas of resilience. Effectively the work of the IBP was about measuring and quantifying the "web of life" providing a better understanding of the planet on which we live (Aronova *et al.*, 2010).

In terms of the methodology adopted in IBPs various research projects, Aronova *et al* (2010) argue that although the Big Science[46] of the large physics and engineering operations were an inspiration for IBP science, its model was not physics but geophysics. So, "[E]xploring the Earth through "measuring the Earth" was the credo of the International Geophysics Year (IGY), "a key to complete understanding of the planet we live on. "Measuring and quantifying a "thin web of living creatures" the "web of life" became one of the IBPs major goals (Aronova *et al* 2010:206)". In reality, according to these scholars, the history of the attempts to emulate the IGY (1957-1958) provides a window into a particular model of Big Science based on data and focused on field observations. That is to say that in the United States for example, the IBP was regarded as a way to promote a Big Science model of research in biology with the aim "to transform ecology one of the most naturalistic and "little science" fields biology into a modern Big Science" (Aranova *et al,* 2010:186).

According to Burgis (2012) when the IBP terminated its activities in 1974 there were 58 countries directly involved in the full programme of the organisation,

46 Aronova *et al* (2010:184) observed that: "After Weinbergs's influential essay, Big Science became identified with the changes in the organization of scientific research that placed scientific production in line with postwar modernization and economic growth, appropriating lessons of wartime mobilization of science".

with a further 40 countries participating in individual projects[47]. Despite being considered a failure by a number of reviewers either because of its allocation of funds to second-rate researchers or its incapacity to put its vision into practice in relation to the failed attempt to establish data centres, Aronova *et al* (2010:222) remark that: "the IBP was instrumental in the creation of centres for ecosystems studies in major universities, which consequently provided an infrastructure for ecosystems research and a network for researchers, helping to elevate ecosystems research into an attractive career choice".

The effort undertook by the IBP intersected with the early development of Holling's career even though Hollings' 1973 paper and his subsequent writings on adaptive management, challenged the machine metaphor[48] fundamental in the work of the IBP. The difference between Holling and the IBP was however not sufficiently large to prevent a strong cross-flow of ideas, and the IBP offered Holling a channel for transferring ideas of resilience to contexts including South Africa (Kwa, 1987:229-230). This is exactly the case when considering how Holling's idea of resilience has been introduced to South Africa.

Van Vuuren (2013:68) notes that, following the successful participation of South African researchers in the IBP as well as in the Problems of the Environment, through the Society for Conservation and Protection of the Environment (SCOPE), a number of national collaborative programmes were created in South Africa, most importantly the National Programme for Environmental Sciences

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47 The projects were classified into seven areas: - IBP-BP (biological Productivity), IBP-PT (Production Terrestrial), IBPT-CT (Conservation Terrestrial), IBP-PF (Production Freshwater), IBP-PM (Production Marine), IBP-HA (Human Adaptability) and IBP-PP (Primary Productivity).

48 According to Kwa (1987), it "provides implicitly a structural analogue for ecosystems. The metaphor conveys a way of understanding nature, provides ecologists with a research programme, and, by implication defines the ways in which ecosystems should be managed". The machine metaphor suggests that ecosystems should be managed through command and control.

(NPES) under the auspices of the Council for Scientific and Industrial Research (CSIR) in 1972. The NPES was placed under the administration of the National Committee for Environmental Sciences (NCES), appointed by the president of the CSIR. Besides the NPES served as the South African National Committee for SCOPE, the programme established in 1970 by the ICSU to act as a focal point of non-governmental international scientific effort in the environmental field.

The main objective of the NPES was "to gain knowledge on present and future environmental problems in South Africa and to seek solutions to these problems through multi-organisational, interdisciplinary research projects" (CSIR, 1982:1). This was put into practice initially through six sub-programmes originating from similar sections in the IBP, namely; Land Water Ecosystems, Terrestrial Ecosystems, Nature Conservation, Human Needs, Resources and the Environment, Marine Pollution, and Waste Management. The NPES claimed to be different from environmental projects undertaken in most other countries and stood as a reflection of South Africa's concern for optimal use of its limited scientific and technological capabilities. This concern recalls also the fact that South Africa's racist policies caused it to be largely excluded from global environment themed events before the advent of democratisation in 1994, such as the United Nations Conference on the Human Environment, held in Stockholm in 1972. So the NPES meant a close collaboration of "all members" of the South African scientific community concerned with environmental matters-brought together in committees, seminars, workshops and active research projects, through a shared interest in maintaining renewable natural resources and environmental quality in South Africa" (CSIR, 1982:2). That is to say that it involved the participation of over 300 scientists from numerous government and provincial departments and institutes, universities, museums and many private individuals in their personal capacity.

Nevertheless those efforts were bracketed within the scope of the IBP. For example, the South African Savanna Ecosystem Project which evolved fast from its planning stage in 1973 to a very active field and laboratory study through the late 1970s, was supported by the pioneering works undertaken by IBPs related research on the structure and functioning of terrestrial ecosystems. The aim of this project was to examine a savanna ecosystem at the Nylsvley Provincial Nature Reserve, with particular attention being paid to the processes which determine "stability and resilience" in Bushveld ecosystems (CSIR, 1982:14). The following paragraph shows its significance for the scientific community and various stakeholders and the premise upon which Holling's idea of resilience in South Africa is hooked up:

> The first major study within a South African Biome was the South African Savanna Ecosystem Project initiated at the Nylsvley Provincial Nature Reserve in the Northern Transvaal Bushveld. It was also the first attempt to bring a large diversity of state and provincial departments, museums, and universities together in an intensive cooperative, interdisciplinary study of a South African ecosystem. The project grew rapidly from its planning phase in 1973 to a very active field and laboratory study through the late 1970s. Up to thirty researchers from seven participating and three government departments were involved at its height. The Savanna Ecosystem Project proved to be the forerunner of other similar projects in the fynbos grassland, karoo and forest biomes (CSIR, 1982:12).

In 1979, a symposium and workshop under the title "Dynamics change in savanna ecosystems" was convened by the South African Savanna Ecosystem Project. That initiative received support from the CSIR, the Department of Environmental Affairs, the Transvaal Provincial Administration, the Department of Agriculture and Fisheries and the National Parks Board (Huntley and Walker, 1982: VI). The papers presented at that symposium and workshop were revised, updated and compiled into a book under the following title, *Ecology of Tropical*

Savannas. The book was edited by B.J. Huntley and B.H. Walker and published in 1982. It put under review the ecological characteristics of tropical savannas, more simply understood as those ecosystems situated between the equatorial rainforest and the deserts and semi-deserts of Africa, Australia and South America. The section of this publication dealing with "dynamics and management" contains a chapter authored by Brian Walker and I. Noy-Meir[49] which is titled, "Aspects of stability and Resilience of Savanna Ecosystems". In this chapter the concept of resilience as articulated in the 1973 paper is introduced to the South African academy as a way to understand the properties of the savanna in the country from the perspective of systems ecology. In this regard Walker and Noy-Meir (1982:556) argue that:

> We are in other words concerned with their stability and resilience and it is the objective of this paper to apply some recent concepts and developments in this field to savannas, in an attempt to gain some insight into their structure and dynamics. We begin with a review of some general concepts, making use of an example from savannas to demonstrate their application. We then proceed (By means of two models) to a more detailed examination of stability behaviour of the most characteristic feature of savannas- the woody: grass vegetation ration- and concluded with a general account of

49 Immanuel Noy-Meir was born in Colonia Avigor, Entre Rios Argentina in 1941. He was awarded a PhD in Biogeography at the Australian National University in 1970. Following the completion of his dissertation on the multivariate analysis of semiarid vegetation in southeastern Australia, he published a number of papers on the application and implication of mathematical methods on vegetation analysis which established him as an authority in the field (Seligman *et al*, 2011:6). He was a Professor Emeritus at The Hebrew University of Jerusalem where he occupied various positions throughout his career. Imanuel Noy-Meir was a systems ecologist. In fact according to Seligman *et al* (2011: 8): "Imanuel's approach to the stability and analysis of grazing systems drew the attention of Brian Walker, who enlisted his cooperation on the study of savannah systems".

> features which are likely to contribute to their overall stability and resilience.

Apart from adopting an understanding of resilience and stability drawn from the 1973 paper, this chapter supports some other claims made by Holling in another paper published in 1979, "Forest insects, forest fires and resilience". To put it simply, Walker and Noy-Meir (1982) agreed that resilience is not a static attribute and that the disturbances that savanna systems may undergo can be a source of opportunities through which they can evolve in order to cope with future disturbances of the same kind. They also conclude that an adaptive management approach is the most appropriate and valuable way to manage savanna systems. Consequently, this chapter is not simply intersecting with Holling's research, it is supporting evidence for some of the knowledge-claims that Holling has already put forward in the 1973 paper and a little earlier, and whose recognition just after their publication in the late 1960s and 1970s had been negligible. It also strongly suggested that the concept of resilience is not idiosyncratic in relation to the physical environment of Canada as ecosystems in Africa essentially have the same adaptive properties. In so doing, many years before the term acquired its prominence in scholarly and policy circles, Holling's idea of resilience was already central in the Savanna Ecosystems Project and a subject of reflection for various stakeholders in South Africa. In the following account by Brian Walker on the origins of Resilience Alliance, the specificity of his role regarding the spread of Holling's resilience idea internationally and in South Africa becomes more apparent:

> Its origins were in the early 1970s. The founder of resilience ideas and theory Buzz [C.S.] Holling, was working at the Animal Resource Institute at the University of British Columbia. He was working with a group of colleagues and wrote a seminal paper in 1973 on resilience, which led to a lot of interest by a lot of people, me included. I read that paper and it changed the way I thought about the work I was

> doing in Zimbabwe. And I contacted Holling and spent a sabbatical with him in 1978. At that time, I met a number of other people who were interested in this kind of work and who corresponded with each other, wrote some joint papers and did bits of work together. And then in the 1990s, Holling and a colleague in the Beijer Institute of Ecological Economics in Sweden (Karl Goran Maler) received a large grant to establish a resilience network. The network functioned for about 5 years from 1995 to 2000, after which time, Buzz Holling retired and I took over as the Director of what became the Resilience Alliance (Walker, 2007:85).

Before delving further into how the idea of resilience found resonance in South Africa, it is necessary to say more about Brian Walker. He was born and raised in Zimbabwe, was awarded his first degree in Agriculture in South Africa, and obtained his Ph.D. in Ecology in Saskatchewan, Canada, in 1968. Walker was a lecturer at the University of Zimbabwe (former University of Rhodesia) for six years from 1969 until 1975. After that, he became Professor of Botany and Director of the Centre for Resource Ecology at the University of the Witwatersrand in Johannesburg until 1985, when he moved to Australia as Chief of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Division of Wildlife and Ecology. He left that position in 1999 and then became the Director of the Resilience Alliance in 2000.

Under the banner of the Savanna Ecosystems Project seven institutions – namely: the University of the Witwatersrand, University of Pretoria, Rhodes University, University of Port Elizabeth, University of Cape Town, University of Orange Free State, and University of Natal - and thirty researchers, were involved. Among them, was Brian Walker from The University of the Witwatersrand, Johannesburg, South Africa. While his work was part of the NPES and somehow an outcome of the IBP like the rest of his peers involved in this project, it is also true that his specific contribution facilitated the establishment

of systems ecology as an academic domain at the University of the Witwatersrand and positioned this institution at the forefront of this field of inquiry internationally (University of the Witwatersrand, 2015:1). Professor Walker established the Centre for Resource Ecology in the Department of Botany in 1980. The current Centre for African Ecology[50] is the successor of the Centre for Resource Ecology, and also the Resource Ecology Group formed after Professor Walker's departure by Professor Mike Mentis in the 1990s (University of the Witwatersrand, 2015:1). The legacy of Professor Walker is still vivid at the University of the Witwatersrand. For example, Professor Bob Scholes (a systems ecologist who has been A-rated by South Africa's National Research Foundation) who took up his Distinguished Professorship at the University of the Witwatersrand in the Global Change and Sustainability Research Institute in January 2014, acknowledged the major influence that Professor Walker had on him (University of the Witwatersrand, 2015:1). In fact, Professor Scholes was "trained under Brian Walker at Wits and Pedro Sanchez at North Carolina State and has over thirty years of field experience in many parts of Africa and the world. He is among the top one per cent of environmental scientists worldwide based on citation frequency, publishing widely in the field of savannah ecology, global change and earth observation" (University of the Witwatersrand, 2015:1).

50 It is also important to note that Professor Barend Erasmus who is the current Director of the Global Change and Sustainability Research Institute, rejuvenated and expanded the CAE when he took over its leadership in 2013 at a time when the CAE membership had shrunk to only two Professors, namely Prof. Owen-Smith and Prof. Bob Scholes (University of the Witwatersrand, 2015). During the course of a conversation that I had with Prof. Erasmus he points out that in South Africa Brian Walker's interpretation of resilience superseded Holling's initial interpretation. Yet his understanding of resilience is informed by his own experience in the field. As a result he often tries to avoid referencing in his own work research on resilience with that related to the Stockholm Resilience Centre (Appendix A).

