UNIVERSITY OF TROMSØ UIT

FACULTY OF BIOSCIENCES, FISHERIES AND ECONOMICS
NORWEGIAN COLLEGE OF FISHERY SCIENCE

# Granularity and its importance for traceability in seafood supply chains

**Kine Mari Karlsen**

A dissertation for the degree of
Philosophiae Doctor

August 2011

# Granularity and its importance for traceability in seafood supply chains

Kine Mari Karlsen

A dissertation for the degree of Philosophiae Doctor

University of Tromsø
Faculty of Biosciences, Fisheries and Economics
Norwegian College of Fishery Science

# Contents

# Acknowledgements

My interest in traceability began in the early 2000s, when I was a student at the Norwegian College of Fishery Science. Stig Nilsen from the company Dåfjord Laks gave a presentation at our school, and pointed out that there will be an increased focus on traceability in the future. This led to a master’s thesis in collaboration with Dåfjord Laks, where Petter Olsen and Edel Elvevoll were my supervisors. Thanks to Stig for sparking my interest in traceability.

In 2004, I started working as a scientist at Fiskeriforskning. Petter, thanks for everything you have taught me about traceability. With your fantastic capabilities, you have succeeded in getting funding for several traceability projects and building a group on traceability at Nofima. Kathryn Donnelly, thanks for your enormous interest in scientific publication. This has resulted in increased scientific publications of our results from completed traceability projects.

During the work with this thesis, I have been guided by my faithful supervisors, Petter Olsen and Edel Elvevoll, as well as Bent Dreyer. Thank you for all your good advice. I want to thank Bent for always making the time to hear me out when I needed to discuss something. You have been a fantastic motivator.

Thanks to all the participating companies and everybody who provided funding. I especially want to thank Kristin Lauritzsen, Eskil Forås, Carl-Fredrik Sørensen, and Rolf Hancke. I have also had good help from my colleagues in this work. Thanks to Kjetil Aune, Bjørn Inge Bendiksen, Øystein Hermansen, Oddvar Dahl og Lena Hagensen. In addition, I want to thank Camilla Isachsen for help with the manuscript.

Finally, I would like to thank my friends and family. Mom and dad, thanks for everything you have taught me. Thanks to my sister-in-law Hilde Karlsen for all help with our family. A special thanks to my husband Tor Ivan Karlsen for your patience. Thanks to our sons, Erik and Sondre, for giving me balance in life.

Tromsø, May 2011
Kine Mari Karlsen

# Forord – Norwegian acknowledgements

Første gang jeg fattet interesse for sporbarhet var som student ved Norges Fiskerihøgskole (NFH) i 2001. Stig Nilsen fra den gangen Dåfjord Laks var invitert til NFH for å fortelle om bedriften. Han mente at sporbarhet ville få større fokus i fremtiden. Resultatet var at jeg skrev hovedfagsoppgaven i samarbeid med Dåfjord Laks, hvor Petter Olsen og Edel Elvevoll var mine veiledere. Takk Stig for ditt engasjement. Du er en viktig årsak til at jeg startet å jobbe med sporbarhet.

I 2004 fikk jeg tilbud om jobb på Fiskeriforskning. Petter, tusen takk for alt du har lært meg om sporbarhet. Med dine fantastiske evner til å søke om midler til forskningsprosjekter har du klart å bygge opp et miljø på sporbarhet på Nofima. Kathryn Donnelly, takk for din sterke drivkraft for publisering. Dette har gjort at vi begynte å publisere resultatene fra avsluttede prosjekter.

Under ph.d.-en har jeg blitt veiledet av mine trofaste følger, Petter Olsen og Edel Elvevoll, i tillegg til Bent Dreyer. Tusen takk for alle god råd underveis. Jeg vil spesielt takke Bent. Du har vært flink å motivere meg, og alltid hatt tid i en travel hverdag. Jeg er imponert over din evne til å sette deg inn i nye problemstillinger.

Tusen takk til alle deltagerne og de som har finansiert prosjektene. En stor takk til Kristin Lauritzsen. Det var veldig inspirerende å samarbeide med deg. Jeg vil også takke Eskil Forås, Carl-Fredrik Sørensen og Rolf Hancke.

Her på huset er det mange som har bidratt underveis i arbeidet med ph.d.-en. Kjetil Aune har vært en viktig støttespiller for meg i søken etter litteratur. Andre som har hjulpet meg er Bjørn Inge Bendiksen, Øystein Hermansen, Oddvar Dahl og Lena Hagensen. En stor takk til Camilla Isachsen for hjelp med manuskriptet.

Jeg setter veldig stor pris på det sosiale her på huset. Dere er et trivelig gjeng! Det blir mye latter i kaffekroken og i lunsjen. Hvordan har hverdagen vært uten dere?

Jeg vil også takke min familie og mine venner. Mamma og pappa, dere fortjener en stor takk for all den tid dere har brukt på meg. Helt i fra jeg var bitteliten har dere tatt meg med overalt hvor dere dro; i fiskebåten, i egnebua, i fjæra, på Finnmarka på fiske. Jeg vet at dere var veldig opptatt av at jeg skulle lære meg å jobbe. En annen viktig lærdom jeg har fra barndommen er å fokusere på det positive. Som dere bruker å si *'det ordner seg alltids'*. Dette har vært nyttig i mange sammenhenger.

Min svingersøster Hilde Karlsen kan jeg ikke få roset nok. Du er alltid positiv og full av energi. Jeg setter veldig stor pris på vennskapet vårt, og tusen takk for all hjelp du har gjort for vår familie i en travel hverdag alt fra barnepass, husvask og klesvask.

Og hva skulle jeg gjort uten min kjære mann, Tor Ivan Karlsen? Tusen takk for at du er den du er og for din enorme tålmodighet. Du har alltid vært en stor inspirasjonskilde for meg, en uunnværlig diskusjonspartner og flink til å gi konstruktive tilbakemeldinger. Til slutt en stor takk til våre sønner Erik og Sondre. Med deres tilstedeværelse viser dere hva som er viktigst her i livet.

Tromsø, mai 2011
Kine Mari Karlsen

# Summary

The purpose of this thesis was to study granularity and its importance for traceability in seafood supply chains. The following hypothesis was applied in this thesis: The implementation of traceability of seafood is affected by the granularity level of the traceable units. Three sub-tasks were carried out to test the hypothesis: 1) identify critical traceability points (CTPs) of seafood products, 2) study critical criteria during implementation of traceability and 3) investigate different granularity levels of traceable units. This thesis documents information lost within and between companies in three supply chains (papers I-III). This knowledge was necessary information when implementing traceability in a fresh fish supply chain in paper III.

Paper III presents an industrial implementation of electronic chain traceability in a fresh fish supply chain. The experience gained from this study showed that implementation is complex and involves many different aspects that affect each other. Critical criteria when implementing traceability were identified. One finding was that identification of costs and benefits of traceability was critical for implementation success. It was concluded increased knowledge of the costs and benefits of traceability was needed.

Different granularity levels of the traceable units were studied in paper IV. One of the findings was that there are different possibilities with regard to granularity levels of batches. The key is to design the traceability system at the right granularity level based on the users' needs for information at acceptable costs.

The finding from this thesis shows that implementation of traceability of seafood is affected by the granularity level of the traceable units. Thus one of the first steps in implementation of traceability should be an evaluation of the optimal granularity level of the traceable units within the involved companies. There should be an open discussion of the distribution of costs and benefits between these companies (Mai et al. 2010). This evaluation will decide the complexity of the traceability system, and can affect the practical solutions and specification of the IT-systems when implementing traceability. Fine granularity level will increase the complexity of the traceability system, and will give higher costs because there will be more information to record, increased numbers of transactions, new systems and procedures (Golan et al. 2004).

# Sammendrag – Norwegian summary


Målsettingen i dette studiet var å studere ulike sporbarhetsnivåer (såkalt granularitet) og disse nivåenes betydning for sporbarhet i verdikjeder for sjømat. En hypotese er at innføring av sporbarhet for sjømat påvirkes av sporbarhetsnivået for de sporbare enhetene. Denne hypotesen ble testet ved å gjennomføre tre aktiviteter: 1) identifisere kritiske sporbarhetspunkter for sjømatprodukter, 2) studere kritiske kriterier ved innføring av sporbarhet og 3) studere ulike sporbarhetsnivåer. I studiet er det dokumentert at informasjonen forsvinner i bedriftene og mellom bedriftene (artiklene I-III). Denne kunnskapen var nødvendig ved innføring av sporbarhet av fersk fisk i artikkel III.

Artikkel III presenterer en praktisk innføring av elektronisk kjedesporbarhet i en hel verdikjede for fersk fisk. Et av funnene er at en slik innføring er kompleks og involverer mange ulike aspekter som påvirker hverandre. Kritiske kriterier for innføring av elektronisk sporbarhet er identifisert. Et annet funn er at identifisering av kostnader og nytte ved sporbarhet er kritisk for å lykkes med en slik innføring. Det er derfor nødvendig med økt kunnskap om kostnadene og nytten i verdikjeder for sjømat.

Sporbarhet kan innføres på ulike nivåer. Dette ble studert i artikkel IV, hvor et av funnene var at det er ulike sporbarhetsnivåer for batcher. Nøkkelen er å lage et sporbarhetssystem med det riktige sporbarhetsnivået basert på brukerens behov til en akseptabel pris.

Resultatene fra studiet viser at innføring av sporbarhet påvirkes av sporbarhetsnivået. Før innføring av sporbarhet bør det derfor gjennomføres en evaluering av optimalt sporbarhetsnivå i de involverte bedriftene. Det bør gjennomføres en åpen diskusjon om fordelingen av kostnader og nytten mellom disse bedriftene (Mai et al. 2010). Denne evalueringen vil bestemme kompleksiteten av sporbarhetssystemet, og kan påvirke de praktiske løsningene og spesifikasjonen av IT-systemene. Fint sporbarhetsnivå vil øke kompleksiteten av sporbarhetssystemet, og vil gi økte kostnader pga. flere antall registreringer (mer informasjon må registreres) (Golan et al. 2004). Nye systemer og rutiner må eventuelt også innføres.

# List of papers

The thesis is based on the following papers:

**Paper I**

Karlsen, K.M. & Olsen, P. (2011). Validity of method for analysing critical traceability points. *Food Control,* 22: 1209-1215.

**Paper II**

Donnelly, K.A.-M. & Karlsen, K.M. (2010). Lessons from two case studies of implementing traceability in the dried salted fish industry. *Journal of Aquatic Food Product Technology,* 19: 38-47.

**Paper III**

Karlsen, K.M., Forås, E., Sørensen, C.-F. & Olsen, P. (2011). Critical criteria when implementing electronic chain traceability in a fish supply chain. *Food Control*, 22: 1339-1347.

**Paper IV**

Karlsen, K.M., Donnelly, K.A.-M. & Olsen, P. (2011). Granularity and its importance for traceability in a farmed salmon supply chain. *Journal of Food Engineering,* 102: 1-8.

In the following, these papers will be referred to by their respective Roman numerals.

# Additional papers

I have been primary author and co-author of several publications. These articles, however, are not part of this thesis.

Donnelly, K.A.-M., Karlsen, K.M. & Dreyer, B. (2011). A Simulated Recall Study in Five Major Food Sectors. *British Food Journal*, in press.

Donnelly, K.A.-M., van der Roest, J., Houldson, S.T., Olsen, P. & Karlsen, K.M. (2011). Food industry information exchange and the role of meta-data and data lists. International Journal of Metadata, Semantics and Ontologies (IJMSO), in press.

Donnelly, K.A.-M., Karlsen, K.M. & Olsen, P. (2009). The importance of transformations in traceability - a case study of lamb and lamb products. *Meat Science*, 83(1): 69-73.

Donnelly, K.A.-M., van der Roest, J., Houldson, S.T., Olsen, P. & Karlsen, K.M. (2009) Improving information exchange in the chicken processing sector using standardized data lists. Communication in Computer and Information Science, 46: 312-321.

Donnelly, K.A.-M., Karlsen, K.M., Olsen, P. & van der Roest, J. (2008). Creating Standardized Data Lists for Traceability – A Study of Honey Processing. *International Journal of Metadata, Semantics and Ontologies (IJMSO)*, 3(4): 283-291.

Karlsen, K.M., Andreassen, O., Dreyer, B., Hermansen, Ø. & Olsen, P. (2011). Sustainability challenges in seafood supply chains. *Food Supply: Economics, Sustainability, and Environmental Effects.* Hauppauge, New York: Nova Science Publishers, submitted.

Karlsen, K.M., Donnelly, K.A.-M. & Olsen, P. (2010). Implementing traceability: Practical challenges at a mineral water bottling plant. *British Food Journal*, 112(2): 187-197.

Karlsen, K.M. & Senneset, G. (2006) Traceability: Simulated recall of fish products. In Luten, J.B., Jacobsen, C., Bekaert, K., Sæbø, A. & Oehlenschläger, J. *Seafood from fish to dish, Quality, safety and processing of wild and farmed fish*. ISBN-10:90-8686-005-2, ISBN-13:978-90-8686-005-0. The Netherlands: Wageningen Academic Publishers, 251-262.

Storøy, J., Senneset, G., Forås, E., Olsen, P., Karlsen, K.M. & Frederiksen, M. (2008). Improving traceability in seafood production. In Børresen, T.E. *Improving seafood products for the consumer, part VI seafood traceability to regain consumer confidence.* Cambridge, UK: Woodhead Publishing Limited, 516-538.

# Abbreviations

| | |
|---|---|
| CTP | Critical traceability point |
| DistriCo | Packing and distributing company |
| DriedProd | Dried salted fish producer |
| FeedCo | Fish feed factory |
| FishVes | Fishing vessels |
| IngredCo | Suppliers of fish feed ingredients |
| ISO | International Organization for Standardization |
| IT | Information technology |
| IUU fishing | Illegal, unregulated and uncontrolled fishing |
| IU | Identifiable unit |
| LandCo | Landing and filleting company |
| LU | Logistic unit |
| NEA | North-East Arctic |
| RFID | Radio frequency identification |
| SalmCo | Salmon farm |
| SalOrg | Sales organization |
| SuperMa | Supermarket |
| TRU | Traceable resource unit |
| TU | Trade unit |
| UCC | Uniform Code Council |
| WetProd | Wet salted fish producer |

# 1 Introduction

The requirements for documenting food products are ever increasing. Extensive national and international legislation has been passed to ensure food safety, and both the industry and the consumers are also becoming more interested in additional knowledge about origin, processes, and other properties concerning the product.

The food scandals of the 1990s put traceability of food on the agenda because of an increased concern regarding food safety and quality (McGrann and Wisemann 2001; McKean 2001). Traceability is defined as the *'...ability to trace the history, application or location of an entity by means of recorded identifications'* (ISO 1994). The food scandals also affected the food safety focus of seafood products (Moretti et al. 2003). The outcome of these scandals was that traceability was included in the European food law regulation EC/178/2002 (2002). At nearly the same time, the September 11 terrorist attacks in the United States of America gave rise to the US Bioterrorism Act (PL107-188 2002), aiming to reduce the impact of terrorist attacks on the food supply chain. In this act, traceability is required.

Lately, increased emphasis has been placed on other applications of traceability. Traceability can be useful to optimize production planning and scheduling, e.g. minimize waste and ensure optimal use of raw materials (Moe 1998; Wang and Li 2006). Traceability can also be used as a part of a competitive strategy (Canavari et al. 2010) and to increase company coordination in supply chains (Banterle and Stranieri 2008; Engelseth 2009).

The ability to trace foodstuffs means that the flow of material and information within a company and/or through a supply chain can be followed. Opara and Mazaud (2001) raised a central question in this regard; what unit to trace? The size of this unit will be different depending on the application of information (Moe 1998). Application of information for quality and process optimization purposes may demand smaller units. Bigger units can be used when the risk of contamination is low, or when the requirements for controlling production processes are less stringent. Thus the levels of the traceable units[1] are depended on a company's internal and external need for traceable information.

## 1.1 Purpose

No published scientific papers have been found discussing different levels of traceable units in seafood supply chains, thus the aim of this study was:

To investigate granularity and its importance for traceability in seafood supply chains

The seafood industry was chosen because there are few research findings relating to the implementation of traceability in seafood supply chains. In addition, this industry is different from other food industries when it comes to size (one fish vs. one animal), the insecurity of the input factors (random delivery of wild-caught fish vs. planned delivery of raw materials), and shelf-life (fish vs. meat), for example.

Granularity describes the level and the size of the units in a traceability system (Bollen et al. 2007). Interesting questions are: How important is granularity for traceability of seafood; how does granularity level affect the ability to trace seafood products; and how will the randomness of the fish supply affect traceability? One hypothesis is that the implementation of seafood traceability is affected by the granularity level of the traceable units. Three sub-tasks were carried out to test this hypothesis:

1. Identify critical traceability points (CTPs) of seafood products.
2. Study critical criteria during implementation of traceability.
3. Investigate different granularity levels of traceable units.

[1] Traceable units are raw materials and products that are uniquely identified and traceable (TraceFood, 2011).

Information lost in seafood supply chains was the first issue studied. A place where information loss occurs is called a CTP (Karlsen et al. 2010). Such points occur when information about a product or process is not linked to a traceable unit and recorded systematically. In other words, this information is not traceable and it is not possible to retrieve information again at a later point. CTP identification is necessary for traceability implementation, because certain recordings are necessary to prevent information loss. This includes recording the relationship between traceable units and the unique identification of the traceable units.

The next step was to identify critical criteria for implementing traceability at a defined granularity level of the traceable units, after which different granularity levels of the traceable units were studied.

## 1.2 Thesis structure

This thesis consists of seven chapters. First, the literature review describing the chosen theoretical perspective is presented, along with what is documented empirically and how previous studies of traceability have been carried out. My theoretical, empirical, and methodological choices regarding the purpose of the thesis were based on this review. The literature review here is divided into three chapters, where theoretical contributions on traceability is described in Chapter 2, empirical findings on traceability in Chapter 3, and methodological challenges in Chapter 4.

Chapter 2 presents the theoretical contribution of traceability. One of the aims of this chapter is to describe the definitions of traceability in different industries to show that there is no common understanding of traceability. The chosen definition of traceability is also presented. Following this, the drivers and benefits of traceability in the food industry are described. There are different drivers of food traceability, and the level of details of information can vary within a company and in a supply chain. This knowledge is critical considering the purpose of this thesis.

Chapter 3 presents the empirical findings of traceability. Among other things, this chapter aims to identify which of the drivers described in Chapter 2 is documented by empirical findings, and which driver is most important. In addition, an overview of scientific fields where traceability has been included is described to document that this is a complex field. We can conclude that traceability is an interdisciplinary field. Empirical findings of costs and benefits associated with traceability are also presented. Identifying costs and benefits is central when companies decide to implement traceability, and the benefits of using traceability can vary in different links in a supply chain. Evaluation and review of previous research will also be given.

Chapter 4 provides overviews of traceability principles, methods used to study traceability, and findings of implementing traceability identified in the literature. The aim of this chapter is to explain my methodological choices and the traceability approach applied. This is important because there is not a common understanding of traceability and granularity, and there are different types of methods used to study traceability. There are few empirical studies of granularity in food supply chains.

Chapter 5 describes the research strategy, which is based on the literature review from Chapters 2, 3, and 4. The design of the research setting is illustrated to provide an overview of the process. In addition, the choices of the seafood supply chains studied and the methods used to collect empirical data are explained.

Chapter 6 presents the study's main findings, and includes a description of CTP identification in the seafood supply chains studied, as well as the critical criteria of the traceability implementation process and different granularity levels of traceable units. This knowledge is relevant when implementing traceability in seafood supply chains. A discussion of the effect of granularity on the implementation of traceability in seafood supply chains is provided.

Chapter 7 includes the thesis conclusion, followed by a discussion of possible implications of the findings: How will these findings influence the theoretical contribution on traceability, methodology on traceability, and practical implementation of traceability? In addition, the limitations of the methods applied in this thesis and further work are presented.

# 2 Theoretical contributions on traceability

According to Ringsberg & Jönson (2010), traceability is a relatively young and immature concept that is difficult to define, and any research into food supply chain traceability represents pre-paradigm research. Still, I have attempted to extract possible theoretical contributions on traceability from the available literature.

Different definitions of traceability as applied in the literature are presented in an attempt to identify whether a common understanding of traceability exists. Consequently, one of the aims of this chapter is to justify the definition of traceability as it is applied in this research. In addition, knowledge of drivers and benefits of traceability in the food industry is relevant to study the purpose of this thesis. Drivers of traceability in other industries (e.g. automotive industry) are not included, because of the need to limit the literature search, and this is a limitation due to the fact that these products are not affected by seasonal demands regarding delivery of the input factor and shelf-life in the same way many foodstuffs are.

## 2.1 Definitions

Several definitions of traceability exists in different industries, which can make the term traceability confusing (Table 1). According to Ford & Triggs (2006), traceability is often used in the general sense. From Table 1 it is clear that differences exist between the definitions of traceability as applied in the information technology industry (IT)[2] and the food industry, e.g. *'...to trace ... within a model...'* and *'... to trace in one of the steps*

---

[2] IT is the area of managing technology, and includes, among other things, computer software, computer hardware, programming languages, and data constructs (Source: www.wikipedia.org). Information and communications technology (ICT) is an extended synonym for IT, and it includes technical equipments to handle and communicate information. Information system (IS) is related to the combination of IT and the activity of people who handle technology. IT is the term used in this thesis with respect to the use of technology to trace seafood products, in an effort to make it easier for the reader to read the text.

*in the chain...'*. This is in line with Ringsberg & Jönson (2010), who state that no common agreement of traceability exists.

Still, several of these definitions have something in common: the ability to *'trace'/'follow'* the *'movement'/path'* of an entity, X. X is in Table 1 defined as *'steps', 'object', 'batch', 'food', 'feed'/'food-producing animal', 'substance',* or *'item'*. The differences between many of these definitions relate to the entity X, in other words what to trace. This is in agreement with Kirova et al. (2008), who point out that several complementary definitions of traceability exist. Olsson & Skjöldebrand (2008), on the other hand, state that traceability is a complex field, thus giving rise to several different definitions of traceability. Another common characteristic of these definitions is the ability to trace information, e.g. *'trace'/'registering' 'information'/'data'*. Such information can be the history, application or location of all processes in the supply chain, or the origin and characteristics of a product.

Olsen & Aschan (2010) state that the International Organization of Standardization (ISO) definition of traceability (1994) is the most precise definition in regards to product traceability. This definition in the only one in Table 1 describing how traceability can be achieved *'...by means of recorded identifications'*. In other words, product information and process information must be recorded in a systematic way in order to be traceable; to trace information within a company, information received on the raw material must be recorded and linked to the production batch, which in turn must be linked to the delivered products. Only then it is possible to retrieve information on the raw materials in the finished products. This is an integral part of the principles of traceability, which are explained in more detail in Chapter 4. This thesis applies the ISO definition of traceability from 1994.

