DOCTORAL THESIS FROM THE DEPARTMENT OF
EDUCATION

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Learning ecosystem complexity

A study on small-scale fishers' ecological knowledge generation

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To Jens and Benjamin.

Abstract

Small-scale fisheries are learning contexts of importance for generating, transferring, and updating ecological knowledge of natural environments through everyday work practices. The rich knowledge fishers have of local ecosystems is the result of the intimate relationship fishing communities have had with their natural environments across generations (see e.g. Urquhart and Acott 2013). This relationship develops strong emotional bonds to the physical and social place. For fishing communities and fishers – who depend directly on local ecosystems to maintain their livelihoods – fishing environments are natural places for living, working and defining themselves. Previous research on fishers' ecological knowledge has mainly been descriptive, i.e., has focused on aspects such as reproduction, nutrition and spatial-temporal distribution and population dynamics, from a traditional view of knowledge that only recognises scientific knowledge as the true knowledge. By doing this, fishers' ecological knowledge has been investigated separately from the learning contexts in which it is generated, ignoring the influence of social, cultural and historical aspects that characterise fishing communities, and the complex relationships between fishers and the natural environments they live and work in. This thesis investigates ecological knowledge among small-scale fishers living and working in the ecosystems of Lake Vättern and the Blekinge Archipelago (Baltic Sea) in Sweden and explores how ecological knowledge is generated with particular regard to the influences of work and nature on fishers' knowledge of ecosystems. The aim of this thesis is to contribute to the knowledge and understanding of informal learning processes of ecosystem complexity among small-scale fishers. This knowledge further contributes to the research field of ecological knowledge and sustainable use and management of natural resources. It addresses the particular research questions of what ecological knowledge fishers generate, and how its generation is influenced by their fishing work practices and relationships to nature.

The thesis consists of three articles. Article I focuses on the need to address the significant lack of theoretical and methodological frameworks for the investigation of the cognitive aspects involved in the generation of ecological knowledge. Article II deals with the need to develop theoretical, methodological and empirical frameworks that avoid romanticising and

idealising users' ecological knowledge in *local* (LEK), *indigenous* (IEK) and *traditional* (TEK) ecological knowledge research, by rethinking it as being generated through work practices. Article III addresses the lack of studies that explicitly explore theories linking complex relations and knowledge that humans form within and of ecosystems. It also addressed the lack of attention from environmental education researchers to theory and empirical studies of 'sense of place' research, with a particular focus on environmental learning. Research into the question of what ecological knowledge fishers generate shows differences in their ways of knowing ecosystem complexity. These differences are explained in terms of the influences of the species being fished, and the sociocultural contexts distinguishing fishers' connection to the fishing profession (i.e., familial tradition or entrepreneurship) (Article I), but also by the fishing strategies used (Article II). Results answering the research question of how work practices influence fishers' knowledge of ecosystem complexity show a way of rethinking their ecological knowledge as generated in a continuous process of work (Article II), thus, far from romantic views of knowledge. Results answering the research question of how fishers' relationships to nature influence their knowledge of ecosystem complexity demonstrate the complex interconnections between psychological processes such as identity construction, proximity maintenance and attachment to natural environments (Article III). Finally, more similarities than differences between fishers' knowledge were found, despite the variation in cases chosen, with regards to landscape, target species, regulations systems and management strategies, fishing environments scales, as well as cultural and social contexts.

Keywords: *small-scale fishers, informal learning, knowledge generation, systems thinking, ecological knowledge, ecosystem complexity, work practices, emotional bonds to place, sustainable fisheries management, environmental learning, Vättern, Blekinge, Baltic Sea.*

Abstrakt

Småskaligt fiske är ett lärandesammanhang som har betydelse för generering, överföring och uppdatering av ekologisk kunskap om naturliga miljöer genom dagliga arbetsrutiner. De rika kunskaper som yrkesfiskare har om lokala ekosystem är ett resultat av den intima relationen fiskesamhällen har haft med sina naturliga miljöer mellan generationer (se till ex. Urquhart och Acott 2013). Detta förhållande utvecklar starka känslomässiga anknytningar till den fysiska och sociala platsen. För fiskesamhällen och yrkesfiskarna - som är direkt beroende av lokala ekosystem för sin försörjning - fiskemiljöer är naturliga platser för att leva, arbeta och definiera sig själva. Tidigare forskning på yrkesfiskarnas ekologiska kunskap har främst varit beskrivande, dvs. har fokuserat på aspekter av fiskarter såsom reproduktion, nutrition och fysisk-tidsmässig utbredning och populationsdynamik, från en traditionell syn på kunskap som endast erkänner den vetenskapliga kunskap som den sanna kunskapen. Genom att göra detta har yrkesfiskares ekologiska kunskap undersökts separat från lärandemiljöer där den genereras, vilket ignorerar inverkan av sociala, kulturella och historiska aspekter som kännetecknar fiskesamhällena, och de komplexa sambanden mellan yrkesfiskarna och de naturmiljöer de lever och arbeta i. Denna avhandling undersöker ekologiska kunskaper bland småskaliga yrkesfiskare som lever och arbetar i ekosystem Vättern och Blekinge skärgård (Östersjön) i Sverige och undersöker hur dessa ekologiska kunskaper genereras med särskild hänsyn till påverkan av arbete och natur på yrkesfiskares kunskaper om ekosystem. Syftet med denna avhandling är att bidra till kunskap och förståelse av informella lärandeprocesser av komplexitet i ekosystem bland småskaliga yrkesfiskare. Denna kunskap bidrar ytterligare till forskningsområdet om ekologisk kunskap och hållbar användning och förvaltning av naturresurser. Den undersöker särskilda frågeställningar om vad för ekologisk kunskap yrkesfiskare genererar, och hur det påverkas av deras fiskemetoder, deras arbete och relation till naturen.

Avhandlingen består av tre artiklar. Artikel I fokuserar på behovet av att ta itu med betydande brist på teoretiska och metodologiska ramar för forskning av de kognitiva aspekterna på generering av ekologisk kunskap. Artikel II behandlar behovet av att utveckla teoretiska, metodologiska och empiriska ramar som undviker att romantisera och idealisera användarnas ekologiska kunskaper i lokal (LEK), inhemsk (IEK) och traditionell (TEK) ekologisk

kunskapsforskning, genom att tänka på den som en kunskap som genereras genom arbetsrutiner eller praxis. Artikel III tilltalar bristen på studier som uttryckligen utforskar teorier som förbinder komplexa relationer och kunskap som människor bildar inom och av ekosystemen. Den riktar också sig till bristen på uppmärksamhet från miljöutbildningsforskare för teori och empiriska studier om "platsanknytning", med särskilt fokus på miljölärande. Forskning kring frågan om vilken ekologisk kunskap yrkesfiskare genererar visar skillnader i deras sätt att förstå komplexitet i ekosystem. Dessa skillnader förklaras genom att visa påverkan av de arterna som fiskas och hur sociokulturella sammanhang skiljer yrkesfiskarnas anknytning till fiskeyrket (dvs. familjär tradition eller entreprenörskap) (Artikel I), men också av fiskestrategier som används (Artikel II). Resultatet som besvarar frågeställningen om hur arbetsmetoder påverkar yrkesfiskarnas kunskaper om komplexitet i ekosystem visar ett sätt att se på deras ekologiska kunskap som genereras i en kontinuerlig process av arbete (Artikel II), alltså långt ifrån romantiska vyer av kunskap. Resultatet som besvarar frågeställningen om hur fiskarnas relationer till naturen påverkar deras kunskaper om komplexitet i ekosystem visar de komplexa sambanden mellan psykologiska processer såsom identitetsskapande, kvarhållande av närhet och anslutning till naturmiljöer (Artikel III). Slutligen hittas fler likheter än skillnader mellan yrkesfiskarnas kunskaper trots variationen i valda fall angående landskap, fiskarter, föreskrifter, system och förvaltningsstrategier, samt kulturella och sociala sammanhang.

Nyckelord: *småskaliga yrkesfiskare, informellt lärande, generande av kunskap, systemtänkande, ekologisk kunskap, komplexitet i ekosystem, arbetsmetoder, känslomässiga band till plats, hållbar fiskeriförvaltning, miljölärande, Vättern, Blekinge, Östersjön.*

List of articles

This thesis is based on the following articles, which are listed below in chronological order. Articles referred to by Roman numerals I, II and III are reproduced with the kind permission of the copyright holders.

I. Garavito-Bermúdez, D., Lundholm, C. and Crona, B. (2016). Linking a conceptual framework on systems thinking with experiential knowledge. *Environmental Education Research* 22 (1): 89-110. doi:10.1080/13504622.2014.936307

II. Garavito-Bermúdez, D. and Boonstra, W. (submitted). Knowing by fishing: Conceptualising ecological knowledge as working knowledge. *SAGE Open Special Issue: Traditional Wisdom*.

III. Garavito-Bermúdez, D. and Lundholm, C. (2016). Exploring interconnections between local ecological knowledge, professional identity and sense of place among Swedish fishers. *Environmental Education Research*. doi:10.1080/13504622.2016.1146662

My contribution to the articles included in this thesis:

Conceptualisation and active co-development of the research idea; co-designing of interview questions; collector of data; developer of the Structure-Dynamic-Function and the Person-Psychological Process-Place analytical tools; responsible for data processing, i.e., interview transcriptions and analysis; main writer and responsible for submissions.

Contents

Introduction.....	15
Aim of the thesis.....	19
Previous research.....	20
Environmental education.....	20
Cognition and learning of complex systems.....	21
Workplace learning.....	22
Human-nature relationships.....	24
Theoretical and analytical approaches.....	26
Learning.....	26
Dialectical constructivism.....	27
Structure-Dynamic-Function framework.....	30
Fishing Styles Analysis.....	31
Person-Psychological Process-Place: a tripartite organising framework.....	32
Methodology.....	34
Case studies.....	34
Research design.....	36
Data collection.....	37
Data analysis.....	39
Ethical considerations.....	40
Theoretical aspects.....	40
Methodological aspects.....	41
Political aspects.....	42
The two studied cases.....	43
Fishery contexts in Sweden.....	43
Case I: The freshwater ecosystem - Lake Vättern.....	44
Participants.....	45
Case II: The marine ecosystem - Blekinge Archipelago (Baltic Sea).....	48
Participants.....	49
Summary of results.....	52

Article I.....	52
Linking a conceptual framework on systems thinking with experiential knowledge	
Article II.....	53
Knowing by fishing: Conceptualising ecological knowledge as working knowledge	
Article III.....	54
Exploring interconnections between local ecological knowledge, professional identity and sense of place among Swedish fishers	
Concluding remarks.....	55
Discussion.....	59
Results in relation to previous research.....	61
Implications of results for research and practice.....	62
Future research.....	62
Acknowledgments.....	64
Tack.....	66
Agradecimientos.....	68
References.....	70

Abbreviations

CEDEFOP	European Centre for the Development of Vocational Training
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FSA	Fishing Styles Analysis
GPS	Global Positioning System
IEK	Indigenous Ecological Knowledge
LEK	Local Ecological Knowledge
NGO	Non-Governmental Organization
OECD	Organisation for Economic Co-operation and Development
PPP	Person-Psychological Process-Place
SBF	Structure-Behaviour-Function
SDF	Structure-Dynamic-Function
TEK	Traditional Ecological Knowledge
WHO	World Health Organization

Introduction

This thesis concerns the investigation of ecological knowledge among small-scale fishers. It specifically addresses the ecological knowledge fishers generate, and the influence of their work practices and relationship with nature on the generation of this knowledge.