Eventually, Walkers' contribution to the spread of Holling's resilience idea was not limited only to South Africa and the research done on resilience and the stability of ecosystems in South Africa, it also became relevant elsewhere in the world. For instance, similarities in terms of the conclusions in Holling and Walker's research became clearer in a paper that they co-authored with D. Ludwig from the Department of Applied Mathematics, University of British Columbia, and R.M. Peterman from the Department of Biological Sciences and Resource Management, Simon Fraser University. That article was published in 1981 under the title "Stability of semi-Arid savanna grazing systems". Its objectives were to investigate the dynamics of semi-arid savannah grazing systems and understand how stable they were likely to be, and how they would behave under different types of management. In this respect, the Southern African experience served as a general case upon which it was shown how different situations can emerge out of inherent differences in the environment or structure of the systems, or from differences in the management. The discussion that followed was inspired by the concept of resilience and highlighted the similarities between' Walker's findings and those of Holling and IIASA's "Ecology Project":

> The original description by Holling (1973) contrasted resilience with the notion of local stability near equilibrium. The latter emphasises resistance to small disturbances, and rapid recovery from disturbance. Thus local stability is associated with low variability. The notion of resilience emphasises the existence of more than one domain of attraction (area bounded by separatrix on the G v. W graphs) and the maintenance of that global structure through variability. In the present situation, reduction of variability changes competitive balances, so that parameters of the system change...
>
> Similar analysis of pest control and forest fires (Wright &Heinselman 1973; Ludwig, Jones & Holling 1978; Holling 1979) lead to the same conclusion. Insecticide spraying of spruce budworm in eastern

> Canada since 1950s has eliminated the boom-and-bust epidemic result pattern, leaving more constant and moderate densities of budworm over larger areas. The result has been an accumulation of susceptible foliage over those same areas. Hence any relaxation of control would result in a more intensive outbreak than ever experienced (Walker, 1981:494-495).

The similarities found between the savannah systems in Southern Africa and other systems (lake ecosystems, Baltic Sea and Boreal forests) studied in resilience related research by Holling and his colleagues were further examined and reinforced through the publication of "Sustainability, Stability, and Resilience" in 1997. That paper was largely inspired by Walker *et al* (1981). As such, it situated itself along the trajectory of the consensus-building work of the 1990s and the establishment of RA in 1999. Its objective, recapitulated below, was to define and refine the concept of stability and resilience and to show their importance in understanding the behaviours of exploited systems:

> Here, we have proceeded from simple conceptual models, such as the raft analogy, to simple but abstract mathematical models, to ecosystem analogues, and finally to fairly detailed models of savannah systems. In no case can these analogies be considered to be complete, nor is knowledge of the systems detailed enough to support a full-blown model with statistical justification. Perhaps one might conclude that all this is merely speculation, unworthy of serious attention. On the other hand, prudent decision making requires that we take account of a variety of plausible hypotheses about the responses to our actions (Ludwig *et al,* 1997:20).

Although articulated in a heuristic manner, Ludwig *et al* (1997) points to the connections observed between resilience research in its spatial core in North America, Europe and South Africa, and the bearing of system ecology in the development of resilience thinking.

8.2.3. Paths of resilience's idea in academic settings and beyond

Although resilience stems from the Latin word, *resiliere,* which means to "to leap back", various disciplines and sub-disciplines have claimed the term etymological evolution and have applied it within distinct experimental, and largely theoretical, contexts (Coaffe, 2013:325). In Table 9, Xu and Marinova (2013) show that the majority of researchers in most countries put the emphasis on resilience thinking in ecological systems and theoretical analysis. In other words, among the countries with more than 10 cited resilience researchers, social resilience is prominent in South Africa and Japan, the highest interest in economic resilience is absent in every country, and the integrated systems or sustainability approach is predominant only in Columbia (where 100 percent of studies fall into this category) and Austria.

Table 9. Numbers and shares of researchers with cited resilience publications (1973-2011). Source: Xu and Marinova (2013).

Country	No. of researchers in resilience	Share in total researchers (‰)	Percentage of resilience researchers in different contexts (%)			
			T-E	ECO	SOC	I-S
USA	605	0.43	63.31	4.79	16.69	15.37
Australia	246	2.57	58.94	6.10	23.58	11.38
UK	218	0.93	57.80	6.42	22.48	13.30
Canada	99	0.65	57.58	2.02	25.25	15.15
Sweden	88	1.78	45.45	15.91	15.91	22.73
Netherlands	62	1.12	53.23	11.29	22.58	12.90

Country	No. of researchers in resilience	Share in total researchers (‰)	Percentage of resilience researchers in different contexts (%)			
			T-E	ECO	SOC	I-S
France	58	0.25	79.31	5.17	12.07	3.45
Germany	53	0.16	54.72	9.43	16.98	18.87
Spain	33	0.24	66.67	0	15.15	18.18
China	29	0.02	68.97	10.34	20.69	0
Switzerland	29	1.13	62.07	6.90	17.24	13.79
New Zealand	29	1.33	55.17	3.45	37.93	3.45
Italy	21	0.20	38.10	19.05	23.81	19.05
South Africa	21	1.07	38.10	4.76	42.86	14.29
Norway	18	0.68	50.00	27.78	16.67	5.56
Japan	17	0.03	35.29	0	47.06	17.65
India	16	0.10	31.25	18.75	31.25	18.75
Denmark	15	0.42	60.00	6.67	20.00	13.33
Israel	14	N/a	91.00	0	0	9.00
Austria	13	0.36	15.38	23.08	23.08	38.46
Brazil	12	0.09	83.33	8.33	8.33	0
Columbia	11	1.48	0	0	0	100.00
Sudan	11	N/a	9.00	0	54.56	36.36
Mexico	10	0.23	60.00	0	10.00	30.00
Finland	10	0.24	70.00	10.00	0	20.00
Portugal	9	0.20	44.44	22.22	33.33	0
Greece	8	0.36	75.00	0	12.50	12.50
Solomon Islands	7	N/a	100.00	0	0	0
Malaysia	6	0.58	100.00	0	0	0
Argentina	6	0.14	50.00	0	33.33	16.67
Hungary	6	0.28	0	16.67	83.33	0
Kenya	6	2.65	66.67	0	16.67	0
Poland	5	0.08	80.00	0	20.00	0
Chile	4	0.66	25.00	0	75.00	0
Singapore	4	0.13	75.00	0	25.00	0
Zimbabwe	4	N/a	50.00	0	50.00	0
Philippines	3	0.41	66.67	0	33.33	0
Indonesia	3	0.14	66.67	0	33.33	0
Nigeria	3	0.49	33.33	66.67	0	0
Russia	3	0.01	33.33	0	33.33	33.33
Romania	3	0.15	100.00	0	0	0
Ghana	3	7.23	0	0	0	100
Syria	3	N/a	100.00	0	0	0
Nepal	2	1.24	0	0	50.00	50.00
Senegal	2	0.42	100.00	0	0	0
Panama	2	4.88	100	0	0	0
Belgium	2	0.05	50.00	0	0	50.00

Country	No. of researchers in resilience	Share in total researchers (‰)	Percentage of resilience researchers in different contexts (%)			
			T-E	ECO	SOC	I-S
Egypt	2	0.06	50.00	0	50.00	0
South Korea	2	0.01	100.00	0	0	0
Iceland	2	0.74	100.00	0	0	0
Cuba	2	0.41	100.00	0	0	0
Slovenia	2	0.26	100.00	0	0	0
Slovakia	2	0.13	0	0	0	100.00
Pakistan	1	0.04	0	0	100.00	0
Mozambique	1	2.67	0	0	100.00	0
Peru	1	0.19	100.00	0	0	0
Sri Lanka	1	0.20	100.00	0	0	0
Bolivia	1	0.70	0	0	100.00	0
Venezuela	1	0.19	0	0	0	100.00
Costa Rica	1	0.64	100.00	0	0	0
Vietnam	1	0.10	0	0	0	100.00
Thailand	1	0.05	0	0	0	100.00
Lesotho	1	21.65	0	0	0	100.00
Ethiopia	1	0.27	0	100.00	0	0
Mali	1	1.71	100.00	0	0	0
Bangladesh	1	N/a	100.00	0	0	0
Belize	1	N/a	100.00	0	0	0
Bhutan	1	N/a	100.00	0	0	0
Fiji	1	N/a	100.00	0	0	0
Guam	1	N/a	100.00	0	0	0

Notes to the Table 9.

1. The source of data for research numbers is UNESCOs database (http://www.uis.unesco.org/Pages/default.aspx?SPSLanguage=EN)

2. T.E., ECO, SOC and I-S represent respectively that the research was conducted in the context of ecological systems or mainly theoretical studies, economic systems, social systems and integrated ecological, social and economic systems or sustainability in terms of resilience

3. N/a- information not available

For Kok *et al* (2013:40-48), the concept of resilience has undergone significant changes after becoming part of social sciences. These changes can be recapitulated in four stages. First, resilience emerged as an ecological concept in

the literature. Secondly it appeared in social sciences in relation to the issues concerning climate change and society. In this regard the resilience system is commonly understood to entail both robustness and strength (i.e. ability to withstand external shocks, and rapidity and flexibility, in response (i.e. the ability to bounce back). Third, the resilient cities as urban (ecological, social, and economic) systems came under scrutiny. Just as there are a number of definitions of "system resilience", there are also various definitions of "urban resilience". Still according to these scholars, when considering any definition of resilience it is important to recognize the distinction between system equilibrium and resilience. In fact a resilient system may experience fluctuations or changes in conditions or structures, and these fluctuations or changes may provide the very basis for an urban system over time.

Also, "urban resilience" does not necessarily address the ability to return to a preceding path of equilibrium after disturbance (see Campanella, 2008). Such a path may disappear, for different reasons which may let alternative paths emerge. Fourth, urban planning started to seek principles for resilient cities with a gradual move from coping with environmental hazards towards a more comprehensive approach that looks at the resilient systems as a whole. Arguably, Kok *et al* (2013) conclude that urban resilience began to be the focal point of investigations in spatial planning during the 1990s. This is because of the search for solutions of how functions under extreme stress could be maintained in resilient communities and later in resilient cities. So, Stumpp (2013:165) suggests that the fact that planning does not match well with uncertainties could be the reason why planning science entered the debate about resilience relatively late. According to this author, politics and practice seem to have been quicker. Thus she posits that urban resilience has its roots in politics, and assumption strengthened by the topic's proximity to disaster risk management.

Witnessing the application of resilience in a broad range of disciplines and fields including geography, engineering, psychology and ecology, Weichselgartner and Kelman (2014:3-9) report that one of their common characteristics is: " the ability of materials, individuals, organisations and entire social-ecological systems, from critical infrastructures to rural communities, to withstand severe conditions and absorb shocks." They add that the ecology literature puts the emphasis on the natural environment, the psychology literature focuses on human constructions, and the geography literature integrates the natural environment, the built environment and society. As a result, there is a plurality of definitions of resilience with each bearing the imprints of intellectual traditions, functional needs of different disciplinary and societal fields, including the difficulties in understanding and translation across disciplines and sectors. They also observe that resilience continues to be externally defined by expert knowledge from various sources like universities, international organisations and governmental agencies. This restricted diversity in the diffusion of resilience idea is crafted out of Holling's human experience as he shows in the following recollection:

> The technical puzzles that I had accumulated over the years became resolved. And the fewer, but deeper and more intriguing paradoxes that I had experienced turned out to provide the foundation for a new understanding of sustainability. Those paradoxes did not emerge in my science, but did appear in the organizations I became part of. Not science, therefore, but human experience. In each case, each organization had been newly created to capitalize on recent understanding, scales of perception, and integrative methods. They were creations of history made by politically sensitive individuals who saw value in combining integrative scholarship within a context of current politics. Each generated large advances to understanding critical attributes of complex systems. Each triggered extensions of collaboration among scholars of different disciplines and nations.

> But, as time passed, each became less responsive to new opportunities (Holling, 2003:2).

Similarly, the rise of resilience as a driver of urban policy has led in turn towards a more integrated, multi-disciplinary and open planning system one in which community stakeholders occupy a central position in the planning process and one in which the planner is portrayed as innovator, creative and holistic (Collier *et al,* 2013:22). Today the concept of resilience is no longer insulated in academic discourses ; it has become prevalent in urban policy documents across the globe, because, in practical terms it is a useful tool enabling analysts and decision makers to identify the likelihood of shifts or transitions amongst various systems configurations (Cruz *et al* , 2013:5). The Stockholm Resilience Centre has given its own assessment of the influence and dissemination of ideas around resilience (see Table 10) but of course resilience has taken multiple permutations and pathways that go beyond those which the centre recognises. This is indicated, for example, in the South African case."

Table 10. Examples of how ideas associated with the resilience concept have diffused and spread to a range of different fora and spheres of influence. Source: Stockholm Resilience Centre (2012).

Organizations/Fora	Evidence of impact	Sphere of influence
New scientific journal	New scientific journal 'Resilience' launched by Taylor and Francis	science
CGIAR	Water Land Ecosystem Programme	practice
Rockefeller Foundation	Rockefeller Global Fellowship Program	practice
Great Barrier Reef Marine Park Authority	Rezoning Programme	practice
Global Sustainability Panel	Report - Resilient People, Resilient Planet	policy
CBD	Aichi Targets , CBO Cities and Biodiv Outlook	policy
Arctic Council	Arctic Resilience Assessment	policy
UNDP Resilience and Development Initiative	Putting Resilience at the Heart of Development: Investing in Prevention and Resilient Recovery	policy
DFID	Defining Disaster Resilience: What does it mean for DFID?	policy
World Economic Forum 2015	Resilient Dynamism	business/practice
Resilience Action Initiative	Incorporating resilience perspective in business models	business
World Business Council for Sustainable Development	Resilience – Vision 2050	business

Johnson and Blackburn (2014:30) notes that the widespread use of the term "resilience" in high level policy circles has been attributed to its more positive or proactive connotations in comparison to a term such as "vulnerability" or "disaster risk reductions". Despite the relative success of the term's expansion in international policy discourse, these authors remark that, the complexities and contradictions of its definition and operationalisation have yet to be solved. In the same vein, Johansson *et al* (2013:33) report that the participation of the Stockholm Resilience Institute "in activities at the global (UN) level has mainly impacted upon policy objective setting rather than on how such objectives could be implemented at the global level".