Table 1 Different definitions of traceability.

| **Term** | **Explanation** |
|---|---|
| **Information technology** | |
| Traceability | *'...the ability to retrace steps and verify that certain events have taken place'* (Cheng and Simmons 1994) |
| Horizontal traceability | *'...to trace correspondent items between different models'* (Lindwall and Sandahl 1996) |
| Vertical traceability | *'...to trace dependent items within a model'* (Lindwall and Sandahl 1996) |
| Software traceability | *'...to trace all the elements that can be considered relevant enough for the organization within a particular project or software product'* (García et al. 2008) |
| Traceability | There are different types of traceability in information systems: 1) Tracking: '*...a method of following an object through the supply chain and registering any data considered of any historic or monitoring relevance'*, 2) Forward traceability: *'...the exploration of where-used relations between objects'*, 3) Backward traceability: *'...the exploration of the where-from relation between objects'* (Jansen-Vullers et al. 2003) |
| **Food industry** | |
| Traceability | '*...ability to trace the history, application or location of an entity by means of recorded identifications'* (ISO 1994) |
| Traceability | *'...the collection, documentation, maintenance and application of information related to all processes in the supply chain in a manner that provides a guarantee to the consumer on the origin and life history of a product'* (Opara and Mazaud 2001) |
| Traceability | *'...the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution'* (EC-178/02 2002) |
| Traceability | *'...the means by which the information is provided'* (Bollen et al. 2006) |
| Traceability | *'...ability to follow the movement of a feed or food through specified stage(s) of production, processing and distribution'* (ISO-22005:2007 2007) |
| Traceability | There are two types of product traceability: 1) Tracing: *'...the ability, in every point of the supply chain, to find origin and characteristics of a product from one or several given criteria'*, 2) Tracking: *'...the ability, in every point of the supply chain, to find the localization of products from one or several given criteria'* (Dupuy et al. 2005) |

| | |
|---|---|
| Traceability | There are two key functions of traceability: 1) Tracking: *'...the ability to follow the path of an item as it moves downstream through the supply chain from the beginning to the end'*, 2) Tracing: *'...the ability to identify the origin of an item or group of items, through records, upstream in the supply chain'* (Schwägele 2005) |
| Chain traceability | *'...ability to track a product batch and its history through the whole, or part, of a production chain from harvest through transport, storage, processing, distribution and sales'* (Moe 1998) |
| Internal traceability | *'...ability to trace...in one of the steps in the chain'* (Moe 1998) |

As previously mentioned, several of the definitions of traceability point to how traceability can be used to trace an item and/or specific information. An interesting question is what information is interesting to trace for the stakeholders?

## 2.2 Drivers

The drivers and benefits of food traceability identified in the literature are presented in Appendix 1. Ten drivers of traceability in the food industry have been identified: 1) legislation, 2) food safety, 3) quality, 4) sustainability, 5) welfare, 6) certification, 7) competitive advantages, 8) chain communication, 9) terrorist threats, and 10) production optimization (Figure 1). Several of these drivers affect each other. For example, certification traceability schemes can give access to the market and can thus represent a competitive advantage (Manos and Manikas 2010), and documentation of animal health can be used for marketing purposes (Schulz and Tonsor 2010). It is likely that this model will be expanded in the near future when other drivers of food traceability are identified.

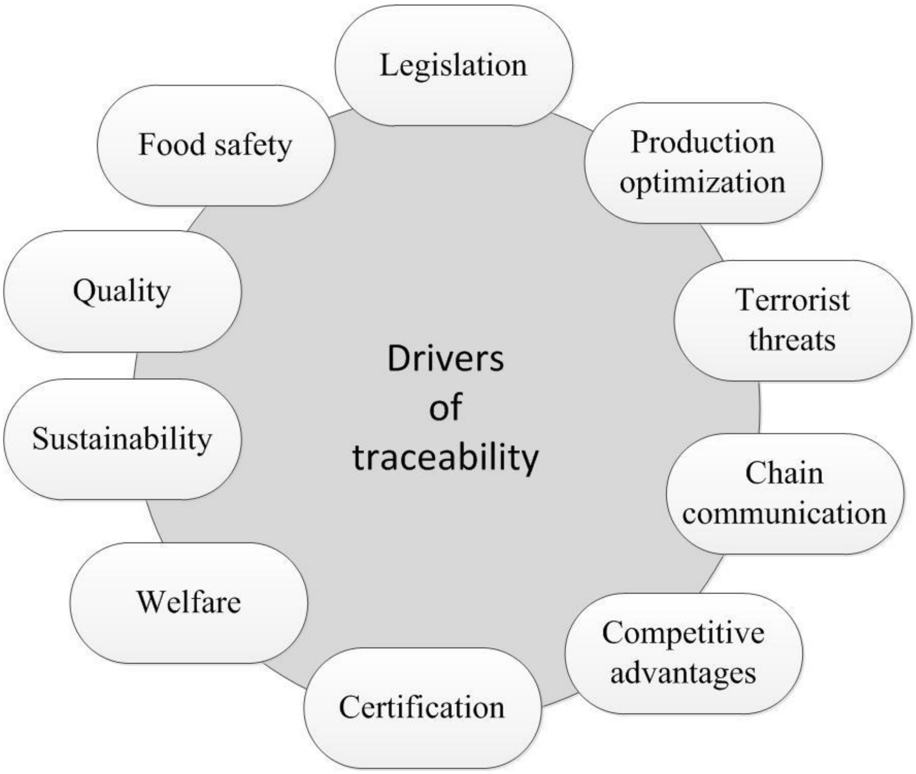


Figure 1 Modified from Olsen (2009): Model of the drivers for traceability in the food industry.

## 2.3 Benefits of internal traceability and chain traceability

Moe (1998) identified benefits of internal traceability and chain traceability (Table 2). The level of detail in information may be higher within a company (internal traceability) than in a supply chain (chain traceability), because it is assumed that the customer is only interested in a limited number of data elements. Using the information for the purposes of quality control and process optimization will require more details.

Table 2 Benefits of internal traceability and chain traceability (Moe 1998).

| Internal traceability | Chain traceability |
|---|---|
| • Better planning to optimize use of resources<br>• Improved process control<br>• Correlation of product data with data of characteristics and processes<br>• Cause-and-effect-indicators to satisfy product standards<br>• Avoid mixing of high- and low-quality materials<br>• Ease of information retrieval in quality management audits<br>• Better foundation for implementing information technology solutions in control and management systems | • Satisfy legal requirements<br>• Avoiding repetition of measurements<br>• Opportunity to market special raw material or product features<br>• Improving incentive for maintaining inherent quality of raw materials<br>• Efficient recall procedures<br>• Better quality and process control |

In this thesis, I have chosen to apply the following definition of traceability: The *'...ability to trace the history, application or location of an entity by means of recorded identifications'* (ISO 1994).

# 3 Empirical findings on traceability

In this chapter, the empirical findings on traceability in the food industry are presented. One of the aims of this chapter is to identify which of the drivers described in Chapter 2 are documented by empirical findings. In addition, an attempt is made to place these empirical findings in the appropriate scientific fields, documenting that traceability is studied in different fields. Empirical findings identifying the costs and benefits of using traceability are also presented. This is relevant when implementing seafood traceability. At the end of this chapter, the lack of research is highlighted.

## 3.1 Previous research

The identified empirical studies on the drivers of traceability in the food industry are presented in Appendix 2. As demonstrated, the majority of these studies were carried out in relation food safety, quality, competitive advantages, chain communication, and production optimization. Some companies have identified benefits of traceability other than compliance with legislation requirements (Wang and Li 2006). No empirical findings have been identified regarding terrorist threats.

An attempt is made to place the articles in Appendix 2 into the appropriate scientific fields. This is a challenging task, because some of these articles span different scientific fields, and, in addition, some fields can include several other fields, which makes it more difficult. For example, supply chain management includes logistics, relationship marketing, and marketing channels (Engelseth 2009). For this reason, I have simplified the scientific fields. The research fields[3] are defined as follows: supply chain management: the management and relationship of actors in food supply chains, as well as cost-benefit analyses within supply chains; engineering: the optimization of processes or systems, including IT; quality management: planning, control, management, and improvement of quality; economics: analyzing the production, distribution, and

[3] Source: www.wikipedia.org

consumption of goods and services, including cost-benefit analyses within one company; and market research: collecting information about markets or customers.

We can conclude that traceability is an interdisciplinary research field (Figure 2). The literature in Appendix 2 shows that several empirical studies of traceability drivers for food related to supply chain management and engineering have been carried out.

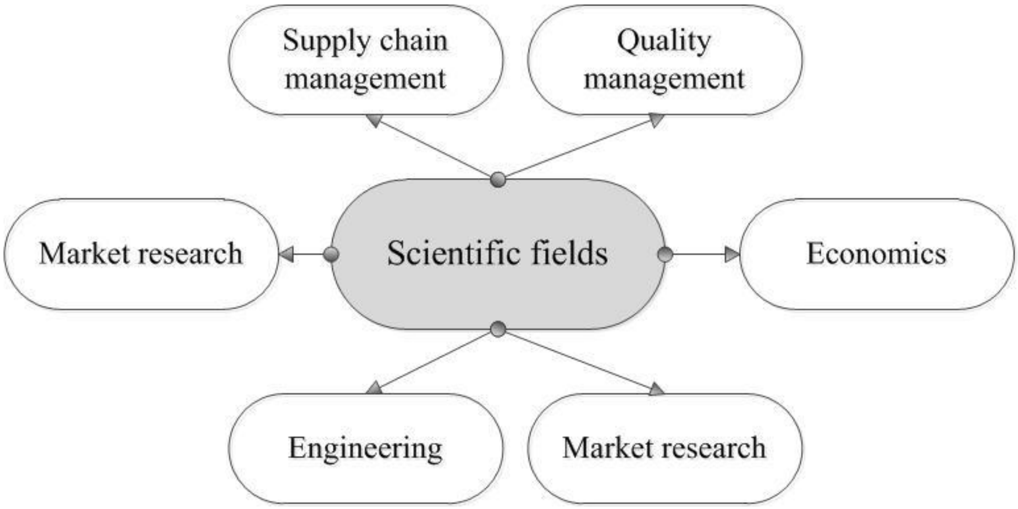


Figure 2 Identified scientific fields in empirical studies of traceability.

The identified empirical findings on costs and benefits in using traceability are presented in Table 3. A study carried out by Golan et al. (2004) concluded that companies decide the complexity of the traceability system based on the costs and benefits of traceable information. Traceability systems are systems for the transfer and exchange of information (Mai 2010), and different types of such systems exist: paper-based and barcode-based systems, as well as systems based on radio frequency identification tags (RFID tags). These systems can have different breadths, depths and precision levels (Golan et al. 2004). Breath is the amount of information to record, depth is the system’s ability to trace a product in a supply chain, and precision level is how precisely the traceability systems can describe the flow or properties of the products.

One problem, identified by Bevilacqua et al. (2009), was that there were no agreements to share the burdens and benefits of traceability. According to Mai et al. (2010), potential benefits vary in the different links in a supply chain. In a study carried out by Sparling et al. (2006), 60 percent of the respondents found that the perception of benefits exceeded perceptions of costs associated with the traceability implementation.

Table 3 Identified empirical findings on costs and benefits in using traceability in the food industry.

| Industry | Focus |
|---|---|
| **Food** | |
| Animal (Disney et al. 2001) | Cost-benefit analysis of animal identification for disease prevention and control |
| Food (Golan et al. 2004) | Traceability in the US food supply |
| Beef (Souza-Monterio and Caswell 2004) | The economics of implementing traceability in beef supply chains |
| Dairy (Sparling et al. 2006) | Costs and benefits of traceability in the Canadian dairy-processing sector |
| Animal (Can-Trace 2007) | Analysis of the cost of using traceability |
| Mineral water (Chryssochoidis et al. 2009) | Cost-benefit analysis of an electronic traceability system |
| **Seafood** | |
| Fish (Mai et al. 2010) | Benefits of traceability in fish supply chains |

## 3.2 Evaluation and review of previous research

Several of the identified drivers of traceability of food are documented by empirical findings: legislation, food safety, quality, sustainability, welfare, certification, competitive advantages, chain communication, and production optimization.

Still, further research is needed for several reasons. First, it is necessary to test the findings in different food supply chains, industries and markets in order to be able to generalize the findings (e.g. carry out cost-benefits analyses). Second, not all the identified benefits within one specific driver are documented empirically, e.g. compliance with EU regulations to prevent illegal, unregulated and uncontrolled fishing

(IUU) (EC-1005/2008 2008). Third, there is a lack of empirical findings on driver of food traceability terrorist threats. Fourth, there is a need to integrate traceability with supply chain activities to increase the value of a traceability system (Wang et al. 2008). Fifth, there is a dearth of empirical findings on granularity and its effect on the ability to trace seafood products.

In this thesis, relevant research fields are engineering and supply chain management: traceability implementation relies on engineering (e.g. optimizing current IT-systems and/or integrating these systems, as well as developing practical solutions), and a certain level of collaboration between the companies and their IT-suppliers is necessary in order to be able to trace a product through the supply chain. The companies must agree to common standards and traceability procedures, and to make information available for exchange. Important decisions to make are which granularity level to use and which types of information to make electronically available, and who should be granted access to specific types of information.

# 4 Methodological challenges

In this chapter, an overview of the used principles of traceability and measurements of traceability in previous studies is provided. The aim of this chapter is to explain my methodological choices and the traceability approach used to study the purpose of this thesis.

The principles of traceability identified in the literature are presented in an attempt to identify similarities and differences. Presumably, some of these principles can be transferred between industries. This is underlined by Jansen-Vullers et al. (2003), who carried out studies of different industries[4] related to traceability requirements. They concluded that these requirements appear to be similar across the industries studied. Consequently, principles of traceability as applied in other industries (such as the automotive industry) are included here.

How traceability is measured in previous studies is also identified. First, the identified methods in the traceability studies of food are presented. In this context, the literature search is limited by focusing on the food industry only because of the need to limit the literature search. Second, empirical findings of challenges associated with implementing traceability are described. Other industries have been included because of a lack of relevant findings related to the implementation of food traceability.

## 4.1 Measurement problems

The principles identified in the literature are presented in Appendix 3. Several publications of traceability studies in the food industry, seafood industry, and other industries have been found.

In the literature, no common understanding as to the principles of traceability exit. According to Kim et al. (1995), traceable resource unit (TRU) is the name given to as entity that is traceable. TRUs are entities with similar characteristics that have gone

[4] Beef, canned sausage products/canned sauce products, furniture, and the pharmaceutical industry.

through the same processes. Traceability is based on a clearly defined relationship between these units.

Moe (1998) points out that identifying batches and activities is necessary to trace a product. Batches can be described according to weights, volumes, etc., and activities can be described according to type and time/duration, e.g. processing, transportation, and storage.

Regattieri et al. (2007) take another view of traceability. They divide a traceability system into four pillars: 1) *'product identification'* (physical characteristics such as volume, weight, dimensions), 2) *'data to trace'* (characteristics of the traceable information e.g. digits), 3) *'product routing'* (activities and movements in a supply chain), and 4) *'traceability tools'* (technical solutions). The core entity *'product'* from Moe (1998) is present in pillar 1, and *'activity'* is present in pillars 1 and 3.

According to Opera (2003), a traceability system consists of six elements: 1) *'product traceability'* (physical location of a product), 2) *'process traceability'* (activities) , 3) *'genetic traceability'* (genetic modification of a product), 4) *'input traceability'* (type and origin of the input), 5) *'disease and pest traceability'* (trace hazards), and 6) *'measurement traceability'* (measurement in the supply chain). *'Process traceability'* is to some degree similar to the *'activity'* as defined by Moe (1998), and is included in pillar 3 as defined by Regattieri et al. (2007). Neither Moe (1998) nor Regatteri et al. (2007) included input, hazards, or measurements in their models.

Storøy et al. (2008) take yet a another view of traceability. Information is divided into 1) *'transformation information'*, and 2) *'product information'*. *'Transformation information'* covers identification of traceable units and transformation relationships, and *'product information'* covers origin, processing history, and location. Identifying traceable units and transformation relationships is the key to tracing a product internally and/or in supply chains (Storøy et al. 2008). Product information can be linked to the identification of traceable units.

This is line with the TraceFish standards[5] (CEN 2003a; CEN 2003b) and the TraceFood framework[6] (2011): Prerequisites for achieving traceability are unique identification of traceable units and recording transformations. Transformations are points where the resources are mixed, transferred, added, and/or split up (Derrick and Dillon 2004). The relationship of the traceable units can be one-to-one, many-to-one, one-to-many or many-to-many. GS1[7] (2007) divides the traceable units into 1) batch, 2) trade unit (TU), and 3) logistic unit (LU). The definitions of these terms are described in Table 4. Olsen & Aschan (2010) described the relationship between batches, TUs, and LUs in one link in a supply chain. TUs and LUs are external traceable units and batch is an internal traceable unit.

Table 4 Explanation of the terms batch, trade unit, and logistic unit.

| **Batch** | **Trade unit** | **Logistic unit** |
|---|---|---|
| *'A batch unites products/ items that have undergone the same transformation processes'* (GS1 2007) | *'...any item (product or service) upon which there is a need to retrieve pre-defined information and that may be priced, or ordered, or invoiced at any point in any supply chain'* (GS1 2007) | *'An item of any composition established for transport and/or storage that needs to be managed through the supply chain'* (GS1 2007) |
| *'...a quantity that has gone through the same process at a specific place and time period before moving to another place.' 'A production batch is the traceable unit that raw materials and ingredients go into before transformed into products placed in new Trade Units and Logistic Units.'* (TraceFood 2011) | *'...the smallest traceable unit that is exchanged between two parties in the supply chain.'* (TraceFood 2011) | *'In practice it is made up by one or more separate TU's. In some cases, the trade unit and the logistic unit are the same.'* (TraceFood 2011) |

[5] TraceFish standards are specifications of the information to be recorded in captured fish and farmed fish distribution chains.

[6] TraceFood is a framework comprising principles, standards, and methods for implementing traceability in the food industry.

[7] An international not-for-profit association designing and implementing global standards and solutions to improve supply chain management.

Bianchi et al. (2000) divided traceability into three dimensions: 1) *'vertical and horizontal traceability'* (whether the interconnection between items are in the same software model or in different models), 2) *'explicit or implicit links'* (types of links between items), and 3) *'structural or cognitive links'* (more detail description of the implicit link). The focus here is software maintenance and comprehension, and it is clear that this view of traceability cannot be compared with the other descriptions of traceability.

Bechini et al. (2005) developed a generic data model for traceability. This model is in line with the view of Kim et al. (1995), which is related to the basic principles of lot and activity. This model also identifies traceability entities, sites, and responsible actors in accordance with the TraceFish standards (CEN 2003a; CEN 2003b) and the TraceFood framework (2011). The quality feature is linked to the traceability entity, which is similar to the view of Storøy et al. (2008).

Several studies have highlighted the lack of unique identification of traceable units and transformation recordings (Frosch et al. 2008; Donnelly et al. 2009a; Karlsen et al. 2010). Transformation documentation is necessary in order to trace products (Donnelly et al. 2009a). The batch size of a product must be defined before any information can be linked to the product and thus be traceable (Bertolini et al. 2006).

In this thesis, the following principles of traceability are applied: Information is traceable by being linked to a unique identification of the traceable units. In addition, the relationship between these units must be recorded (the so-called transformation). These principles are illustrated with a simplified example in Figure 3. A catch of wild-caught fish is identified as A. The catch information is linked to this identification. The landed fish is sorted into different containers on the basis of species, fish size, and quality. The fish in container A1 is used in the production of batch A1-1. In Figure 3, this is illustrated with a box of fish. The identifications of the traceable units are linked together, and the measure of the yield of the fish from one landing can thus be linked to catch information, which in turn can be used to plan production and coordinate the activities of the fishing fleet to maximize profit for both fishing vessels and production plant. In the real world, this is more complicated, however, as documented later in this thesis.

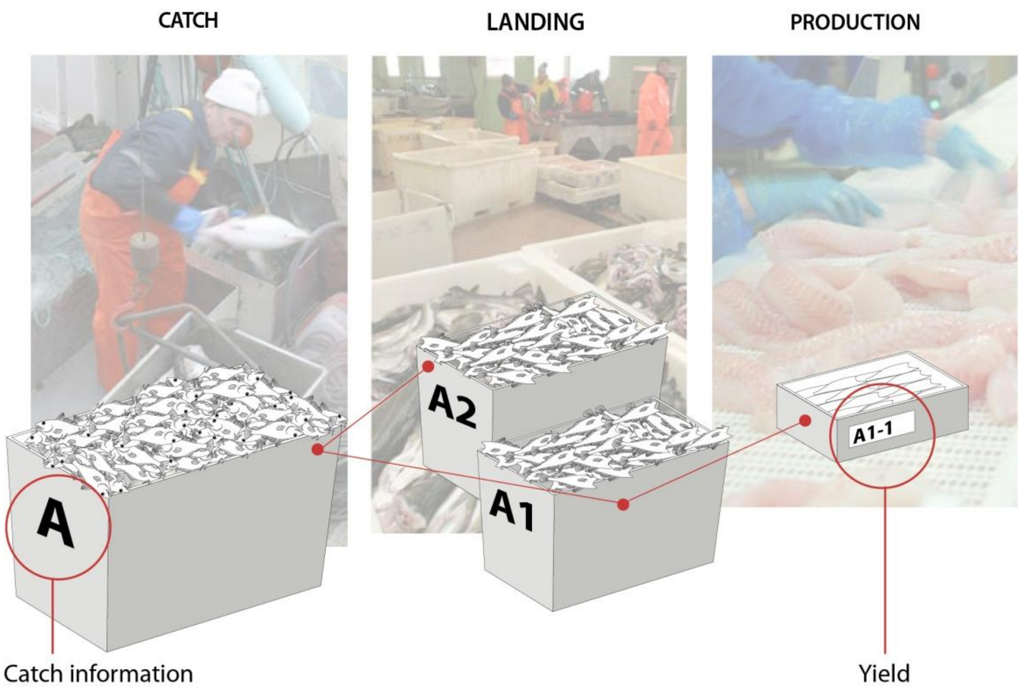


Figure 3 Simplified example of the principles of traceability as applied in this thesis. Illustrator: Oddvar Dahl, photo: Frank Gregersen, Nofima.

Opara and Mazaud (2001) raised a central question in terms of implementing food traceability; which entities are traced? The level of granularity affects the precision of product traceability (Riden and Bollen 2007). Finer granularity levels will yield increased precision of traceability. Table 5 shows some of the identified descriptions of granularity in traceability studies. Granularity is used in different areas and ways to study software systems and material flow in food production.