Small-scale fisheries constitute informal learning contexts characterised by everyday learning through work practices. The type of small-scale fishing that is investigated in this thesis is defined as small-scale and high-tech according to FAO's categorisation (2016), which is performed in boats (of between 6 to 12 metres in length, with capacity for 2 to 5 people) equipped with a GPS, an inboard diesel motor, a radio and sometimes sonar. According to FAO (ibid), small-scale fisheries often come into conflict with industrial or large-scale fisheries. The pros of small-scale fisheries in comparison with large-scale fisheries are: lower running costs and fuel consumption, lower ecological impact, higher employment opportunities, higher versatility, lower construction costs, and less expensive technology (ibid). Moreover, small-scale fisheries represent learning contexts of importance for generating, transferring and updating knowledge of natural environments, in line with the sustainability and sustainable development goals highlighted by Reid et al. (2004). These goals are: lifelong learning, long-term sustainability of local environments, poverty reduction and community-resource management, and they constitute the base of global development and sustainability (World Bank, 2007).

Fishers' knowledge of ecosystems concerns their understanding of the complexity of interactions between ecosystems' biotic and abiotic components. Ecosystems are defined as "biological systems composed of all the organisms found in a particular physical environment, interacting with it and with each other" (Oxford English Dictionary, 2010). Hence, complexity in ecosystems can be explained as networks of feeding ("trophic") interactions among species, which co-occur within a particular habitat (Dunne 2009). This place-based knowledge is a component of the intellectual and cultural property of many fishing communities, and has been closely related to everyday work practices in the literature (e.g., Neis, 1992; Pálsson, 1995; Pálsson, 1998; Neis et al., 1999; Stanley & Rice, 2003; Crona, 2006; Lauer & Aswani, 2009; Hind, 2012; Boonstra & Hentati-

Sundberg, 2014). The rich knowledge of natural resources held by fishers is the result of the intimate relationship between fishing communities and their local natural environments (e.g., Davis & Ruddle, 2010). This intimate relationship creates strong emotional bonds across generations (e.g., Urquhart & Acott, 2013), which influence local traditions and lifestyles, and bring important elements for identity construction (see Scannell & Gifford, 2010; Proshansky et al., 1983; Twigger-Ross & Uzzell, 1996). For these fishing communities and fishers – who depend directly on local ecosystems to maintain their livelihoods – fishing environments represent natural places for living, working and defining themselves.

Research on environmental education focusing on ecological knowledge held by local users is limited to a few examples (i.e., Reid et al., 2002, 2004), as is research in the cognitive and learning sciences regarding people's understanding of natural complex systems (e.g., Salner, 1986; Sterman, 1997; Goldstone & Sakamoto, 2003; Ben-Zvi-Assaraf et al., 2005; Magntorn et al., 2007; Booth-Sweeney & Sterman, 2007), and in particular on ecosystems' complexity (e.g., Hmelo et al., 2000; Hmelo-Silver et al., 2004; Hmelo-Silver et al., 2008). Research on workplace learning and the human-nature relationship concerning informal learning in contexts of natural resource management is non-existent.

During the last three decades, mostly scholars and practitioners from outside the educational research field have investigated fishers' ecological knowledge. These researchers and practitioners have made important efforts and progress, particularly those working with *local ecological knowledge* (LEK), *indigenous ecological knowledge* (IEK) and *traditional ecological knowledge* (TEK). These 'etiquettes', commonly used in the research literature, refer to the ecological knowledge held by different users or holders; for instance, the terms *indigenous* and *traditional* often denote aboriginal and indigenous peoples, and *local* is sometimes used for fishing people. However, these distinctions are not clear in the research literature and, thus, etiquettes are avoided in this thesis, because there are difficulties in differentiating between what kind of knowledge is local, indigenous or/and traditional. For this reason, this thesis refers to users' or fishers' *ecological knowledge*.

Previous research on fishers' ecological knowledge has mainly focused on the description of target species, ecological aspects, and population dynamics (e.g., Poizat & Baran, 1997; Neis et al., 1999; Calheiros et al., 2000; Davies et al., 2004; Hamilton et al., 2005; Silvano & Valbo-Jørgensen, 2008). It has also been characterised by a traditional view of knowledge that only recognises scientific knowledge as the true knowledge (with important exceptions, e.g., García-Allut, 1999; Olsson & Folke, 2001; Crona, 2006;

Berkes, 2009; Lauer & Aswani, 2009; Briggs, 2013). Consequently, fishers' ecological knowledge has been studied as knowledge that contrasts with scientific knowledge, which means that fishers' ecological knowledge has been seen as somehow non-scientific. Moreover, it has been investigated separately from the learning contexts in which it is generated through work practices, thus ignoring the influence of social, cultural and historical aspects that characterise fishing communities, and the complex relationships between fishers and the natural environments in which they live and work.

This sort of approach, commonly used in LEK, IEK and TEK research (particularly on fishers' ecological knowledge), needs to be reconsidered in order to approach the multiple dimensions affecting the generation and use of ecological knowledge. This implies important challenges that concern, firstly, the need to address the significant lack of theoretical and methodological frameworks for the investigation of the cognitive aspects involved in the generation of ecological knowledge (with a few exceptions, e.g., Hmelo-Silver, 2008). Secondly, the need to develop theoretical, methodological and empirical frameworks that avoid romanticising and idealising users' ecological knowledge (see Briggs, 2013, for an overview), and which view knowledge as private, mysterious and ungraspable. A neo-Romantic paradigm – which also has characterised TEK-based approaches in environmental education – presents TEK (or users'/holders' knowledge) as a supposedly ideal relationship between humans and the world. Thirdly, the challenge of linking theory on human-nature relationships and knowledge generation. Currently, there is a lack of studies that explicitly explore theories linking the complex relations and knowledge that humans form within and of ecosystems (e.g., Urquhart & Acott 2013). In particular, there is a lack of attention from environmental education researchers (with a few exceptions, e.g., Ardoin et al., 2012) to theory and empirical studies on sense of place (Kudryavtsev et al., 2012), with a specific focus on the significance of sense of place in environmental learning (see Thomashow, 2002; Mueller Worster & Abrams 2005; Morehouse, 2008; Ardoin et al., 2012).

Working with these challenges in this thesis required the incorporation of different perspectives such as pedagogy, psychology, sociology, human geography, ethnography and ecology – making this thesis an interdisciplinary piece of work. These disciplines bring important theoretical, methodological and empirical tools for the investigation of life conditions, as well as the emotional and professional aspects connected to fishers' knowledge of local natural environments. For understanding and exploring the generation of small-scale fishers' knowledge of ecological complexity, a dialectical constructivist approach was chosen as the theoretical base. Dialectical constructivism principles not only provide validity to co-existent forms of knowing (see Jovchelovitch, 2007), but they

also support the idea that fishers' ecological knowledge is generated through their experience in situations (Schunk, 2004). In this sense, their knowledge is the result of the interactions between them and the sociocultural and natural environments in which they live and work.

This thesis consists of three articles that address the challenges listed above, and makes a unique contribution to the understanding of learning about ecosystem complexity by using a dialectical constructivist perspective (Moshman, 1982). Supporting the idea that thinking takes place in contexts, and that individuals' knowledge is generated through their experiences in situations (Schunk, 2004), this thesis also contributes to the understanding of informal learning in the context of natural resource management. In so doing, it develops analytical frameworks and theories for the investigation of ways of knowing ecosystems by local users/holders; it also conceptualises users' ecological knowledge as knowledge generated in work practices and further develops analytical frameworks for the investigation of 'sense of place' in environmental learning research.

Aim of the thesis

The aim of this thesis is to contribute to the knowledge and understanding of informal learning processes of ecosystem complexity among small-scale fishers. This knowledge will further contribute to the research field of ecological knowledge and sustainable use and management of natural resources. More specifically, the thesis focuses on the following research questions:

- What ecological knowledge do professional small-scale fishers generate?
- How is the generation of ecological knowledge among professional fishers influenced by their fishing work practices?
- How is the generation of ecological knowledge among professional fishers influenced by their relationship to nature?

Previous research

This section presents an overview of the previous research on environmental education, as well as of research in the cognitive and learning sciences, and of workplace learning and the human-nature relationships. These are research fields of relevance for addressing the questions of what kind of ecological knowledge do fishers generate, and how it is affected by their work practices and natural environment.

Environmental Education

Research on environmental education, focusing specifically on ecological knowledge held by local users, is limited to a few examples such as Reid et al. (2002, 2004; see also Reid & Scott, 2013). These scholars discuss the value of *traditional ecological knowledge* (TEK) in environmental education, and examine the epistemological and philosophical difficulties of employing TEK in contexts of informal learning about sustainability. This knowledge has been described as a mixture of knowledge, practices and beliefs concerning natural environments (Reid et al., 2002) such as, for example, the migratory patterns of a species of bird, fish or land animal. Traditional ecological knowledge is a practice-oriented knowledge that invokes religious, spiritual and cultural values and relationships to nature (ibid). According to these scholars, these difficulties relate first to the concept of TEK; secondly, to the neo-Romantic paradigm by which TEK-based approaches are tackled in ecosystem management and ecological relationships; and thirdly, to tensions when conceptualising TEK as a body of knowledge in resource management (see also McFarlane, 2006; Ruddle & Davis, 2010; and Briggs, 2013) and environmental education.

In line with these difficulties, Reid et al. (2002, p. 115) affirmed that the concept of TEK is far from settled and is used interchangeably with, for instance, indigenous ecological knowledge (IEK), local environmental knowledge, first people's knowledge, and non-Western indigenous knowledge. This is probably because indigenous and local environment knowledge refers to systems of knowledge based on traditional and cultural practices and spiritual beliefs. Not surprisingly, conceptualisations of indigenous knowledge are controversial and disputed among many social

scientists, who consider that the use of the term *indigenous* conceals inequalities and a neo-colonialist view on knowledge (Lauer & Aswani, 2009).

In parallel, the use of TEK tends to be juxtaposed with scientific knowledge. In this sense, the variety of usages and definitions of TEK, or whether it be the users/holders' ecological knowledge (i.e., hunter-fisher-gatherer communities) is problematic when it is integrated into sustainable resource management and common property resources. Authority and power relationships supporting or contesting the validity of the ecological knowledge held by local communities are still prevalent through global environmental discourses and environmental education (through literacy practices).

A neo-Romantic paradigm in TEK-based approaches in environmental education, presents TEK as a supposedly ideal relationship between humans and the world. Importantly, from both a research and practice point of view, this knowledge paradigm influences the different ways of conceptualising traditional knowledge "*as private, mysterious or ungraspable (...) being removed from the scrutiny of public debate and analysis about its role in environmental education and resource management*" (Reid et al., 2004, p. 251).

Cognition and learning of complex systems

"*Complex systems are commonly found in natural and physical sciences*" (Hmelo et al., 2000, p. 247), and there is an increasing interest in researching cognition and learning about natural complex systems, such as the respiratory system, Earth system and ecosystems, in the last twenty years (e.g., Salner, 1986; Sterman, 1997; Goldstone & Sakamoto, 2003; Hmelo et al., 2000, 2004, 2008; Ben-Zvi-Assaraf et al., 2005; Magntorn et al., 2007; Booth-Sweeney & Sterman, 2007).