Moreover Coaffe (2013:325) observe that the changing practices of resilience have emerged both as functions of time in relation to a variety of changing socio-political and economic pressures which have altered the meaning, and operational function of resilience as a result of having evolved overtime. For

example, In the United Kingdom (UK), he observes that while it rose mostly as a policy associated to countering the threat of international terrorism and the need for emergency planning reform, resilience has now become a policy metaphor for embedding "foresight", robustness, and adaptability in variety of place-making and localist planning activities. This integration of a number of practices of resilience at a local level can be considered as the latest generation of resilience practices that planners are increasingly being asked to adopt by various actors (i.e. state) which have implications for society. Following the same line of argument, Coaffe and O'Hare (2008:173) provide a suggestive definition of "urban resilience":

> In recent years, the activity of protecting against and planning response to the wide range of security challenges that threaten cities and urban areas- from natural disasters such as flooding and anthropogenic climate change to crime and terrorism- has been referred to as "urban resilience". In this sense, urban resilience refers to both the design alterations (structural , architectural, land-use planning) managerial and governance measures that seek to prevent or mitigate the physical and social vulnerability of areas, ultimately to protect life, property and economic activity.

Furthermore the spatiality underlying the concept of "urban resilience" shows different facets depending on the context but the roots connecting it with ecology are not annihilated. In fact different ways of conceptualising space in relation to urban resilience appear in the literature. In the case of disturbed sites of individual reefs, Nystroms and Folke (2001:902) define "spatial resilience" as "the dynamic capacity to cope with disturbance and avoid thresholds at spatial scales larger than individual ecosystems. Dynamic interaction and interdependencies between systems are taken into account by spatial resilience".

In the urban context, Cumming (2013: 902) notes that "spatial resilience" can be considered as interplay, at different scales, between spatial attributes of the

system and the different system constituents (such as elements, interactions, adaptive capacity, memory and history) that are typically included in definitions of resilience." Pival (2012:24) defines it as "a metaphor that gives Sarajevo an appearance of a territory that always has involved the coexistence of different religions without building the ghettos, giving to the city a special cultural identity and image". Anderson (2006:35) speaks of "urban landscape mosaic" in order to refer to the complexity of residential, commercial, cultural-education, land uses, patches of remnant vegetation, secondary green areas such as parks or cemeteries, and other land uses. The growing of particular built forms such as "the bunker" parallels the rise of the concept of urban resilience. With this respect, Duffield (2011:19) notes that the bunker comprises "strongholds or defended zones that, using anything from physical walls to visual cues or cyber-barriers, have spatially demarcated inside-outside boundaries and defended portals." For Braun (2014:61), resilience broadly appears in the form of a mode of government, in which the government's aim is not to punish, nor to prevent or discipline, but rather to modulate "natural processes" by creating a "milieu" at different scales in urban systems.

By embracing complexity theory in resilience thinking, says Turner (2013:2), resilient systems tend to be seen as self-organised composed of independent agents whose aggregate of individual responses entails a systemic response to external shocks or change. In this manner, he observes that resilient systems go hand in hand with a neoliberal understanding of social response and efficiencies. In effect, in the face of climate change and the unsatisfactory international efforts to curb carbon emissions, the city is regarded as the most pressing and promising site to anticipate and respond to uncertain futures (Wakefield and Braun, 2014:4). For example, Funfgeld and McEvoy (2012:212) report that climate risks management is concerned with maintaining the *status quo* in a way that it retains a well-functioning system, such as government organisations,

operating in agreement with its stated objectives. Paradoxically, from a risk management perspective, the bulk of decision makers at the forefront of these bureaucratically managed organisations would comprehend a deep transformation as a system failure rather than as part of a healthy process of maintaining resilience. This example points directly to what has become the concept of resilience after the consensus-building work of the 1990s. In this regard, Braun (2014:50) insists that:

> In important respects, then , it is the concept of "resilience", with its concern to keep humanity within its "safe" operating space (the system observed in terms of carbon emissions and their global effects) while at the same time producing flexible institutional social, and spatial forms that can withstand shocks (the system observed in terms of climate variability and its local effects), that today connects diverse and at times contradictory urban practices into a *dispositive or* "systems of correlation".

O'Hare and White (2013, 275-276) concur that resilience promises to be able to carve order from chaos and build a capacity to respond (and adapt) to uncertain risks. They report lessons from planning practices which acknowledge "a series of disconnects within three key areas: meaning, policy, milieu and place all of which are brought into sharp focus by the integrative, political, and spatial dimensions of planning." Similarly, Welsh (2012:21) reminds us that:

> Resilience holds out the promise of knowing "when" change enters a system, in turn holding out the promise of managing change, of ameliorating its unacceptable effects. However, paradoxically through that technology it also holds the promise of avoiding fundamental change. Certainly it introduces flexibility and adaptability but framed in terms of maintaining systems function as the priority, with responsibility for maintaining function something distributed throughout the system. As such it could be said to

> produce active citizens and active institutions whose act is to maintain the status quo rather than conceive of challenging it.

For instance, Hordjik *et al* (2014) try to understand the recent changes in the delegation of state responsibilities for the management of water resources to regional bodies and the provision of drinking water and sanitation to local government, with emphasis on the role and power of municipal authority in this process. These authors explore to what extent these emerging configurations unfold into a move toward resilience, transition and even transformation. Resilience in this research is part of Pelling's classification of adaptation practices together with transition and transformation. The main quality of resilience in Pelling's classification is "the desire to maintain functional integrity. "Adaptation as resilience" focuses on improving existing practices without questioning underlying assumptions, and hence allows unsustainable or socially unjust practices to continue." Transition means incremental changes in governance systems, but with the overarching norms, principles and sociopolitical regime remaining unchanged. Transformation involves strong sustainable development goals, which can only be reached through radical changes in the value system underpinning the dominant capitalist production, including the public-private dichotomy that has favoured private actors and marginalised the role of the state. These authors use the term "water governance" as a reference to "the multi-actor processes through which objectives are set (hence the political and often conflictual processes), and the term "water management" for the implementation and functioning of water infrastructure". The findings of this research are drawn out of four case studies, Guarulhos (Brazil), Arequipa, and Lima (Peru) and Durban (South Africa).

The four cases studies bear noticeable differences in relation to population size, economic base and geographical characteristics, but they also share important features in terms of water governance which render the comparison possible.

Even though all but Durban are in water-abundant countries, they all face water scarcity. Besides, the distribution of water resources within Peru and Brazil is uneven, and the management and distribution of water resources in South Africa is problematic because of the absence of "bulk infrastructure". In fact in all the three case studies, the authors found that there have been substantive reforms in water governance, aligned with and mirroring the shifting political regime at the national level. Some reforms can be seen as "transformation" in the light of the radical changes that have taken place, such as the shift from a central, hierarchical organisation of water governance to a decentralised and more participatory system. The shift to the basin as a territorial unit for integrated water management is also a paradigmatic change. In Brazil, the radical shift from an authoritarian to a democratic regime was characterised by the huge amount of attention given to participation and deliberation in general, hence a change in development goals to a more inclusive society. This is translated into the importance given to participation and deliberation in water governance. In South Africa, water governance has been shaped both by the transition to the "post-apartheid society" and the focus on human rights in the constitution. In Peru, the focus has been on decentralisation and concertation during the return to democracy, but less apparent in the new water governance framework.

The change in mode and goals of governance are more a function of "transition", signifying changes in governance structures within the existing regime structures. But this example is neither representative of the use of Holling's resilience idea nor of the state of research on resilience in general. In fact a look at the SRCs publications shows that questions related to - urban issues in relation to resilience constitute only fifteen per cent of the overall research ouputs (55 per cent goes to "Multi-level and adaptive governance, learning and transformation" theme, twenty-five per cent to" Global and cross-level dynamics in the anthropocene" theme, and twenty per cent to "Regime shifts") (SRC,

2012:8). Besides, notwithstanding the popularity of the term, the evidence-based research for "urban resilience" is still comparatively small (Muggah, 2014:9).

Conclusion

In two sections, this chapter highlights the institutional and conceptual arrangements that precede a wide circulation of resilience concepts internationally starting in the late 1980s, and the extent to which subsequent research on resilience and resilience related policies bear their imprints as well as the traces of Holling's previous experience in Canada. It appears that regardless of the extent of its circulation across geographical spaces and disciplinary spaces, Holling's concept of resilience remained embedded in the epistemic culture which grounded his initial research in Canada from the 1960s to the 1970s. For example, Holling and his colleagues at IIASA, articulated the organismic holism which is now informing the "adaptive management" advocated by the Resilience Alliance to counter the machine metaphor at the centre of system ecologists' approach to management of ecosystems in the 1970s. Such an articulation was inspired by the work he undertook earlier in Canada and is boosted by the publication of the 1973 paper. Also, the fact that organismic holism "is based on a cultural idea of individuality and society" make the claims of universal validity of the resilience approach doubtful (Kirchoff *et al,* 2010:25). This view is consistent with a position that Holling took in the 1973 paper, "Resilience and Stability of Ecological Systems". In that article, Hollings (1973:16) used the expression "spatial mosaic" to strengthen its argument against the tradition of analysis in theoretical and empirical ecology largely influenced by the Newtonian notions of equilibrium then dominant in biology and engineering. In relation to space itself, he broadly put forward two propositions loosely connected with its quantitative and qualitative aspects. The first one is that the "natural world" is not very homogeneous over space, and the

second one is that the role of this spatial heterogeneity has not been well explored in ecology due to limited logistic resources.

Understood as a way of storing *knowledge a posteriori*, Holling's 1973 paper, became part of the "resilience" of at least some groups of human beings. Thus it is an artifact which operates like *knowledge a priori* able to trigger "new" understandings of empirical referents of the resilience concept contextually and advise actions that should be taken accordingly. However, following the consensus-building work around resilience in the 1990s and the influence of Sweden through the Resilience Alliance, Beijer Institute International or more recently with the Stockholm Resilience Centre, the concept of resilience became increasingly politically conservative and economically reformist. As such it embodied aspects of Swedish foreign policy rooted in mainstream sustainability and serves as a tool to maintain the status quo on certain matter related to world politics. As a result, it reifies paradoxically a homogenising and transferable abstraction of some selected or/and edited contents of the very "social-ecological systems" that enabled it to come into being, to expand that warranty and its legitimacy in the process of its circulation internationally. This is particulary relevant in South Africa because in many cases the concept of resilience has been used either to understand specific features of its natural environment or to read anew realities in the cities whose materialities might have not changed significantly since the post-apartheid political dispensation.

9. Holling's idea of resilience and the promise of change in South Africa

Introduction

The scientific and political arrangements which led to the circulation of the resilience concept worldwide since the 1990s framed *the promise*[51] of successful adaptation to far-reaching socio-ecological transformations. Alongside this promise came the near inevitable challenges associated with the growth of the epistemic communities which drew on the idea of resilience. There was a tension between the diversification of resilience research and attempts by the Resilience Alliance (RA), in particular, to maintain the coherence of the concept. In 2006, these challenges surfaced in the course of the RAs meeting in South Africa's Kruger National Park; the first time that non-Resilience Network members were integrated as board members (Parker and Hackett, 2012:37)[52].

The selection of the Kruger National Park, and South Africa more broadly, as the venue for this key international gathering had at least two points of significance for the evolving concepts of resilience. First, the ecosystems of the Kruger National Park were used by Professor Brian Walker, a South African scholar and a close associate of Holling, to introduce the ideas of resilience in systems ecology to a South African audience with Kruger Park being one of the first places in the world to explicitly adopt ideas of adaptive management (Interview with Prof. Barend Erasmus, 2016). As such, a concept initially derived through research on

51 Whether resilience ever offered such a promise is a matter of debate. By drawing an at least implicit parallel between resilience thinking and socio-political transformations in post-Apartheid South Africa, Holling (2006) was claiming resilience as a tool of radical transformation.

52 The year 2006 was important for the idea of resilience in another way as this was when the SRC was established in Sweden.

the North American Boreal forest was now relayed to a new audience through establishing its significance to local ecosystems. Importantly, also, work on the African Savanna was relayed back into the international discourse on resilience through a direct collaboration between Holling and Walker.

However, South Africa in 2006 offered a wider significance. Holling was well aware of the symbolic significance of hosting a meeting of the RA in South Africa, a little over one decade after the ending of apartheid. He drew the parallels between the "post-apartheid society" which offered the promise of transformation with the idea of resilience which offered the hope of adaptive transformations to a wider world. He wrote:

> For me, the light bright events come from the birth of twin grandsons, living on Vancouver Island. They turn my mind from the present dark colours of international and U.S. politics and governance, and add balance in the promise youth opens for the future. And, on the same positive note, I have also met large groups of new and old friends, on two recent trips-one trip to South Africa and one to Montreal, where we met bubbling communities of people, young and old, experimenting with new options for interracial design and novel social and scientific experimentation. The collapse of apartheid in South Africa has slowly opened huge potential and hope. This is just the opposite of the public mood I see in the United States. (Holling, 2006: 1)

In the previous chapter it has been demonstrated that the role of the International Biological Programme in relation to the spread and recognition of systems ecology internationally highlights how Holling's resilience idea was introduced to South Africa; and the early contribution of this country to the development of the resilience concept through the intellectual leadership of Professor Brian Walker at the University of Witwatersrand, Johannesburg, was addressed. The process of introduction of the resilience concept in South Africa

resulted in strengthening some of the knowledge claims made a bit earlier by Holling and his colleagues at IIASAs "Ecology Project". It helped to universalise the resilience concept and its application in tropical ecosystems. It is clear that through the person of Brian Walker ideas of ecological resilience were transferred at a relatively early stage to South Africa, and that there was further development of these concepts within South Africa, with a rebound to international thinking through, for example, Brian Walker's Directorship of the Resilience Alliance. Thus far, however, South Africa's engagement with resilience was primarily through its use in systems ecology. But, knowledge production in post-apartheid South Africa took the form of a triple helix model[53] as knowledge producers in South Africa, a middle-power[54] in scholarly terms, were responding to both a global discourse including a concept such as resilience/urban resilience and aspirations of a local constituency which was demanding local relevance or appropriateness (9.1).The broadening out of the concept happened as it was incorporated within the national system of innovation, and was introduced into urban policy (9.2).