Table 5 Identified description of granularity in traceability studies.

| Term | Description |
|---|---|
| 1. Granularity | *'The size of unique identified TUs defines the operational visibility or granularity in a traceability information system'* (Senneset et al. 2010) |
| 2. Granularity | *'...level of ambition and degree of accuracy and granularity they want for the data in their traceability system'* (Arason et al. 2010) |
| 3. Granularity | *'...different levels of detail (granularity) through the supply chain'* (Bollen 2004) |
| 4. Granularity | *'Granularity can go down to a very refined level (e.g. a package belonging to a lot). Sometimes, it may even be necessary to trace a milk package from its lot to a barrel of milk'* (Kondo et al. 2007) |
| 5. Granularity | *'...reflects the levels and size of IUs* that are handled by the particular system'* (Bollen et al. 2007) |
| 6. Granularity in software engineering | *'...the traceability granularity is reduced allowing a better matching between related artifacts'* (Noll and Ribeiro 2007) |
| 7. Granularity in software engineering | *'...the relationship between the granularity of the traceability model'* (Bianchi et al. 2000) |

*Identifiable unit

The two definitions of granularity used in software engineering (Items 6 and 7 in Table 5) are less relevant for the purposes of this thesis, because these definitions focus exclusively on the field of IT. The most relevant definition of granularity for the purposes of this thesis is Item 5: *'...reflects the levels and size of IUs...'* by Bollen et al. (2007). One inherent weakness in this definition is that the granularity is only defined by the size of the units. Consequently, the definition of granularity applied in this thesis is as follows: Granularity describes different levels of traceable units, and is determined by the size of a traceable unit and the number of the smallest traceable units necessary to make up the traceable unit at a specific granularity level. Fine granularity means smaller unit sizes, and coarse granularity means larger unit sizes. Since the total amount we want to trace is given at a specific granularity level, there is an increase relationship between the size of each unit we trace, and the number of units we need to trace. This is illustrated in Figure 4.

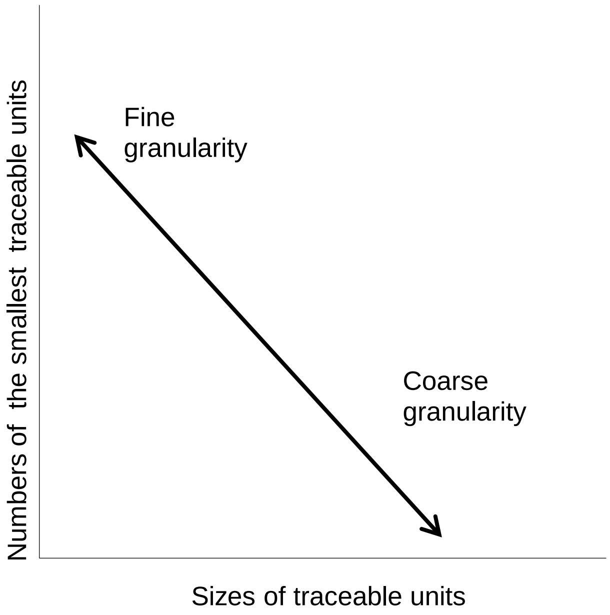


Figure 4 Different granularity levels of traceable units.

## 4.2 Measures for traceability in previous studies

Methods identified in food traceability studies are presented in Appendix 4, which shows that different types of methods have been used to study traceability: action research, interviews, focus groups, survey, traceability control mechanisms[8], case studies, modelling, simulation, and choice of architecture (Figure 5). Many of these studies combine several methods to study a specific perspective of traceability.

---

[8] Traceability control mechanisms are defined as *'…methods and instruments used for authentication and testing that what we receive is what the documentation says '* (TraceFood, 2011).

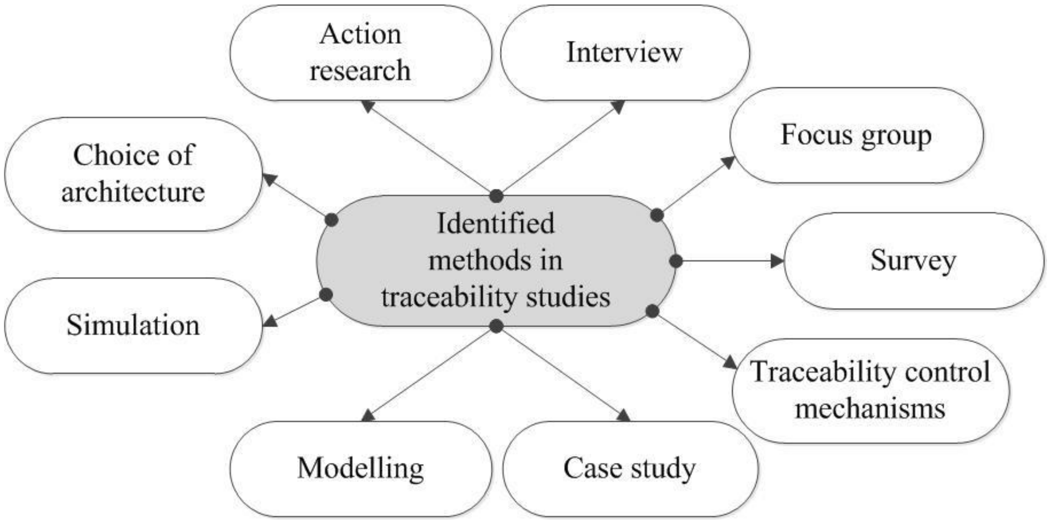


Figure 5 Identified methods for measuring food traceability.

Previous studies have shown that information about seafood products and production processes can be lost internally within companies, as well as between companies in supply chains (Pálsson et al. 2000; Frederiksen and Bremner 2001; Frederiksen 2002; Bertolini et al. 2006; Karlsen and Senneset 2006; Randrup et al. 2008). Challenges associated with achieving traceability of fish or any food are related to the prevention of information-loss with regards to the mixing and splitting of resources during the production processes.

Regattieri et al. (2007) point out the dearth of systematic and operative studies with relevance for the industry. According to Frederiksen (2002), more detailed studies of each step of the supply chains are needed to better document each process. Such studies are important to improve the traceability of seafood. According to Riden and Bollen (2007), there is a need to study different granularity levels to identify the potential of increased precision in traceability. They assumed that this has not been studied in detail due to lack of framework, concept, and terminology.

The identified empirical studies into traceability implementation are presented in Table 6. Here, experiences from other industries are included because of few relevant empirical findings of traceability implementation in the seafood industry. The majority of these studies had focused on traceability implementation using IT without including the company practices and procedures. The most relevant findings for the purpose of this thesis are presented by Sohal (1997), Frederiksen (2002) and Senneset et al. (2007). Sohal identified six critical factors for developing and implementing traceability in an automobile manufacturer, Frederiksen developed and validated a traceability system in a fresh fish supply chain, and Senneset et al. pointed out eight essential criteria for the implementation of electronic chain traceability in a supply chain for seafood (hereafter called critical criteria), in addition to describing three different architectures[9] for information exchange in supply chains. According to Sohal (1997), people are central during these types of implementation processes.

[9] 1) Point-to-point connections, 2) the use of external database, and 3) a net-centric service. See Senneset et al. (2007) for more information.

Table 6 Identified empirical studies into traceability implementation.

| Industry | Focus |
|---|---|
| **Food** | |
| Cheese (Regattieri et al. 2007) | Integration of barcodes and RFID tag* technology |
| Pig (Hernández-Jover et al. 2009) | Evaluation of implementation of traceability and food safety requirements |
| Fresh vegetables (Bevilacqua et al. 2009) | Reengineering of a supply chain and a traceability system |
| Pig (Madec et al. 2001) | Electronic identification and data recording |
| **Seafood** | |
| Fresh fish (Frederiksen et al. 2002) | Info-fish. Development and validation of Internet-based traceability |
| Albacore tuna (Thompson 2005) | Design and development of an onboard electronic traceability system |
| Farmed salmon (Senneset et al. 2007) | Challenges regarding implementation of electronic chain traceability |
| Fresh fish (Abad et al. 2009) | RFID tag* for real-time traceability and cold chain monitoring |
| Shrimp (Huang and Yang 2009) | Integration of RFID tag* and quick-response code-based system for in-house management |
| **Other industries** | |
| Automotive (Sohal 1997) | Implementation problems and benefits in a automobile manufacture |
| Variety of industry[10] (Billo and Bidanda 1998) | Structured approach for designing and implementing traceability system |

* Radio frequency identification tag

[10] Such as ammunition production, vehicle overhaul, metal fabrication, automotive industry and health care.

There is a lack of empirical documentation as to the importance of people in the implementation of traceability. Few articles were identified, documenting challenges associated with practices and procedures and the importance of the human factor during the implementation of traceability. No articles were found that study the effect randomness of the fish supply has on the ability to trace seafood (such as wild-caught fish). There is a lack of empirical studies of granularity and its effect of traceability in seafood supply chains. In addition, very few publications focus on chain traceability in seafood supply chains in general.

In this thesis, I have chosen to use the TraceFood framework and the TraceFish standards,[11] because it is presumed to be most relevant literature contribution for the purposes of this thesis. The TraceFood framework includes basic principles of traceability and guidelines for good traceability practices.[12]

[11] Currently, efforts are made to create international standards for seafood products based on the Tracefish standards. The names of these standards are ISO/DIS 12875 and ISO/DIS 12877. See http://www.nofima.no/marked/en/prosjekter/2536779084257644110 for more information.

[12] These guidelines include implementation steps, stakeholder analyses, generic information models, communication modes, etc.

# 5 Research strategy

In this chapter, the design of the research setting is described to give an overview of how this study was carried out. Then, claims are explained to describe how the seafood supply chains were chosen and which methods were used to collect empirical data.

## 5.1 Research design

Figure 6 describes the design of the study. First, CTP identification was carried out in three case studies (papers I-III), then, critical points during a traceability implementation were identified in one of these supply chains (paper III), and finally, the identification of different granularity levels of traceable units were examined (paper IV).

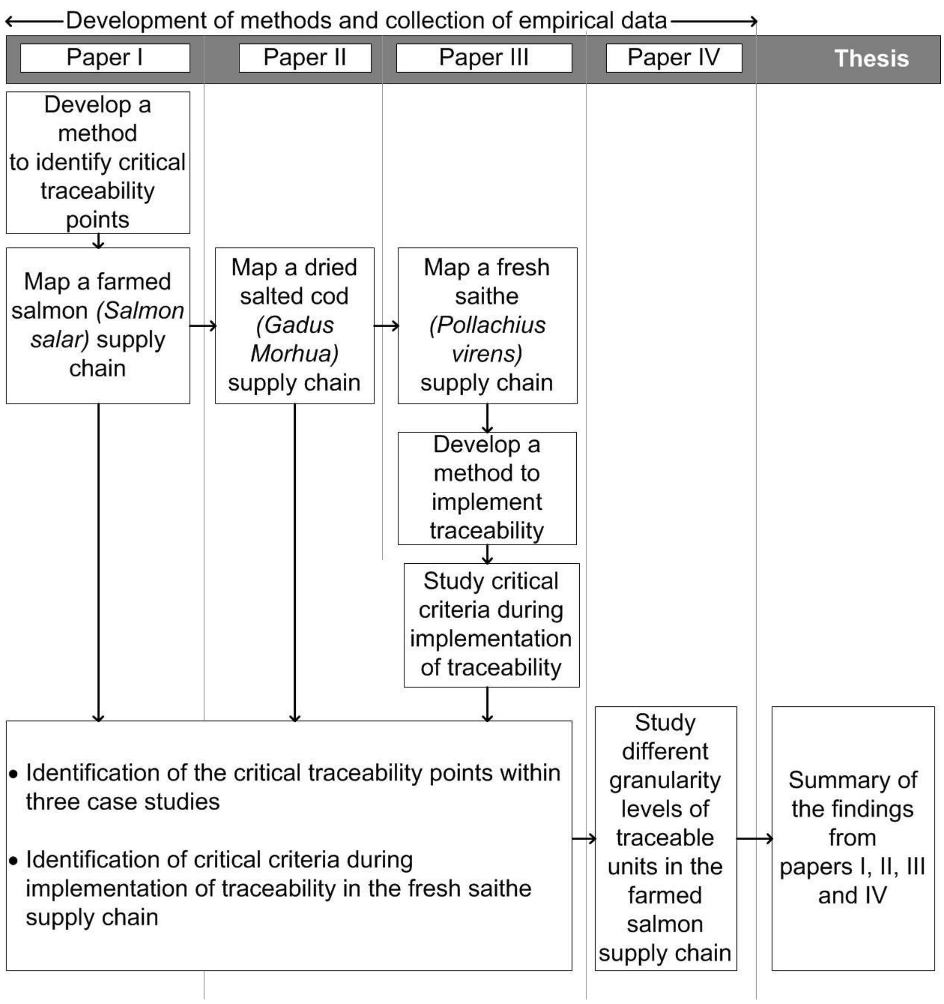


Figure 6 The design of the study.

## 5.2 The research setting

The Norwegian fishery industry was chosen for this thesis because of increased demands for seafood product documentation, and the literature review concluded that further studies were needed. In 2008, the Norwegian seafood industry comprised 6 798 fishing vessels, 503 processing companies, and 1 267 grow-out licences in aquaculture (NSEC 2008). The export value of seafood from Norway was NOK 39.1 billion. The Norwegian fishery industry can be divided into two production concepts: production of farmed species (hereafter called aquaculture concept) and wild-caught fish (hereafter called capture-based concept). The aquaculture concept is characterized by regular deliveries of raw materials with similar product properties (e.g. quality, fish size, and species), whereas the capture-based concept is faced with challenges related to deliveries where the quantity of fish can vary greatly, as does fish size, and species.

### 5.2.1 Paper I

The first step in this research was to identify CTPs in a farmed salmon *(Salmon salar)* supply chain. A fish feed factory (FeedCo), three suppliers of ingredients for fish feed (IngredCo), and a sea-based salmon farm (SalmCo) were included in paper I. These companies had a supplier-customer relationship, and FeedCo and SalmCo were vertically integrated. The starting point in the supply chain was the delivery of ingredients from IngredCo, and the end point was the delivery of farmed salmon ready for slaughter (semi-finished product) from SalmCo. Input factors other than fish feed and juveniles were not included at SalmCo because of the need to narrow the focus of paper I.

Farmed salmon was chosen as a case study for paper I, because this seafood product is an important product in Norwegian aquaculture. This specific supply chain was studied because the owner of FeedCo and SalmCo was in need of more detailed documentation of the ingredients, the fish feed and the farmed salmon. They wanted to use this information to improve their internal control, and to meet increased demands for documentation of farmed salmon coming from customers and the Norwegian government. They were particularly interested in documenting the catch area of the wild-caught fish used to produce fishmeal and fish oil to avoid high levels of dioxin in the farmed salmon. In addition, better analyses of the ingredients (e.g. testing for salmonella) could prevent contamination in the production of fish feed. Better documentation of the raw materials used in the fish feed production was also interesting, as this could be used to identify the affected silo in the event of contamination, and to identify the supplier responsible. Increased documentation can also be used to document procedures at the well-boat to prevent contamination there.

A well-proven method to identify CTPs did not exist when the study in paper I was carried out. Consequently, methods to identify CTPs were developed. Several studies on materials management have used quantitative research methods (Ellram 1996), however these methods are not suited for obtaining in-depth data about a research question. Ellram (1996) recommends using qualitative methods to gain more knowledge about a phenomenon. The qualitative methods direct observation, structured interview, and document analysis were used in paper I, because it was assumed to yield in-depth data, fit to answer one of the sub-tasks in this thesis. These methods were based on the following literature: Pálsson et al. (2000), Frederiksen and Bremner (2001), Pugh (1973), Kim et al. (1995), Moe (1998), and the TraceFish standard for farmed fish distribution chains (CEN 2003a). Another supply chain was studied in paper II to investigate whether similar findings occur in another case study.

### 5.2.2 Paper II

The second step was to identify CTPs in a dried salted cod *(Gadus morhua)* supply chain. A wet salted fish producer (WetProd) and a dried salted fish producer (DriedProd) were included in paper II. These companies did not have a supplier-customer relationship. An attempt was made to carry out a process mapping to identify CTPs in two companies with a supplier-customer relationship without success. The starting point was reception of the wild-caught fish and salt at WetProd and the end point was the delivery of pallets of dried salted cod from DriedProd.

Dried salted cod was chosen as a case study in paper II, because this seafood product is an important product in the Norwegian capture-based industry, and this industry meets increased demands of documentation of this product, especially as required by law. EU illegal, unregulated, and uncontrolled (IUU) regulations demand documentation of the origin of all wild-caught fish exported from third countries, included Norway, to the EU by way of a document called a catch certificate (EC-1005/2008 2008). This requirement is an attempt to prevent IUU-fishing. This means that companies must stay in control of the splitting and mixing of fish during production process in order to issue the necessary documentation. Documenting the origin of the wild-caught fish can be challenging, because of all the sorting and resorting of the fish during production. Little research has been carried out on the effects of this catch certificate on the Norwegian fishery industry.

The methods used for identifying CTPs in paper I turned out to be quite time-consuming to carry out, and these methods are not easily transferable to another case study because they were designed to study a specific case. A general method of analyzing the flow of material and information, as well as information loss in food supply chains, was developed by Olsen and Aschan (2010). This method was used in paper II, as well as in the study of several other food supply chains. It is thus assumed to be a legitimate method for identifying information lost within and between companies.

The results from papers I and II showed that information was lost in the two seafood supply chains studied. To be able to trace a seafood product, it is necessary to carry out recordings of the relationships between the traceable units and unique identification of the traceable units at CTPs to prevent information loss. The experiences gained from papers I and II were used to design a method for implementing seafood traceability, which led us to paper III.

### 5.2.3 Paper III

The third step in this research was to implement traceability in a fresh saithe *(Pollachius virens)* supply chain. A whole supply chain was chosen, and the companies in the chain had a supplier-customer relationship. Fishing vessels (FishVes), a landing and filleting company (LandCo), a packing and distributing company (DistriCo), and a supermarket (SuperMa) with a manned fish and meat counter were included in paper III. In addition, a sales organization (SalOrg) was involved. SalOrg was responsible for organizing the trade between the fisherman and LandCo, which was documented by a document called landing note. The landing note was the starting point in paper III, because this document contained relevant information about the origin of the wild-caught fish (catch area, catch data, gear type, etc.), and the end point was the consumer packaging at SuperMa.

The fresh saithe supply chain was chosen as a case in paper III, because SuperMa wanted more information about the fish, and to the implementation of traceability for this seafood product was presumed to be relatively easy, due to limited mixing and splitting of fish during the production process in comparison to other seafood products (e.g. dried salted cod).

A scientific method for the implementation of electronic chain traceability of seafood has not been identified. Consequently, a method for the implementation of traceability based on the TraceFish standard for captured fish distribution chains (CEN 2003b) and the TraceFood framework (2011) was developed (Figure 7).

Action research was chosen as the approach to this case, because it was assumed to give the most information during an implementation process of seafood traceability. This process had four different phases: 1) mapping phase, 2) planning phase, 3) implementation phase, and 4) analysis phase.

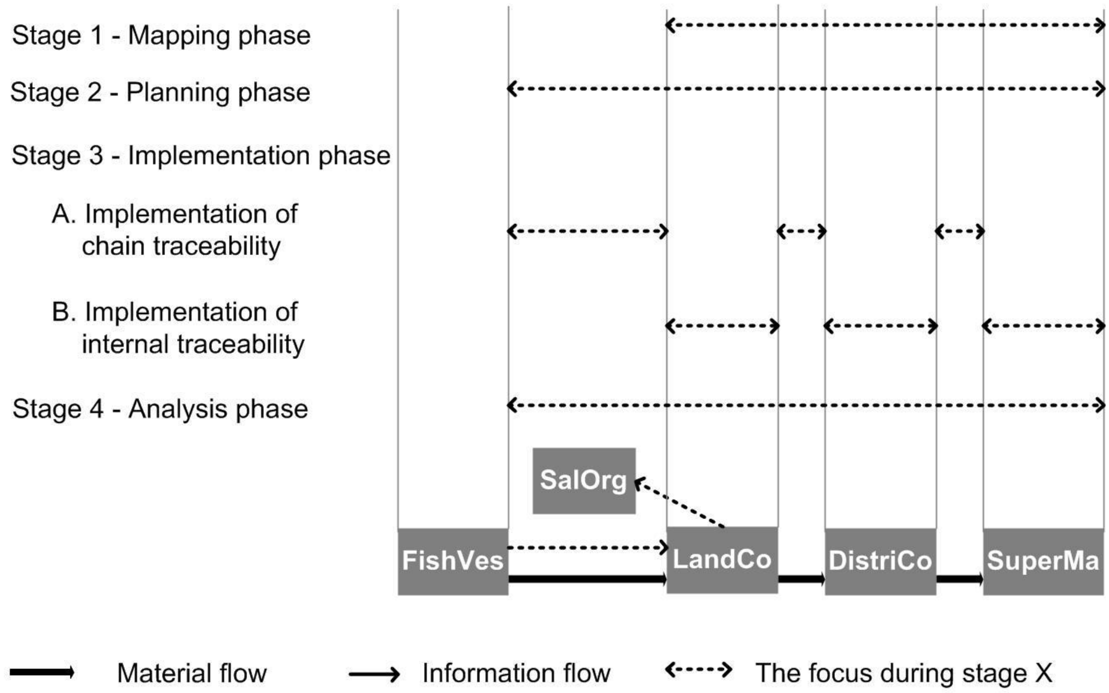


Figure 7 Method for the implementation of traceability in a fresh saithe supply chain (paper III).

CTP identification in this supply chain was carried out in the mapping phase, where a combination of the two methods described in paper I and by Olsen & Aschan (2010) was used. Paper I describes the use of interviews, observation, and document analysis in a specific case study. Olsen & Aschan (2010) designed a general method to analyze the flow of materials and information in food supply chains with a special focus on the structured interview. In addition, the software systems used by LandCo, DistriCo and SuperMa were identified in collaboration with the companies involved.

The findings from the mapping phase were used in the planning phase, which included a plan for unique identification of traceable units and companies, adjustments to production practices and procedures, and re-engineering of the IT-systems. The identification of CTPs was used to implement traceability, with the aim to carry out certain recordings at these CTPs to prevent information loss. A net-centric service was chosen as the architecture for paper III, because this architecture made it possible to exchange information between the companies in the studied supply chain by linking their software systems, while each company still retained full control of their own information. Consequently, this architecture was assumed to be the best choice when implementing electronic chain traceability in a whole supply chain.

The implementation plan was used in the implementation phase. Several parallel activities were carried out during this phase, which can be divided into two categories: 1) implementing chain traceability: installing traceability databases for uploading, handling, requesting, and illustrating information at SalOrg, LandCo, DistriCo, and SuperMa, and applying the net-centric solution; and 2) implementing internal traceability: developing and testing practical solutions to prevent information lost at LandCo, DistriCo and SuperMa. In addition, the companies involved and their IT-suppliers discussed different solutions for exchanging information between the software systems within the companies.