As a result of the interest in learning about the complexity of ecological and biological systems, Hmelo et al. (ibid) developed the *Structure-Behavior-Function* (SBF) model based on Goel and Chandrasekaran's theory (1989). The SBF model provides a vocabulary for reasoning about and describing systems. The model also draws attention to the structures, behaviours and functions of systems, and interactions between these components, and is a way of looking at and conceptualising system understanding in artificial intelligence research. In the SBF model, *Structure* refers to the physical structures of a system; *Behavior* refers to the dynamic mechanisms (that cause changes in the structural state of the system) and workings that allow

the structures to carry out their function; and *Function* refers to the overall purpose of the system or subsystem. Hmelo et al. (ibid) found that the main difficulty researchers face when analysing systems is behaviour. This difficulty relates to the fact that the behaviour of systems can be difficult to see and is dependent on causal processes (some action causes a state, which enables further action). Consequently, these scholars highlighted invisibility and (time-delayed) causality as cognitive challenges for learning about complex natural systems. Systems thinking has been suggested as a way of approaching the understanding of systems that focuses on recognising the interconnections between parts of a system, and synthesising them into a unified view of the whole (Senge, 1990). Further research on learning about complex systems (Hmelo-Silver et al., 2008) recognised scientific literacy as an essential component for systems thinking, and the importance of foster systems thinking for sustainability (e.g., Habron & Goralnik, 2012). Systems thinking has also been used as a method in processes of natural resource co-management (e.g., Bosch et al., 2007).

Scientific literacy (National Science Education Standards, 1995) is defined as “*the knowledge and understanding of specific concepts and processes required for personal decision-making*” (p. 20). Such literacy, particularly that relating to ecological systems, has been studied by other scholars such as Puk and Stibbards (2011) and educators, e.g., Booth-Sweeney (2012), who discuss the development of systems understanding in relation to meaning-making processes. In this thesis, scientific literacy is considered relevant to the development of system thinking among professional fishers, as all the fishers that participated in this research have completed at least upper secondary school (see Table 2).

In this thesis, the use of the SBF model proposed by Hmelo et al. (2000) became difficult in analysing what kind of ecological knowledge fishers were generating. Difficulties were related to the application of the concepts of *Structure*, *Behavior* and *Function* in relation to the complexity of real ecosystems. These difficulties and the development of this model for analytical purposes are presented in the next section.

The significance of work practices in the generation of ecological knowledge held by local users will now be described.

Workplace learning

“*The recognition that learning occurs within the world and that it is necessary for the development of working knowledge and skills is not new*” (Lee et al., 2004, p. 2). Workplace learning has generated an increasing

interest in learning and how it can be facilitated in workplaces among researchers, policymakers and employers. Research on workplace learning has gone through two developmental trends according to Illeris (2008); the first trend concerns education and qualifications, as these were recognised as necessary for the development of vocational competences among adults. They can be understood as a way of preparing individuals for constant changes in their professional lives. The second trend emerged through the recognition of the need to update, develop, recreate and reorganise professional qualifications (i.e., to improve knowledge, skills and attitudes). It refers particularly to the adaptation of schools and educational programmes to changing work situations and contexts. Furthermore, in parallel with the focus given to adult education, research on workplace learning has focused on adult learning in working contexts. In line with this, lifelong learning is based on two principles according to Ellström and colleagues (1996): 1. individual learning is not completed in adolescence but continues throughout life, and 2. learning does not only occur in contexts of formal education but also in workplaces and in everyday life (i.e., ‘informal’ or ‘everyday’ learning). It may be conscious, planned and designed through different forms of experiential learning situation, participation in networks, coaching, consultation and mentorship (Ellström et al., 1996). However, research on workplace learning and lifelong learning concerning environmental learning (referring to the knowledge, skills and attitudes advancing global environmental change) in contexts of resource management is almost non-existent.

However, research on environmental knowledge has discussed the role of experiential knowledge among adults for environmental conservation. Fazey et al. (2006) have highlighted the existence of two forms of experiential knowledge, i.e., “expert” and “non-expert”. To these scholars, increasing experience directly influences individuals’ ability to notice, organise, present and interpret information. Expert knowledge thus exhibits a deep understanding that is developed through extensive experience. In this thesis, the notion of *reflection-in-action* suggested by Schön (1987) is of relevance for learning about ecosystem complexity among small-scale fishers, particularly regarding the updating of knowledge. Reflection-in-action refers to personal reflection on one’s own work practices, and those of others, that confers a professionalism and status on the ecological knowledge held by local users/holders that is far from notions of beliefs, stories and subjective perception that has particularly characterised indigenous ecological knowledge research (Briggs, 2013). Briggs (2013) also criticises the idealised and romanticised notions of ecological knowledge, and points out their partial and inaccurate character (see also Johannes, 2003).

A professional status is important for the discussion of how ecological knowledge is generated among users/holders of natural resources, and how it is transferred and updated through work practices. Giving this knowledge a professional status provides a paradigm for its integration into natural resources management and sustainability practices, which is, however, still rare and can be extended to other groups of ‘professional’ or ‘expert’ users (Davis & Wagner, 2003) such as hunters, woodmen/women, farmers, hunters and reindeer herders or indigenous communities that have nature as their workplace. This professional approach to users’/holders’ ecological knowledge assumes learning to be a continuous process (Lundholm & Plummer, 2010) of interaction between individuals and their social communities of practices, which in turn presumes active, intentional, interactional engagement in experience and thinking (Cairns & Malloch, 2008). Olsson and Folke (2001) offer the example of integrating adults’ learning in local ecological knowledge research. These scholars found that “*ecological knowledge is mainly generated and reshaped through a combination of scientific information, local monitoring, imitation, and practices of governmental authorities*” (p. 91). Thus, this thesis investigates fishers’ ecological knowledge by assuming that it is a combination of different ways of knowing (see Jovchelovitch, 2007) in terms of scientific or declarative knowledge derived from literacy (i.e., from formal education), and non-scientific or procedural (tacit) knowledge derived from experience (i.e., from work practices) (Anderson, 1989). Declarative knowledge refers to knowing facts and concepts, and procedural knowledge to knowing how to do things (ibid).

Human-nature relationships

According to Reid et al. (2004), “*the core concepts of much environmental discourses focus on the human-nature relation, nature preservation and variants of holism, together with an emphasis on appropriate human lifestyles*” (p. 252). In line with these foci, the complex relations between humans and nature – meaning-making and bonding to a place or natural resources – have been the subject of investigation in several disciplines such as ethnography, human ecology, demography, sociology, and environmental psychology (e.g., Moeller & Engelken, 1972; Proshansky et al., 1983; Bonaiuto et al., 1996; Twigger-Ross & Uzzell, 1996; Williams & Stewart, 1998; Davenport & Anderson, 2005; Jorgensen & Stedman, 2006; Morgan, 2010; Scannell & Gifford, 2010; Raymond et al., 2010). However, there is a lack of studies that explicitly explore theories linking the complex relationships, learning and knowledge that humans form in and of ecosystems (e.g., Urquhart & Acott, 2013). In parallel to this, environmental education research has recognised the importance of sense of place in

environmental learning (see Thomashow, 2002; Mueller Worster & Abrams, 2005; Morehouse, 2008; Ardoin et al., 2012), as well as a lack of attention from environmental education researchers (with a few exceptions, e.g., Ardoin et al., 2012) to theory and empirical studies on sense of place (Kudryavtsev et al., 2012).

In the next section, the theoretical point of departure and analytical frameworks for analysing how small-scale fishers learn about ecosystem complexity are presented.

Theoretical point of departure

The aim of this thesis is to contribute to the knowledge and understanding about the informal learning processes of ecosystem complexity among small-scale fishers. In this section, the relevant approaches to learning and definitions of learning are presented. Additionally, this section presents the theoretical basis and methodological frameworks for the analysis of cognition, as well as the professional aspects and life conditions influencing fishers' knowledge of their natural environments.

In this thesis, learning is viewed from a dialectical constructivist perspective. Different dimensions involved in learning situations – such as knowledge, emotions and communication – the interrelations between them, and their significance for the generation of ecological knowledge are addressed. Dialectical constructivism focuses on the complex and changing relationships between individual cognitive development and the dynamic world.

The Structure-Dynamic-Function framework, the Fishing Styles Analysis framework and the Person-Psychological Process-Place framework are used methodologically for the analysis of data. These three frameworks provide the theoretical, methodological and empirical elements of importance for answering the research questions of what kind of ecological knowledge fishers generate, as well as how their ecological knowledge is generated and influenced by their work practices and natural environment, respectively.

Learning

Different forms of learning are distinguished by the European Centre for the Development of Vocational Training (CEDEFOP), i.e., formal, informal and non-formal learning. According to CEDEFOP (2008), formal learning occurs in an organised and structured environment, which means it is explicitly designed as learning in terms of objectives, time and resources. It also leads to validation and certification, and is intentional from the learner's perspective. Contrary to this, informal learning is considered to be the results from daily activities related to work, family and leisure. It is not organised or

structured (in terms of objectives, time and learning support), and is often unintentional from the learner's perspective. Non-formal learning involves planned activities that are not explicitly designed (in terms of objects, time and support), and is intentional from the learner's perspective.

In line with this, definitions of learning vary substantially between disciplines, in various fields and even within fields (see Barron et al., 2015). In educational research, learning can be seen as the interaction between an individual's mind and a socially constructed world. In this sense, Cairns and Malloch (2008) see learning as "*an outcome of an interactional engagement in experience and thinking*" (p. 9). Illeris (2008) acknowledges that learning includes two types of processes: "*an external interaction process between individual and his/her social, cultural and material environment, and an internal psychological process of elaboration and acquisition of new impulses that connect with the results of prior learning*" (p. 35). Modern brain research (see Furth, 1987, and Damasio, 1994) offers evidence for the important connection between cognition, emotions and motivation in acquisition process. Therefore, Illeris (ibid) suggests that all learning situations involve three dimensions:

1. The dimension of knowledge, understanding, skills, abilities, and attitudes.
2. The dimension of emotions, feelings, motivations, and volition.
3. The social dimension of interaction, communication and cooperation.

These three dimensions are emphasised in this thesis, in line with its aim of contributing to knowledge and understanding of informal learning processes, in relation to work practices and fishing places.

In this thesis, learning is – in line with Illeris (ibid) – defined as the process of generating knowledge and understanding of ecosystem complexity. In this, both emotional and social dimensions are important aspects for small-scale fishers to learn about ecosystem complexity. Additionally, learning is the foundation of knowledge transference – through apprenticeship from older to younger fishers – and updating through professional reflection and testing hypotheses.

Dialectical constructivism

Taking into account the above dimensions according to Illeris (ibid), the investigation of the generation of ecological knowledge among professional

fishers is approached through a constructivist perspective (Bruning et al., 1999; Simpson, 2002), in particular the dialectical constructivism paradigm.