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53 This concept refers to a move from a dominating industry-government dyad in industrial society to a growing triadic relationship between university-industry-government in relation to knowledge production in society. More attention has been given to this concept in chapter 3.

54 South African scholars have some agency in scholarly circles, and are not (always) simply receptors and interpreters of concepts produced in the dominant North. In fact for most studies, South Africa after the 1994 political transition was classified as a middle power (Hamill and Lee, 2001: 36). But the concept of middle power was well suited to the bipolar nature of the international system. So the analytical usefulness of the term became increasingly criticised after the end of the Cold War (Westhuizen, 1998:437).

9.1. The triple helix model, the national system of innovation and the significance of resilience focussed research in South Africa

As indicated as early as 1972, universities, industry, government and diverse individuals were brought together in the National Programme for Environmental Sciences (NPES). Through the NPES, South Africa seemed to display some emergent features of what is now recognised as the triple helix model. Although this program tried to emphasis the South African character of its contribution, there was an increasingly critical commentary on South Africa's dependence on foreign technology and knowledge (Edwards and Hecht, 2010: 620). Hart *et al* (2013:5) observe that:

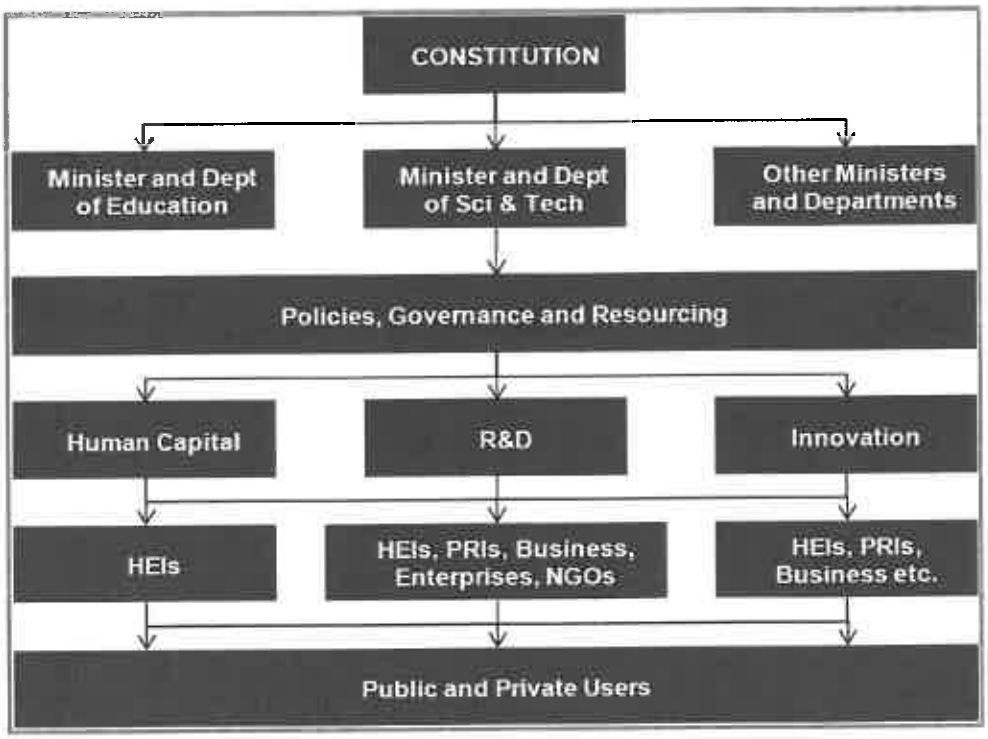
> The national system of innovation (NSI) became characterised by its weak state coordination, concentration of South Africa's resource and commodity base, its low-skill economic base and marginal positioning within global economy (Scerri 2012). Of course, there were some scientific breakthroughs and innovations during the apartheid period, these were few and mainly in specific sectors, for example health procedures and military, mining and agricultural technology. The focus on NSI indicates the insufficient inclusion of small and large private enterprises from many sectors in the NSI and the narrow definition of the NSI.

With the above insight in mind, the existence of a triple helix during the apartheid era becomes problematic. Also, from the mid-1980s, Garrett and Edwards (2007:14) argue that many South African townships were in a *de facto* state of civil war while international opposition to apartheid reached its pinnacle through economic embargoes and foreign disinvestment along with political condemnation. It is in the midst of this period that Professor Walker left South Africa for Australia in order to join the Commonwealth Scientific and Industrial

Research Organisation in 1985. His departure was at a time of intellectual brain drain and intellectual isolation which weakened scholarly work in the South African national system of innovation (Scerri, 2012).

Immediately, after the ANC-led new government came to power, there were attempts to resuscitate the intellectual life of South Africa, and build a National System of Innovation (Table 11). Hart *et al* (2013:5) note that since 1994 a number of policy documents have been produced providing a framework for this goal, starting with the *White Paper on Science and Technology* (DACST 1996) and culminating most recently with the Final Report of the DST Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa (DST 2012). The concepts of "innovation" and "national system of innovation" were also significant in some other documents. For instance, according to *Innovation Towards A Knowledge-Based Economy: Ten Year Plan for South Africa (2008-2018)*, "[I]nnovation is, of course, the key to scientific and technological progress, but our starting point is not innovation for its own sake. South Africa's innovation revolution must help to solve our country's deep and pressing socioeconomic challenges" (DST, 2008:1).

Table 11. South African National System of Innovation. Source: Department of Economic Development South African Provincial Government



Through the 1996 White Paper on Science and Technology, the Minister of Arts, Culture and Technology of the then Mandela government put forward an understanding of knowledge production embedded in the triple helix model:

> Science and Technology (S&T) are essential components of the government's strategy for creating the South Africa of the future. The importance of S&T is recognised outside government as well, by other political parties, business, the higher education sector, the science councils, labour, NGOs and civil society.
>
> The vision for South African Science and Technology presented in this White paper has been developed as South Africa uses S&T to become economically competitive on a global scale, and on the other hand to provide essential services, infrastructure and effective health care for all South Africans (DASCT, 1996:5).

In line with its conception of innovation, science and technology seen from the perspective of the ANC government, follows a logic of Big Science adjusted to some accents of South African history regarding "past" injustices. But the setting and realisation of these socio-economic objectives are framed within the confines of "global imperatives" such as those related to a market economy or to the hierarchical relationship of power among states (DASCT, 1996:8).

Jordaan (2003) argues that emerging middle powers like South Africa are different from traditional middle powers like Sweden (Table 12). In the light of the experience of the India, Brazil, South Africa Forum (IBSA), this distinction is sharply captured in the following words:

> To sum it up: the emerging middle powers base their demands in international institutions on a discourse of global justice and democratic multilateralism. But a critical analysis of their foreign policy behaviour demonstrates a tendency to use multilateral institutions to promote possession goals in the first place. How can we explain the unexpected selfishness of the middle powers? Firstly, economic growth is an overriding foreign policy goal of all IBSA states' because unlike developed middle powers (e.g. Canada and Scandinavian states) the emerging players still have to deal with persistent poverty and great income inequalities in their societies. In effect the civilian end of environmental protection can be scarified if it is thought to limit economic growth. Secondly, unlike traditional middle powers the IBSA states are leaders of underrepresented developing regions. This constellation is used very ably by IBSAs foreign policy makers in order to ascend towards the global players' league- sometimes on cost of milieu goals and global responsibility.

Even though they may sound similar in their approach towards environmental issues, less commitment should be expected from a country like South Africa in comparison to another like Sweden in this matter. Nonetheless, in terms of knowledge production, these countries do have some important commonalities.

For example, the majority of researchers in most countries put the emphasis on resilience thinking in ecological systems and theoretical analysis this is also true when considering the body of knowledge of the RA (Xu and Marinova, 2013). However since its creation, the SRC has been trying to balance natural and social sciences in their studies of social and ecological systems. That is not the case yet in South Africa because among the countries with more than 10 cited resilience researchers, Xu and Marinova (2013) observes that it emerged with a particular inclination toward "social resilience" having the University of Cape Town among the fifteen most productive research organisations in the resilience knowledge domain[55] (Figure 15).

55 However the resilience knowledge domain in South Africa is pervaded by the various genealogies of the term in scientific disciplines. It doesn't belong solely to the resilience concept associated with Holling's research in systems ecology and beyond.

Table 12. Distinguishing between emerging and traditional middle powers. Source: Jordaan (2003)

	Traditional middle powers	Emerging middle powers
CONSTITUTIVE DIFFERENCES		
Democratic tradition	Stable social democracies	Relatively unstable, recently democratised with some very undemocratic aspects
Time of emergence as middle powers	During the Cold War	After the Cold War
Position in world economy	Core	Semi-periphery
Domestic distribution of wealth	Very equal	Highly unequal
Regional influence	Low	High
Origins of perceived neutrality	Regional ambivalence and relative unimportance	Regional self-association and significance
BEHAVIOURAL DIFFERENCES		
Regional orientation	Fairly low	Moderately high
Attitude to regional integration and cooperation	Ambivalent	Eager (often assuming leadership role)
Nature of actions to effect deep global change	Appeasing and legitimising	Reformist and legitimising
Purpose of international identity construction	Distance from powerful in region	Distance from weak in the region

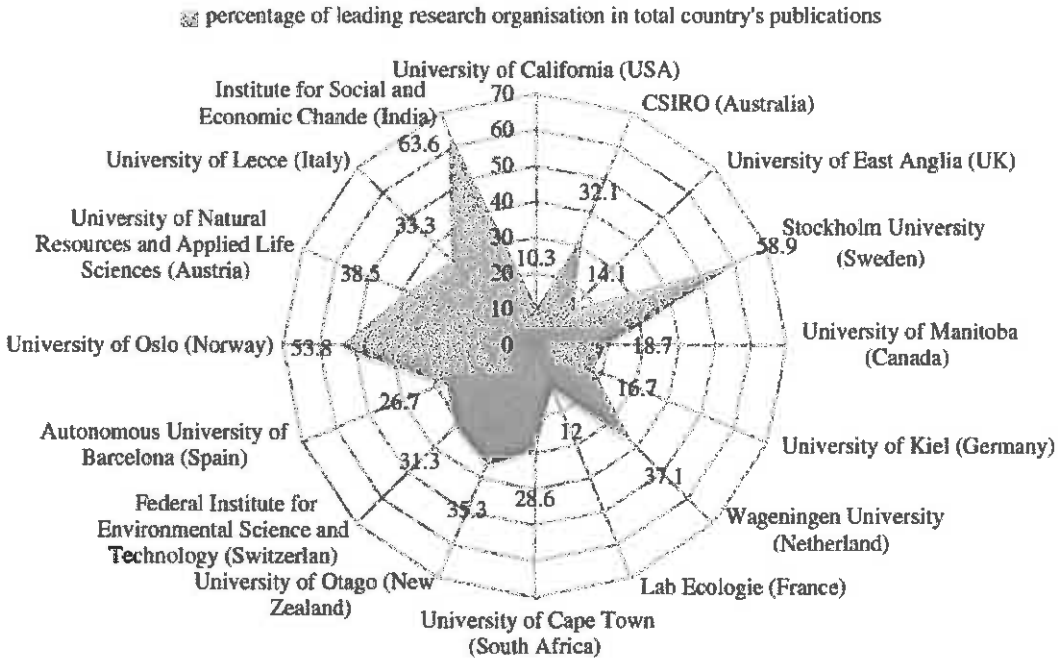


Figure 15. Percentage of the leading resilience research for the top 15 countries and most productive countries in resilience knowledge domain (1973-2011). Source: Xu and Marinova (2013).

Furthermore on the African continent, South Africa dominates scientific production and as a share of world publications, it scores the highest African performance in the field of (Plant and Animal Science" (1.55 %) followed by the same country's percentage of "Environment/Ecology" (1.29%) (Martinez, 2011:10). Through the National Research Foundation[56] (NRF), South Africa - is a member of RA. Graeme Cumming who is affiliated with the NRF is a RA board member. The NRFs key objectives embody the vision stressed in the 1996 White

56 The NRF itself is an entity of the Department of Science and Technology which "promotes and supports research through funding, human resource development and provision of National Research Facilities in all fields of natural and social sciences" (NRF, 2015:1). Its key objectives are to ensure that appropriately qualified people and high-level infrastructure result in knowledge able to position South Africa as a global competitor (NRF, 2015:2).

Paper on Science and Technology. But the 1996 White Paper is only one of the major policy documents of the DST, others include the 2002 National Development Research Strategy (NRDS), the New Strategic Management Model for South Africa's Science and Technology Systems (2004) with its Policy on Governance Standards for Science, Engineering and Technology Institutions and a Framework for the Development of a National Science and Technology Expenditure Plan- and the 2007 Ten- Year Innovation Plan (South African Government, 2015). And its (1996 White Paper) still resonates loudly in the Ten-Year innovation Plan designed to assist "South Africa's transformation towards a knowledge-based economy, in which the production and dissemination of knowledge leads to economic benefits and enriches all fields of human endeavour" (DST, 2008: iv).