Critical criteria for implementing traceability were identified during this implementation. A critical criterion was identified if there was a mismatch between the implementation plan and real implementation activities, and a willingness to find an optimal solution to trace the fish was not present. A critical criterion could be a barrier to success for the implementation of traceability in the whole supply chain or it could slow down the implementation process. The implementation of electronic chain traceability in paper III did not succeed 100 percent. It was clear that a company would not be motivated to carry out an implementation process if they could not recognize the benefits of traceability.

Based on the experiences gained from paper III, it was clear that knowledge of costs and benefits associated with traceability must be increased, as this can help companies determine optimal granularity levels for the traceable units before the implementation process begins: what can the traceable information be used for, and what information is relevant for whom? No published research papers have been found discussing different granularity levels of traceable units in seafood supply chains. This is thus studied in paper IV.

### 5.2.4 Paper IV

In paper IV, different granularity levels of fish feed and farmed salmon were studied using empirical data from paper I. This supply chain was chosen, because relevant data to calculate the different sizes of traceable units at FeedCo and SalmCo had already been collected (such as production capacity at FeedCo and the total number of received juveniles at SalmCo).

The definition of granularity applied reflects different levels of traceable units. The TU and LU at FeedCo and SalmCo were determined by applying the definitions of traceable units from the TraceFood framework (2011). Different batch levels were identified at FeedCo and SalmCo. The coarsest granularity level of fish feed batches studied was ‘one year’, because it was assumed that a coarser granularity level would not be relevant for FeedCo with respect to traceability.

# 6 Research and findings

This chapter presents the main findings of this thesis, and is divided into three sections: 1) identification of CTPs in the studied seafood supply chains, 2) identification of critical criteria during the implementation of traceability, and 3) different granularity levels of traceable units. These results provide an empirical basis on which to draw conclusions in regards to the hypothesis of this thesis. A discussion of the presented findings aims to summarize and tie together the results from papers I-IV, and to discuss the effect of granularity on the implementation of traceability in seafood supply chains.

## 6.1 Critical traceability points

21 CTPs were identified within and between IngredCo, FeedCo and SalmCo (Figure 8). The most important findings with regards to traceability were insufficient recordings of the relationships between the traceable units (CTPs 1-18) and the lack of unique identifiers for the traceable units (CTPs 19-21). These identifiers are vital for achieving traceability (Kim et al. 1995; Moe 1998; CEN 2003a; Denton 2003). The identified CTPs can be divided into two types: 1) recordings of the relationships between traceable units (hereafter called CTP-relation), and 2) unique identification of the traceable units (hereafter called CTP-ID). An interesting question in this context is which types of CTPs would occur in another seafood supply chain.

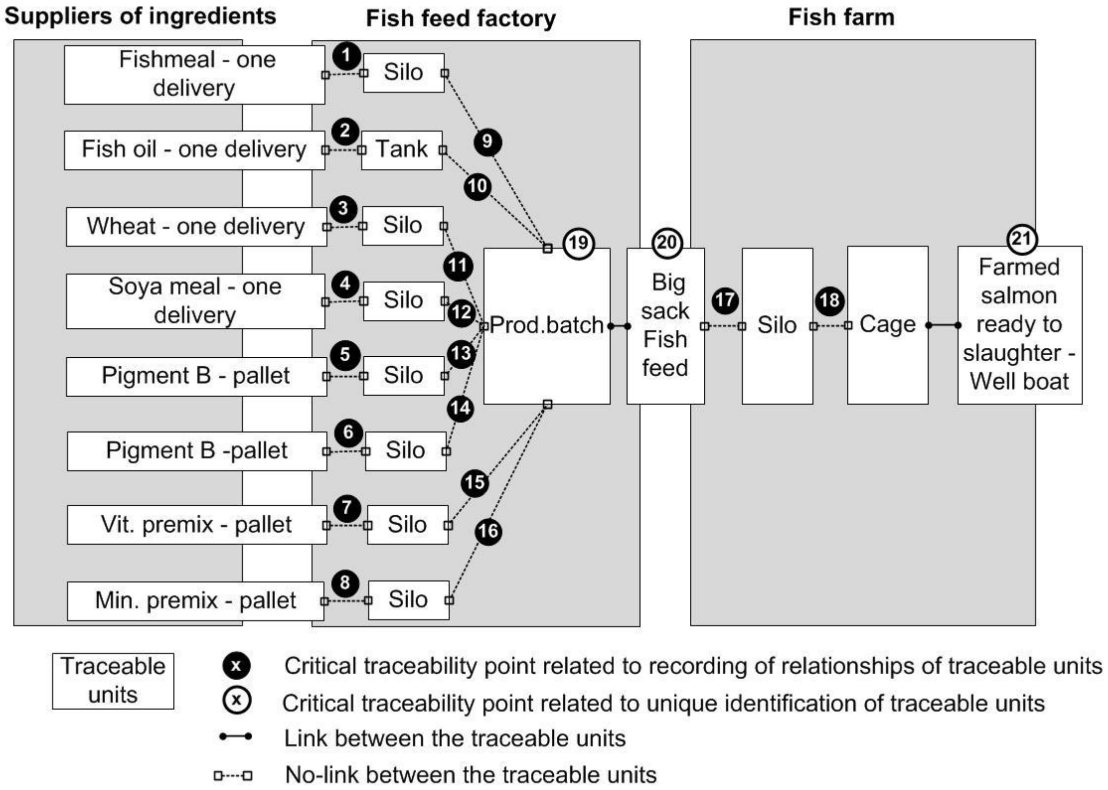


Figure 8 Critical traceability points in the farmed salmon *(Salmon salar)* supply chain studied (paper I).

15 CTPs were identified within and between the fish vessels, supplier of salt, WetProd, and DriedProd (Figure 9). The findings with regards to traceability were insufficient recordings of the relationships between the traceable units (CTP-relations 1-10) and lack of unique identifiers for the traceable units (CTP-IDs 11-15). As indicated, there are two types of CTPs identified in papers I and II.

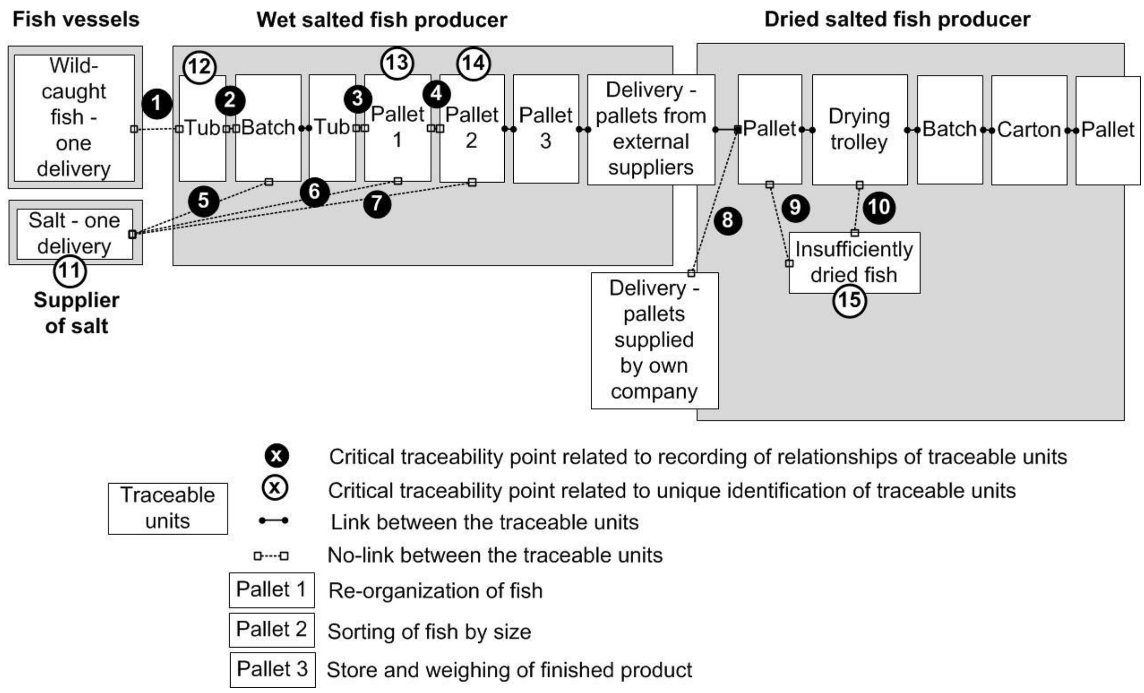


Figure 9 Critical traceability points in the dried salted cod *(Gadus morhua)* supply chain studied (paper II).

20 CTPs were identified within and between FishVes, suppliers of ice, boxes, plastic and bags, LandCo, DistriCo, and SuperMa (Figure 10). The findings with regards to traceability were insufficient recordings of the relationships between the traceable units (CTP-relations 1-13) and the lack of unique identifiers for the traceable units (CTP-IDs 14-20).

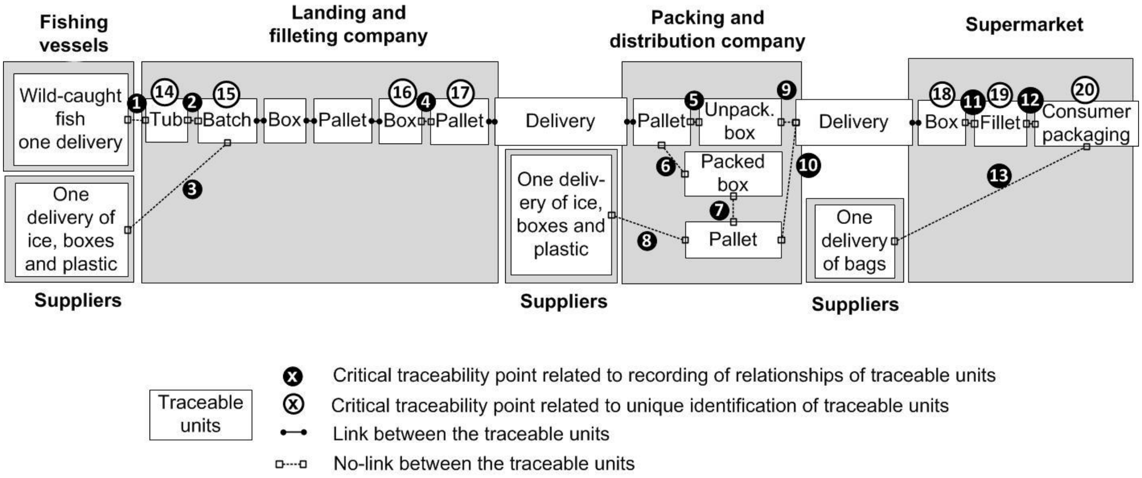


Figure 10 Critical traceability points in the fresh saithe *(Pollachius virens)* supply chain studied (paper III).

Previous studies have shown that information about food products can be lost (Pálsson et al. 2000; Frederiksen and Bremner 2001; Frederiksen 2002; Bertolini et al. 2006; Karlsen and Senneset 2006; Randrup et al. 2008), and that there is a lack of unique identification of traceable units and transformation recordings (Frosch et al. 2008; Olsen and Aschan 2010). Identical findings were documented in papers I, II, and III (Figures 8, 9 and 10).

The findings from papers I-III show that the number of CTP-relations is higher than that of CTP-IDs (Figure 11). FeedCo had the highest number of CTPs (18 CTPs in total). This is a result of their use of 8 different raw materials to produce fish feed, and not recorded the mixing and splitting of these input factors. WetProd also had a high number of CTPs (10 CTPs in total). This company had few input factors (wild-caught fish and salt); the high number of CTPs was caused by a production process where the wild-caught fish was split and mixed several times. SalmCo had the lowest numbers of CTPs.

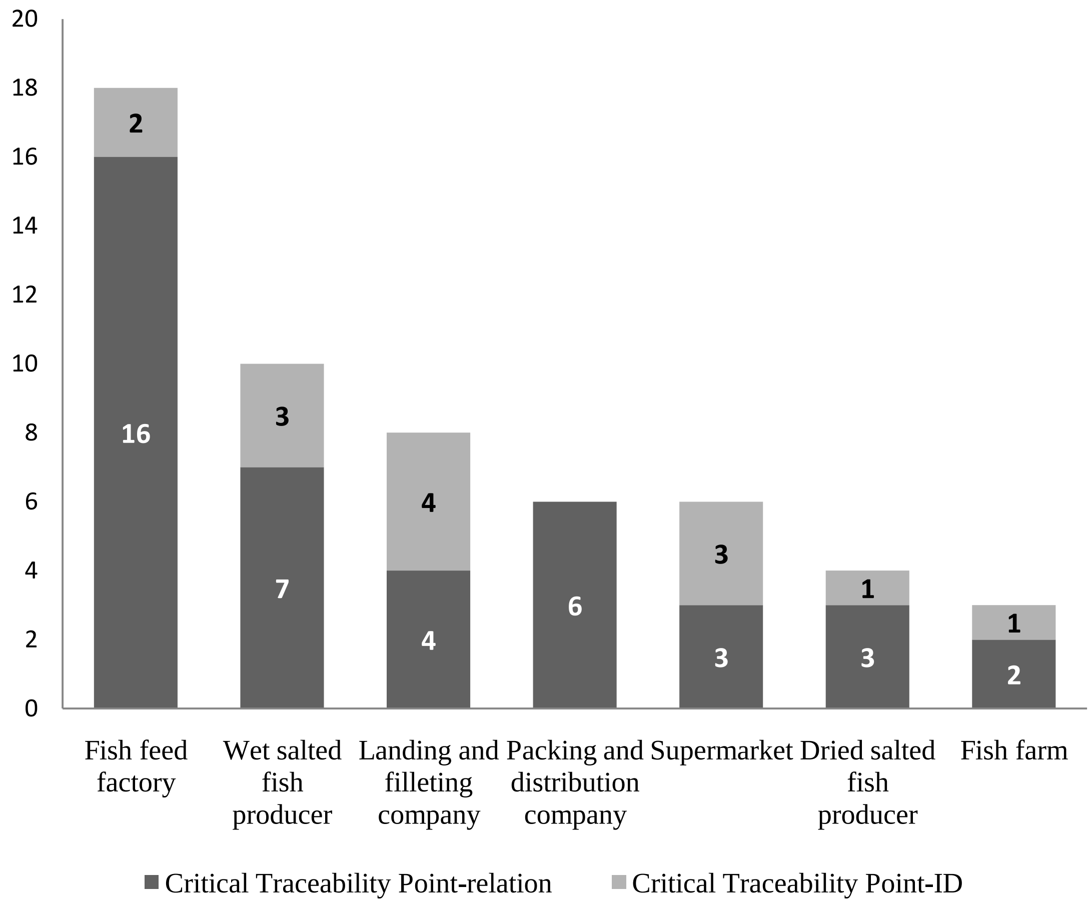


Figure 11 Numbers of identified critical traceability points in papers I-III.

Identifying CTP-relations and CTP-IDs is essential when implementing traceability in a seafood supply chain. This leads us to paper III, where the aim was to carry out necessary recordings at the CTPs to prevent information loss by completing an implementation of traceability in a seafood supply chain.

## 6.2 Critical criteria in traceability implementation

Paper III presents an implementation of electronic chain traceability in a fresh fish supply chain. Experience gained from this study showed that implementation is complex and involves many different aspects that affect each other.

According to Hobbs (2004), Moe (1998), and Regattieri et al. (2007) internal traceability is a necessary condition for achieving chain traceability. This study clearly demonstrated that internal traceability must be present before it is possible to achieve chain traceability. In addition, the development of optimal practical solutions to prevent information lost can be a challenge.

One finding was that regular access to wild-caught fish was a major hurdle for achieving chain traceability of fresh saithe in the long-run. Halfway through the study, LandCo withdrew from the project due to a lack of supply to wild-caught fish. The exchange of information between SalOrg and SuperMa thus became irrelevant, because one link in the studied supply chain was lost. Several attempts were made to replace LandCo without success. A motivated company that had a relationship with both SalOrg and DistriCo could not be found. Complete traceability was not possible in the studied supply chain. This is in line with the findings from the study carried out by Karlsen & Senneset (2006), illustrating that a supply chain is not stronger than the weakest link.

A number of critical success criteria were identified as a result of this implementation (Figure 12). The ability to identify benefits to be gained from implementation of electronic chain traceability was identified as one of these. If a company cannot identify any benefits in carrying out an implementation, the motivation will soon wane. This will affect the willingness to invest in any technology needed to achieve better documentation of produced products.

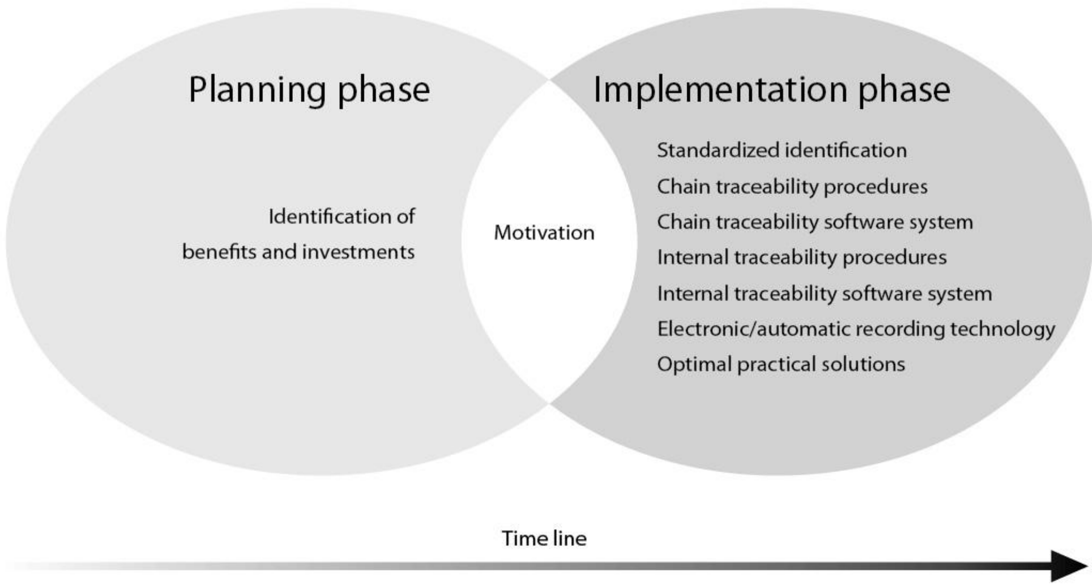


Figure 12 Summary of critical criteria in the planning and implementation phases of traceability, as identified by Senneset et al. (2007) and in paper III. Illustrator: Oddvar Dahl, Nofima.

The willingness of the companies to co-operate and their motivation to implement traceability had enormous impact on the implementation process. The motivation varied significantly between the different links of the chain. Motivation at SuperMa was high. LandCo and DistriCo had the lowest level of motivation, and they had not identified the benefits that could be derived from a traceability solution or even partly identified these benefits, which affected their willingness to invest in internal traceability systems and allocate working hours to the project. SalOrg was motivated by new legislation, which required better documentation of the fish (i.e. catch certificate). SuperMa was motivated by a desire to be able to trace fresh fish, because they wanted more information about this product (e.g. catch area, catch date, processing method, gear type). SuperMa also pointed out that better documentation throughout the cooling chain would help the parties involved identify who was responsible if the fresh fish was of poor quality. Efficient information exchanges could also be used to achieve shorter storage times at LandCo and DistriCo, which would result in a longer shelf-life of the fresh fish at SuperMa. SuperMa was an important customer of DistriCo's, so the motivation for DistriCo was mainly related to satisfying customer needs. LandCo was unsure of the benefits they could derive from a traceability solution, and DistriCo did not put pressure on LandCo for improved documentation, so motivation for LandCo to implement traceability was rather low.

Communicating and understanding the benefits of a traceability system is important for successful implementation of traceability (Sohal 1997). Many authors have identified several benefits of traceable products (Töyrylä 1999; Opara and Mazaud 2001; Frederiksen 2002; Hobbs 2004; Wang and Li 2006; Chryssochoidis et al. 2009; Mai et al. 2010; Mai 2010). Still, there are companies that have not yet recognized the benefits of using traceability (Wang and Li 2006).

Paper III shows that SuperMa and DistriCo find higher value in traceability than LandCo. Mai et al. (2010) reported similar findings in a processing company and a trading company. The benefits of traceability only became apparent once product information and process information were linked to the traceable units as described in Chapter 4. Internal traceability was partly present in paper III, and this is a criterion for being able to reap the benefits of a traceability solution, because relevant information is recorded within the companies.

Implementing an efficient traceability solution may require big investments (Sohal, 1997). There are different types of costs associated with traceability implementation (e.g. administrative, material, operational, equipment/technology, initial and ongoing costs) and these investments are highly variable (Can-Trace 2007; Mai et al. 2010). One finding in paper III was that the investments necessary for successful traceability are dependent on several factors. These investments were affected by which software solutions and electronic recording equipment were available in the company. Other factors affecting investments were the degree of integration required in the software systems for successful internal traceability (simple or full integration), investments in new IT-solutions, and necessary re-engineering of current IT-systems. In paper III, the costs of increased traceability seemed to be higher at LandCo than at SuperMa and DistriCo. Another finding in paper III was that the companies would not make the investments necessary for better product documentation if they could not identify the benefits they stood to gain by making these investments. This is in agreement with Mai (2010), who suggested the financial burden of implementing traceability is borne by the processing firms, while the firms in the supply chain closer to the end-consumer achieve gains.

In paper III it became clear that the motivations behind implementing a traceability solution may vary, and identifying the costs and benefits of traceability is critical for the implementation. Consequently, more studies including cost-benefit analyses are needed to help companies determine the optimal granularity levels of traceable units, which leads us to paper IV.

## 6.3 Granularity level of traceable units

In paper IV, different levels of traceable units were studied in a farmed salmon supply chain. The TU for fish feed was each big sack, and the TU for farmed salmon was each delivery to slaughter plant. There were no LUs, because fish feed and farmed salmon TUs were not packed together during transportation.

There are different possibilities with regard to granularity levels for batches of fish feed and farmed salmon. Moe (1998) pointed out that information may be more detailed within a company than in a supply chain, because the use of information for the purposes of quality control and process optimization within a company would require more detail than information exchanges with customers (product name, origin).

The coarsest granularity level for fish feed was ‘one year’ of fish feed production (Figure 13). This unit yields big batch sizes and the degree of information gained is very low. The information is irrelevant for optimization purposes, which requires smaller units (Moe 1998). It seems obvious that a batch size of ‘one year’ is too coarse in terms of optimization and improving process control in fish feed production. A batch size of ‘one month’ could be a possible alternative for FeedCo. Identification of the application of information using such batch size should be tested at FeedCo to identify potential benefits and costs.