Among many definitions of constructivism and the variety of approaches to it (see Harris & Graham, 1994), Moshman (1982) offers a classification of constructivism into three paradigms: exogenous, endogenous and dialectical constructivism. According to Moshman (ibid), exogenous constructivism assumes that knowledge is derived from individuals' external environment and, thus, knowledge generation is fundamentally a re-construction of structures, such as information and behaviour patterns, that are pre-formed in external reality (see Bandura, 1977). This paradigm remains connected to a behaviouristic view of learning and teaching (ibid). By contrast, endogenous constructivism places an internal emphasis on the construction of new knowledge from existent knowledge by individuals, rather than the environment (ibid) based on Piaget's theorisation of cognitive development (see Piaget, 1970, 1977). In this sense, individuals' adaptation to their environment is a 'by-product' of their intrinsic organisation. In between the exogenous and endogenous paradigms stands dialectical constructivism, which considers the complex and changing relationships between individual development and the dynamic world. In this manner, the dialectical paradigm emphasises the principle that the source of all knowledge lies in the continuing interactions between individuals and their environment (Moshman, 1982).

The dialectical paradigm is useful for the investigation of knowledge, knowledge generation and knowledge use for three reasons:

1. It supports the idea that thinking takes place in contexts, and that individuals' knowledge is generated through their experiences in situations (Schunk, 2004).
2. It takes into account sociocultural interactions between individuals and their environments and the activities in which they are engaged and the institutions of which they are a part.
3. It embraces the assumption that knowledge is the result of accumulative knowing that is socially validated – which is an argument that highlights the social nature of knowledge construction that characterises all knowledge – and that different forms or ways of *knowing* (i.e., scientific and experiential) co-existence in human cognitive development at the individual and collective level (see Jovchelovitch, 2007).

In this way, dialectical constructivism provides validity for different ways of knowing, contrary to other perspectives that presume misconceptions or

misunderstandings when individuals' forms of knowing differ from scientific explanations. This view of the knowledge held by fishers harmonises with the theoretical fundamentals for the analysis of small-scale fishers' ecological knowledge. From this perspective, the influences of nature and work practices on fishers' knowledge of ecosystems become central aspects of investigation (Fig. 1).

The view of Schunk (2004) on knowledge and knowledge generation is of particular importance in this thesis in relation to learning, which he defines as the process of generating knowledge and understanding of ecosystem complexity. This thesis pays attention to two important elements in its investigation of fishers' knowledge of their natural environments; first, that knowledge is generated at the individual level in fishers' minds and within particular fishing contexts, and secondly, that this knowledge is generated through fishers' experiences of work and nature.

Figure 1. Aspects of investigation.

Figure 1 illustrates the major aspects considered in this thesis for the investigation of what the ecological knowledge of small-scale fishers looks like, and how it is generated. In addition, it addresses the influence of fishers' relationship with nature and their work practices on the generation of knowledge of their natural environment.

In the following section, analytical frameworks are presented for the examination of the learning process of generating knowledge and understanding of ecosystem complexity. These frameworks address what kind of ecological knowledge fishers generated, and how it is affected by their work practices and natural environment.

Structure-Dynamic-Function framework

The ecological knowledge of users that have a professional relationship with natural resources and their environments, i.e., small-scale fishers, was investigated using a modified Structure-Behavior-Function (SBF) model (Hmelo et al., 2000). Considering the difficulties in the use of the concepts *Structure*, *Behavior* and *Function* suggested by these scholars, the term *Behavior* was replaced by *Dynamics* due to the absence of the components' interactions on the systems structure, and also the changes over time of these interactions on systems behaviour. This was done in order to reduce confusion regarding interpretations of what *Behavior* means, that is, the behaviour of individual components (e.g., fish behaviour) or behaviour of the entire ecosystem (e.g., regime shift or other persistent changes). In addition, the term *Dynamics* denotes change, movement and action that describe more properly the energy flows and feeding interactions over time. Furthermore, the notion of *Function* was given another meaning, and was approached from the perspective of ecosystem services, hence, looking also at the values fishers ascribe to the ecosystem instead of intrinsic processes related to energy use and cycle matter used by the SBF (see Hmelo et al., 2000). Here, ecosystem services are viewed as “*the goods or services provided by the ecosystem to society*” in Hein et al.'s words (2006, p. 211).

The final adapted framework made by myself – henceforth referred to as *Structure-Dynamic-Function* (SDF) – also takes into account existent approaches of ecosystem complexity as presented, for example, by Dunne (2009,) and Hein et al. (2006). In this adaptation, *Structure* is the description of ‘who eats whom’ in the ecosystem (including human beings) (Dunne, 2009), based on the identification of biotic components and their feeding interactions. *Dynamic* is defined as the changes over time of these feeding interactions, and the flows of biomass in response to direct and indirect trophic and other types of interactions (ibid). *Function* is defined as the function of the ecosystem in relation to human use and values in the form of ecosystem services (Hein et al., 2006).

By considering learning as the process of generating knowledge and understanding of ecosystem complexity, fishers' understanding of ecosystem structure, dynamics and functions are described as mental representations (of ecosystem complexity). From a dialectical constructivist perspective, these mental representations are considered as schemata in which fishers organise categories of information and relationships between them.

Fishing Styles Analysis

Professional work practices, in terms of work process and strategies, were explored using the Fishing Style Analysis (FSA) framework. In the FSA framework, fishing styles are defined as “*a collectively, shared and enacted, durable, habitual patterns of systematic and coherent actions, which aim to create congruence between normative notions about how fishing should be practiced, and fishers’ dependence on different social and ecological contexts*” (Boonstra & Hentati-Sundberg, 2014, p. 5). According to these authors, style is a concept used in rural sociology that refers to what people do and how they interpret their doing.

According to these scholars, the FSA framework was created from the need to develop a new approach for the scientific investigation of the diversity of fisheries and fishers. It is widely observed that an ‘average’ fisher hardly exists; fishers differ concerning target species, gear use, trips lengths, fishing locations, etc. (e.g., Christensen & Raakjær, 2006). Fisheries science has so far put a lot of effort into explaining *how* fishers differ (e.g., Marchal, 2008; Ulrich et al., 2012), rather than *why* these differences exist (Hind, 2012). It is, for example, still quite common to postulate intentions or motivations underlying different fishers’ practices, such as the maximisation of benefits or energy intake. As a result, fisheries science has still not opened the “*black box category*” of non-strategic motivations underlying the diversity of fishers’ practices (Van Putten et al., 2012, p. 229; see also Hall-Arber et al., 2009; Urquhart et al., 2011). Included in this category are, e.g., values, norms, habits, motivations, culture, life histories, character and personality traits, and how all these are shaped by structural constraints and opportunities, such as economic, political, ecological and technological changes (McClay & McGoodwin, 1995; Pollnac & Poggie, 2008, see also Pollnac, 1988).

The FSA framework was used to identify fishing styles performed among the fishers interviewed. Coastal fishers were classified into one of the three Swedish Baltic fishing styles identified by Boonstra and Hentati-Sundberg (2014), who implemented this analytical tool for the classification of fisheries in the Swedish Baltic Sea. By mixing multivariate statistical analysis of fishing practices between 1996 and 2009 in terms of their effects (i.e., catches, landings and trips) and means used (i.e., gear, vessel types, technologies), and doing interviews with 34 fishers in four different Swedish counties (Gotland, Blekinge, Kalmar, and Västra Götaland), Boonstra and Hentati-Sundberg identified three different fishing styles:

1. Archipelago fishing

2. Coastal fishing
3. Offshore trawling

These three styles differ in terms of the organisation and diversity of fishing practices, the normative opinions and values that the fishers' hold, and their dependence on social and environmental contexts.

Person-Psychological Process-Place: a tripartite organising framework

The interest to explore fishers' relationships with their local natural environments (particularly their professional and familial connection to these environments), as well as possible influences of cognition on identity and emotional bonds to ecosystems, led to the use of the Person-Psychological Process-Place (PPP) analytical framework, which incorporates multiple dimensions in human-nature relationships. The PPP framework was developed for a study of place attachment by Scannell and Gifford (2010) and integrates a variety of definitions in the sense of place literature through the analysis of three main dimensions: *Person*, *Psychological Process* and *Place* (Fig. 2).

Figure 2. The tripartite model of place attachment (Scannell & Gifford 2010) modified for the study of fishers' sense of place.

The *Person* dimension refers to who is attached and who may overlap at individual and group levels. In this framework, the person is the individual professional fisher and the community of fishers that were interviewed. In this sense, place attachment “*involves the personal connections individual has to place*”, and “*the symbolic meanings of place*” (ibid) (p. 3) shared by the members of a community.

The *Psychological Processes* dimension considers the psychological aspects of individuals and groups and the environment of which they are a part. These scholars consider *affect*, *behavior* and *cognition* as the main psychological aspects embedded in place attachment. Affect is seen as an emotional connection to a place that can represent “*an array of emotions from love to contentment to fear, hatred and ambivalence*” (p. 3). Behaviour is an expression of attachment through a positive action of significance to maintain closeness between individuals and to a place or natural resource. Finally, cognition is seen as a psychological aspect associated with memories, beliefs, meaning and knowledge (e.g., ecological) of personal importance for individuals in relation to a place. It engages the construction of place-meaning when bonding to a place, and facilitates closeness to it.

Moreover, these scholars recognise that, through memory, individuals build place-meaning and connect it to the self. Place provides information about one’s distinctiveness, representing who individuals are, thus “*connections to place may be cognitive, and can sometimes be incorporated (...) into one’s self-definition*” (p. 3).

Finally, the *Place* dimension refers to a place itself in terms of its physical and social aspects. On the one hand, ‘physical’ refers to settings of different types, such as built environments (houses, streets, cities) and natural environments (lakes, forests, landscapes). On the other hand, *place* represents a social arena for boundedness between members of a community, meaning that place attachment is necessarily social (e.g., Hunter, 1974). For this reason, we can talk of ‘sense of community’ (e.g., Scannell & Gifford, 2010) in two different ways: community of *interest*, i.e., where community members are linked through lifestyles or interests, and community of *place*, i.e., where members are connected to geographical locations. To summarise in Stedman’s words, “*local community culture influences place meanings, but also might the nature of physical environment influence community culture*” (2003, p. 673).

Methodology

This section presents the design and methods chosen for data collection and analysis, as well as the selected fishery contexts and participants, and ethical considerations.

With the aim of contributing to knowledge and understanding of the informal learning processes of ecosystem complexity among small-scale fishers, two case studies were selected: a freshwater ecosystem, i.e., Lake Vättern, and a marine ecosystem, i.e., Blekinge Archipelago (Baltic Sea) in Sweden.

Case studies

Case study is the method used in this qualitative research (Creswell et al., 2007; Gerring, 2007) – a common method in the social sciences. According to Gerring (ibid), “*case connotes a spatially delimited phenomenon (a unit) observed at a single point in time or over some period of time. It comprises the type of phenomenon that an inference attempts to explain*” (p. 19); this key unit can be an individual (in psychology), a social group such as family, ethnic, or religious group (in sociology and anthropology), or nations, states, regions, or organisations (in political science).