The Ten-Year Innovation Plan directs South Africa's main projections for 2018 into five "grand challenges" articulated in the following areas, the farmer to pharma value chain to strengthen the bio-economy; space science and technology; energy security; global-change science with a focus on climate change; human and social dynamics (DST, 2008:11). The aim of these "grand challenges" is to stimulate multidisciplinary approaches to research and to provoke South Africa's researchers to answer current questions, create new disciplines and develop new technologies so as to respond to global change. As a result, the Ten-Year innovation Plan led to a 10-year national research plan for the Global Change Grand Challenge (the Global Change Research Plan). In this plan, "resilience" is understood from the RAs perspective and research on social-ecological systems inspired by the SRC occupies a central position in the overall conceptual framework. Among the fifty contributing authors of this document there is Prof. Barend Erasmus and Prof. Bob Scholes both former members of the Centre for African Ecology and current members of the Global Change Sustainability Research Institute at the University of the Witwatersrand (two

institutions where Prof. Brian Walker and Holling's resilience idea left a lasting impact). Unsurprisingly, the section which in the Global Change Research Plan deals with "Innovation and sustainability" is also concerned about "resilience and capability" (Table 13). Among other things, it points out a gap in understanding the resilience concept in urban contexts:

> There is an increasing recognition that the sustainability of urban social-ecological systems is a function of their functional integrity and resilience. The application of the concept of resilience (well developed in ecological studies) to urban social-ecological systems is still immature (both locally and internationally) and the opportunities it presents needs further definition (DST, 2009:22).

In 2011, the NRF issued a call for research programmes with the ambition to close this gap. For that purpose, three research institutions were selected to share a grant through the Global Change, Society, and Sustainability Research Programme[57] (GCSSRP), the South African Research Chair in Spatial Analysis and City Planning[58] (SARChI) at the University of the Witwatersrand, the Think Tank

57 Broadly, GCSSRP is a long-term large-scale structured and coordinated research funding instrument implemented to address the identified fundamental research questions and provide research-based evidence required for socioeconomic development, sustainability and social cohesion (NRF, 2014).

58 SARChI is a newly established research programme funded by the National Research Foundation (NRF) and led by the South African Research Chair of City Planning and Spatial Analysis, Prof. Philip Harrison. This research chair is hosted by the school of Architecture and Planning at the University of the Witwatersrand. Its physical address is: South Basement, John Moffat Building, East Campus, University of the Witwatersrand, 1 Jan Smuts Ave, Johannesburg, 2000. Its primary research objective is to "support, develop and promote forms of development planning that will contribute to making cities in poor and middle-income countries more liveable, sustainable, efficient and equitable" (SARchI, 2014). The initial focal point of the research is Johannesburg, and the city-region of which Johannesburg is a part. This focus may be extended to other city-regions in the Global South.

on Resilient Urban Systems in Transition[59] (TRUST) at the University of Pretoria, and Economic Performance and Development[60] (EPD) at the Human Science Research Council in Cape Town.

In the midst of either the Ten Year innovation Plan or the Global Change Research Plan, South Africa's particularities emerge not so much because of its distinctive scientific contribution to issues around global change but because of its geographical environment:

> Important changes are taking place in the global climate, but there is still great uncertainty about how the earth systems operate. South Africa is positioned to serve as a unique laboratory given its proximity to the Antarctic, the Southern Ocean, and the Agulhas and Benguela currents and to make a major contribution to understanding climate change. This is above all, a strategic consideration...

59 TRUST is an initiative funded by the National Research Foundation, led by both Professor. C. Cloete and Professor. C. du Plessis from the Department of Construction Economics, University of Pretoria. This initiative consists of an inter-transdisciplinary project that - uses the integrated skills of planning, evaluation, design - thinking and ecological engineering in an iterative systems approach to understand the drive behind resilience, developing appropriate solutions for - a resilient built environment, and - building national capabilities scientific research around resilience. The research focus of TRUST is "the resilience of aspirational cities as manifested in the Gauteng urban system with a specific focus on the City of Tshwane" (TRUST, 2014).

60 EPD is a unit within the Human Sciences Research Council which seeks the evidence and understanding required to deal with the unsustainable level of employment and poverty in South Africa. Prof. Ivan Turok is the Deputy Executive Director of EPD. The purpose of this unit is to "help transform economic outcomes by strengthening policy and implementation through generating and sharing relevant, reliable and timely knowledge and ideas" (HSRC, 2014). As such, EPD collaborates with decision-makers, offers advice and assistance in developing the range of policy measures required at national, provincial, and local levels. Its physical address is: 14th floor Plein Park Building 69-83 Plein Street, Cape Town, South Africa 8001.

> South Africa is well positioned to lead research on the continent in terms of understanding and projecting changes to the physical systems; the impact of these changes; and mitigation to limit their long term effects. Mitigation climate change also provides an economic opportunity for South Africa; therefore the country needs to develop a strategy to take advantage of the **so** called "Green economy" (DST, 2008:22)".

Table 13. Four major cross-cutting knowledge challenges and 15 key research themes as identified by theGlobal Change Research plan. Source: DST (2009).

Understanding a changing planet	Reducing the human footprint	Adapting the way we live	Innovation for sustainability
1. Observation, monitoring and adaptive management	1. Waste minimisation methods and technologies	1. Preparing for rapid change and extreme events	1. Dynamics of transition at different scales - mechanisms of innovation and learning
2. Dynamics of the oceans around southern Africa	2. Conserving biodiversity and ecosystem services, e.g. clean drinking water	2. Planning for sustainable urban development in a South African context	2. Resilience and capability
3. Dynamics of the complex internal earth systems	3. Institutional integration to manage ecosystems and ecosystem services	3. Water security for South Africa	3. Options for greening the developmental state
4. Linking the land, air and sea		4. Food and fibre security for South Africa	
5. Improving model predictions at different scales			

The above quotation reflects also South Africa's middle power status in the international system. On the one hand it illustrates the expectations placed on South Africa by the "West" regarding a regional leadership in Africa after 1994 (Schoeman, 2000). On the other hand it shows South Africa's inability to "unilaterally and single-handedly shape the global outcomes in any direct manner. This inability guides middle powers towards utilising and asserting themselves through international organisations, relying on the authority afforded **these** institutions in order to manage and maintain the prevailing world

order (Jordaan, 2003:169)". So, the "global imperatives" of the 1996 White Paper are still the order of the day even in the Global Change Research Plan. Besides the conceptualisation of South Africa's transformation from a resource based economy[61] into a "green economy", both in theory and practice is still in its infancy (Greenfund, 2014:1). Therefore "to take advantage of the so called "Green economy" resonates with Imraan Patel's (Chief Director : science and Technology for economic Impact, DST) following assertion : "Marketing, South Africa and Southern Africa as a priority area for globally relevant research will enable us to add value to, as well as benefit from, international research collaborations" (CSIR, 2009:1). But in circumstances where South Africa's geographical environment is not sufficient to bring recognition to the country as an "an attractive and a priority area for research", the Global Change Research Plan adds some features of South Africa that could make such aspiration more legitimate:

1. Its social composition, which make it a microcosm of the world- the ratio of rich to poor people approximates the global average (which is rare in a single country), and accentuates the problem of finding equitable solutions to address of developed and developing sectors of society.
2. Its outstanding record of scientific research, the solid basis of knowledge on which it is able to build, and its sophisticated scientific infrastructure-many South Africa scientists are recognised world leaders in their fields.
3. Its pressing problems, deserving urgent attention, that offer the prospect of finding innovative solutions- As a dry country, South Africa's water supplies are stretched to the limit. Resources are

61 Historically, South Africa's economy has been depending on mining and benefiting largely from its deposits of platinum, gold, diamonds and coal to the point that the mining industry provided a platform for the development of the manufacturing and financial sectors (Bormann and Gulati, 2014:6).

> also being depleted, resulting in, for example, shortages of electricity supply. Solutions found for South Africa would be applicable to many other countries (DST, 2009:11).

The search and praise of universalism transparent in what in the above list may serve as research interests or may tease scientific curiosity have been reinforced by the political dispensation of 1994. Since the 1996 White Paper, science and technology were portrayed as the means to find the solutions to some of the material problems attached to the democratic political transition in South Africa. Those problems are now portrayed in the Global Change Research Plan more as an advantage which may distinguish South Africa as "an attractive and a priority area for research" rather than a limit to the realisation of socio-economic goals mentioned in policy documents since 1994. As a result they reflect the fact that from the stand point of its geographical location, South Africa as a middle power doesn't have the capabilities to affect global structural change connected to the biological base of its economy. Because its willingness to integrate the international system match more with the obedience to "global imperatives" rather than the urge to correct the material base of injustices whose endurance acquired the appearance of a norm in South African society. In other words even though science and technology have been framed as Big Science since 1994, they seem unable to lead the kind of material change bestowed upon them by the first democratically elected government in the country. This is of direct relevance to the Global Change Research Plan whose partial operationalisation through the NRFs research programme, the Global Change, Society and Sustainability, echoes the research undertaken either by the RA or SRC on resilience and social-ecological systems and the critiques of this body of knowledge (Harrison *et al,* 2014; Du Plessis, 2008 & 2009; Du Plessis and Cole, 2011; Swanepoel and du Plessis, 2013; Turok, 2014; Seeliger and Turok, 2013).

9.2. The incorporation into urban policy

During a conversation with Prof. Philip Harrison, he noted that, in his view, the popularisation of the concept of "urban resilience" to the urban policy domain in South Africa could be credited to Prof. Ivan Turok, and specifically to his use of resilience in conceptually framing the *State of the Cities Report* that he had been commissioned by the South African Cities Network to co-ordinate. In the following paragraph, Prof. Turok recounts how he came across the resilience idea and introduced it in South Africa:

> I came back to South Africa in April 2010 after living in the UK for many years. A month or two later I was invited to act as the lead author and coordinator of the 2011 State of SA Cities Report. I wanted to ensure that it was more coherent than the previous version so I began to think about a suitable theme that might link the different elements (economic, social, environmental, governance, financial etc) together. I had been reading the resilience literature out of curiosity and I realised that it was a potential 'umbrella' concept that could act as a unifying device. I wrote a three page proposal to the SA Cities Network to make the case for resilience as the overarching theme, and after some discussion and debate, they agreed. The rest is history. Resilience became the title of the report and various other researchers began to explore the concept. The National Research Foundation also sponsored a research programme which included resilient cities in as one of the key themes. I was successful in getting one of their grants, and wrote several papers on resilience from this, with my co-author Leanne Seeliger (Appendix B).

Turok refers to the strand of resilience literature coined with the governance of risk and threat to the social body which has been highlighted in Chapter 8. But there is neither a direct reference to C.S. Holling in Prof. Turok's account of the concept of "urban resilience" in South Africa nor in the cited literature which

informs the concept of "urban resilience" in the *State of South Africa's Cities Report* (2011). The significance of a quest for analytical coherence in the writing of SACNs reports tends to supersede the materiality of the geographical space in South Africa in the ways in which Prof. Turok recalls his experience. Yet the very rationale behind his use of the concept of resilience at the introduction of the *State of South Africa's Cities Report (2011)* puts the idea of difference centered in the notion of space among some of the reasons why "resilience" is able to circulate and be modified from place to place while keeping its analytical coherence:

> The concept of resilience implies something locally specific and unique-the intrinsic characteristics of place-and how this systemic quality relates to wider circumstances. Places are likely to vary in their resilience depending on their people, institutions and physical attributes. The concept offers fresh thinking and new ideas to encourage the questioning of assumptions and making new connections. It challenges conventional wisdom and prompts analysts and activists to think differently about cities, and particularly about the processes of change within them. The theme raises novel questions for urban research and introduces different ways of exploring important societal concerns. It also has a normative, policy aspect implying a desirable, dynamic quality for cities to be able to steer a way forward in the face of adversity or shifting social and political norms (SACN, 2011:12).

In fact the *State of South Africa's Cities Report (2011)* was written under the broad theme resilient cities while the *State of Cities Finance Report (2011)* was an application of ideas of resilience to the financial fortunes of South African cities. "Urban resilience" in these reports is interpreted and defined in two ways. Firstly it is understood within the scope of engineering resilience so as to mean

"the capacity of a city to withstand and recover from external shock, such as economic downturn or climate disaster (SACN, 2011:12)". The second aspect draws from ecological resilience and "refers to the capacity of a city to chart a different pathway in challenging conditions. It involves adapting and shaping the development trajectory in order to improve the city's position in some deeper, structural aspect. (SACN: 12)." For example, Seeliger and Turok (2013: 194-197) explore the ways in which the resilience perspective can help better understand the challenges facing informal urban settlements and trace a better trajectory. Through a case study of the Enkanini informal settlement in the large town of Stellenbosch in the Western Cape province of South Africa, they argue that adaptive governance may be a useful approach to build resilience. According to these authors, adaptive governance is an approach to system management that puts together the insights of experimental learning in complex systems with the sensibilities of organisational theory. They add that policy actions remain purposely open to change in accordance with their impact underground and are flexible in relation to shifting circumstances.