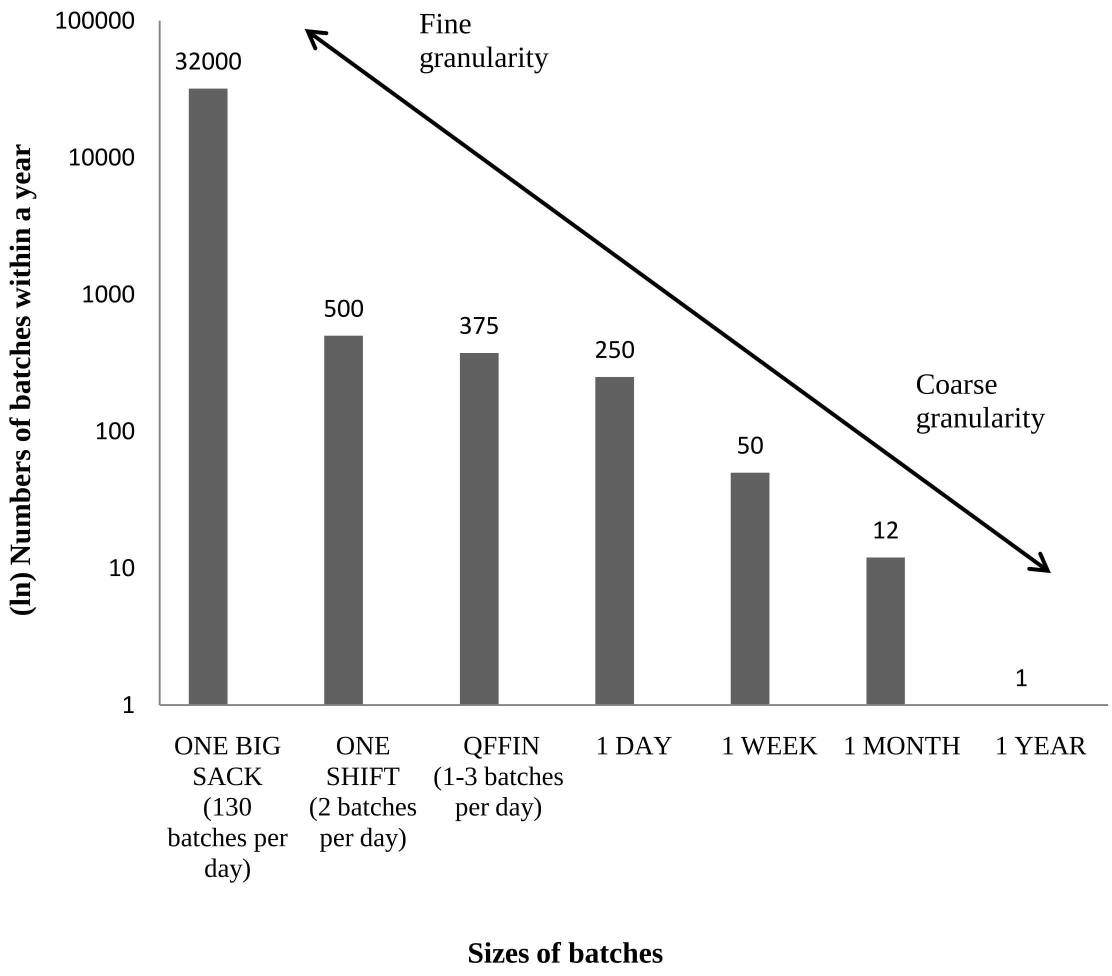


Figure 13 Granularity of fish feed (paper III).

QFFIN - Quantity of produced Fish Feed related to an Internal Number.

If the same discussion is applied to farmed salmon, some interesting findings emerge. When the traceable units have equal properties, it would be beneficial to have control over the production processes (Senneset et al. 2007). A batch size for farmed salmon that has gone through the same processes, and that has the highest number of identical properties, would be ‘each cage’ (Figure 14). Another batch size alternative for farmed salmon would be ‘all cages’. SalmCo had 10 cages, and the farmed salmon in the different cages did not go through the same processes. For example, the farmed salmon in Cage 1 could have been treated for lice and were fed fish feed type ‘x’, whereas the farmed salmon in Cage 2 were not treated for lice and were fed fish feed type ‘z’. A batch size of ‘all cages’ would yield less detailed information and less control over the production process than a batch size of ‘each cage’.

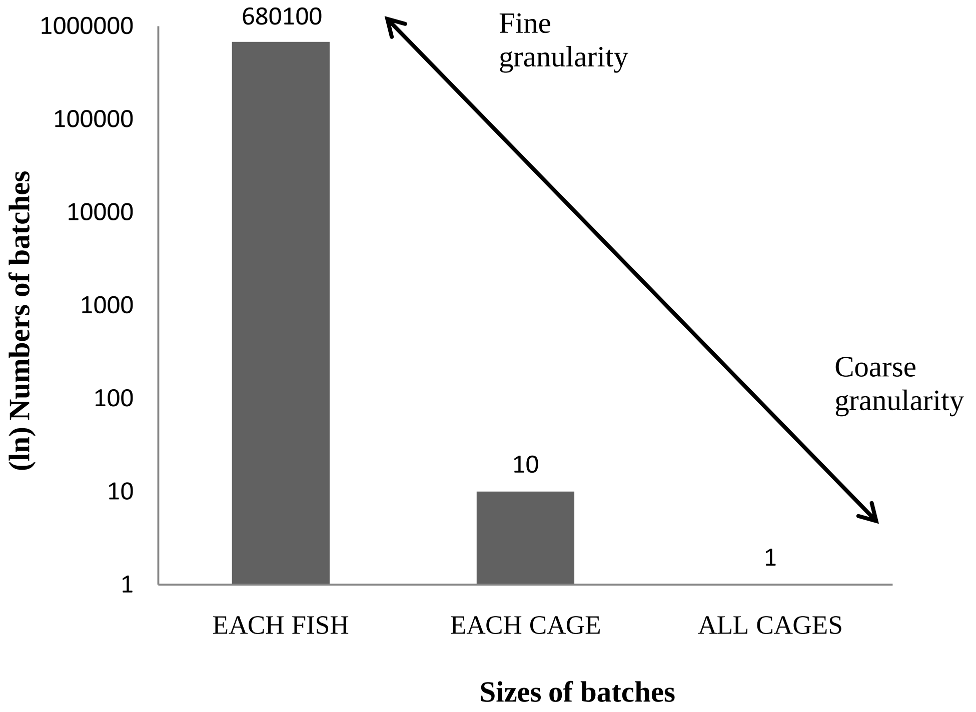


Figure 14 Granularity of farmed salmon (paper III).

An interesting question is whether a batch size of ‘each fish’ would enhance production control at SalmCo more than would a batch size of ‘each cage’? Håstein et al. (2001) claim that labelling each individual fish would fulfil future demands for traceability. According to Bollen et al. (2007), it is possible to add more information to the units by adopting finer unit granularities. The questions here are whether being able to trace each individual fish will provide more information about the fish and what is the benefits of using this granularity level of farmed salmon?

The farmed salmon in one cage at SalmCo (approx. 70,000) all went through the same processes. The salmon all got identical medication, feed, etc. The batch sizes of ‘each cage’ and ‘each fish’ at the same location share the same properties. Provided the salmon from one cage was not mixed with salmon from other cages, a batch size of ‘each fish’ would not yield any more information than a batch size of ‘each cage’ at

SalmCo. It is assumed that recorded information for each farmed salmon in previous links in the supply chain can be different (e.g. origin, parent fish). If this is the case, SalmCo can achieve better documentation of each farmed salmon by individual labelling. This will increase investments and require more working hours. SalmCo must identify the benefits and costs associated with new investments in order to be able to determine whether such labelling is beneficial, in addition to evaluate practical solutions to trace the fish.

Paper IV showed that granularity can have different levels, the granularity level will increase (finer granularity) with decreased batch sizes and increased number of the smallest batches necessary to make up the batch at a specific granularity level. FeedCo and SalmCo must identify the benefits and costs associated with new investments in order to be able to make a decision as to which granularity level to use. The key is to design a traceability system that offers the right degree of information at an acceptable cost (Cheng and Simmons 1994).

## 6.4 Discussion

Different granularity levels in seafood supply chains and its effect of traceability is discussed in the sections below with a broader perspective than in papers I-IV. The European Food Law is an example of a coarse granularity level of the units. This legislation requires one-up-one-down traceability (EC-178/02 2002): *'Food and feed business operators shall be able to identify any person from whom they have been supplied with a food, a feed, a food-producing animal, or any substance intended to be, or expected to be, incorporated into a food or feed'*. The companies in the Norwegian seafood industry fulfil this granularity level already, because all companies have control over the deliveries from/to their suppliers and customers for economic transactions. Thus there are no new investments for the companies using this granularity level.

The IUU regulation is an example of legislation that requires a finer granularity level of the traceable units than does the Food Law. All wild-caught fish imported to the EU from third countries must be documented by a catch certificate (EC-1005/2008 2008). Information contained in this document includes catch information, production, transportation, and importer declarations. This regulation affects all Norwegian seafood producers and exporters exporting wild-caught fish to the EU. The catch certificate from Norway is based on the Norwegian system of landing notes (CatchCertificate 2011). A central element in this regulation is that a catch certificate must be issued for each consignment of wild-caught fish to the EU where the catch information of this fish is included. If one consignment consists of several catches of wild-caught fish, the producer has to stay on top of the production process in order to be able to issue a catch certificate. The question here is which granularity level of the traceable units to use in order to satisfy the requirements of this legislation? The answer to this question is not straightforward, due to various production concepts and production practices in the Norwegian capture-based industry (e.g. fresh fish, wet salted fish, dried salted fish, and stock fish).

The dried salted fish production at DriedProd in paper II is an example of a fine granularity level for traceable units. They achieved internal traceability by documenting the splitting and mixing of fish during production by assigning internal numbers to the units. They believe that their ability to keep track of production routines has become an invaluable management tool. For example, they explained that the improved traceability system had enabled them to track the quality of a supplier's fish and allowed them to take immediate action when problems with quality were reported. They also reported that implementing internal traceability has led to greater efficiency in production.

Another example of fine granularity level is the approach used in paper III, where the goal was to trace the traceable units step by step through a whole supply chain. The application of information in one company can affect the granularity level in another company. This can be illustrated by two scenarios: Scenario 1) SuperMa wanted information about the catch area (e.g. the North-East Atlantic Ocean). LandCo did not need to carry out detailed recordings during production, because all the landed fish at LandCo was caught in this catch area. If DistriCo received fish from another catch area, they would have to keep this fish separate during packing. Scenario 2) SuperMa wanted information about the gear type (e.g. long-line); all fish caught with the same gear type must be kept separate during the production and packing processes at LandCo and DistriCo.

It is clear that how users apply the traceable information affects the granularity level needed. The Food Law requires a coast granularity level, which all Norwegian seafood producers fulfil. The companies can choose to use traceability to gain other benefits by implementing finer granularity levels for their traceable units, such as increased internal control or supply chain communication. The chosen granularity level will determine the complexity of the traceability system and affect the practical solutions and specification of the IT-systems in the implementation of traceability.

A summary of the identified drivers of traceability in the studied seafood supply chains is provided in Table 7. The theoretical contributions of the ten drivers of traceability in the food industry are used to systematize these findings. The identified drivers of traceability for the studied companies were legislation, food safety, quality, competitive advantages, chain communication, and production optimization (six of ten). The most important driver of traceability was production optimization (five companies), followed by competitive advantages and quality (four companies), legislation (three companies), and food safety and chain communication (two companies). Other studies have identified similar empirical findings for drivers of traceability in the food industry, see Appendix 2.

Table 7 Summary of the identified drivers of traceability in the studied supply chains.

| Drivers | Dried salted cod supply chain | | Fresh saithe supply chain | | | | Farmed salmon supply chain | |
|---|---|---|---|---|---|---|---|---|
| | Wet-Prod | Dried-Prod | Sal-Org | Land-Co | Distri-Co | Super-Ma | Feed-Co | Salm-Co |
| 1 | | | X | | | | X | X |
| 2 | | | * | | | | X | X |
| 3 | | X | * | X | X | X | | |
| 4 | | | * | | | | | |
| 5 | | | * | | | | | |
| 6 | | | * | | | | | |
| 7 | | | * | | X | X | X | X |
| 8 | | | * | | | | X | X |
| 9 | | | * | | | | | |
| 10 | | X | * | X | X | | X | X |

1 ) Legislation, 2) food safety, 3) quality, 4) sustainability, 5) welfare, 6) certification, 7) competitive advantages, 8) chain communication, 9) terrorist threats, and 10) production optimization. * Not relevant, because SalOrg was not a part of the material flow.

According to Mai et al. (2010), potential benefits to using traceability can be different in different links in a supply chain. FeedCo and SalmCo had the highest numbers of drivers for traceability: legislation, food safety, competitive advantages, chain communication, and production optimization (five of ten drivers of traceability). WetProd had no drivers of traceability.

A study carried out by Sparling et al. (2006) documented a difference between factors that motivated companies to use traceability before implementation and actually achieved benefits from using traceability after implementation. DriedProd had implemented traceability, while the other studied companies in this thesis had not or had only partly implemented traceability. The identified drivers for the studied companies would probably have changed after an implementation of traceability.

It is clear that the implementation of seafood traceability is affected by the granularity level of the traceable units, but how will the randomness of the fish supply affect traceability? The implementation of traceability at a fine level of granularity for wild-caught fish is probably more challenging than for farmed fish because of the differences between these two production concepts. In aquaculture, producers have much more control of the raw materials they receive; the fish size and quality of the farmed salmon is quite stable, and different species are not mixed together. This makes it easier to coordinate and plan the time of production of farmed salmon. The slaughter plant can coordinate with the fish farms when they have capacity to receive and produce the farmed salmon.

The capture-based concept has much less control over the quantity of wild-caught fish delivered, and the variation in fish size, quality, and number of species is great, especially in the Norwegian conventional fisheries.[13] In these fisheries the sizes of fishing vessels and gear types vary greatly, and the volume of wild-caught fish delivered from e.g. a vessel using Danish seine can be very big compared to a delivery from a smaller vessel using jig. LandCo received landings from the conventional fisheries ranging from 23 kg to 100.381 kg in 2007, for example, and WetProd received landings ranging from 9 kg to 28.586 kg. In the Norwegian pelagic fisheries, the landed quantities of fish from each fishing vessel are higher than in the conventional fisheries, the fish sizes are more regular, and the number of different fish species is low. LandCo received landings from the pelagic fisheries ranging from 12.054 kg to 698.142 kg in 2007. WetProd did not received landings from these fisheries in 2007. If a company wants to trace deliveries back to each fishing vessel, the volume is important, because separating smaller landings of wild-caught fish will affect the efficiency of production and practices. This illustrates how the context can impact implementation of traceability in seafood supply chains at different granularity levels.

[13] Fishing with the following gear types: gill-net, long-line, Danish seine, jig, fish traps, and pots.

For the capture-based supply chains, the number of batches within a year of the granularity levels varies from year to year due to the randomness of wild-caught fish deliveries. The landing information from WetProd and LandCo is presented in Figures 15 and 16. The landed North-East Arctic (NEA) cod at WetProd was caught with four different gear types: gill-net, jig, long-line, and Danish seine. The most widely used gear type in 2007 was the gill-net. Most of the catch volume of NEA-cod was caught between January and March.

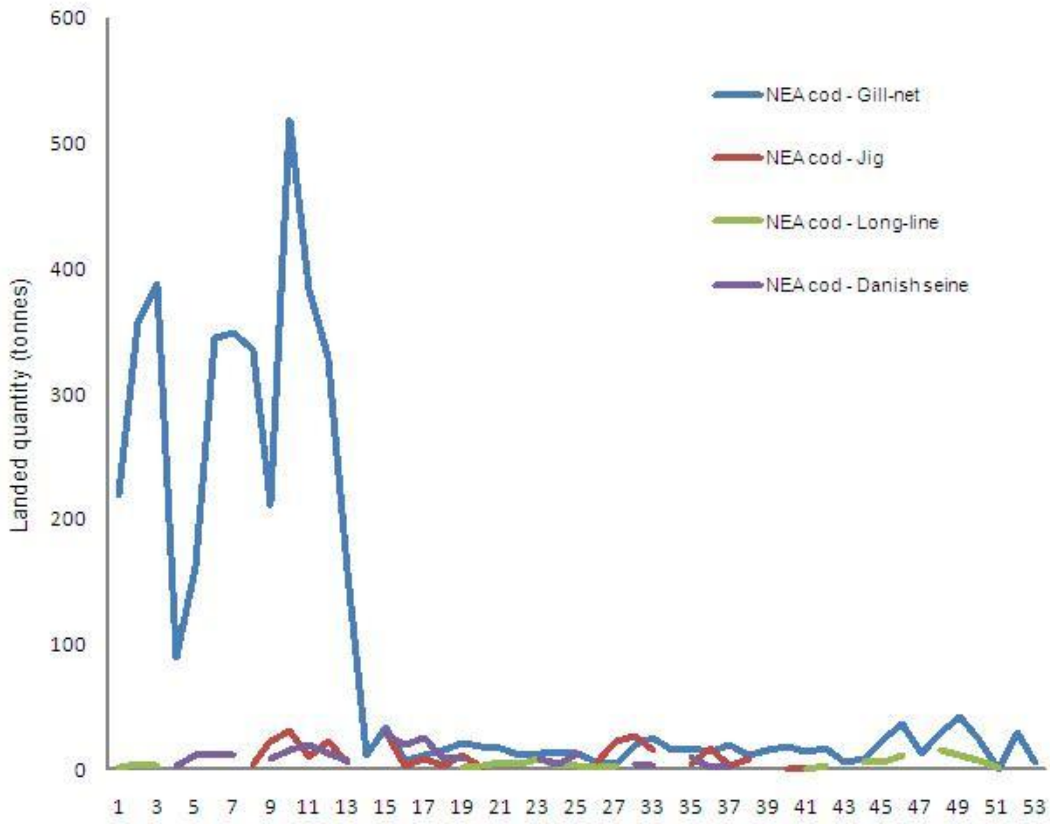


Figure 15 The landing information of the North-East Arctic (NEA) cod at the wet salted fish producer in 2007. Source: The Norwegian Directorate of Fisheries.

The landed saithe at LandCo was caught with five different gear types: gill-net, jig, long-line, purse seine, and trawl. The most important gear types in 2007 were the gill-net and long-line. The catch volume of saithe was relatively stable during 2007, with the highest landing volumes between February and April. The landed volume of saithe at LandCo was much lower than the landed quantity of NEA-cod to WetProd.

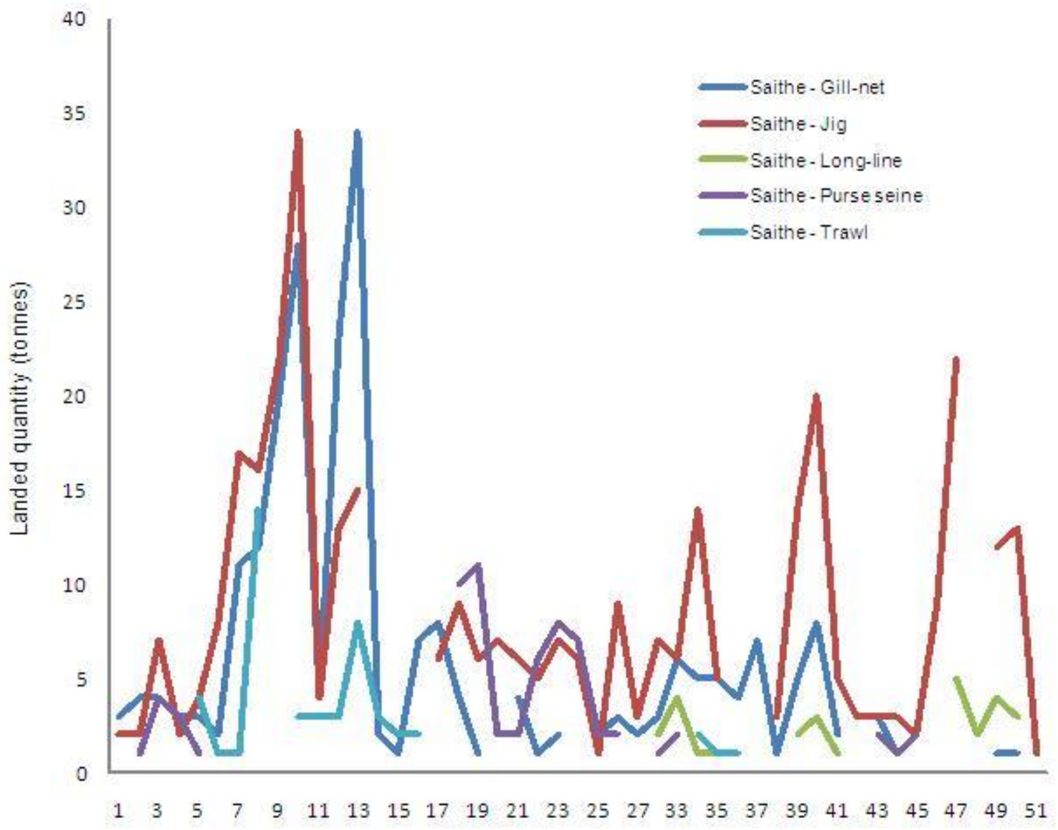


Figure 16 The landing information of saithe at the landing and filleting company in 2007. Source: The Norwegian Directorate of Fisheries.

For both WetProd and LandCo, landing frequencies vary across a year. For example, if the batch size is defined as a one-month production, a January batch will be big compared to a June batch. At WetProd, large quantities of wild-caught fish was landed in a short period of time, making it difficult to trace at a fine granularity level, such as each fishing vessel or each gear type. Mixing several catches together is a practical adjustment for achieving an efficient production, and according to WetProd, this was inevitable, because separating all the small catches would be very time-consuming (paper II). A fine granularity level can present big challenges due to the randomness of landing rates for wild-caught fish. This will also affect the other companies in the specific supply chains. Consequently, an important factor to include in a discussion of optimal granularity level of batches in capture-based industry is finding practical solutions for traceability.

# 7 Concluding remarks

This study aimed to investigate granularity and its importance for traceability in seafood supply chains. One finding in this thesis is that user application of traceable information affects how fine or coarse the granularity level has to be. The European Food Law requires a coast granularity level all Norwegian seafood producers already satisfy. Companies can choose to use traceability to gain other benefits by implementing finer granularity levels for their traceable units.

A traceability system can be simple (one-up-one-down traceability); costs would be low and implementation would be easy. Traceability can also be complex. Fine granularity levels will increase the complexity of the traceability system, and will entail higher costs, because there is more information to record, a higher number of transactions, and new systems and procedures would possibly have to be introduced (Golan et al. 2004).

There are different costs and benefits to using traceability, and companies apply traceable information differently. Any implementation of traceability in seafood supply chains should thus include an open discussion of the distribution of costs and benefits between companies in the chain (Mai et al. 2010). An evaluation of costs and benefits using traceability will determine the complexity of the traceability system and can affect practical solutions and IT-system specifications in the implementation process. Granularity thus plays a key role in the implementation of seafood traceability. Another important factor to consider when discussing granularity level is optimization of the practical solutions used to trace the seafood products. This is especially important for wild-caught fish because of the significant variations in landing frequencies throughout the year, as well as great variations in landed quantity from each fishing vessel, fish size, and species of fish.