This method was chosen for this thesis for several reasons. Firstly, case study permits a better understanding of the whole by focusing on a key part or unit (ibid). In this thesis, the key part or unit is professional fishers; thus, by placing the emphasis on fishers, it is possible to get a better understanding of the phenomenon of ‘generation and use of ecological knowledge among users linked professionally to natural resources’. Secondly, the intensive study of a single case can involve a larger class of cases. Thus, the chosen unit does not depend on its size, but rather on the spatial and temporal delimitation of the phenomenon in question (ibid). By focusing on two case studies, this thesis explores a variety of ways of knowing ecosystems across cases that have fundamental differences. Comparative cases produce a more generalisable knowledge and a better understanding of ‘how’ and ‘why’ differences arise. In this sense, the cases were selected for differences in:

- landscapes – a freshwater ecosystem and a marine ecosystem.
- target species with traditional and economic values (Table 7), and under threat status, i.e., Arctic char and American crayfish (freshwater species) (Table 4), and European eel, cod, herring, and sprat (marine species) (Table 6).
- the cultural and social contexts of fishing activities, such as the fishing traditions of eel and Arctic char, and familial fishing tradition versus entrepreneurship.
- the scale of the fishing environments – one fishing scale (small-scale) in the freshwater ecosystem, and two fishing scales in the marine ecosystem (small-scale and large-scale).
- the regulation systems and level of management strategies – regional and national in the freshwater ecosystem, and national and international (i.e., EU and Baltic countries) in the marine ecosystem.

Thirdly, the term ‘case study’ can imply that “*the unit(s) under special focus is not perfectly representative of the population, or is at least questionable*” (ibid, p. 20), which could be an indicator of low validity and reliability when results are not representative or generalisable (e.g., Stenbacka, 2001; Golafshani, 2003). Nonetheless, generalisations from case studies can be of two different types: ‘analytical generalisation’ and ‘statistical or empirical generalisation’ (Lundholm, 2004). Lundholm refers to analytical generalisation as a way of generalising results to a level of theory or theories. Statistical or empirical generalization is when results from the selected cases can be generalised to a population. In the line with this distinction, the results from the case studies in this thesis are generalisable at the theoretical level by the use of various analytical frameworks for investigating informal learning processes:

- Investigating individuals’ understandings of their ecosystems, regardless of the different kinds of professional users and ecosystems – the Structure-Dynamic-Function framework.
- Exploration of the relationship between users’ ecological knowledge and their work practices – a combination of the Fishing Styles Analysis and Structure-Dynamic-Function frameworks.
- Analysing the connections between ecological knowledge, identity and sense of place – the Person-Psychological Process-Place framework.

Furthermore, the results could also be generalised at the empirical level, considering a population of professional users with similar backgrounds, in similar cultural and social contexts, and living in similar ecosystems. Finally, as will be discussed later, the results show more similarities than differences between the two case studies.

Research design

The research design has taken into consideration the theoretical assumptions derived from dialectical constructivism for the investigation of knowledge (i.e., what kind of knowledge), knowledge generation and knowledge use. In line with this, the data were in-depth structured interviews and naturalistic observations of fishing practices and of fishers' workplaces (e.g., fish stores and harbours) and homes.

By combining these methods, important information regarding fishers' ways of knowing, living, working and self-defining as locals and professionals (including emotional aspects) were captured. Information concerning fishers' social, cultural and historical experience in fishery contexts, and the interactions between fishers, their work, and their environments, were also captured. These aspects are significant for explaining the social character of fishers' understanding, which combines declarative and procedural knowledge (Anderson, 1989).

This thesis recognises the value of using naturalistic observation and in-depth structured interviews as complementary methods. The naturalistic observation method (McLeod, 2015) is a way of observing people in their normal environment, while making as little impact on the environment and the individual's behaviour as possible.

Figure 3 shows the two main steps constituting the research design. As a first step, interviews with fishers of Lake Vättern and a few observations of them during fishing and at fishing stores were done. The second step was interviews with fishers in the Blekinge Archipelago – Case Study 1 – and a few observations at their homes and harbours. New and specific questions concerning ecosystem services (see theme 3 and questions on 'c' in Table 1) and their feelings about the fishing profession and the ecosystem were added (see theme 5 in Table 1) to the interviews in the Blekinge Archipelago, along with the same interview questions used in case study one.

Figure 3. Research design.

Data collection

A total number of 20 fishers agreed to participate in the research – 14 of 22 (all of them were asked) in Lake Vättern, and 6 of 110 (35 were asked) in the Blekinge Archipelago. These fishers were selected according to certain criteria such as age, fishing target species, localisations, work status (i.e., retired or active) and fishing scale (i.e., small-scale and large-scale). Unfortunately, despite the intention to include both small-scale and large-scale in the marine fishers' case, it was a difficult task. Thirty-five phone calls were made and only six fishers agreed to take part. This is not unusual in Sweden and, according to Bruckmeier (2005) and others, large-scale professional fishers have much less confidence in researchers or the environmental movement than do small-scale or subsistence fishers.

Interviews with participants were done in August-September 2009, October-November 2010, January 2011, and April-May 2013. Interviews were done and audio-recorded at fishers' homes, workplaces (i.e., fish shops) or coffee shops, and lasted for one to three hours, and all fishers were interviewed

individually (with the exception of F6 and F7 – a father and son). A few observations were made and video-recorded during fishing, and photographs of boats and family, fishing gear and caught fish were taken at the fishers' homes, at fishing stores and at harbours.

The interview questions were formulated according to Crona's (2006) research on fishers' knowledge of species in relation to the fishing gear used, ecological processes, and changes in the ecosystem over time. Table 1 presents these questions, which were structured around five central themes. Further questions – derived from interviews with fishers at Lake Vättern – were added to the interviews in the Blekinge Archipelago, in order to gain more information about ecosystem services (see theme 3 in Table 1), and the fishers' feelings about the profession and the ecosystem (see theme 5 in Table 1).

Theme	Questions	Article
1. Fishers' socio-cultural background and life history	How long have you been a professional fisher? How did you start fishing professionally? What is good and bad about this profession?	Articles I, II and III
2. The use of fishing gears and equipment	Which kind of gear do you use? How selective is it? Do you fish during the day or/and night?	Article II
3. Knowledge about biological and ecological characteristics of target species and fishing grounds, b) local ecological changes, and c) ecosystem services	a) a) What target species do you fish in the lake/Baltic Sea? Where and when do you find these target species? Where do target species breed in the lake? Who eats what? b) (e.g.) How have the stocks changed? Do you have any idea why these changes have occurred? How have these changes influenced fishing species? c) (e.g.) Why is the	Articles I, II and III

ecosystem of the lake/Baltic Sea important? What are the services provided by this ecosystem to people? Which services are important for you?

4. Views of ecosystem management and fishery policy	(e.g.) Are you participating in some arrangement for fishery management in the area? Do you know the goals of these arrangements? Is it important to manage fishing in a sustainable way? What solutions do you propose for sustainable fishing? What does future look like in 15 years?	Articles I and II
5. Feelings about the fishing profession and the ecosystems	(e.g.) How does it feel to be out on the lake/Baltic Sea and go fishing? How and why did you become a professional fisher? Do you think your profession challenges you? What is important to you when you fish?	Articles I and II

Table 1. Interview questions structured around five central themes in respective articles.

Data analysis

Manual transcriptions of the interviews were done, and then they were analysed deductively through the use of the analytical frameworks (the Structure-Dynamic-Function (SDF) framework, the Fishing Styles Analysis (FSA) framework, and the Person-Psychological Process-Place (PPP) framework). The analysis and categorisation of the data were then checked with the co-authors for accuracy and coherence. Interview statements that were vague or unclear, or belonged to another category, were removed or re-categorised. When agreement between author and co-authors was reached,

the most illustrative and clear quotes were selected for presentation. Table 2 shows the corresponding frameworks for data analysis in each article.

Article	Number of participants	Study case	Data collection	Analysis
I	20	Lake Vättern	In-depth structured interviews and a few observations	SDF framework
II	6	Blekinge Archipelago	In-depth structured interviews and a few observations	FSA and SDF frameworks
III	14	Lake Vättern and Blekinge Archipelago	In-depth structured interviews and a few observations	PPP tripartite and SDF frameworks

Table 2. Overview of the participants, data collection and employed analytical framework in chronological order.

Ethical considerations

Investigating knowledge gained from participants' informal learning processes meant that ethical considerations concerning theoretical, methodological and political aspects needed to be considered. I address these aspects separately below, although they are interconnected across the whole thesis through the aims, research questions, theoretical and methodological choices, and research design.

Theoretical aspects

Research on *local*, *indigenous* and *traditional* ecological knowledge has been approached through a traditional paradigm of knowledge (with important exceptions, e.g., García-Allut, 1999; Olsson & Folke, 2001; Crona, 2006; Berkes, 2009; Lauer & Aswani, 2009; Briggs, 2013). This

means that the ecological knowledge of local users has often been limited to comparison with scientific knowledge and treated almost as its opposite, being hardly validated because of its situated nature. In line with Berkes (2009), who considers that instead of only capturing this knowledge as (scientifically validated) information, it should be investigated as ‘ways of knowing’. Moreover, this research tradition has focused on the structural level of ecosystems; for instance, on knowledge about a specific fish stock in terms of spawning and distribution. Furthermore, this approach has restricted the investigation and integration of research only to local users and their knowledge of their ecosystems’ complexity in the context of management; and is perhaps influenced by complex power relations (e.g., Nygren, 1999) between who represents these “*forms of knowledge*” (e.g., Jovchelovitch, 2007).

Instead of approaching knowledge through this traditional paradigm, this study approaches it through a constructivist paradigm – namely dialectical constructivism (Moshman, 1982). It assumes that all “*forms of knowledge*” are situated in specific sociocultural and historical contexts of which individuals are a part, and co-exist in human cognitive development at the individual and collective levels (Jovchelovitch, 2007). This epistemological approach complies with the research aims and questions of this thesis, as well as the theoretical frameworks used.

Methodological aspects

Ethical considerations of methodological aspects concern two main aspects:

1. The role of the researcher
2. Responsibility in relation to participants

First, dialectical constructivism harmonises with my professional and scientific view of knowledge, and allows me to recognise myself as a ‘knowledge explorer’ who has learned from fishers’ professional knowledge. This attitude characterised the in-depth structured interviews and observations (recorded as video and pictures), which I believe made fishers feel comfortable in responding fully to questions. Furthermore, it seems that fishers did not perceive me as a ‘scientific authority’, but rather as an ‘outsider’ and a ‘curious female foreign student’ that wanted to know about their profession. Thus, I believe, my gender and race made the participants feel non-threatened and helped them to trust me. I have assumed full responsibility for making the fishers’ voices heard, and I hope I have done justice to their knowledge and feelings.

Secondly, fishers were informed about the research aims by a letter sent months before the data collection began. By doing this, anonymity and confidentiality were guaranteed in accordance with Good Research Practice (Swedish Research Council, 2011), by keeping fishers' identities secret from each other and from the governmental fishing authorities. A second contact was made by phone, asking if the fishers were interested in participating in this research. A third contact was made a few days before the interview in order to confirm participation. At the time of the interview, fishers were asked to consent to an audio recording of the interviews and also photography. Verbal consent of C6 for the use of pictures in Article I was asked for over the phone. Finally, the data collected have been stored in a security Backup. The identity of fishers remains anonymous in both audio and video-recordings, as I deliberately chose to not record their names.