Moreover Turok (2014) uses the concept of resilience as an analytical tool to assess if the metropolitan areas (Gauteng metros, coastal metros) in South Africa fulfilled their mandate in relation to the promotion of resource redistribution, urban reconstruction, and socioeconomic development. In doing so, Turok manages to interrogate the object of his study both with aspects of engineering resilience and ecological resilience as it has been distinguished by Holling in 1996. He concludes that spatial patterns of urban development inherited from the previous political dispensations remain unchanged and cities have not prepared well for urbanisation. The reasons for that seeming status quo, he notes, are vested interests, institutional inertia, and the inhibition of the crafting of more appropriate city-level solutions by sectoral and centralised policies. The result is the continuing fragmentation of urban investment decisions which

prevent more compact built forms to emerge. Along with the above, poverty traps persist in the absence of policies to increase access to jobs and livelihoods for people living in informal settlements.

It is important to note that while the *State of the South Africa's City Report* popularised the concept of resilience within the policy domain it did not introduce the concept. In fact, the idea of resilience was used by Ramutsindela (2007), although in this sense to refer to the persisting negative impact of the former homeland boundaries in the drawing of provincial boundaries.

Harrison *et al,* (2014:3) note that there is also a literature about South Africa whose understanding of resilience is linked to social psychology. This literature is mostly concerned with how youth in townships deal with their vulnerability to numerous threats including crime, violence, loss of employment, HIV/AIDS. This use of the term resilience is present also in the account by Shale (2010) in a study of Philippi in Cape Town who shows how poor communities draw on resources such as burial societies in building the necessary social capital that allows them to adapt resiliently to change. It is also present in Gossmann (2011) who explains how crucial individual strategies of resilience are in a context such as Diepsloot in Johannesburg.

The other strand of use in South is related to environmental concerns and to climate change in particular. It is true that these issues have received low priority in comparison to social issues which tend to be perceived as more urgent in the political agenda (Shaffler and Swilling, 2013:247-248) but there have been individuals who have stressed these concerns and in doing so have drawn on ideas of resilience, even before they were popularised in the urban policy domain. An important example is in the work of Professor Chrisna du Plessis at the University of Pretoria.

It is du Plessis whose conception and use of the term resilience in South Africa is perhaps most - closely related to its origins in the social-ecology of C.S Holling. This influence appears, however, in some of her research outputs as the outcome of a broader inclination towards the literature on climate change and sustainability rather than a particular attempt to connect her work with C.S. Holling or exclusively with the concept of resilience. In this regard, Du Plessis (2009) notes that what is often referred to as "sustainable development" is an attempt by humans to keep improving the quality of life of the most people on earth, while preventing the human species from becoming extinct as a result of its own failures to live within planetary ecosystem boundaries or adapt to changing conditions. She proposes that the failure of the sustainability project lies in its uncritical acceptance of the currently dominant worldview based on a deterministic, mechanistic understanding of nature, and suggests like many other commentators that in order to effect meaningful transformation of global development trajectories, it is necessary to change the worldview that underlies the current development paradigm to mirror an understanding of the world as a complex living system. Resilience appears in her thinking as a function of "urban sustainability" which is grounded in an ecological worldview having three main concerns:

1. The continued existence of the city is determined by the integrity and resilience of the various systems at different levels and scales that combine to form the urban social-ecological systems (SES)
2. The quality of life of the citizens in the city is determined by the quality of the relationships of which they form part, and by the extent to which these relationships uphold the values and praxeology provided by the ecological worldview.

3. At a larger scale, the role of the city is to maintain the wholeness of the global SES by fostering respectful and mutually beneficial relationships at local and global scales that contribute to the wellbeing of the entire system.

For Du Plessis, "urban sustainability" is not necessarily about how to make 'correct' choices of technology or social and economic ideologies, or provide solutions to a set of pre-determinate and often everlasting problems (e.g. poverty, pollution, crime, or waste). But it is about understanding the social and biophysical dynamics that trigger desirable and undesirable phenomena so as to adapt to changes and participate most effectively in the natural evolution of the city while keeping the urban and global SESs from crossing critical thresholds.

In another paper, she draws her inspiration from earlier ecological approaches to urban development, together with more recent thinking in the field of sustainability science, resilience thinking and complexity theory. Du Plessis (2008) proposes a conceptual framework for understanding cities as social-ecological systems. In this regard she suggests that "cities should be understood as (1) complex, adaptive systems that are (2) integrated across spheres of matter, life and human social and cultural phenomena (or mind), (3) are structured and nested systems that allow interaction across scales and levels of organisation, and (4) that what differentiates cities (and SESs) from other types of ecosystems is the introduction of abstract thought and symbolic construction that allows for considered novelty, communication of ideas across time and space, and therefore learning and reflexive thinking." This proposed conceptual framework requires the urban sustainability debate to shift from a quest for ultimate rules for city planning and design, to discover ways that accept and accommodate change and novelty while building the capacity for resilience in the interplay between noosphere and biosphere.

Also, Du Plessis and Cole (2011) advocate for a paradigm shift in the construction sector. In their research, they propose that stakeholder behavioral change can be more effectively and permanently motivated through a change in paradigm, and investigate how such a change could reshape key concepts and approaches to stakeholder engagement. This shift entails a move from a mechanistic world view to a whole/living system world view. They identify three key shifts in thinking that influence the model of sustainability in a whole/living systems paradigm: from complicated to complex systems, from an equilibrium model to a non-equilibrium model, and from an anthropocentric to an ecocentric worldview. The implications of this paradigm shift for the debate on the stakeholder engagement are three-fold. Firstly, according to a system view the most significant change will happen through changing the mindset and values of stakeholders. Secondly, it implies a redefinition of who qualifies as stakeholders and thus their roles. Thirdly, this new paradigm changes the practices of stakeholders by way of including the stories and aspirations of the place.

While ideas of resilience in South African urban thinking may go back some time, it is in the recent past post the *State of the South African Cities (2011)* report that resilience has made its impact in South African urban policy. Professor Harrison participated in the writing of South Africa's National Development Plan (NDP) as a member of National Planning Commission. He indicated that the idea of resilience is not strongly present in the plan overall but that he was able to introduce it into Chapter Eight of the plan and specifically into the spatial principles which were later incorporated into the Spatial Planning and Land Use Management Act - SPLUMA (2013). 'Spatial resilience' was included as a principle together with "spatial justice", "spatial sustainability", "spatial efficiency" and "spatial quality". In the conversation that I had with him, he acknowledged that it is his reading of the *State of South Africa's Cities Report (2011)* which informed his understanding of resilience at the time that the NDP was finalised in 2012 and

was especially interested in the idea in relation to the urban bounce-back needed from the 2008/09 global and national economic crisis.

Groesser (2013:73) shows how the concept of resilience has been introduced in the Growth and Development Strategy (GDS), *Jo'burg 2040* in the light of the agency of one of the main authors of GDS 2040, Mr. Stephen Narsoo:

> As with most policy agendas in South Africa, the idea of resilience came from the discourses of development in focus in the global north. Events in the US from 2006 to 2009 had sparked a rapidly growing discourse around the concept of resilience (Interview with Narsoo, 2013). Gas (petrol) prices were increasing and in 2008 the financial crisis hit. Studying for his masters in Urban Planning at UCLA from 2006, Mr Narsoo admitted that he was very influenced by the concept of resilience because of what he was seeing around him. A book by Paul Roberts, *The End of Oil (2004)*, and classes taught by various experts in disaster management further fuelled his interests (ibid). The First time he came across the term "urban resilience" was in the book *The Resilient City: How modern Cities recover from disaster* by Vale *et al.* (2005). The book spoke about the notion of durability of the city.

The Resilient City: How modern Cities recover from disaster by Vale *et al* is part of the literature which informs Professor Turok's use of the resilience concept in the *State of South Africa's Cities Report (2011).* Still, even in the case of Mr. Narsoo and GDS, there is no direct reference to C.S. Holling as a source of inspiration.

It is, however, eThekwini Municipality, where resilience has been most forcefully used as a result of its incorporation within the Rockfeller Foundation's 100 - Resilient Cities Programme which started in December 2013. The inception of this programme has been more or less influenced by the research undertaken at

the Stockholm Resilience Centre. However, Dr, Debra Roberts, the Chief Resilience Officer of this programme in Durban, provides a good illustration of how heterogeneous and pliable the concept of resilience can be. In one of the several meetings that the city of Durban held in partnership with the Rockfeller Foundation, - below is how Botes (2014:6) recalls Dr. Roberts' stance on resilience:

> Roberts explained that there are many potential contributing factors to the state of resilience and many points of entry to build resilience, and that Durban needs to choose a point of entry into the resilience "universe". A key starting point for Durban's resilience strategy is 'strong leadership'. Roberts used the example of good leadership linked to the promotion of efficient transportation and environmental integrity and the resulting multiple and interrelated impacts on social cohesion, reduced environmental impacts and strengthening the economy. Roberts also highlighted that African cities have a unique advantage in that they have not yet destroyed their natural resource base which provides ecological infrastructure and services that will be critical in ensuring ongoing resilience.

In a correspondence regarding Holling and the Stockholm Resilience Centre's (SRC) possible influence on her work and the city of Durban's articulation of the resilience idea, Dr. Roberts writes : "On the Holling issue as a biologist I am of course aware of Holling's work and that of SRC but neither of those have played a significant role in the developing of our understanding of resilience" (Appendix C).Yet as shown in chapter 8, the SRC listed the Rockfeller Foundation among the organisations which have been influenced by its works. But in the same correspondence, Roberts added that it is the recent work of geographers Mark Pelling and Bill Solecki which influenced her understanding of resilience (Appendix...2015). The influential work of these two scholars falls within the broader remit of climate change literature. Besides in an earlier paper in which she recounts the institutional and resource challenges and opportunities in

bringing different sectors in eThekwini Municipality (the local government in charge of the management and planning of the city of Durban) to acknowledge and respond to their role in climate change, Debra Roberts (2008:397) confines the meaning of resilience almost solely within the strategy to adapt rather than to transform:

> What sets cities such as Durban apart however, is the strong and early focus on climate change adaptation. This contrasts with the tendency to prioritise mitigation, which usually typifies local government's initial engagement with climate change. What appears to motivate these "early adapters" is the need to improve local level resilience in the face of increasing climatic uncertainty in order to achieve various development services delivery objectives. In Durban there is the added pressure of ensuring that post-apartheid development gains are not undermined or lost, and that the escalating and urgent development challenges still facing the city are not exacerbated by climate change.

In short the literature related to resilience in relation to urban policy in South Africa or about South Africa is not homogenous, whether in relation to the various epistemic communities using this terms or because of the more diffuse aspects of interdisciplinary research. It should be noted that it is also not uncontested. Donk and Gaigient (2014), for example, provide a critique[62] of how

62 However following an examination of the resilience literature deriving from the work of C.S. Holling, Donk and Gaigien (2014) conclude with a critical assessment on how the concept of resilience is used in the National Development Plan (NDP) in South Africa. In this regard, a critique of resilience is articulated in three points. First it is noticed that the resilience literature assumes a norm that does not reflect the daily reality of a large part of the global population or in this case South Africa. This literature considers shocks and stresses as an event, an occurrence something that is seen as "abnormal", yet this supposed state of abnormality (precariousness) is in fact a significant part of the social fabric which characterises poor communities. Secondly, resilience theory is not addressing sufficiently the systemic factors which cause social

the concept of resilience is used in the NDP. The extent to which the idea of resilience is sustained with urban policy in South Africa remains however to be seen.

Conclusion

The popularisation of the concept of resilience to urban policy in South Africa benefited from the agency of a number of individuals who have engaged jointly with both academic and policy-related work. But the use of the concept of resilience in post apartheid South Africa is not often related explicitly to Holling's research. In contrast the influence of the work done at the Stockholm Resilience Centre (SRC) is evident in the Global Change Research Plan and less so in the contribution of the city of Durban in the Rockfeller Foundation's 100 Resilient Cities Programme. However the local contribution and the significant body of knowledge which has been generated in South Africa or about South Africa on issues related to resilience and social-ecological ecosystems - justify more than they shaped the political arrangements backing a wider circulation of Hollings idea of resilience internationally, especially since the 1990s. For example the SRCs publications show that questions related to urban issues in relation to resilience constitute only 15 per cent of the overall research ouputs (55 per cent goes to "Multi-level and adaptive governance, learning and transformation"

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vulnerability and weaken resilience. It fails to examine how power, ecology and development intersect. Finally the bearing of system thinking on resilience theory makes it abstract and out of touch with the particularity of place.

theme, 25 per cent to" Global and cross-level dynamics in the anthropocene" theme , and 20 per cent to "Regime shifts") (SRC, 2012:8).

Besides, notwithstanding the popularity of the term, the evidence-based research for "urban resilience" is still comparatively small (Muggah, 2014:9). South Africa is not an exception in this case. Whether it is at the international level or locally in South Africa, the body of knowledge on resilience especially in relation to urban contexts has been often criticised for being politically conservative and economically reformist (Donk and Gaigien, 2014). If that may seem acceptable elsewhere, in South Africa, it contradicts the rationale behind its popularisation by Ivan Turok and sets the country back to the fundamentals of the 1994 political transition (Ramutsindela, 2007; Turok, 2014; Bhorat *et al,* 2014). In this regard, reflecting on his experience as a planner in the city of Johannesburg, Harrison (2014: 68-78) captures some of the underlying tensions between scholarly writing, policy and lived realities that Holling's contribution on resilience theory relatively overcame:

> Planning theory may have honed my conscience and improved my capacity to deliberate in a complex environment, but it did not provide me guidance, or even an orientation, on substantive matters...There were instances that I outline below as illustrative cases where academic writing did provide an intellectual resource for me in developing and arguing a case for policy reform in the city administration, although the support from scholarly writing was always secondary to the persuasive power of direct exposure to alternative experience...If I had benefitted from the ontological defence provided by speculative realism, I may have been more confident in my attempts to link intellectual support to an engagement with materiality of the city. I may have argued the case for policy reform more effectively while remaining open to the speculative question: 'What if things were otherwise?'