All traceability systems should be designed based on the needs of its users. It is pointless to build a great palace for a single family, where only 10 percent of the area is used daily; a better solution would be to build a house suited to the needs of the family, where the whole house is used every day. The key is to identify the optimal granularity level for the traceable units. Optimal granularity offers sufficiently detailed information in a traceability system at acceptable costs.

## 7.1 Implications

The findings in this thesis have theoretical and methodological, as well as practical implications. In the below sections, these implications are discussed in more detail.

### 7.1.1 Theoretical implications

The literature review in this thesis has shown that no common understanding of the definitions and principles of traceability exist, nor is there a sound theoretical platform with respect to granularity and implementation of traceability. Important factor to consider in the implementation of traceability is the human factor, but very few articles with this perspective exist. The literature illustrates that granularity influences the precision of traceability, but this has not been studied in detail due to a lack of framework, concepts, and terminology. Based on the review, it is clear that traceability is an interdisciplinary research field, and it spans the natural sciences as well as the social sciences.

The results from this study show that the definition of granularity chosen was relevant and useful in terms of studying the granularity level of traceable units in seafood supply chains. In addition, the findings indicate that granularity is an important factor in theory development in the traceability field. These findings confirmed that identifying costs and benefits and the role of people are critical success factors in the implementation of traceability. This research has also demonstrated that context, such as aquaculture concept vs. capture-based concept and conventional fisheries vs. pelagic fisheries, is important for the implementation of traceability.

In addition, these findings have generated new knowledge about granularity and its importance for traceability. The implementation of traceability is affected by the granularity level. At a coarse granularity level, for instance, basic traceability requirements in the European Food Law, entail low costs, but also low benefits. The optimal granularity level for seafood companies is the level where the benefits gained exceed the costs incurred. The findings from this research showed that the implementation process was negatively affected when the costs exceeded the potential benefits of using traceability. Further theoretical developments on how granularity impacts costs and benefits in the implementation of traceability are needed. This is important to better understand why implementations of traceability succeed or fail. Theoretical contributions related to how costs and benefits are distributed in the supply chain are crucial to understanding why some parts of the supply chain choose to implement finer granularity levels than do other parts. This is also important for better understanding the level of granularity at which traceability can and should be implemented by law, as well as the levels at which such systems are implemented purely by market-driven benefits.

### 7.1.2 Methodological implications

The methods applied to identify CTPs in the studied supply chains seem to work well and generated relevant knowledge to implement traceability in seafood supply chains. One disadvantage is that the background of the researchers and their understanding of the principles of traceability can affect the result. Another disadvantage to the methods applied here, was that they did not include mapping the IT-systems used by the companies studied. This is relevant knowledge for the implementation of electronic traceability.

One of the first steps in this process was to choose supply chains and companies. The choice to study seafood supply chains was fruitful, because the results showed that the implementation of seafood traceability is affected by the granularity level of traceable units, and the random nature of wild-caught fish deliveries can influence traceability. An interesting question is whether we would have seen similar results to those documented in this thesis if similar studies were carried out on other companies, vertically vs. non-vertically integrated supply chains, companies of different sizes, other seafood products, and other seafood supply chains? And how important is the time frame for collection of empirical data?

The outcome of this research showed that an important factor that will affect the result in such studies is the degree of commitment to the implementation of traceability within the companies. If a company has decided to implement traceability before the process is mapped, this will affect the findings: we will probably not find any or few points where information is lost. Thus identical companies with similar production practices for a seafood product can have different points where information is lost. Presumably, similar situations are present in vertically integrated vs. non-vertically integrated companies and small and medium enterprises vs. large enterprises. The production procedures for seafood products may vary, meaning different points where information is lost can occur. Consequently, more research is needed to see whether we can find similar findings in a similar company in another supply chain.

A fresh saithe supply chain was chosen for implementation of electronic chain traceability because it was presumed to present the least challenges, due to a low degree of mixing and splitting of fish during production. The implementation did not succeed 100 percent. The results showed that motivation influences the implementation process. The choice of companies should thus be based on motivation rather than production process. In this study, the companies' motivations to implement traceability were driven by desires to meet new legislation requirements, satisfy customer needs, gain more information about the product in the supermarket, better document the cooling chain, and achieve shorter storage times in the supply chain, which would result in extended shelf-life for the fresh fish at the supermarket. The question remains: was this the right seafood product to choose? Fresh fish is a low-value product, and the value of the seafood product may have affected the implementation process.

The methods chosen to study the implementation of traceability in this study appear to be adequate. The TraceFood framework (2011) presents guidelines for the implementation steps, which was useful in the development of the methods. Less emphasis was placed on the mapping and planning phases in this framework. Our experience was that many of the questions included in the stakeholder analysis in the Tracefood framework were important because they influence the implementation process. In our study, we spent a lot of time trying to find answers to these questions, such as *'Why should an actor invest in a traceability system?'; 'What are the costs and benefits related to process improvement and changes with respect to traceability?'; 'Which investments are necessary for a successful implementation of traceability?'; 'How do we cover costs related to improved traceability information and information quality and granularity?'*; and *'What production equipment and which IT-systems are directly or indirectly affected by a new system?'* It would have been useful if the stakeholder analysis had been described more in detail. A method for analyzing costs and benefits associated with traceability that may guide companies in their choice of granularity levels before commencing the implementation process should be included in this framework. Measurements of different granularity levels should be based on an evaluation of the costs and benefits at a specific granularity level. The results from this study can be useful in this regard, when the framework is developed further.

### 7.1.3 Practical implications

The results from this research showed that the implementation of seafood traceability is affected by the granularity level of traceable units. Analyzing the variables and determining the optimal granularity level for these units should thus be carried out before implementation. The planning phase is important, and taking the time to do it right is recommended over just rushing to get to the implementation phase. A bad job in the planning phase can affect the implementation process. Consequently, it is important to carry out a stakeholder analysis before implementing traceability to identify the companies involved, their roles, and the optimal granularity level.

An important factor that must be considered in this discussion is how granularity levels will affect production practices and IT-systems in a company. One should determine whether it is going to be problematic to develop practical solutions for achieving traceability. A fine granularity level will have greater impact on practices and IT-systems than a coarse granularity level, and the costs will also be higher. A finer granularity level will increase the chance of reaping the benefits of using traceability. In other words, implementation of a coarse granularity level is easier and cheaper than a fine granularity level, but the benefits are also lower. The key is to find the optimal granularity level where the benefits exceed the costs. Consequently, the costs and potential benefits associated with implementing traceability should be identified.

Other elements to include in the stakeholder analysis are discussions of whether to implement internal traceability only or to also include chain traceability and determining which type of traceability system to use. The knowledge obtained from the stakeholder analysis is useful when designing a traceability system and practical implementation of traceability.

Another finding in this research was that motivation is extremely important for success with traceability implementation. Motivation, in turn, is closely connected to the identification of costs and benefits. Therefore, it is recommended to have an open discussion of the distribution of the costs and benefits between the involved companies when implementing chain traceability.

## 7.2 Limitations of the study

A comprehensive study of the Norwegian seafood supply chains regarding granularity and its effect for traceability was not carried out here. Consequently, the main limitation of this study is the inability to generalize the findings. One of the criticisms with case-studies concerns how the result from a case study cannot usually be generalized (Eisenhardt 1989; Ellram 1996; Yin 2003). According to Ellram (1996), data collected in such studies is insufficient for generalization. A single case study cannot produce external validity (Mentzer and Flint 1997). In order to increase external validity, it is necessary to do 6-12 case studies (Ellram 1996). On the other hand, the supply chains for seafood products and the production of these products around the world vary greatly (Denton 2003). This can make generalizations, even on the basis of collected data from several studies, difficult. In addition, there can be differences in findings in similar companies when it comes to information lost; one company might have implemented traceability, whereas another has no such traceability system. Halldórssen et al. (2003) thus recommend providing a detailed description of the study, so other people can analyse the similarities of different studies with the same focus.

Data collected in case studies is still interesting, however, because case study research will provide valuable information about a phenomenon (Seuring 2008), develop knowledge (Näslund 2002), and create new theories (Dyer et al. 1991; Ellram 1996; Yin 2003; Kovàcs and Spens 2005). In order to be able to generalize, the first step is to obtain more information about the actual situation in one specific seafood supply chain (Figure 17). Step 2 would be to include this in the theory. By studying several seafood companies, one can assume that a generalization of some of the findings from the studies can be made (Steps 3, 4, and 5).

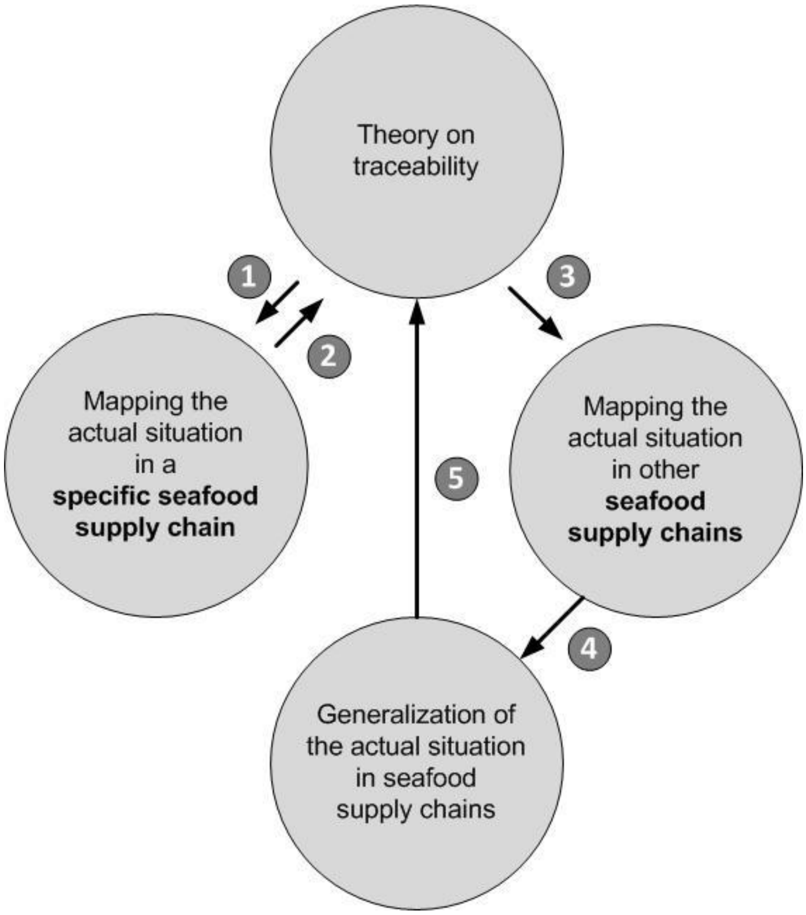


Figure 17 From mapping a specific seafood supply chain to generalization of the collected data.

Another limitation of this study is that transport links were not mapped. The storage temperature of fresh fish during transportation is critical for the quality, but not so critical for fish feed, for example. The choice to include or exclude the transport link in mapping processes to identify CTPs should thus be based on the importance of temperature documentation during the supply chain of the studied seafood product.

## 7.3 Further work

Identifying applications for traceability and benefits of traceable information in seafood supply chains is a clear area for further studies. There is also a need to increase knowledge of optimal granularity levels for traceable units by carrying out real industry studies. A central issue raised by Souza-Monteiro and Caswell (2004) is *'who bears the cost and who reaps the benefits of traceability'*? Other interesting questions are: Are the benefits and investments different depending on the companies' position in a supply chain? Are there more advantages to internal traceability compared to chain traceability? Are there different benefits and investments of traceability for different foodstuffs ('high'-value products vs. 'low'-value products)? What is the optimal granularity level for different seafood companies? How will the production concept and use of technology affect the optimal granularity level?

Production optimization through traceability is presumed to have potential in the Norwegian seafood industry, especially in capture-based concept. Several factors affect decision-making processes onboard fishing vessels and at productions plants (Margeirsson 2008), such as choice of catch area and type of production. Traceability can be useful for gaining access to relevant product information and process information to support decision-making processes. It is presumed that the activities of fishing vessels and production plants can be better coordinated by implementing traceability in the Norwegian capture-based industry to maximize profitability for both links in the chain.

Documentation of sustainability is another area for further research. Traceability is presumed to be useful in terms of improving the exchange of information, for example to improve fish management regimes in the capture-based concept and site management regime in aquaculture concept (Karlsen et al. 2011). Documentation of sustainability using traceability is not straightforward, however, because several definitions of sustainability and sustainable development are available depending on the perspectives, scientific fields, problem areas, and goals (Brown et al. 1987; Garcia and Staples 2000; Omann 2004). In addition, the meaning of the term sustainability is highly dependent on the setting, level, and perspective (Brown et al. 1987). Thousands of indicators of sustainability exist in the seafood industry. It could be relevant to trace some of these, such as fuel consumption. Other indicators are less relevant, such as employment numbers. Which indicators to trace will depend on the ability to trace the indicators and needs of the user.

# References


Abad, E., Palacio, F., Nuin, M., Zárate, A.G.D., Juarros, A., Gómez, J.M. & Marco, S. (2009). RFID smart tag for traceability and cold chain monitoring of foods: Demonstration in an intercontinental fresh fish logistic chain. *Journal of Food Engineering,* 93(4): 394-399.

Ammendrup, S. & Barcos, L.O. (2006). The implementation of traceability systems. *Revue Scientifique Et Technique-Office International Des Epizooties,* 25(2): 763-773.

Arana, A., Soret, B., Lasa, I. & Alfonso, L. (2002). Meat traceability using DNA markers: Application to the beef industry. *Meat Science,* 61(4): 367-373.

Arason, S., Ásgeirsson, E.I., Margeirsson, B., Margeirsson, S., Olsen, P. & Stefánsson, H. (2010). Decision support systems for the food industry. In Kacprzyk, J. & Jain, L.C.E. *Handbook on decision making.* Berlin, German: Springer, 295-315.

Asensio, L. & Montero, A. (2008). Analysis of fresh fish labelling in Spanish fish retail shops. *Food Control,* 19(8): 795-799.

Banterle, A. & Stranieri, S. (2008). The consequences of voluntary traceability system for supply chain relationships. An application of transaction cost economics. *Food Policy,* 33(6): 560-569.

Bechini, A., Cimino, M.G.C.A., Lazzerini, B., Marcelloni, F. & Tomasi, A. (2005). A general framework for food traceability. *Proceedings of the 2005 Symposium on applications and the Internet Workshops (SAINT-W`05).* Trento, Italy: The Institute of Electrical and Electronics Engineers (IEEE), The Computer Society, 366-369.

Bechini, A., Cimino, M.G.C.A., Marcelloni, F. & Tomasi, A. (2008). Patterns and technologies for enabling supply chain traceability through collaborative e-business. *Information and Software Technology,* 50(4): 342-359.

Bertolini, M., Bevilacqua, M. & Massini, R. (2006). FMECA approach to product traceability in the food industry. *Food Control*, 17(2): 137-145.

Bevilacqua, M., Ciarapica, F.E. & Giacchetta, G. (2009). Business process reengineering of a supply chain and a traceability system: A case study. *Journal of Food Engineering*, 93(1): 13-22.

Bianchi, A., Fasolino, A.R. & Visaggio, G. (2000). An exploratory case study of the maintenance effectiveness of traceability models. *Proceedings IWPC 2000, 8th International Workshop on Program Comprehension*. Limerick , Ireland: The Institute of Electrical and Electronics Engineers (IEEE), 149 -158.

Billo, R.E. & Bidanda, B. (1998). Modeling effective material tracking systems a case study in wireless technology. *Industrial engineering solutions`98, Conference Proceedings*, 10-17.

Bollen, A.F. (2004). Traceability in fresh produce supply chains. In Tanner, D.J.E. *ISHS Acta Horticulturae 687: International Conference Postharvest Unlimited Down under 2004*. Sydney, Australia, 279-288.

Bollen, A.F., Riden, C.P. & Cox, N.R. (2007). Agricultural supply system traceability, part I: Role of packing procedures and effects of fruit mixing. *Biosystems Engineering,* 98(4): 391-400.

Bollen, F.P., Riden, C.P. & Opara, L.U. (2006). Traceability in postharvest quality management. *International Journal of Postharvest Technology and Innovation* 1(1): 93-105.

Brown, B.J., Hanson, M.E., Liverman, D.M. & Merideth, R.W. (1987). Global sustainability: Toward definition. *Environmental Management,* 11(6): 713-719.

Can-Trace, (2007). *Cost of traceability in Canada: Developing a measurement model.* Report March 2007. ISBN 978-0-662-46769-4. Ottawa, Canada: Agriculture and Agri-Food Canada.

Canavari, M., Centonze, R., Hingley, M. & Spadoni, R. (2010). Traceability as part of competitive strategy in the fruit supply chain. *British Food Journal,* 112(2): 171-184.

CatchCertificate. (2011). *This is catchcertificate.no*. The Norwegian sales organizations. Available at: www.catchcertificate.no. Downloaded 23.02.2011.

CEN. (2003a). *CEN workshop agreement 14659 - Traceability of fishery products - Specification of the information to be recorded in farmed fish distribution chains.* Brussels, Belgium: European Committee for Standardization.

CEN. (2003b). *CEN workshop agreement 14660 - Traceability of fishery products - Specification of the information to be recorded in captured fish distribution. chains.* Brussels, Belgium: European Committee for Standardization.

Cheng, M.J. & Simmons, J.E.L. (1994). Traceability in manufacturing systems. *International Journal of Operations & Production Management,* 14(10): 4-16.

Chrysochou, P., Chryssochoidis, G. & Kehagia, O. (2009). Traceability information carriers. The technology backgrounds and consumers' perceptions of the technological solutions. *Appetite,* 53(3): 322-331.

Chryssochoidis, G., Karagiannaki, A., Pramatari, K. & Kehagia, O. (2009). A cost-benefit evaluation framework of an electronic-based traceability system. *British Food Journal,* 111(6-7): 565-582.

Denton, W. (2003). Tracefish: The development of a traceability scheme for the fish industry. In Luten, J.B., Oehlenschläger, J. & Òlafsdòttir, G.E. *Quality of fish from catch to consumer*. Wageningen, The Netherlands: Wageningen Academic Publishers, 75-91.

Derrick, S. & Dillon, M. (2004). *A guide to traceability within the fish industry.* ISBN 1-900134-18-7. Copenhagen, Denmark: SIPPO, Eurofish and Humber Institute of Food & Fisheries.

Disney, W.T., Green, J.W., Forsythe, K.W., Wiemers, J.F. & Weber, S. (2001). Benefit-cost analysis of animal identification for disease prevention and control. *Revue Scientifique Et Technique De L Office International Des Epizooties,* 20(2): 385-405.

Donnelly, K.A.-M., Karlsen, K.M. & Olsen, P. (2008). Creating standardised data lists for traceability: A study of honey processing. *Int. J. Metadata, Semantics and Ontologies,* 3(4): 283-291.

Donnelly, K.A.-M., Karlsen, K.M. & Olsen, P. (2009a). The importance of transformations in traceability - a case study of lamb and lamb products. *Meat Science,* 83(1): 69-73.

Donnelly, K.A.-M., van der Roest, J., Höskuldsson, S.T., Olsen, P. & Karlsen, K.M. (2009b). Improving information exchange in the chicken processing sector using standardised data lists. *Special Issue of the Journal on Data Semantics of Springer*, 312-320.

Donnelly, K.A.-M. (2010). *Factors affecting implementation of the information exchange for traceability in food supply chains*. Doctoral thesis. Faculty of Biosciences, Fisheries and Economics. Department of Arctic and Marine Biology. University of Tromsø. Tromsø, Norway.

Dreyer, C., Wahl, R., Storøy, J., Forås. & Olsen, P. (2004). Traceability standards and supply chain relationships. In Aronsson, H.E. *Proceedings of the 16th Annual Conference for Nordic Researchers in Logistics, NOFOMA 2004, Challenging Boundaries with Logistics*. Linköping, Sweden, 155-170.

Dupuy, C., Botta-Genoulaz, V. & Guinet, A. (2005). Batch dispersion model to optimise traceability in food industry. *Journal of Food Engineering,* 70(3): 333-339.

Dyer, W., Gibb, J. & Wilkins, L. (1991). Better stories, not better constructs, to generate better theory: A rejoinder to Eisenhardt. *Academy of Management Review,* 16(3): 613-619.

EAN.UCC. (2002). *Traceability of fish guidelines*. European Article Number International and Uniform Code Council, 7th November.

EC-178/02. (2002). *Regulation (EC) no 178/2002 of the European parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establish the European food safety authority and laying down procedures in matters of food safety*. The European Parliament and the Council of the European Union.

EC-1005/2008. (2008). *Council regulation (EC) no 1005/2008 of 29 September 2008 establishing a community system to prevent, deter and eliminate illegal, unreported and unregulated fishing, amending regulations (EEC) no 2847/93,(EC) no 1936/2001 and (EC) no 601/2004 and repealing regulations (EC) no 1093/94 and (EC) no 1447/1999*. European Commission.

Eisenhardt, K.M. (1989). Building theories from case study research. *Academy of Management Review,* 14(4): 532-550.

Elbers, A.R.W., Moser, H., Ekker, H.M., Crauwels, P.A.A., Stegeman, J.A., Smak, J.A. & Pluimers, F.H. (2001). Tracing systems used during the epidemic of classical swine fever in the Netherlands, 1997-1998. *Revue Scientifique Et Technique De L Office International Des Epizooties,* 20(2): 614-629.

Ellram, L.M. (1996). The use of the case study method in logistic research. *Journal of Business Logistics,* 17(2): 93-138.

Engelseth, P. (2009). Food product traceability and supply network integration. *Journal of Business & Industrial Marketing,* 24(5/6): 421-430.

Ford, M. & Triggs, J.D. (2006). Traceability requirements in electronics assembly. In Pham, D.T., Eldukhri, E.E. & Soroka, A.J.E. *Intelligent production machines and systems.* Cardiff, UK: Elsevier, 656-662.

Frederiksen, M. (2002). *Fresh fish with traceable quality*. Doctoral thesis. Danish Institute of Fisheries Research. Department of Seafood Research, Department of Biotechnology. Technical University of Denmark. Lyngby, Denmark.

Frederiksen, M. & Bremner, A. (2001). Fresh fish distribution chains. An analysis of three Danish and three Australian chains. *Food Australia,* 54(4): 117-123.

Frederiksen, M., Østerberg, C., Silberg, S., Larsen, E. & Bremner, A. (2002). Info-fisk: Development and validation of an Internet based traceability system in a Danish domestic fresh fish chain. *Journal of Aquatic Food Product Technology,* 11(2): 13-34.

Frosch Møller, S. (2005). *The importance of data quality and traceability in data mining. Applications of robust methods for multivariate data analysis.* Doctoral thesis. Danish Institute for Fisheries Research. Technical University of Denmark. Copenhagen, Denmark.