Political aspects

Considering that educational research aims to understand what is happening in the real world, and the need to act in order to affect what is happening (Tickle 2001), I recognise that there are possible political implications of this research, particularly concerning fishery management in Sweden. I believe I stand for the fishers I met during my research, and hope that this thesis will be a vehicle for their voices to be heard; this became a kind of political agenda for me after listening to them. This political agenda became more complex than I initially thought, and I confronted an ethical dilemma (see Tickle, 2001; Spark, 1994) about the right to speak for the fishers, respect for the trust they had given me, and my commitment to their circumstances. The fishers expressed their wishes and fears for the future of small-scale fisheries in a capitalistic world, and their love and pride for being what they wanted to be: fishers, just like their ancestors. They expressed a frustration and sadness in being the last generation of small-scale fishers (as their sons and daughters cannot inherit their profession, licence, nets or boats as they did), and for the extinction of fishing communities' cultural and traditional legacy, including their knowledge. Thus, I assumed my moral responsibility as researcher by showing the importance and value of their knowledge, which is embedded in sociocultural contexts, and how users' ecological knowledge should be investigated in future research on *local, indigenous and traditional ecological knowledge*.

Finally, I have consciously decided to avoid etiquettes of my own approach to the theoretical and methodological considerations I have presented above. I recognise that my approach can partially be traced to feminist ethics, as it is grounded on a value-based model (Miller et al., 2012).

The two studied cases

This section presents the most important aspects characterising the two case studies of this thesis. These aspects refer firstly to the Swedish fishery context to which Lake Vättern and Blekinge Archipelago belong; secondly, to the physical – geographical and biological (target species) – aspects as well as management strategies in both ecosystems; and, lastly, to the background of the freshwater and coastal fishers who participated.

Fishery contexts in Sweden

Freshwater and marine ecosystems cover more than three-quarters of the Earth's surface (The Environmental Literacy Council, 2016), and have been recognised as sources of health and wealth (Food and Agricultural Organization of the United Nations, 2014). The fishery sector (including aquaculture) provides work to tens of millions and supports the livelihoods of hundreds of millions (ibid). Being part of this global context, two case studies were chosen for the investigation into fishers' ecological knowledge in Sweden. One corresponds to a freshwater ecosystem and the other to a marine ecosystem – Lake Vättern and the Blekinge Archipelago. Given that Sweden has been part of the European Union (EU) since 1995, the EU Common Fisheries Policy dictates the Swedish fisheries policy, and the Swedish Board of Fisheries is responsible for the conservation and management of Sweden's fish stocks (European Parliament, 2010). Fisheries management is mainly based on the total allowable catches and quota system (ibid).

Case I: The freshwater ecosystem – Lake Vättern

Lake Vättern is situated in the middle of four counties and twenty-one municipalities in the south of Sweden, is the sixth largest lake in Europe (1912 km²), and the second largest in Sweden (Fig. 4). Currently, about 250,000 people use water from Vättern for their daily consumption, and many of them benefit by fishing (County Administrative Board in Jönköping, 2009). The fishing of Arctic char (*Salvelinus salvelinus*) has been strongly reduced but has been economically compensated for by the fishing

of crayfish. Today, this foreign species, the American crayfish (*Pacifastacus leniusculus*), provides a significant income for some users and stakeholders – especially professional fishers (ibid). The Swedish Board of Fisheries supported the surrounding region in 2004 as a “Co-management Initiative Project”, which worked successfully for the development of regional fisheries co-management. In October 2009, this project, characterised by the inclusion of multiple stakeholders in a dialogue for learning, enhancement of trust, and influence on decision-making on resource extraction was ended, resulting in an institutional and permanent co-management structure (see Lundholm & Stöhr, 2014; Stöhr et al., 2014).

Figure 4. Geographical area of study. Right: Lake Vättern (1). Left: Sweden.

Fishing in Lake Vättern is classified into four categories: leisure fishing (sport fishing and household fishing), tourist fishing, fish farming and professional fishing (defined by different methods, species focus and fish water) (County Administrative Board in Jönköping, 2009). This last category requires the possession of a professional fishing license given by the County Administrative Board, is small-scale and high-tech (FAO, 2011), and is performed in small boats for 2-3 people with a GPS, an inboard diesel motor, a VHF radio and sonar. Catching fish is done using selective nets with a mesh size of between 40 and 60 mm. Crayfish fishing is carried out using cages of mesh size 50 mm, with two or four round escape-openings of 28 mm in diameter. The minimum size for individual fish is 10 cm.

Participants

A brief characterisation of the participating professional fishers in Lake Vättern is presented below, showing the most relevant information regarding their backgrounds.

Fisher ¹	Age ² Years	Educational level ³	Time- experience Years	Fishing gear and scale ⁴	Relation to the profession
F1	65	Upper secondary school	42 in leisure fishing 15 in profession fishing	Gill-net, cage Small-scale	Construction worker Learning from an old fisher (neighbour)
F2	68	College	29 in professional fishing	Gill-net, cage Small-scale	Experience with fishers as expert at Natural Protection Agency
F3	41	Upper secondary school	All life in leisure fishing 21 in professional fishing	Gill-net, cage Small-scale	Carpenter, industry worker. Grandfather and father fishers
F4	62	Upper secondary school	All life in leisure fishing 30 in professional fishing	Gill-net, cage Small-scale	Construction worker Father fisher, he took over father's licence
F5	62	Upper secondary school	27 in professional fishing	Gill-net, cage Small-scale	Mechanic Two friends, professional fishers

¹ F denotes freshwater fisher, and C denotes coastal fisher. The number indicates the chronological order in which fishers were interviewed.

² At the moment the interview was done.

³ According to the Organisation for Economic Co-operation and Development (OECD) (2015), 88% of the population between 25 and 64 years has at least high-school education in Sweden.

⁴ Fishing in both case studies was small-scale and high-tech according to FAO's categorisation, and performed in boats of between 6 and 12 metres in length, with capacity for 2 to 5 (it says 2-3 above) people and equipped with a GPS, an inboard diesel motor, a radio and sonar.

F6	52	Upper secondary school	32 in professional fishing	Gill-net, cage Small-scale	Industry worker introduced to the fishing profession by his father-in-law
F7	27	Upper secondary school	All life in leisure fishing 8 in professional fishing	Gill-net, cage Small-scale	Father. Following in father's footsteps.
F8	66	College	45 in professional fishing	Gill-net, cage Small-scale	Works as teacher Forest worker and entrepreneur
F9	51	Upper secondary school	15 in professional fishing	Gill-net, cage Small-scale	Fishers in the family
F10	67	Upper secondary school	33 in professional fishing	Gill-net, cage Small-scale	Fishers in the family. His son.
F11	52	Upper secondary school	32 in professional fishing	Gill-net, cage Small-scale	Fishers in the family
F12	72	Upper secondary school	All life 50 in professional fishing	Gill-net, cage Small-scale	Father was leisure fisher, brother is professional fisher
F13	61	College	5 in professional fishing	Gill-net, cage Small-scale	Water engineer in Sweden and abroad
F14	49	Upper secondary school	10 in professional fishing	Cage Small-scale	Tourist fishing guide Plumber

Table 3. Information about freshwater fishers' backgrounds.

The target species of importance for freshwater fishers are presented in Table 4:

Freshwater Fishers	Target species	Freshwater Fishers	Target species
F1	common whitefish, Atlantic salmon American crayfish, European perch, north pike, Artic char	F8	Atlantic salmon, American crayfish, European perch, Artic char, common whitefish
F2	Atlantic salmon, American crayfish, Artic char, European perch, common whitefish	F9	burbot, American crayfish
F3	Atlantic salmon, American crayfish, European perch, common whitefish, Artic char	F10	vendace, Atlantic salmon, common roach, American crayfish, common whitefish, European perch, Artic char, brown trout, north pike, zander, European eel
F4	American crayfish, common whitefish, European perch, Atlantic salmon, Artic char	F11	American crayfish, common whitefish, European perch, Artic char, brown trout, north pike, zander
F5	American crayfish, Artic char, common whitefish, European perch	F12	American crayfish, common whitefish, Artic char
F6	American crayfish, common whitefish, European perch, Atlantic salmon, Artic char, brown trout	F13	American crayfish
F7	American crayfish, common whitefish, European perch, Atlantic salmon, Artic char, brown trout	F14	American crayfish

Table 4. Freshwater fishers' target species (English common names).

Case II: The marine ecosystem – Blekinge Archipelago (Baltic Sea)

The Archipelago of Blekinge is situated in Blekinge County in the southwest of Sweden, and is bordered by Småland, Scania and the Baltic Sea (Fig. 5). The Archipelago of Blekinge is characterised by a mosaic landscape and comprises hundreds of islands. In 2011, it became one of the UNESCO Biosphere Reserve areas in Sweden. The Archipelago of Blekinge comprises 156,000 ha of water and 54,000 ha of land. A total of 85,000 people live in the reserve and another 4,000 on the islands around the coast (UNESCO, 2013). Fishing and agriculture are important sources of income for the local people, as well as the increasing tourism and leisure industries (ibid). In 2011, there were 115 licenced professional fishers in the archipelago, which was 8% of all professional fishers in Sweden (Environmental Protection Agency, 2013). Between 1995 and 2011, the number of professional fishers here decreased by 60%, which has been a negative factor for the conservation and development of the cultural values of this biosphere area, particularly for small-scale and coast fishing (ibid). In addition, the fishing of cod (*Gadus morhua*), salmon (*Salmo salar*) and European eel (*Anguilla anguilla*), among other species, has been strongly reduced but economically mitigated by the fishing of vendace (*Coregonus albula*).

Figure 5. Geographical area of study: to the right Archipelago of Blekinge with the localities of Sölvesborg and Sturkö, and to the left Sweden.

Professional fishing in the Archipelago of Blekinge requires a professional fishing licence from the Blekinge County Administrative Board. Moreover, engaging in commercial fishing in the sea with a ship whose length is five metres or more, requires a vessel permit (Swedish Agency for Marine and Water Management, 2013). The Swedish Agency for Marine and Water Management is responsible for giving vessel permissions. Fishers were selected on the basis of age, localisation and target species such as European eel, cod, turbot and herring. The type of fishing carried out by this group is small-scale and high-tech (FAO 2011), and is performed in various small boats equipped with a GPS, an inboard diesel motor, a VHF radio and sometimes sonar. Fishing is done using nets of different sizes (depending of the target species), a fish-trap and a trawl.

Participants

A brief characterisation of the professional fishers in Blekinge Archipelago – who participated in this thesis – is presented below, showing the most important information regarding their backgrounds.

Fisher ⁵	Age ⁶ Years	Educational level ⁷	Time- experience Years	Fishing gear and scale ⁸	Relation to the profession
C1	39	Upper secondary school	25-30 in leisure fishing 30 in professional fishing	Net Small-scale	Grandfathers, father
C2	65	Upper secondary school	46 in leisure fishing 28 in professional fishing	Fish trap, net Small-scale	Five generations fishers, father and two brothers

⁵ F denotes freshwater fishers, and C denotes coastal fishers. The number indicates the chronological order in which fishers were interviewed.

⁶ At the moment the interview was done.

⁷ According to the Organisation for Economic Co-operation and Development (OECD) (2015), 88% of the population between 25 and 64 years has at least a high-school education in Sweden.

⁸ Fishing in both case studies was small-scale and high-tech, according to FAO's categorisation, performed as it was in boats between 6 and 12 meters with capacity for 2 to 5 people and equipped with a GPS, an inboard diesel motor, a radio and sonar.