Eventually, things could be otherwise as the embrace of the unexpected and the fascination for of the unknown at the core of Holling's development of resilience concept prove to be pliable to the various contexts in which resilience theory is being applied across spaces, material or otherwise. That is to say that resilience thinking "requires a bigger and different kind of clever. It demands that we recognise the limits to predictability and control inherent in complex systems-be they lakes, forests, businesses or whole communities- and admit that we cannot command the world entirely as we would wish (McLaughlin, 2010:18)". It demands all that while travelling through knowledge infrastructures that restrict the very possibilities of what it promises within a politically conservative and economically reformist international system.

10. General conclusion

The task of this thesis revolved around answering the question: how particular conceptions, experiences, and material constructions of space inform the knowledge that is being produced by planners and urbanists around resilience projects internationally and in South Africa? To address this core question, the thesis engaged with two secondary questions:

1. What is the interplay between the material and hermeneutics aspects of space in C.S Holling's initial research on resilience, and what are its imprints on the manifestations of the resilience idea?
2. How has the idea of resilience as used by planners and urbanists in South Africa emerged?

The thesis' central argument is that different spaces allow the production of knowledge to happen; while inscribing themselves in the knowledge which is

being produced they restrict the ways of knowing to a set of methods confined within the parameters they have displayed in advance. As such the knowledge being produced in a given space somehow retains some features of that space, even when it circulates in very different spaces afterwards. Thus in this thesis, elements of Crawford Stanley Holling's life history have been put into perspective so as to provide a historical trajectory upon which of the spaces imbued in the various contexts hosting pivotal activities on the production and refinement of the resilience idea were explored. These elements were also used as a point of departure from where the idea of resilience originates and circulates internationally and in the context of South African cities. Throughout this entire process, it was the very idea of space, the significance that some of its types (i.e. forest, laboratory or city) and features (i.e. institutional or material) hold together or not as a form of relevance and influence over different stages of the development of the resilience idea (understood both as a historical event and a knowledge object) which were interrogated. In so doing, the role of human experience and knowledge infrastructures in the formation of scientific knowledge and the promotion of global norms have been highlighted.

However, this argument is multi-layered because it broadly encompasses several answers unpacking the variety and specific features of space in question. That is the reason why the chapters have been written in a form of interlocking essays. Each of them emphasised some aspects in the relationship between knowledge and space so as to serve as an argument for the overall thesis. Whilst the human being, C. S. Holling, who is at the centre of this research process can be recast in terms of "positionalities" (race, class, gender, historicity etc.), the very notion of "context" central in his life history is a base where questions can be investigated relating to the malleability of space and its relations to knowledge production across historical change and lifespan (see Dhunpath and Samuel, 2009). For example, the "global positionality" of certain nation-states is in fact a

reproduction across different geographical spaces of selected place-like aspects of their territories (Sheppard, 2002:322). Even the meaning of a particular instance of space such as the laboratory is subject to change across historical periods and along the lifespan of a scientist like C.S. Holling (Guggenheim, 2012). It follows then that the synthetic potential of life history through which some of these nuances and details are explicated is actually an expression of the analytical skills of the one doing the research (personal skills of the scholar) rather than being a mere outcome the method used (Bertaux and Kohli, 1984:232-233). That is a glimpse of the contribution of this study which is entirely explicated in Chapter 1, and of the novelty of its methodology which is a blend of elements of social constructivism, artefactual constructivism, and life history and critical discourse analysis as seen in Chapter 2.

The distinctiveness of place in relation to scientific knowledge is as problematic as the empirical grounding of 'placelessness' (Gieryn, 2000; Lefebvre, 2009). That is particularly relevant for the case–in-point in this dissertation. In effect the concept of resilience with its emphasis on material heterogeneity of space while simultaneously spatially situated and mostly defined by existing prominent academic, international organisations, states that institutions able to expand their constructs globally display this paradox (Weichselgartner and Kelman,2014). In other words, it uncovers the limits of the universality of scientific knowledge and at the same time tends to hide them because of its position within the existing unequal and asymmetrical distribution of capacities (cognitive, material and symbolic) to produce what is deemed to be accepted as valid knowledge and legitimate scientific practice globally. It is both along and against the aforementioned traction that the rest of the chapters reflect the multilayered argument of this thesis and the ways in which each of its layers is interwoven in the different emphases put in each chapter.

In Chapter 3, a light is shone on what counts as knowledge, and the role of power in enabling the legitimacy of any such as these accounts. Although knowledge is not framed in a single category, the similarities and differences in knowledge production across locales are examined through a historical perspective, and their implications for the knowledge economy are pointed out. In this regard, the Chapter positioned social-ecological research both as the point of convergence for the study of knowledge in this thesis, and as an asset in the knowledge economy as well as in its international politics.

Chapter 4 outlined the historical perspective adopted in this thesis in relation to the study of space. In doing so, it unravelled some of the reasons why questions related to the non-human agency of space have been bracketed in Western academic writing. It also insisted on the necessity to re-examine some of those questions and their implications for the writing of the rest of the thesis. That is to say that this chapter furthered the "new materialist" reasoning around non-human agency by pointing specifically at the cognitive influences that the physical dimensions of space exert over human beings and in the processes of knowledge production in general. Yet this chapter also insists on the fact that the heterogeneity of the materiality of space enables the idea of difference associated with its notional foundation to be mobilised or silenced so as to suit different analytical ends. In doing so, it becomes clearer that the contradictions that may exist among these analytical ends mirror well the inherent political dimensions associated with space and knowledge production as explained in Chapter 3.

Chapter 5 provided an illustration of the variety of spaces which can be encountered in a study dealing with a laboratory. In the same vein, it showed that human and non-human agencies are manifested differently across space and time. In a nutshell, this chapter is written as a story displaying the

relationships between the North American Boreal forest, Sault Ste Marie Laboratory in Ontario, Canada, and C.S. Holling. It pointed out how human beings, and the natural and built environments, interact dialectically in the ways in which knowledge is being produced. Thus the examination of Holling's research activities in the 1950s in this chapter has shown that an analysis having a laboratory as a focal point, is likely to encounter entanglements between different forms of knowledge, various conceptions and material constructions of space all at once. That is to say that the plantations in Ontario or the construction of the Sault Ste Marie laboratory to name but a few elements, participate in the formation of Holling's experience and the narration of his research outputs.

Chapter 6 situated C.S Holling's research in the material world of North America in the 1960s and 1970s so as to provide a better sense of the variety and entanglements of spaces and knowledge. It pointed out the connections between nature and culture, both the influences of human and non-human agencies in relation to issues of deforestation and urbanisation; the interplay between politics, science and economy; and, a transition from a discipline to interdiscipline in natural and social sciences. The substance of these historical developments constitutes the epistemic culture of the 1960s and 1970s whose traces are noticeable in Holling's body of work related to resilience. So it is demonstrated that between 1952 and 1974, Holling's research is a formal expression of the mission of the Sault Ste Marie laboratory and that very mission is not divorced from the social dynamics and epistemic culture which emerged in Canada and broadly in North America in the 1960s and 1970s.

In Chapter 7, it is demonstrated that the main elements of the epistemic culture of the 1960s and 1970s in Canada are interwoven in the works authored by C.S Holling from the 1950s until the late 1980s. The malleability of space and the

distinction of its influences over the work of Holling as a researcher have been examined. To put it succinctly, the concept of resilience has been used as a case-in-point to explore how space in its variety influenced the evolving thinking of C.S. Holling, consisting in making connections between social and ecological systems which include cities and then converged within the concept of "social-ecological systems". Also, the chapter identified which spaces participated in the constitution of Holling' s 1973 paper, and showed their entanglements in Holling's narration of what the paper is about. It is found that between the 1960s and the 1970s, 'the city' became prominent in his work on three levels. Firstly the concerns of the North American cities movement in the 1960s resonated in the articulation of introductory and concluding sections of some of his papers. Secondly, the city became a truth-spot in which both the laboratory (and urban/culture) and the field (and forest/nature) interacted in order to legitimise his knowledge-claims. Thirdly, the city became part of the urban system connected to the ecological systems in Holling's evolving thinking. It is also found that the use of computer models and systems analysis while enabling the re-articulation of the concept of resilience hid the bearings that Holling's multiple engagements with spaces left on the formation of his research outputs

Chapter 8 dealt with the scientific, political and infrastructural arrangements which fostered a wider circulation of the concept of resilience from the 1990s onwards. While the resilience concept remained rooted in the epistemic culture of the 1960s and 1970s in Canada, the similarities that the material world in which that epistemic culture was grounded shared with other spaces like Sweden kept informing the *science of politics and* the *politics of science* around Holling's idea of resilience. In fact from the 1990s onward, the resilience concept inspired by C.S Holling became increasingly part of a politically conservative and economically reformist mainstream sustainability discourse. The role of technique and the impact of the geographical spaces were superseded by the

construction of international politics enabling a wider circulation of the concept of resilience. So, the chapter tried "to analyse how processes of interaction produce and reproduce the social structures-cooperative or conflictual-that shape actors' identities and interests and the significance of their material contexts" (Wendt, 1995:81). Eventually, the importance of the material context was acknowledged in relation to the role of knowledge infrastructures (the Resilience Alliance, Beijer International Institute, Stockholm Resilience Centre...) in the circulation of the resilience idea. In fact while Holling's resilience idea has been initially focused on matters of radical change in relation to ecosystems dynamics, the politics around the epistemic authority that it acquired across disciplines and its influence on policies since its early days in Canada is at best reformist.

Chapter 9 demonstrated that the International Biological Program and Brian Walker in particular played a significant role in extending the applicability of the resilience concept in tropical ecosystems which included South Africa. The works deriving both from this organisation and individual ended up reinforcing some of the knowledge claims put forward in the dawn of the 1970s by Holling and his colleagues at IIASAs "Ecology Project" and in Canada. Even though this led to a supporting role by South Africa in the early development of resilience in the 1970s, by the 1990s and onwards the contribution of this country became overshadowed by the various arrangements through which Sweden took the lead in enhancing the circulation of the resilience concept and social-ecological research internationally. Also subsequent research programmes initiated in South Africa emphasise the country's geographical and societal specificities as a way to attract major international projects directly or indirectly related to Holling's inspired concept of resilience or climate change. As a result many projects dealing with resilience locally have been often criticised for their

politically conservative and economically reformist tendencies (Donk and Gaigien, 2014).

In short, the fusion of artefactual constructivism and social constructivism in Chapter 2 helped to shape the analysis in Chapter 8 and surface some of its implications in Chapter 9 because: "[B]uildings stabilise social life. They give structure to social institutions, durability to social networks, persistence to behaviour patterns. What we build solidifies society against time and its incessant forces for changes" (Gieryn, 2002:31). In fact whilst the production of knowledge in South Africa or about South Africa in relation to resilience and social-ecological ecosystems facilitated the universalisation of their (resilience and social-ecological ecosystems) reach and application in tropical ecosystems, the South African impact on the *politics of science* and the *science politics* resonating with a wider circulation of Holling's idea of resilience, especially since the 1990s, remains minimal. The *politics of science* and the *science politics* linked with the circulation of Holling's idea of resilience partly refers to the human dimension of "the reification of space within knowledge production" which in this thesis "implies that man is capable of forgetting his own authorship of the human world, and further, that the dialectic between man, the producer, and his products is lost to consciousness. The reified world is...experienced by man as a strange facticity, an *opus alienum* over which he has no control rather than as the *opus proprium* of his own productive activities" (Berger and Luckmann quoted in Wendt, 1995:410)". In relation to its non-human dimension, it underpins the agencies that the variety of spaces relevant in this thesis have in the universalising/legitimising processes of situated knowledge (Chapters 5, 7 & 8). Hence, neither the notional nor the material differences of space are often adequately addressed in planning practice or theory as observations on and from the city of Johannesburg could suggest (Harrison *et al,* 2014;Storie, 2014).

Moreover a significant strand of planning theorists adopted a fundamental principle of social constructivism which denies agency to anything other than a human. According to this principle, "people act towards objects, including other actors, on the basis of the meanings that the objects have for them' (Wendt, 1992:296-297). Such a view reflects only partly the task accomplished throughout the chapters of this thesis. It excluded a new materialist stand which according to Fox and Alldred (2015:399), "supplies a conception of agency not tied to human action, shifting the focus for social inquiry from an approach predicated upon humans and their bodies, examining instead how relational networks or assemblages of animate and inanimate affect are affected (Delanda, 2006p.4; Mulcahy, 2012, p.10; Youdell & Armstrong, 2011, p.145)." Such a non-human agency is crucial in understanding the roles that space played in the production of knowledge,Broadly, the relationships between knowledge and space in scientific practices have been an important topic in science studies' debates. Gieryn (2002:113) recalls that:

> All scientific knowledge claims have a provenance: they originate at some place, and come from there. However, as they become truth, these claims shed the contingent circumstances of their making, and so become transcendent (presumably true everywhere, supposedly from nowhere in particular). Turning the argument around: scientific claims are diminished in their credibility as they are situated somewhere, as if their truthfulness depended upon conditions located only there.

In this regard, the concept of resilience can be pliable to the different contexts in which resilience theory is being applied but it does not change the spatial disparities in knowledge, professional skills, and technology established prior its initial enactment in Canada. The influence of space is however not only restricted to the initiation of a theory or idea. Ideas or concepts continue evolve as they are geographically circulated. In the case of resilience the fairly generic spatial

category of "cities" brought a new influence to bear on the emerging idea of resilience from the late 1960s. This shifted resilience from ecological studies towards the social sciences, and allowed for the complex terrain of human action to be included within the concepts of resilience, even if the traces of an origin in the natural sciences remained.