Frosch, S., Randrup, M. & Frederiksen, M. (2008). Opportunities for the herring industry to optimize operations through information recording, effective traceability systems, and use of advanced data analysis. *Journal of Aquatic Food Product Technology,* 17(4): 387-403.

Galvão, J.A., Margeirsson, S., Garate, C., Viarsson, J.R. & Oetterer, M. (2010). Traceability system in cod fishing. *Food Control,* 21(10): 1360-1366.

García, H., Santos, E. & Windels, B. (2008). Traceability management architectures supporting total traceability in the context of software engineering. *Sixth International Conference in information Research and Application - i.Tech 2008*. Varna, Bulgaria, 17-23.

Garcia, S.M. & Staples, D.J. (2000). Sustainability reference systems and indicators for responsible marine capture fisheries: A review of concepts and elements for a set of guidelines. *Marine and Freshwater Research,* 51(5): 385-426.

Golan, E., Krissoff, B., Kuchler, F., Calvin, L., Nelson, K. & Price, G. (2004). *Traceability in the US food supply: Economic theory and industries studies.* Agricultural Economic Report Number 830. Washington, DC: United States Department of Agriculture.

GS1. (2007). *The GS1 Traceability standard: What you need to know*. Brussels, Belgium: GS1.

GS1. (2010). *GS1 GTC Control points & compliance criteria - food*. Issue 3, June 2010. Brussels, Belgium: GS1.

Halldórsson, Á. & Aastrup, J. (2003). Quality criteria for qualitative inquiries in logistics. *European Journal of Operational Research,* 144: 321-332.

Hamilton, V.L. & Beeby, M.L. (1991). Issues of traceability in integrating tools. *IEE Colloquium on `Tools and Techniques for Maintaining Traceability During Design'*. London, UK: The Institute of Electrical and Electronics Engineers (IEEE), 4/1-4/3.

Hernández-Jover, M., Schembri, N., Toribio, J.A. & Holyoake, P. (2009). Evaluation of the implementation of new traceability and food safety requirements in the pig industry in Eastern Australia. *Australian Veterinary Journal,* 87(10): 387-396.

Hobbs, J.E. (2004). Information asymmetry and the role of traceability systems. *Agribusiness,* 20(40): 397-415.

Hobbs, J.E., Bailey, D.V., Dickinson, D.L. & Haghiri, M. (2005). Traceability in the Canadian red meat sector: Do consumers care? *Canadian Journal of Agricultural Economics-Revue Canadienne D Agroeconomie,* 53(1): 47-65.

Huang, E. & Yang, J.-C. (2009). The integration of seafood traceability systems for shrimp value chain systems. *International Journal of Computers,* 3(2): 201-210.

Håstein, T., Hill, B.J., Berthe, F. & Lightner, D.V. (2001). Traceability of aquatic animals. *Revue Scientifique Et Technique De L Office International Des Epizooties,* 20(2): 564-583.

ISO-22005:2007. (2007). *Traceability in the feed and food chain -- General principles and basic requirements for system design and implementation*. International Organization of Standardization.

ISO. (1994). *Quality management and quality assurance vocabulary - ISO 8402*. International Organization of Standardization, 17.

Jansen-Vullers, M.H., van Dorp, C.A. & Beulens, A.J.M. (2003). Managing traceability information in manufacture. *International Journal of Information Management,* 23(5): 395-413.

Jensen, T.K., Nielsen, J., Larsen, E.P. & Clausen, J. (2010). The fish industry - Towards supply chain modeling. *Journal of Aquatic Food Product Technology,* 19: 214-226.

Karlsen, K.M., Andreassen, O., Dreyer, B., Hermansen, Ø. & Olsen, P. (2011). Sustainability challenges in seafood supply chains. *Food supply: Economics, sustainability, and environmental effects.* Hauppauge, New York: Nova Science Publishers, submitted.

Karlsen, K.M., Donnelly, K.A.-M. & Olsen, P. (2010). Implementing traceability: Practical challenges at a mineral water bottling plant. *British Food Journal,* 112(2): 187-197.

Karlsen, K.M. & Senneset, G. (2006). Traceability: Simulated recall of fish products. In Luten, J., Oehlenschläger, J., Jacobsen, C., Bekaert, K. & Særbo, A.E. *Seafood research from fish to dish, quality, safety and processing of wild and farmed fish.* Wageningen, The Netherlands: Wageningen Academic publishers, 251-262.

Kehagia, O., Chrysochou, P., Chryssochoidis, G., Krystallis, A. & Linardakis, M. (2007). European consumers' perceptions, definitions and expectations of traceability and the importance of labels, and the differences in these perceptions by product type. *Sociologia Ruralis,* 47: 400-416.

Kim, H.M., Fox, M.S. & Gruninger, M. (1995). An ontology for enterprise modelling. *Proceedings of the Fourth Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises WET ICE `95*. Los Albamitos, USA: The Institute of Electrical and Electronics Engineers (IEEE), Computer Society Press, 105-116.

Kirova, V., Kirby, N., Kothari, D. & Childress, G. (2008). Effective requirements traceability: Models, tools, and practices. *Bell Labs Technical Journal,* 12(4): 143-157.

Kondo, A.A., Medeiros, B.C., Madeira, E.R.M. & Bacarin, E. (2007). Traceability in food for supply chains. *In proc. of the 3rd International Conference on Web Information Systems and Technologies (WEBIST 2007)*. Barcelona, Spain: The Institute for Systems and Technologies of Information, Control and Communication (INSTICC), 121-127.

Korthals, M. (2008). Ethical rooms for maneuver and their prospects *vis-á-vis* the current ethical food policies in Europe. *Journal of Agricultural and Environmental Ethics,* 21: 249-273.

Kovàcs, G. & Spens, K.M. (2005). Abductive reasoning in logistic research. *International Journal of Physical Distribution & Logistics Management,* 35(2): 132-144.

Leat, P., Marr, P. & Ritchie, C. (1998). Quality assurance and traceability - the Scottish agri-food industry's quest for competitive advantage. *Supply Chain Management,* 3(3): 115-117.

Lindwall, M. & Sandahl, K. (1996). Practical implications of traceability. *Software - practice and experience,* 26(10): 1161-1180.

Lo Bello, L., Mirabella, O. & Torrisi, N. (2004). Modelling and evaluating traceability systems in food manufacturing chains. *13th IEEE International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE'04)*. University of Modena and Reggio Emilia, Italy: The Institute of Electrical and Electronics Engineers (IEEE), Computer society, 173-179.

Madec, F., Geers, R., Vesseur, P., Kjeldsen, N. & Blaha, T. (2001). Traceability in the pig production chain. *Revue Scientifique Et Technique De L Office International Des Epizooties*, 20(2): 523-537.

Mai, N., Bogason, S.G., Arason, S., Arnason, S.V. & Matthiasson, T.G. (2010). Benefits of traceability in fish supply chains - case studies. *British Food Journal,* 112(8-9): 976-1002.

Mai, T.T.N. (2010). *Enhancing quality management of fresh fish supply chain through improved logistics and ensured traceability*. Doctoral thesis. Faculty of Food Science and Nutrition, School of Health Sciences. University of Iceland. Reykjavik, Iceland.

Manos, B. & Manikas, I. (2010). Traceability in the Greek fresh produce sector: Drivers and constraints. *British Food Journal*, 112(6): 640-652.

Margeirsson, S. (2008). *Processing forecast of cod - decision making in the cod industry based on recording and analysis of value chain data*. Doctoral thesis. Faculty of Engineering. University of Iceland. Reykjavik, Iceland.

McGrann, J. & Wisemann, H. (2001). Animal traceability across national frontiers in the European union. *Revue Scientifique Et Technique De L Office International Des Epizooties,* 20(2): 406-412.

McKean, J.D. (2001). The importance of traceability for public health and consumer protection. *Revue Scientifique Et Technique De L Office International Des Epizooties*, 20(2): 363-371.

Mentzer, J.T. & Flint, D.J. (1997). Validity in logistic research. *Journal of Business Logistics*, 18(1): 199-216.

Meuwissen, M.P.M., Velthuis, A.G.J., Hogeveen, H. & Huirne, R.B.M. (2003). Traceability and certification in meat supply chains. *Journal of Agribusiness,* 21(2): 167-181.

Moe, T. (1998). Perspectives on traceability in food manufacture. *Trends in Food Science & Technology*, 9(5): 211-214.

Moretti, V.M., Turchini, G.M., Bellagamba, F. & Caprino, F. (2003). Traceability issues in fishery and aquaculture products. *Veterinary Research Communications,* 27(1): 497-505.

Mousavi, A., Sarhadi, M., Fawcett, S., Bowles, S. & York, M. (2005). Tracking and traceability solution using a novel material handling system. *Innovative Food Science & Emerging Technologies,* 6(1): 91-105.

Noll, R.P. & Ribeiro, A.M.B. (2007). Enhancing traceability using ontologies. *Proceedings of the 2007 ACM symposium on Applied computing*. Seoul, Korea: The Association for Computing Machinery (ACM), 1496-1497.

NSEC. (2008). *Statistical overview 2008*. Norwegian Seafood Export Council. Available at: www.seafood.no. Downloaded 15.01.2011.

Näslund, D. (2002). Logistics needs qualitative research - Especially action research. *International Journal of Physical Distribution & Logistics Management,* 32(5): 321-338.

Olsen, P. (2009). Food traceability process mapping. Standard method for analyzing material flow, information flow and information loss in food supply chains. In Donnelly, K.A.M. & Olsen, P. *Harmonizing methods for food traceability process mapping and cost/benefit calculations related to implementation of electronic traceability systems - Workshop hosted by Nofima association with the TRACE project 25-26 February 2009.* Report 15/2009. ISBN: 978-82-7251-679-5. Tromsø, Norway: Nofima.

Olsen, P. & Aschan, M. (2010). Reference method for analyzing material flow, information flow and information loss in food supply chains. *Trend in Food Science and Technology*, 21(6): 313-320.

Olson, T.K. (2005). *Potential changes in relative competitiveness in response to changes in the demand for traceability and assurance: A case study of Chilean salmon aquaculture*. Doctoral thesis. International Food and Agribusiness. Utah State University. Logam, Utah.

Olsson, A. & Skjöldebrand. (2008). Risk management and quality assurance through the food supply chain – Case studies in the Swedish food industry. *The open Food Science Journal,* 2: 49-56.

Omann, I. (2004). *Multi-criteria decision aid as an approach for sustainable development analysis and implementation*. Doctoral thesis. Karl-Frantzens University. Graz, German.

Opara, L.U. (2003). Traceability in agriculture and food supply chain: A review of basic concepts, technological implications and future prospects. *Food, Agriculture & Environment,* 1(1): 101-106.

Opara, L.U. & Mazaud, F. (2001). Food traceability from field to plate. *Outlook on Agriculture,* 30(4): 239-247.

Pálsson, P.G., Storøy, J., Frederiksen, M. & Olsen, P. (2000). *Traceability and electronic transmission of qualitative data of fish products.* Nordic Council of Ministers project nr. 66031400. Lyngby, Denmark: Danish Institute for Fisheries Research, Department of Seafood Research.

Peres, B., Barlet, N., Loiseau, G. & Montet, D. (2007). Review of the current methods of analytical traceability allowing determination of the origin of foodstuffs. *Food Control,* 18(3): 228-235.

Pèrez-Villarreal, B., Amàrita, F., Bald, C., Pardo, A. & Sagardia, I. (2008). Validation of traceability in the seafood production chain. In Børresen, T.E. *Improving seafood products for the consumer, part VI seafood traceability to regain consumer confidence.* Cambridge, UK: Woodhead Publishing Limited, 539-565.

Pettitt, R.G. (2001). Traceability in the food animal industry and supermarket chains. *Revue Scientifique Et Technique De L Office International Des Epizooties,* 20(2): 584-597.

PL107-188. (2002). *Public Health Security and Bioterrorism Preparedness and Response Act of 2002*. The Senate and House of Representatives of the United States of America in Congress.

Pouliot, S. & Sumner, D.A. (2008). Traceability, liability, and incentives for food safety and quality. *American Journal of Agricultural Economics,* 90: 15-27.

Pugh, N.R. (1973). Principles of product traceability. *American Society Quality Control,* 4: 65-69.

Ramesh, B., Dwiggins, D., Devries, G. & Edwards, M. (1995). Towards requirements traceability models. *Proceedings of the 1995 International Symposium and Workshop on Systems Engineering of Computer Based Systems.* Tucson, AZ, USA: The Institute of Electrical and Electronics Engineers (IEEE), 229-232.

Randrup, M., Storøy, J., Lievonen, S., Margeirsson, S., Árnason, S.V., Ólavsstovu, D., Møller, S.F. & Frederiksen, M.T. (2008). Simulated recalls of fish products in five Nordic countries. *Food Control,* 19(11): 1064-1069.

Raschke, A., Strich, S., Huppke, S., Neugebauer, M., Geuther, E., Bertling, W., Walders, B., Reiser, C. & Hess, J. (2006). Induction and detection of long-lasting peptide-specific antibody responses in pigs and beef cattle: A powerful technology for tracing meat processing chains from stock farmers to sales counters. *Food Control,* 17(1): 65-74.

Regattieri, A., Gamberi, M. & Manzini, R. (2007). Traceability of food products: General framework and experimental evidence. *Journal of Food Engineering,* 81(2): 347-356.

Riden, C.P. & Bollen, A.F. (2007). Agricultural supply system traceability, part II: Implications of packhouse processing transformations. *Biosystems Engineering,* 98: 401-410.

Ringsberg, H. & Jönson, G. (2010). Perspectives of food supply chain traceability *Conference proceedings - The 12th World conference in transport research*. Lisbon, Portugal: World Conference on Transport Research Society (WCTRS), 1-26

Roheim, C. & Sutinen, J.G. (2006). *Trade and marketplace measures to promote sustainable fishing practices.* Issue paper no. 3. Paris, France: International Centre for Trade and Sustainable Development.

Ruiz-Garcia, L., Steinberger, G. & Rothmund, M. (2010). A model and prototype implementation for tracking and tracing agricultural batch products along the food chain. *Food Control,* 21(2): 112-121.

Sant'Ana, L.S., Ducatti, C. & Ramires, D.G. (2010). Seasonal variations in chemical composition and stable isotopes of farmed and wild Brazilian freshwater fish. *Food Chemistry,* 122(1): 74-77.

Schmid, A. & Connelly, J. (2009). *Round table on eco-labelling and certification in the fisheries sector - Proceedings*. 22-23 April 2009. The Hague, The Netherlands: Agriculture, nature and food quality, Organisation for economic co-operation and development (OECD), and Food and agriculture organization (FAO).

Schröder, U. (2008). Challenges in the traceability of seafood. *Journal für Verbraucherschutz und Lebensmittelsicherheit,* 3(1): 45-48.

Schulz, L.L. & Tonsor, G.T. (2010). Cow-calf producer preferences for voluntary traceability systems. *Journal of Agricultural Economics,* 61(1): 138-162.

Schwägele, F. (2005). Traceability from a European perspective. *Meat Science,* 71(1): 164-173.

Sebestyen, G., Nedevschi, S., Saplacan, G., Cerghizan, M., Todor, N. & Rusu, M. (2008). Towards a traceability solution on the food supply chain. *The 8th International conference on technical informatics (Conti' 2008)*. Timisoara, Romania: The Institute of Electrical and Electronics Engineers (IEEE), 1-6.

Senneset, G., Forås, E. & Fremme, K.M. (2007). Challenges regarding implementation of electronic chain traceability. *British Food Journal,* 109: 805-818.

Senneset, G., Midtstraum, R., Forås, E., Vevle, G. & Mykland, I.H. (2010). Information models leveraging identification of returnable transport items. *British Food Journal,* 112(6-7): 592-607.

Seuring, S.A. (2008). Assessing the rigor of case study research in supply chain management. *Supply chain management: An international journal*, 13(2): 128-137.

Shackell, G.H. (2008). Traceability in the meat industry – the farm to plate continuum. *International Journal of Food Science & Technology*, 43(12): 2134-2142.

Skoglund, T. & Dejmek, P. (2007). Fuzzy traceability: A process simulation derived extension of the traceability concept in continuous food processing. *Food and Bioproducts Processing*, 85: 354-359.

Smith, G.C., Tatum, J.D., Belk, K.E., Scanga, J.A., Grandin, T. & Sofos, J.N. (2005). Traceability from a US perspective. *Meat Science*, 71:174-193.

Sohal, A.S. (1997). Computerized parts traceability: An implementation case study. *Technovation*, 17(10): 583-591.

Souza-Monterio, D.M. & Caswell, J.A., (2004). *The economics of implementing traceability in beef supply chains: Trends in major producing and trading countries.* Working Paper No. 2004-6. Amherst, MA: University of Massachusetts.

Sparling, D., Henson, S., Dessureault, S. & Herath, D. (2006). Costs and benefits of traceability in the Canadian dairy-processing sector. *Journal of Food Distribution Research*, 37(1): 154-160.

Stanford, K., Stitt, J., Kellar, J.A. & McAllister, T. (2001). Traceability in cattle and small ruminants in Canada. *Revue Scientifique Et Technique De L Office International Des Epizooties*, 20(2): 510-522.

Starbird, S.A. & Amanor-Boadu, V. (2006). Do inspection and traceability provide incentives for food safety? *Journal of Agricultural and Resource Economics,* 31(1): 14-26.

Storøy, J., Senneset, G., Forås, E., Olsen, P., Karlsen, K.M. & Frederiksen, M. (2008). Improving traceability in seafood production. In Børresen, T.E. *Improving seafood products for the consumer, part VI seafood traceability to regain consumer confidence.* Cambridge, UK: Woodhead Publishing Limited, 516-538.

Thakur, M. (2010). *Operational techniques for implementing traceability in bulk product supply chains*. Doctoral thesis. Iowa State University. Ames, Iowa.

Thakur, M. & Donnelly, K.A.-M. (2010). Modelling traceability information in soybean value chains. *Journal of Food Engineering*, 99(1): 98-105.

Thakur, M. & Hurburgh, C.R. (2009). Framework for implementing traceability system in the bulk grain supply chain. *Journal of Food Engineering*, 95(4): 617-626.

Thakur, M., Wang, L. & Hurburgh, C.R. (2010). A multi-objective optimization approach to balancing cost and traceability in bulk grain handling. *Journal of Food Engineering*, 101(2): 193-200.

Thompson, M., Sylvia, G. & Morrissey, M.T. (2005). Seafood traceability in the United States: Current trends, system design, and potential applications. *Comprehensive Reviews in Food Science and Food Safety*, 4(1): 1-7.

Thompson, M.J. (2005). *Integrating traceability with onboard handling to enhance product quality and marketability of Eastern Pacific troll-caught Albacore tuna (Thunnus alalunga)*. Master in science. Oregon State University.

Tracefood. (2011). *Tracefood wiki*. EU-project TRACE. Available at: http://www.tracefood.org/index.php/Main_Page. Downloaded 01.04.2011.

Turchini, G.M., Quinn, G.P, Jones, P.L., Gooley, G. (2009). Traceability and discrimination among differently farmed fish: A case study on Australian murray cod. *J.Agric. Food Chem.*, 57(1): 274-281.

Töyrylä, I. (1999). *Realising the potential of traceability - a case study on usage and impacts of product traceability*. Doctoral thesis. Department of Industrial Management. Helsinki University of Technology. Helsinki, Finland.

van Rijswijk, W., Frewer, L.J., Menozzi, D. & Faioli, G. (2008). Consumer perceptions of traceability: A cross-national comparison of the associated benefits. *Food Quality and Preference*, 19(5): 452-464.

Viaene, J. & Verbeke, W. (1998). Traceability as a key instrument towards supply chain and quality management in the Belgian poultry meat chain. *Supply Chain Management,* 3(3): 139.

Voulodimos, A.S., Patrikakis, C.Z., Sideridis, A.B., Ntafis, V.A. & Xylouri, E.M. (2010). A complete farm management system based on animal identification using RFID technology. *Computers and Electronics in Agriculture,* 70(2): 380-388.

Wang, F., Fu, Z., Moga, L.M. & Zhang, X. (2009). Adoption of traceability system in Chinese fishery process enterprises: Difficulties, incentives and performance. *Journal of Food, Agriculture & Environment*, 7(2): 64-69.

Wang, X. & Li, D. (2006). Value added on food traceability: A supply chain management approach. *IEEE conference on service operations and logistics, and informatics (SOLI 2006)*. Shanghai, China: The Institute of Electrical and Electronics Engineers (IEEE), 493-498.

Wang, X., Li, D. & O´Brien, C. (2008). Optimisation of traceability and operations planning: An integrated model for perishable food production. *International Journal of Production Research*, 1-22.

WWF. (2009). *Assessment study of on-pack, wild-capture seafood sustainability certification programmes and seafood ecolabels*. Report. Zürich, Switzerland: Accenture AG and World Wildlife Fund (WWF) International.

Yasuda, T. & Bowen, R.E. (2006). Chain of custody as an organizing framework in seafood risk reduction. *Marine Pollution Bulletin,* 53(10-12): 640-649.

Yin, R.K. (2003). *Case study research: Design and methods 3rd ed.* ISBN 0-7619-2553-8. Thousand Oaks, California: Sage Publications.

Zadernowski, M.R., Verbeke, W., Verhè, R. & Babuchowski, A. (2001). Towards meat traceability critical control point analysis in the Polish pork chain. *Journal of International Food & Agribusiness Marketing,* 12(4): 5- 22.

Zhang, X., Zhang, J., Liu, F., Fu, Z. & Mu, W. (2010). Strengths and limitations on the operating mechanisms of traceability system in agro food, China. *Food Control,* 21(6): 825-829.