C3	34	Upper secondary school	30 in leisure fishing 19 in professional fishing	Net, fish trap Small-scale	Grandfathers, father, and a brother
C4	69	Upper secondary school	All life in leisure fishing 55 in professional fishing	Net, fish trap Small-scale	Grandfathers, father
C5	42	Upper secondary school	All life in leisure fishing 17 in professional fishing	Net, fish trap Small-scale	Grandfather leisure fisher Grandfather professional fisher Two brothers
C6	63	Upper secondary school	All life 48 in professional fishing	Net Small-scale	Grandfather Father A brother

Table 3. Information about coastal fishers' backgrounds.

Target species of importance for coastal fishers are presented below in Table 6.

Coastal Fishers	Target species
C1	European eel, Atlantic salmon, cod, turbot
C2	cod, Atlantic salmon, herring, European eel
C3	Atlantic salmon, cod, European eel, turbot
C4	turbot, cod, European eel
C5	north pike, common whitefish, European perch, cod, herring, turbot
C6	Atlantic salmon, herring, turbot, cod

Table 6. Coastal fishers' target species (English common names).

Table 7 (below) shows the target species of significance for both freshwater and coastal fishers in the studied cases.

English common name	Scientific name	English common name	Scientific name
American crayfish	<i>Pacifastacus leniusculus</i>	Brown trout	<i>Salmo trutta</i>
Common whitefish	<i>Coregonus lavaretus</i>	European eel	<i>Anguilla Anguilla</i>
Vendace	<i>Coregonus albula</i>	Burbot	<i>Lota lota</i>
Atlantic salmon	<i>Salmo salar</i>	Common roach	<i>Rutilus rutilus</i>
Artic char	<i>Salvelinus salvelinus</i>	(North) pike	<i>Esox Lucius</i>
Carp bream	<i>Abramis brama</i>	Herring	<i>Clupea harengus</i>
Zander	<i>Sander lucioperca</i>	Turbot	<i>Scophthalmus maximus</i>
European perch	<i>Perca fluviatilis</i>	Cod	<i>Gadus morhua</i>

Table 7. English common and scientific names of fishers' target species in freshwater and coastal case studies.

Summary of results

This section offers a summary of the most relevant findings in relation to the research questions. The findings contribute to knowledge and understanding of informal learning processes of ecosystem complexity among small-scale fishers. Article I focuses on what ecological knowledge was generated by professional small-scale fishers. Article II emphasises the influence of fishing work practices on knowledge generation. Finally, Article III investigates the influence of fishers' relationships to nature on the generation of their ecological knowledge.

Article I: Linking a conceptual framework on systems thinking with experiential knowledge.

Using the Structure-Behavior-Function model, this article focuses on the question of what kind of ecological knowledge professional small-scale fishers generate in the freshwater fishery of Lake Vättern. For this purpose, the Structure-Dynamic-Function (SDF) framework was adapted for investigating fishers' cognitional processes involved in understanding ecosystem complexity from a dialectical constructivist paradigm. It shows that the understanding of ecosystem complexity consists of knowing ecosystem *structure* (i.e., feeding interaction among species and other organisms over time), *dynamics* (i.e., changes in the factors of disturbance affecting fish stocks) and *functions* (i.e., the resources that the ecosystem provides to humans).

Based on results, two patterns of knowing ecosystems were identified. Fishers who focused on several target species, had a wide experience of the fishing profession, and had familial connections to it, (i.e., came from fishing families) showed a deep knowledge of ecosystem structure and dynamics in comparison to fishers who focused only on one or a few target species, had less experience and no familial connection. This first group of fishers was able to elaborate on complex networks of concepts in dealing with invisible processes of the system that are assumed to be generated only from scientific literacy. Fishers' ecological knowledge was mainly related to aspects such as reproduction, nutrition and temporal-spatial distribution.

Furthermore, invisibility and time delay causality were two main aspects challenging fishers' systems thinking.

Assuming that knowledge of ecosystem is influenced by fishers' interaction with their environment, this article concludes that the generation of their ecological knowledge is influenced by: i) the number and diversity of target species, ii) fishing gear, iii) length of professional experience, iv) familial sociocultural contexts, and v) scientific literacy derived from formal education and media information. Moreover, knowledge of ecosystem is a combination of different forms of ways of knowing, i.e., declarative (derived from literacy referring to facts and concepts) and procedural knowledge derived from experience (e.g., observation, imitation), referring to *how* to do things. Declarative knowledge relates, for instance, to the existence of microorganisms, processes of energy fluxes, cycle matter and the water cycle. Procedural knowledge concerns how to catch fish, i.e., where and when to put out nets, how to repair nets, and how to sell the catch.

Finally, the SDF framework was a useful tool for describing fishers' ecological knowledge as it takes into consideration the general aspects of ecosystem complexity, and can be extended to other environmental learning contexts of significance for *local*, *indigenous* and *traditional* ecological knowledge research.

Article II: Knowing by fishing: Conceptualising ecological knowledge as working knowledge

This article focuses on the influence of work practices on the generation of fishers' ecological knowledge, and how local ecological knowledge can be conceptually and methodologically operationalised as being grounded in processes of work. In the analysis, the Fishing Styles Analysis and the Structure-Dynamic-Function frameworks were combined to investigate Swedish coastal fishery practices. This article assumes that users' knowledge of their local ecosystems has a dual character, i.e., declarative (or discursive) and procedural (or practical), and that it originates and evolves mainly through work activities such as apprenticeship, professional reflection, and testing hypotheses. These assumptions have substantial conceptual and methodological consequences that support the focus on the 'process' or 'ways of knowing' in the generation of ecological knowledge, rather than on its 'content' such as a 'body' or 'system' of knowledge.

Results from the Blekinge case study suggest that fishers' economic dependency on target species can be considered as a driving factor in the generation of ecological knowledge, which interdepends on specific

everyday work activities, and long-term work experience. This means that the more species fishers target, the greater their knowledge of ecosystems in terms of understanding complexity at the structural, dynamical and functional levels. Thus, these results are congruent with the results from case study one.

Lastly, the focus on work practices in this article helps to avoid romanticising knowledge that has characterised research on *local*, *indigenous* and *traditional ecological knowledge*, and concludes that the emergence of diverse ways of working, and styles of fishing, coincide with the loss and generation of ecological knowledge. For fisheries management, it is important to be aware of the range of diversity in fisheries, the social-ecological impact of different fishing styles, and the knowledge that is both the cause and the effect of this diversity.

Article III: Exploring the interconnections between local ecological knowledge, professional identity and sense of place among Swedish fishers

Investigating the influence of fishers' relationships to nature on the generation of their ecological knowledge, this article addresses 'sense of place' and the dimensions of *person*, *psychological process* and *place*. The dimension of *person* includes individual aspects (experience, profession and self-definition) and social aspects (cultural and historical processes and events); *psychological process* refers to emotional (affects), behavioural (desire to remain close to a place) and cognitional (beliefs, meanings and memories) aspects; and *place* refers to physical aspects (things and their surroundings) and social (arena and symbols) elements. The article presents a wide overview of these dimensions that influence and are influenced by fishers' ecological knowledge – that is, how this knowledge influences natural environments, and how natural environments influence knowledge. Thus, this article explores the interconnections between fishers' knowledge, their local and professional identities as fishers, and their emotional connection to the fishing places in the two case studies. It thus also addresses the complexity of elements, all being aspects of environmental learning in the contexts of natural resource use and management.

The results show two different ways of being linked to the fishing profession, i.e., as a family tradition or a business opportunity. Fishers with family connections expressed strong feelings for the profession as a 'lifestyle' inherited from their ancestors, and as an identity created at an early age through experience of fishing in social and cultural contexts. In contrast, non-traditional fishers or fishers without this family connection

seemed to see fishing mainly as a livelihood. They expressed a variety of emotions about the fishing profession and fishing environments that were often linked to their fishing identities. Furthermore, actions for maintaining closeness to fishing places were found in the form of engagement in resource management at a local level, changing policy for the recruitment of young fishers, and the promotion of sustainable fishing practices. These results suggest that fishers' understanding of their ecosystem's complexity enhances their attachment to it, and promotes emotions and behaviours for proximity maintenance or desire to remain close to a place and to fishing environments.

Finally, this article highlights the interconnections of the dimensions that characterise the complexity of human-nature relationships, which is far from the traditional way of investigating knowledge as separate from the social, cultural and historical contexts in which it is generated and used. These findings have important implications for future research on *local*, *indigenous* and *traditional* ecological knowledge.

Concluding remarks

Answering the first research question of what ecological knowledge professional small-scale fishers generate, Article I showed fishers' understanding of ecosystem complexity to be a fundamental part of their core professional knowledge, which consists of three main aspects:

1. Ecosystem structure – the identification of biotic components and feeding interaction.
2. Ecosystem dynamics – the recognition of changes in the ecosystem by identifying drivers of change and their causal effects on fish stocks.
3. Ecosystem function – the identification of resources provided by ecosystems to fishers and the local community in terms of material and non-material benefits.

Concerning the second research question of how the generation of fishers' knowledge is influenced by their work practices, Article II demonstrated that users' ecological knowledge should be re-conceptualised as knowledge generated through work process, and not the romantic and idealistic view of knowledge as somehow private, mysterious and ungraspable. The results showed the influences of work practices on fishers' ecological knowledge, in line with the reciprocal relationship between knowledge and practice. Fishers' knowledge of ecosystem complexity (in terms of structure,

dynamics and functions) influences their work practices (fishing styles and strategies) and their work practices influence their knowledge of the ecosystem. For instance, fishers who focus on only a few target species develop a limited understanding of the ecosystem's three main aspects of complexity, as compared to those who focus on several species and develop a deep or wide understanding of them. Furthermore, the results of Article II suggested that familial connections to the profession are important for the generation of ecological knowledge. In this sense, fishers that have a familial connection to the profession understand, from a young age, the complexity of the ecosystem; this aspect was explored in detail in Article III. The correct knowledge, skills and attitudes involved in these work activities are commonly learnt informally through apprenticeships, by testing hypotheses through experience, and through constant reflection on one's own practices. In the case of traditional fishers, they learnt the profession from their fathers, grandfathers or male relatives at an early age. In the fishers' own words, they 'inherit the fishing profession as a lifestyle'. In contrast, non-traditional fishers also learnt the profession from older fishers, but had no familial connection to professional fishing, and became professional fishers for economic reasons. In both cases, fishers updated their professional competences and qualifications through, for instance, learning effective fishing techniques and safety training.

Article III answered the third research question of how the generation of fishers' ecological knowledge is influenced by their relationship to nature. It showed that fishers' relationships to nature influence their knowledge of the three main aspects of ecosystem complexity, i.e., structure, dynamics and function. Fishers with a familial connection to the fishing profession develop a strong connection to nature, which is influenced by what nature represents for fishers. Traditional fishers, or fishers that 'inherit' the fishing profession, share family memories and strong emotions that link them to fishing environments through their local and professional identities. This connection to nature seems to have an important impact on fishers' desire to remain close to a place, which in turn means that sustainable fishing practices are important for fishers, because they permit them to stay close to their natural environments. If they fish sustainably, fishing environments (including species), fishing traditions and the fishing profession are kept alive.

These findings demonstrate the complexity of relationships between fishing communities and the fishing places on which they depend for living, working and defining themselves. Importantly, fishers' ecological knowledge is a major component of the intellectual and cultural property of these communities, and a result of the very intimate relationships between fishing communities and their local natural environments and resources.