From North America, the emergent idea of resilience travelled to Europe and elsewhere in the world, including South Africa. New spatial influences were brought to bear. In some cases, such as Sweden, the context within which the idea was received had an arguably important role in the translation of the idea, and actively reshaped the way in which the idea was used. In other cases, such as South Africa, local space was important to the way the idea was translated but there was less reverse influence on the way in which the concept was evolving internationally. In all cases, however, space is shown through this thesis to have a presence in the way in which knowledge is constructed and adapted. In this respect, Tuin and Dolphijn (2010:159) note that " [T]he strength of new materialism is precisely to be found in its ability to show that agential, or the *non-innocent* nature of all matter, seems to have escaped both modernist (positivist) and postmodernist humanist epistemologies." Indeed within a modernist (positivist) or a mere social constructivist view it is impossible to grasp the "pre-cognitive and embodied knowledges" which surfaced out of the assessment of the relationships between knowledge and space in this thesis. Below, Schultze and Boland (2000:1980) trace the origin of this problem in relation to the modernist view and Gieryn's statement above :

> Modernity, beginning with Enlightenment and industrialization, breaks away from the locality, tradition and cyclical time associated with place (Sack, 1992). It fosters a time-space configuration of space (Casey, 1993), an abstraction that divorces space from time through the "lifting" of social life above the here and now (Giddens, 1991), and the dissolution of ties that hold local practices in their place.

> Giddens (1990) refers to this as "time-space distanciation", which results in the homogenization of the social world.

Defined as such, this problem is arguarbly what Lefebvre (1991) means by the assertion "to produce space".Lefebvre (2009) has his research interests way beyond the enlightenment, albeit he notes that the production of space has only appeared, mainly, in the explosion of the "historical city", the general urbanization of society, the problem of spatial organization and so forth. "Today", he notes, the analysis of production suggests that we have moved from the production of things in space to the production of space itself (Lefebvre, 2009:186). Lefebvre argues that the passage from the production in space to production of space happened because of the growth of productive forces themselves and because of the direct intervention of knowledge in material production. He adds that this knowledge eventually becomes knowledge about space and information on the totality of space. Still, the production in space is never ground to a halt; rather, it tends to be channelled in a different direction. In fact information, technology, and cybernetics, in Lefebvre's words, "which is to say the quasi-instantaneous transmission of information and its almost punctual concentration into place, transform knowledge while covering space" (Lefebvre, 2009:200). In this respect, Beauregard (2015:59-60) adds that "[R]ecognized by planning theorists, the material world is then relegated to being merely context for or consequence of social action. Space and things passively await manipulation. In rational model approaches to practice, that world is relevant only because it is the object of planning expertise (Black1990)."

Nonetheless different manifestations of knowledge hold the potential to maintain or disrupt the existing variety of spaces. The extent to which novelty is allowed in the production of knowledge is likely to be in contention with given spaces (including their human and non human components) if it does not conform to their structural continuities and/or their incremental fashioning. As

such knowledge (re)production carries the hallmarks of the kinds of engagement we have with given spaces, and the kinds of society we design, live in, disrupt or maintain. Planning is an epitome of these kinds of engagement. But in most part of the world change within planning systems is incremental and planning practices are often reformist in character (Harrison et al, 2008).

According to Harrison et al (2008:3) " [A]s the demands of context change, as new development pressures emerge, and as existing planning systems increasingly appear to be out of step with reality, so adjustments are made which usually take the form of modifications to what has gone before." From this perspective, the possibility of radical change is confined to rare instances of cataclysmic change, after war, revolution, and to some extents in transition from socialism in Eastern Europe, China, Tanzania and Ethiopia, or transition from Apartheid in South Africa. So within planning, radical change appears almost *unthinkable*. That is to say that the (epistemic) culture (s) within planning "sets up an opposition between the thinkable and the unthinkable, between what is worthy subject and what is unmentionable, what is interesting *per se* and what is uninteresting *per se*" (Kenneth,1973:241). For example, while planners work with property maps, desktop computers or cellular telephones, the rule of human is unquestioned because these nonhuman things are almost absent from the way practice is theorized (Beauregard,2015:1). The same fate is reserved to the non-human agency of some spaces which are part of planning practices. Yet a consideration of the complexity of the roles of spaces in knowledge production as highlighted throughout the chapters of this thesis can assist planning theory in making the connections between theoretical knowledge and planning practice in the "real world".

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Appendix (A)

Erasmus, B.2015. *CAE and Prof. Brian Walker*. Interviewed by Serge Ntamack [email]. 9 & 21st December 2015.

On 9 December 2015 at 09:23, Serge Ntamack <1013755@students.wits.ac.za> wrote:

Dear Prof. Erasmus,

I am PhD student at the School of Architecture and Planning and my supervisor is Prof. Harrison. Below is the abstract of my dissertation:

In this thesis, elements of Crawford Stanley Holling's life history are put into perspective so as to provide a historical trajectory upon which the spaces imbued

in the various contexts hosting pivotal activities on the production and refinement of resilience idea are explored. These elements are also used as a point of departure from where the idea of resilience originates and circulates internationally and in the context of South African cities. Throughout this entire process, it is the very idea of space, the significance that some of its types (i.e. forest, laboratory or city) and features (i.e. institutional or material) hold together or not as a form relevance and influence over different stages of development of resilience idea (understood both as a historical event and a knowledge object) which are interrogated. In so doing, the role of human experience and knowledge infrastructures in the formation of scientific knowledge and promotion of global norms is highlighted.

In the course of my research, I came across the pioneering works of of Prof. Walker in systems ecology in South Africa and at Wits. But also the significance of its research in resilience theory and the introduction of resilience idea in South Africa. In this regard, the contribution of the CAE (or its early versions) in these developments is not negligible.

I would like to know if at some point in time the CAE (or more accurately some of its early versions) was involved in the International Biological Programme (1964-74)? Or if it has been collaborating with partner organizations in Canada while being under the leadership of Prof Walker? And my last question is in relation National Research Plan in South Africa. I noticed that you are one of the authors of this document. Could you please let me know

(according to you) who has been introducing the resilience idea in South Africa and to what extent C.S. Holling' works have been influential in the drafting of that document ?

I will appreciate any thoughts that you might want to share in relation to the questions that I asked.

Thank you.

Serge

On 21 December 2015 at 17:03, Barend
Erasmus <Barend.Erasmus@wits.ac.za> wrote:

Hi Serge
Thanks for your interest. It would be best to come and see for a chat, rather than me compiling a long email. Prof Walker was at Wits before I arrived here. The key person you need to talk to about Brian Walker, and CAE, is Prof Norman Owen-Smith.
More people you absolutely have to talk about resilience ideas coming to SA, are Prof Bob Scholes, and Prof Kevin Rogers, both at Wits, and then Harry Biggs, ex SANPARKS, but now retired. Resilience is entrenched as part of the adaptive management programme of SANPARKS, and Kevin Rogers and Harry Biggs was instrumental in getting that done, probably one of the only examples in the world.
More resilience practitioners in SA: Reinette (Oonsie) Biggs (Stellenbosch), Dr Belinda Reyers (Stockholm Resilience centre).
Come and chat,
Barend

Prof Barend Erasmus
Exxaro Chair in Global Change and Sustainability Research and
Director: Global Change and Sustainability Research Institute (GCSRI)
University of the Witwatersrand
On 21 December 2015 at 17:03, Barend
Erasmus <Barend.Erasmus@wits.ac.za> wrote:

Hi Serge

Thanks for your interest. It would be best to come and see for a chat, rather than me compiling a long email. Prof Walker was at Wits before I arrived here. The key person you need to talk to about Brian Walker, and CAE, is Prof Norman Owen-Smith.

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More resilience practitioners in SA: Reinette (Oonsie) Biggs (Stellenbosch), Dr Belinda Reyers (Stockholm Resilience centre).

Come and chat,

Barend

Prof Barend Erasmus
Exxaro Chair in Global Change and Sustainability Research and
Director: Global Change and Sustainability Research Institute (GCSRI)
University of the Witwatersrand
+27 11 717 6602 (office)

Turok, I. 2016. *Urban resilience and human agency in South Africa.* Interviewed by Serge Ntamack. [email]. 15 May 2015.

From: Serge Ntamack [mailto:1013755@students.wits.ac.za]

Sent: 15 May 2016 10:46 AM

To: Ivan Turok

Subject: "urban resilience" and human agency in South Africa

Dear Prof. Turok,

I am a PhD student at the School of Architecture and Planning and my supervisor is Prof. Harrison. In the course of my research. I came across your work on "urban resilience" in South Africa. Also my supervisor mentioned your name as a key agent in the introduction of the "urban resilience" concept in South Africa. Could you please tell me more about how you played such a role and what informed your own understanding of "resilience" at the moment when it happened?

Below is the abstract of my dissertation:

In this thesis, elements of Stanley Crawford Holling's life history are put into perspective so as to provide a historical trajectory upon which the spaces imbued in the various contexts hosting pivotal activities on the production and refinement of resilience idea are explored. These elements are also used as a point of departure from where the idea of resilience originates and circulates internationally and in the context of South African cities. Throughout this entire process, it is the very idea of space, the significance that some of its types (i.e. forest, laboratory or city) and features (i.e. institutional or material) hold together or not as a form relevance and influence over different stages of development of resilience idea (understood both as a historical event and a knowledge object) which are interrogated. In so doing, the role of human experience and knowledge infrastructures in the formation of scientific knowledge and promotion of global norms is highlighted.

Thank you.

Serge

Appendix (B)

On 15 May 2016 at 21:15, Ivan Turok <iturok@hsrc.ac.za> wrote:

Hi Serge

I came back to South Africa in April 2010 after living in the UK for many years. A month or two later I was invited to act as the lead author and coordinator of the 2011 State of SA Cities Report. I wanted to ensure that it was more coherent than the previous version so I began to think about a suitable theme that might link the different elements (economic, social, environmental, governance, financial etc) together. I had been reading the resilience literature out of curiosity and I realised that it was a potential 'umbrella' concept that could act as a unifying device. I wrote a 3 page proposal to the SA Cities Network to make the case for resilience as the overarching theme, and after some discussion and debate, they agreed. The rest is history. Resilience became the title of the report and various other researchers began to explore the concept. The National Research Foundation also sponsored a research programme which included resilient cities in as one of the key themes. I was successful in getting one of their grants, and wrote several papers on resilience from this, with my co-author Leanne Seeliger.

I attach the introductory chapter of the 2011 SOCR (which explains in very simple terms why resilience is a useful concept, and refers to some of the literature I had been reading) and a journal article I subsequently wrote based on the SOCR.

Kind regards

Ivan

Professor Ivan Turok

Executive Director

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Appendix (C)

Roberts, D. 2015. PECS Keynotes Speech/Dr.Roberts/Resilience Idea. Interviewed by Serge Ntamack [email] 9 December 2015.

From: Serge Ntamack [mailto:1013755@students.wits.ac.za]
Sent: Wednesday, December 09, 2015 11:31 AM
To: Debra Roberts
Subject: PECS 2015 Keynotes speech /Resilience idea

Dear Prof. Erasmus,
I am a PhD student at the School of Architecture and Planning at the University of Witwatersrand and my supervisor is Prof. Harrison. Below is the abstract of my dissertation:
In this thesis, elements of Stanley Crawford Holling's life history are put into perspective so as to provide a historical trajectory upon which the spaces imbued in the various contexts hosting pivotal activities on the production and refinement of resilience idea are explored. These elements are also used as a point of departure from where the idea of resilience originates and circulates internationally and in the context of South African cities. Throughout this entire process, it is the very idea of space, the significance that some of its types (i.e. forest, laboratory or city) and features (i.e. institutional or material) hold together or not as a form relevance and influence over different stages of development of resilience idea (understood both as a historical event and a knowledge object) which are interrogated. In so doing, the role of human experience and knowledge infrastructures in the formation of scientific knowledge and promotion of global norms is highlighted.
In the course of my research I had to engage with a glimpse of your works and their significance in the South African context. In order to further my

understanding on this subject, could you please let me the extent to which C.S. Holling' works or Resilience Alliance or The Stockholm Resilience Centre has been influential or not in the ways in which you have been articulating your own works in South Africa. In the same vein, could you please provides me a copy of your keynotes at PECS 2015 (Postcards from the edge: transitioning from blue sky to coal...)?

It will be very helpful for the development of my dissertation to have your views on the questions that I asked but also to read your PECS' keynote.

Thank you.
Serge

On 9 December 2015 at 16:27, Debra Roberts <Debra.Roberts@durban.gov.za> wrote:

Hi Serge – that makes more sense.
There is no written text for my presentation at the PECS conference – but I understand they have the videos of the keynotes up on the SRC website now if you want to listen to it you could download it from there. On the Holling issue – as a biologist I am of course aware of Holling's work and that of SRC – but neither of those have played a significant role in developing our understanding of resilience.
Best wishes
Debra

From: Serge Ntamack [mailto:1013755@students.wits.ac.za]
Sent: Wednesday, December 09, 2015 4:33 PM

To: Debra Roberts

Subject: Re: PECS 2015 Keynote speech /Dr. Roberts/Resilience idea

Thank you so much for your answer. Could you please let me know what played a significant role in your understanding of resilience?

Regards

Serge

On 9 December 2015 at 19:14, Debra Roberts <Debra.Roberts@durban.gov.za> wrote:

The recent work of Mark Pelling and Bill Solecki.

Best wishes Debra

Declaration

I declare that this dissertation is my own unaided work. It is being submitted for the Degree of Doctor of Philosophy in Town and Regional Planning to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

05th September, 2017.