# Appendix 1

Identified drivers of traceability in the food industry

| Driver | Benefits of using traceability |
|---|---|
| Legislation | • Compliance with regulation (Opara and Mazaud 2001; Bollen 2004; Schwägele 2005; Smith et al. 2005; Thompson et al. 2005; Wang and Li 2006; Senneset et al. 2007; Skoglund and Dejmek 2007; Schröder 2008; Sebestyen et al. 2008; Thakur and Hurburgh 2009)<br>• Compliance with regulation to identify pigs (Madec et al. 2001)<br>• Compliance with regulation to identify the origin (Peres et al. 2007)<br>• Compliance with regulation to prevent illegal, unregulated and uncontrolled fishing (IUU) (Schmid and Connelly 2009)<br>• Fulfilment of legal requirements for product documentation and traceability (Arason et al. 2010) |
| Food safety | • Minimise quantity of recalls (Moe 1998; Dupuy et al. 2005; Smith et al. 2005; Sparling et al. 2006; Regattieri et al. 2007)<br>• Animal tracking to document origin (Stanford et al. 2001)<br>• Documentation of movement and health history (McGrann and Wisemann 2001)<br>• Better disease emergency management (Elbers et al. 2001)<br>• Increased control of animal diseases (McKean 2001; Pettitt 2001; Smith et al. 2005; Ammendrup and Barcos 2006)<br>• Reduce consequences of animal diseases (Disney et al. 2001)<br>• More efficient crisis management (Smith et al. 2005)<br>• Increase safety control (Golan et al. 2004)<br>• Cost reduction of product recalls (Golan et al. 2004; Can-Trace 2007)<br>• Bio-security protection of the livestock populations (Smith et al. 2005)<br>• Easier to isolate and reduce risk (Sparling et al. 2006; Yasuda and Bowen 2006)<br>• Increase the liability incentives (responsibility of companies for consequences of unsafe food) (Can-Trace 2007; Pouliot and Sumner 2008)<br>• Better food safety assurance (Hernández-Jover et al. 2009) |

| | |
|---|---|
| Quality | • Improve quality management and control (Viaene and Verbeke 1998; Zadernowski et al. 2001; Frederiksen 2002; Golan et al. 2004; Wang and Li 2006; Riden and Bollen 2007; Galvão et al. 2010; Mai et al. 2010)<br>• Better quality assurance (Leat et al. 1998; Hobbs et al. 2005)<br>• Reduction of risks (Opara and Mazaud 2001)<br>• Control and verification of quality assurance schemes (Arana et al. 2002)<br>• Quality feedbacks in supply chains and improved transparency in cool chains (Bollen 2004; Bollen et al. 2006)<br>• Verification of quality information (Can-Trace 2007)<br>• Improved quality (Wang et al. 2009)<br>• Better food product documentation (Arason et al. 2010) |
| Sustainability | • Meet requirements in certification schemes to document sustainability (e.g. Marine Stewardship Council, KRAV, Friend of the Sea) (Roheim and Sutinen 2006; Schmid and Connelly 2009; WWF 2009)<br>• Documentation of sustainability and sustainable origin (Arason et al. 2010) |
| Welfare | • Documentation of animal health and welfare (Madec et al. 2001)<br>• Welfare management (Voulodimos et al. 2010)<br>• Verification of animal health (Schulz and Tonsor 2010) |
| Certification | • Meet requirements in standards to document food safety, quality and sustainability (e.g. EUROPGAP, British Retail Consortium, ISO22000: 2005) (Roheim and Sutinen 2006; Frosch et al. 2008; Bevilacqua et al. 2009; Schmid and Connelly 2009)<br>• Increased coordination of supply chain actors (Banterle and Stranieri 2008)<br>• May secure and calm consumers by using labels (e.g. certification, safety and quality labels) (van Rijswijk et al. 2008)<br>• Added value and market access through certification traceability schemes (Manos and Manikas 2010) |

| | |
|---|---|
| Competitive advantages | • Increase sales value products (Golan et al. 2004)<br>• Increase market position (Souza-Monterio and Caswell 2004)<br>• Labelling products with attributes which are hard for the consumer to detect (e.g. production of food using genetic modification) (Golan et al. 2004)<br>• Provide evidence of good agriculture practice (Bollen 2004)<br>• Differentiate products (Smith et al. 2005; Pouliot and Sumner 2008; Mai et al. 2010)<br>• Enter a market and use as a marketing tool (Wang and Li 2006)<br>• Increase perception of customers (Sparling et al. 2006)<br>• May improve consumer´s confidence (van Rijswijk et al. 2008)<br>• Brand protection (Frederiksen et al. 2002; Olsson and Skjöldebrand 2008)<br>• Protect reputation of product, company or country (Olsson and Skjöldebrand 2008; Pouliot and Sumner 2008)<br>• Increased documentation of origin and prevention of mislabelling (Sant'Ana et al. 2010)<br>• Reduce number of customer complaints (Mai et al. 2010)<br>• Fulfilment of commercial requirements (product documentation) (Arason et al. 2010)<br>• Strengthen the consumers' relationship to a company (Mai et al. 2010)<br>• Improve information management (Canavari et al. 2010) |
| Chain communication | • Improve supply chain management (Viaene and Verbeke 1998; Smith et al. 2005; Wang et al. 2009; Mai et al. 2010)<br>• Better assurance (Pettitt 2001)<br>• Allocation of responsibilities, assurance and reassurance of customers and consumers, validate and resolve complaints (Opara and Mazaud 2001)<br>• Improve supply chain communication (Frederiksen et al. 2002)<br>• More efficient logistics/distribution systems (Meuwissen et al. 2003; Smith et al. 2005)<br>• Lower-cost distribution systems (Golan et al. 2004)<br>• Better real-time exchange of information (Bollen 2004)<br>• Reduction of risk: Companies protect their investments by demanding documentation of the origin from the suppliers (Smith et al. 2005)<br>• Verification of information (Raschke et al. 2006)<br>• Increase authentication (Shackell 2008)<br>• Increase transparency in supply chains (Schröder 2008; van Rijswijk et al. 2008) |

| | |
|---|---|
| | • Documentation of ethical issues (Korthals 2008)<br>• Play a role to prevent fraud (Pèrez-Villarreal et al. 2008)<br>• Documentation of healthy products (Wang et al. 2009)<br>• Increase coordination of supply chain actors to provide food safety and quality (Engelseth 2009)<br>• Faster exchange of information and easier verification of information (Chryssochoidis et al. 2009)<br>• Support decision support actions (Arason et al. 2010) |
| Terrorist threats | • Use traceability as a respond to the threat of bioterrorism (e.g. contamination of food) (Olson 2005; Thompson et al. 2005; Thakur et al. 2010) |
| Production optimization | • Increase internal controls (Moe 1998; Opara and Mazaud 2001)<br>• Avoiding unnecessary recordings of information (Moe 1998)<br>• Better production planning and scheduling (minimize waste, optimal use of raw materials, optimized production planning, extent product life cycle, avoiding un-economic mixture of resources, ability to act when product not fulfil a standard) (Moe 1998; Wang and Li 2006)<br>• Increase inventory control (Smith et al. 2005)<br>• Reducing time and effort of transactions (Bechini et al. 2008)<br>• Improve catch management and production planning (Margeirsson 2008)<br>• Reducing recording errors (Bechini et al. 2008; Chryssochoidis et al. 2009)<br>• Increase productivity and reduce costs (Huang and Yang 2009)<br>• Reducing transaction costs (Dreyer et al. 2004; Chryssochoidis et al. 2009)<br>• Process improvements (cold chain management, warning of equipment failure, predictive maintenance tool, improving energy management, providing automatic record-keeping for regulatory compliance, eliminating personal training costs, reducing insurance costs) (Ruiz-Garcia et al. 2010)<br>• Better control by increased documentation of production costs (Thakur et al. 2010)<br>• Support decision support actions (Arason et al. 2010) |

# Appendix 2

Identified empirical findings of drivers for traceability in the food industry

| Drivers and benefits of using traceability | Industry | Focus | Research fields |
|---|---|---|---|
| **Legislation** | | | |
| **Food** | | | |
| Compliance with regulation to identify pigs | Pig (Madec et al. 2001) | Identification of individual animals | Engineering |
| **Food safety** | | | |
| **Food** | | | |
| Better disease emergency management | Animal (Elbers et al. 2001) | Traceability system in the Netherlands | Engineering |
| Increase safety control, cost reduction of product recalls | Food (Golan et al. 2004) | Traceability in US food supply chains | Supply chain management |
| Minimise quantity of recalls, easier to isolate and reduce risk | Dairy (Sparling et al. 2006) | Costs and benefits of traceability in the Canadian dairy-processing sector | Supply chain management |
| Minimise quantity of recalls | Cheese (Regattieri et al. 2007) | Integration of barcodes and RFID tag technology | Engineering |
| Better food safety assurance | Pig (Hernández-Jover et al. 2009) | Evaluation of implementing traceability and food safety requirements | Market research |

| Quality | | | |
|---|---|---|---|
| **Food** | | | |
| Improve quality management and control | Pork (Zadernowski et al. 2001) | Critical traceability point analysis | Quality management |
| Improve quality management and control | Food (Golan et al. 2004) | Traceability in the US food supply chains | Supply chain management |
| Quality feedbacks in supply chains and improve transparency in the cool chain | Fruit (Bollen et al. 2006) | Traceability in postharvest quality management | Engineering and quality management |
| Better food product documentation | Food (Arason et al. 2010) | Decision support system for the food industry | Engineering and quality management |
| **Seafood** | | | |
| Improve quality management and control | Fish (Frederiksen 2002) | Traceable quality of fresh fish | Engineering and quality management |
| Improved quality | Fish (Wang et al. 2009) | Adoption of traceability system in Chinese fishery processing industry | Economics |
| Improve quality management and control | Fish (Mai et al. 2010) | Benefits of traceability in fish supply chains | Supply chain management |
| Improve quality management and control | Cod (Galvão et al. 2010) | Traceability system in cod fishing | Quality management |

| | | | |
|---|---|---|---|
| **Sustainability** | | | |
| **Seafood** | | | |
| Meet requirements in certification schemes to document sustainability | Seafood (WWF 2009) | Assessment of on-pack, wild-capture seafood sustainability certification programmes and seafood eco-labels | Supply chain management |
| **Welfare** | | | |
| **Food** | | | |
| Documentation of health and welfare | Pig (Madec et al. 2001) | Identification of individual animals | Engineering |
| Verification of animal health | Animal (Schulz and Tonsor 2010) | Cow-calf producer preferences for voluntary traceability system | Economics |
| Welfare management | Livestock (Voulodimos et al. 2010) | Animal identification using RFID tag technology | Engineering |
| **Certification** | | | |
| **Food** | | | |
| Increased coordination of supply chain actors | Food (Banterle and Stranieri 2008) | The consequences of voluntary traceability system for supply chain relationship | Supply chain management |
| May secure and calm consumers by using labels | Food (van Rijswijk et al. 2008) | Consumer perception of traceability | Market research |

| | | | |
|---|---|---|---|
| Added value and market access through certification traceability schemes | Food (Manos and Manikas 2010) | Traceability in the Greek fresh produce sector | Supply chain management |
| **Competitive advantages** | | | |
| **Food** | | | |
| Increase sales value products, labelling products with attributes which are hard for the consumer to detect | Food (Golan et al. 2004) | Traceability in US food supply chains | Supply chain management |
| Increase market position | Beef (Souza-Monterio and Caswell 2004) | The economics of implementing traceability in beef supply chains | Supply chain management |
| Increase perception of customers | Dairy (Sparling et al. 2006) | Costs and benefits of traceability in a Canadian dairy-processing sector | Supply chain management |
| May improve consumer´s confidence | Food (van Rijswijk et al. 2008) | Consumer perceptions of traceability | Market research |
| Improve information management | Fruit (Canavari et al. 2010) | Traceability as part of competitive strategy | Supply chain management |
| **Seafood** | | | |
| Differentiate products, reduce numbers of customers complaints, strengthen consumers’´ relationship to a company | Fish (Mai et al. 2010) | Benefits of traceability in fish supply chains | Supply chain management |

| Chain communication | | | |
|---|---|---|---|
| **Food** | | | |
| Lower-cost distribution systems | Food (Golan et al. 2004) | Traceability in the US food supply chains | Supply chain management |
| Increase coordination of supply chain actors to provide food safety and quality | Strawberry (Engelseth 2009) | Integration of traceability and supply networks | Supply chain management |
| Faster exchange of information and easier verification of information | Mineral water (Chryssochoidis et al. 2009) | Cost-benefit evaluation of an electronic traceability system | Economics |
| Support decision support actions | Food (Arason et al. 2010) | Decision support system for the food industry | Engineering and quality management |
| **Seafood** | | | |
| Improve supply chain communication | Fresh fish (Frederiksen et al. 2002) | Development and validation of an Internet based traceability system | Engineering |
| Improve supply chain management, documentation of healthy products | Fish (Wang et al. 2009) | Adoption of traceability system in Chinese fishery processing industry | Economics |
| Improve supply chain management | Fish (Mai et al. 2010) | Benefits of traceability in fish supply chains | Supply chain management |

| | | | |
|---|---|---|---|
| **Production optimization** | | | |
| **Food** | | | |
| Reducing time and effort of transactions, reducing recording errors | Food (Bechini et al. 2008) | Patterns and technologies for enabling supply chain traceability through collaborative e-business | Engineering |
| Reducing recording errors, reducing transaction costs | Mineral water (Chryssochoidis et al. 2009) | Evaluation of cost-benefit of an electronic traceability system | Economics |
| Support decision support actions | Food (Arason et al. 2010) | Development of decision support systems for the food industry | Engineering and quality management |
| **Seafood** | | | |
| Improve catch management and production planning | Cod (Margeirsson 2008) | Processing forecast of cod | Engineering |
| Increase productivity and reduce costs | Shrimp (Huang and Yang 2009) | Integration of seafood traceability system for shrimp supply chain | Engineering |

# Appendix 3

Identified principles of traceability in relevant literature

| Industry | Focus |
|---|---|
| **The concept of traceability** | |
| **Food** | |
| Food (Moe 1998) | Theoretical issues of traceability |
| Animal (McGrann and Wisemann 2001) | Harmonization of standards and technical aspects |
| Agriculture (McKean 2001) | Two components of products traceability: 1) unique identification and 2) verification |
| Agriculture (Opara 2003) | The concept of traceability |
| Agriculture (Hobbs 2004) | Three functions of traceability systems: 1) ex post reactive systems, 2) ex post systems, and 3) ex ante quality verification |
| Pasta (Bertolini et al. 2006), mineral water (Karlsen et al. 2010) | Identification of critical points |
| Fruit (Bollen et al. 2007), perishable food (Bollen et al. 2006) | Granularity |
| Fruit (Riden and Bollen 2007),meat (Donnelly et al. 2009a) | Transformations |

| | |
|---|---|
| Honey (Donnelly et al. 2008), chicken (Donnelly et al. 2009b), soybean (Thakur and Donnelly 2010) | Standardized list of data elements |
| Food (Engelseth 2009) | Integration of organizational resources and technical resources |
| Meat (Donnelly et al. 2009a) | Linking of traceability, product and process information |
| **Fish** | |
| Fish (Pálsson et al. 2000; Karlsen and Senneset 2006; Randrup et al. 2008), fresh fish (Frederiksen and Bremner 2001) | Information lost |
| Fish (Moretti et al. 2003) | Verifying traceability schemes for fish |
| Fish (Pèrez-Villarreal et al. 2008) | Validation of traceable information |
| Herring (Frosch et al. 2008), farmed salmon (Storøy et al. 2008) | Identification of critical points |
| **Other industries** | |
| Not specified (Hamilton and Beeby 1991) | Use of traceability in software development |
| Not specified (Cheng and Simmons 1994) | Assessing traceability at three levels of manufacturing system: 1) strategy, 2) planning and design, and 3) operations |
| Automobile (Kim et al. 1995) | Traceability ontology |

| | |
|---|---|
| **Models** | |
| **Food** | |
| Food (Lo Bello et al. 2004) | Modelling and evaluating traceability systems in food chains |
| Food (Bechini et al. 2005) | Generic data model for food traceability |
| Food (Bechini et al. 2008) | Traceability models using unified modelling language (UML) |
| Food (Sebestyen et al. 2008) | Service-oriented architecture of traceability |
| Grain (Thakur and Hurburgh 2009) | Model for information exchange |
| Food (Senneset et al. 2010) | Generic information model |
| **Other industries** | |
| Not specified (Ramesh et al. 1995) | Traceability model at different levels of granularity |
| Not specified (Bianchi et al. 2000) | Traceability models |
| Not specified (García et al. 2008) | Traceability management architectures |
| **Framework** | |
| **Food** | |
| Food (Bechini et al. 2005) | Framework of food traceability |
| Food (Regattieri et al. 2007) | Framework for product traceability |

| | |
|---|---|
| Food (TraceFood 2011) | Framework for traceability of food (TraceFood) |
| **Seafood** | |
| Seafood (Yasuda and Bowen 2006) | Chain of custody as an organizing framework in seafood risk reduction |
| **Other industries** | |
| Variety of industry[14] (Billo and Bidanda 1998) | Material tracking design framework |
| **Standards and guidelines** | |
| **Food** | |
| Food and feed (2007) | Traceability in the feed and food chain – General principles and basic requirements for system design and implementation |
| Food (GS1 2010) | Checklist for global traceability for the food supply chain |
| **Seafood** | |
| Fish (EAN.UCC 2002) | Traceability of fish guidelines |
| Farmed fish (CEN 2003a) | Specification of the information to be recorded in farmed fish distribution chains (TraceFish) |

[14] Such as ammunition production, vehicle overhaul, metal fabrication, automotive industry and health care.

| | |
|---|---|
| Captured fish (CEN 2003b) | Specification of the information to be recorded in captured fish distribution chains (TraceFish) |
| Fish (Derrick and Dillon 2004) | A guide to traceability within the fish industry |
| **Other industries** | |
| General (GS1 2007) | Global traceability standard - Requirements for full chain traceability |

# Appendix 4

Identified methods for measuring food traceability

| Industry | Measurement perspectives | Selection |
|---|---|---|
| **Action research** | | |
| Meat (Mousavi et al. 2005) | Traceability system | One company |
| Fruit (Bollen et al. 2007; Riden and Bollen 2007) | Packing procedures, effects of mixing and transformations | One company |
| Farmed fish (Senneset et al. 2007) | Implementation of electronic chain traceability | One supply chain |
| **Interview** | | |
| Fish (Karlsen and Senneset 2006) | Simulated recall | 16 seafood products |
| Fish (Randrup et al. 2008) | Simulated recall | 18 seafood products |
| Food (van Rijswijk et al. 2008) | Consumer perception of traceability | 163 informants from four countries |
| Mineral water (Chryssochoidis et al. 2009) | Cost-benefit | One company |
| Food (Engelseth 2009) | Supply network integration | Four fresh food supply chains |
| Fruit (Canavari et al. 2010) | Competitive strategy | 17 informants |
| Honey and chicken (Donnelly 2010) | Using standardised data lists | Chicken: Five responses; Honey: Eight responses |

| | | |
|---|---|---|
| **Focus groups** | | |
| Food (Kehagia et al. 2007) | European consumer perceptions | 24 focus groups in 12 countries |
| Food (Chrysochou et al. 2009) | Consumer perceptions of the technological solutions | 12 focus groups in 12 European countries |
| **Survey** | | |
| Food (Banterle and Stranieri 2008) | Supply chain relationship | All Italian companies certified under UNI 10939:2001 |
| Fish (Wang et al. 2009) | Difficulties, incentives and performance of traceability | Management of companies in a specific geographic area |
| Meat (Schulz and Tonsor 2010) | Cow-calf producer preferences for traceability systems | 2000 producers in US, 609 responses |
| **Traceability control mechanisms** | | |
| Animal (Arana et al. 2002) | Individual identification | Muscle samples from animals from a specific area |
| Food (Peres et al. 2007) | Determination of origin of foodstuffs | Review article |
| Farmed and wild-caught fish (Turchini 2009) | Distinguish between farmed and wild-caught fish – stable isotopes | Twelve samples of cod from four different farms |
| **Case study** | | |
| Meat (Donnelly et al. 2009a) | Transformation | One company |
| Cod (Galvão et al. 2010) | Traceability system | Two companies |

| | | |
|---|---|---|
| Food (Olsen and Aschan 2010), mineral water (Karlsen et al. 2010) | Identification of CTPs | Food: Unknown numbers of companies; Mineral water: One company |
| Fresh food (Manos and Manikas 2010) | Identification of drivers and constraints | 22 companies |
| **Modelling** | | |
| Food (Dupuy et al. 2005) | Batch dispersion | Not relevant in the study |
| Food (Pouliot and Sumner 2008) | Incentives for food safety and quality | Not relevant in the study |
| Food (Wang et al. 2008) | Optimization of traceability | Not relevant in the study |
| Fish (Jensen et al. 2010) | Supply chain modelling | Two scenarios |
| **Simulation** | | |
| Animal (Disney et al. 2001) | Economic effects of improved animal identification systems | Simulations of five animal identification levels for cattle and slaughter plants, and four levels for swine |
| Food (Skoglund and Dejmek 2007) | Continuous processes | One production line |

| Mixed use of methods | | |
|---|---|---|
| Fresh fish (Frederiksen 2002) | Traceable quality - case study, action research | Case study: two supply chains; Action research: one supply chain |
| Herring (Frosch Møller 2005) | Decision-making process for quality and production control - case study, multivariate data analysis | Case study: one supply chain |
| Meat (Hobbs et al. 2005) | Traceability: Do consumers care? - experimental auctions with consumers | Groups of 12-14 people |
| Food (Starbird and Amanor-Boadu 2006) | Incentives for food safety - case study, modelling | One company and its suppliers |
| Dairy (Sparling et al. 2006) | Cost and benefits – interview and survey | Interview: six interviews with dairy-processing companies, survey: 130 responses |
| Fresh fish (Asensio and Montero 2008) | Labelling in fish retail shop – observation in shops | 285 traditional fish shops and 155 fish shops |
| Fresh fish (Abad et al. 2009) | Use of RFID tag – laboratory tests and demonstration in supply chain | One supply chain |
| Pig (Hernández-Jover et al. 2009) | Evaluation of traceability implementation - pilot study, survey | Pilot study: several evaluations with different numbers of sites; Survey: 30 producers |
| Fourth range vegetable products (Bevilacqua et al. 2009) | Reengineering of a supply chain and traceability – process modelling, technique, action research | One supply chain |
| Fresh fish (Mai 2010) | Quality management - case study, cost-benefit analysis (interviews), laboratory reference methods | Interviews: different numbers of companies |

| | | |
|---|---|---|
| Grain (Thakur 2010) | Operational techniques - mathematical models, mixed-inter program, case study | Case study: two supply chains |
| Food (Zhang et al. 2010) | Strengths and limitations of traceability systems - interviews, focus groups | Semi-structured interviews: 110 agribusinesses;<br>Focus groups: three |
| **Choice of architecture** | | |
| Food (Sebestyen et al. 2008) | Towards a traceability solution for food | Not relevant in the study |
| Shrimp (Huang and Yang 2009) | Integration of seafood traceability system for shrimp supply chain | One factory |
| Food (Ruiz-Garcia et al. 2010) | Testing implementation of a prototype | Not relevant in the study |
| Livestock (Voulodimos et al. 2010) | Animal identification using RFID tag | Microsoft.NET framework |
| Food (Senneset et al. 2010) | Identification of returnable transport items | Not relevant in the study |

# PAPER I

**Karlsen, K.M. & Olsen, P. (2011). Validity of method for analysing critical traceability points. *Food Control,* 22: 1209-1215.**

# PAPER II

**Donnelly, K.A.-M. & Karlsen, K.M. (2010). Lessons from two case studies of implementing traceability in the dried salted fish industry. *Journal of Aquatic Food Product Technology*, 19: 38-47.**

# PAPER III

Karlsen, K.M., Forås, E., Sørensen, C.-F. & Olsen, P. (2011). Critical criteria when implementing electronic chain traceability in a fish supply chain. *Food Control,* 22: 1339-1347.

# PAPER IV

**Karlsen, K.M., Donnelly, K.A.-M. & Olsen, P. (2011). Granularity and its importance for traceability in a farmed salmon supply chain. *Journal of Food Engineering,* 102: 1-8.**

ISBN 978-82-8266-016-7