In summary, the major findings of this thesis are:

1. Fishers' ecological knowledge is constituted by declarative knowledge that refers to facts and concepts, and procedural knowledge that refers to how to catch fish, repair fishing-nets, and how to sell the catch.
2. Fishers' knowledge of ecosystem complexity comprises cognitive challenges for the understanding of certain ecological processes imperceptible to the human eye, which generate unexpected causes and effects on the whole ecosystem.
3. Fishers' understanding of ecosystem complexity can be considered as a skill or core knowledge required in professional fishing, and systems thinking is central to this understanding.
4. Fishers' knowledge of ecosystem complexity is grounded in work practices that assume learning to be a central process for the generation, transfer and updating of knowledge through apprenticeship and hypothesis-testing.
5. Fishers' understanding of their ecosystem's complexity enhances their attachment to that place, and promotes positive emotions and behaviours for proximity maintenance.
6. Fishers' knowledge of ecosystem complexity influences their identities, particularly local and professional.

The results showed a deep connection between fishers' work practices and their relationships to nature. Article III showed that multiple dimensions of human-nature relationships are included (*person, psychological process and place*) and that they are interconnected, such as, fishers' emotional bonds to their environments and how this influences their work practices and knowledge of ecosystem complexity, illustrate this. These findings present a strong argument for reaffirming that users' ecological knowledge should be reconsidered as knowledge generated through work processes – a key argument addressed in Article II. It offers a view of knowledge that is far from an ideal relationship between humans and the world, and which are based on psychological, social, historical, cultural and physical aspects of the relationships people establish with nature.

However, the influence of nature on fishers' ecological knowledge implied what kind of ecological knowledge fishers generated (Article III), which can be seen as work knowledge. The more species fishers target, the more knowledge they acquire about ecosystem complexity at the structural and

dynamical levels. This finding was shown in articles I and II and refers to ecological knowledge as experience-based knowledge, skills and attitudes.

Answering to the question of what kind of ecological knowledge fishers generated, and how work practices and nature influenced this knowledge, fishers' knowledge became graspable, understandable and open for the scrutiny of public debate and analysis about its role in environmental education and resource management. The way of seeing knowledge and knowledge generation can be extended to research on other users or holders, i.e., *local, indigenous and traditional ecological knowledge*.

Finally, more similarities than differences were found across the two studied cases, despite the variation in landscape, target species, regulation systems, management strategies, fishing environments scales, and the cultural and social contexts characterising Lake Vättern and Blekinge Archipelago. These comparative cases produced a more generalisable knowledge regarding what kind of knowledge fishers generate about their local ecosystems, and a better understanding of the influences of their work practices and relations to nature on it. This knowledge might be comparable and extended to other groups of users/holders through the use of the analytical frameworks and theories developed in the thesis.

In the next section, a discussion of the findings is presented in relation to the aim, the research questions and previous research on environmental education, the cognitive and learning sciences, workplace learning, and the human-nature relationship. In addition, it considers the implications of empirical investigation of fishers' ecological knowledge.

Discussion

This section discusses the major findings in relation to the aim of study, which is to contribute to knowledge and understanding of informal learning processes of ecosystem complexity among small-scale fishers. First, a major finding is that two types of knowledge constitute fishers' ecological knowledge: declarative (or discursive) and procedural (or practical). This finding answers the research question of what ecological knowledge the fishers generated. Second, another major finding is that fishers' knowledge of ecosystem complexity is grounded mainly in processes of work such as apprenticeships, testing hypotheses and reflection on their own practices. It means that the generation, transfer and updating of knowledge is mainly done through apprenticeship and hypothesis-testing. This finding answers the question about the influence of work practices on fishers' ecological knowledge. Third, another major finding concerns the influence of ecological knowledge on local and professional identities. Knowledge of ecosystem complexity is considered core professional knowledge for small-scale professional fishing. In line with this, the knowledge of fishing environments influences professional and local identities. Natural environments influence fishers' self-identification as locals and the fishers expressed a strong connection to these places (including the fish). Their environments constitute a key element of who they are, and where they belong. For instance, fishers that focus on eel fishing define themselves as 'eel-fishers', and belong to a particular eel-fishing community several generations old in that particular place (Blekinge Archipelago). The last major finding is that fishers' understanding of their ecosystem's complexity enhances their attachment to it and their behaviours for proximity maintenance – this finding relates to the research question about the influence of fishers' relationships to nature on their ecological knowledge.

These findings allow the conclusions:

- Different work practices generate different understandings of ecosystem complexity.
- Different relationships to nature generate different understandings of ecosystem complexity.

- Knowledge of ecosystem complexity is strongly related to local and professional identities. In turn, the development of local and professional identities is strong related to fishing and its social, cultural and physical environments.

This thesis thus highlights the influence that work practices, relationships to nature and the development of local and professional identities have on the generation of ecological knowledge. It also shows the interconnection between multiple dimensions of human relationships with nature for the generation and use of knowledge of ecosystem complexity. Finally, it shows the significance of the dimensions involved in learning as suggested by Illeris (2008): a dimension of knowledge (skills, abilities, attitudes), a dimension of emotions (feelings, motivations, volition) and a social dimension (interactions, communication and cooperation). By defining learning as the process of generating knowledge and understanding of ecosystem complexity, this thesis shows the importance of informal learning contexts for knowledge generation, updating and transfer among small-scale professional fishers. For instance, fishers without familial connections to the fishing profession learnt in a different way from the fishers who have this connection. This is clearly illustrated by the case of the eel-fishers in Blekinge Archipelago, who inherited the profession from their fathers or grandfathers. This group of (traditional) fishers has particular work practices and local and professional identities that few others have, and stands in contrast to non-traditional American crayfish fishers, who do not have the same relationship to nature or the same knowledge of ecosystem complexity, and see themselves as entrepreneurs, rather than fishing people.

The dialectical constructivist perspective (Moshman, 1982) – which emphasises the principle that the source of all knowledge lies in the continuing interactions between individuals and their environment – has been fundamental to the investigation of ecological knowledge in this thesis. The dialectical constructivist paradigm contributed to the investigation of learning ecosystem complexity in a new and more complete way, in contrast to previous studies on *local ecological knowledge*, *indigenous ecological knowledge* and *traditional ecological knowledge*. Departing from the idea that thinking takes place in contexts, and that individuals' knowledge is generated through their experiences in situations (Schunk, 2004), this thesis contributes to the understanding of informal learning in the context of natural resource management.

Results in relation to previous research

This thesis highlights earlier contributions made by Reid et al. (2002; 2004) in environmental education, by Hmelo (Hmelo-Silver) et al. (2000; 2004; 2008) in the cognitive and learning sciences, by Fazey et al. (2006), Olsson and Folke (2001) on adults learning about environmental conservation and natural resource management, and the research by Ardoin et al. (2012) and Kudryavtsev et al. (2012) on sense of place in environmental learning.

First, these contributions have exposed the need of developing theories and analytical frameworks for the investigation of ways of knowing ecosystems by their local users/holders. Secondly, they have highlighted the tension of conceptualising 'traditional ecological knowledge' as a body of knowledge, as well as the difficulties of using a neo-paradigm or romantic views of this knowledge as a 'mystical harmony', 'primeval' and 'sacred' (see also McFarlane, 2006; Ruddle & Davis, 2010; and Briggs, 2013). Thirdly, the summary of research concerning 'sense of place' in environmental education, points to a lack of attention from researchers to theory and empirical studies, which has meant that 'sense of place' has remained almost unexplored in environmental learning research (with a few exceptions).

This thesis addressed these issues by i) developing the Structure-Dynamic-Function (SDF) framework for the investigation of ways of knowing ecosystems among professional fishers; ii) connecting theoretical and analytical frameworks for the investigation of fishers' ecological knowledge by using the SDF and FSA (Fishing Styles Analysis) frameworks as grounded in processes of work; and iii) linking the frameworks of the SDF and Person-Psychological Process-Place for the investigation of fishers' ways of knowing, feeling, working, living, and self-defining as locals and professionals. These results, taken together, provide new ways of investigating ecological knowledge held by local users/holders, focusing on informal learning about natural environments. It also emphasises three dimensions of learning situations: the dimension of knowledge, understanding, skills, abilities and attitudes; the dimension of emotions, feelings, motivations and volition; and the social dimension of interaction, communication and cooperation suggested by Illeris (2008).

Based on this theoretical three-dimensional view of learning situations, the findings presented in this thesis acknowledge that ecological informal learning needs to be investigated, while taking into account the importance of connecting knowledge and understanding of ecosystems to work practices, and to emotional bonds to natural environments and places.

Implications of results for research and practice

The findings presented in this thesis have significant consequences for research on ecological knowledge and environmental learning, and for practices concerning sustainable use and the management of natural resources – in particular for fishery policy. They highlight the significance of small-scale fishing as an informal learning context for global development and sustainability (World Bank, 2007), and acknowledge the role of small-scale fishing in enhancing learning of ecology, influenced by local and professional self-identification, positive behaviours for proximity maintenance and attachment to their communities. The achievement of global development and sustainability goals might depend on rethinking what kind of ecological knowledge fishers generate and how it is impacted by work practices and nature. Furthermore, the findings of this thesis might provide new insights concerning the role of emotions and attachment of fishers – and other local users – in natural resource management, through democratic processes of participation.

In addition, this thesis addresses implications that concern the fishers themselves and their circumstances; the fishers allowed me to bring forth their voices of proudness and love for the fishing profession, tradition and nature, but also the frustration, fear and sadness over possibly being the last generation of small-scale fishers and for the extinction of fishing communities' cultural and traditional legacies. Hopefully, these findings will call attention to the rapid and almost inevitable industrialisation of fisheries and to future possibilities which will permit small-scale users to continue to live, work and identify themselves with their natural environments. In this manner, this thesis contributes to previous research on management practices and highlights the struggle that small-scale fishers are dealing with today by:

- Showing and highlighting the threats faced by local professional fishers that carry relevant knowledge, attitudes, emotions, motivations and social interactions required for sustainability learning.
- Presenting evidence of sustainable work practices for keeping and promoting small-scale fishing.

Future research

In regard to future research on informal learning processes of ecosystem complexity and methodology, I recommend the use of combined methods such as in-depth interviews – inside and outside the contexts where

knowledge is generated – and natural observations of fishing work processes (apprenticeships) for the collection of data. These methods capture fishers' knowledge and emotions about their natural environments, where they live, work and define themselves. In particular, interviews outside fishers' work places allow them to reflect about their own work practices, knowledge, skills and feeling.

In this thesis, these methods were effective for capturing key information, especially taking into account the limited time for doing the data collection, the difficulties of reaching fishers and their localisation in different geographical areas of Sweden.

Furthermore, two more recommendations for future empirical research on ecological knowledge held by fishers or other users/holders are suggested: first, to make observations of individuals during work practice over a long period of time, and second, future studies on large-scale fishers would provide new and complementary information that extends the theoretical and analytical frameworks developed and supplied here. This second proposal is relevant for exploring the influence of fishing scales and strategies on large-scale fishers' ecological knowledge.

Finally, research including case studies carried out in other informal environmental learning contexts – such as forestry, agriculture, wildlife and reindeer herding – with different cultural, social and historical characteristics, might provide additional insights along with greater attention to, and development of, theoretical and analytical frameworks.

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