



**UNIVERSITY  
OF ICELAND**

# Net-works

The technological development and economic significance of the pelagic trawl

Sylvía Marsibil Bates

Dissertation towards the degree of Doctor of Philosophy

**SCHOOL OF HUMANITIES  
FACULTY OF PHILOSOPHY, HISTORY AND ARCHAEOLOGY**

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University of Iceland

School of Humanities

Faculty of Philosophy, History and Archaeology

2025

Deild heimspeki, sagnfræði og fornleifafræði Háskóla Íslands  
hefur metið ritgerð þessa hæfa til varnar  
við doktorspróf í sagnfræði

Reykjavík, 12. febrúar 2025

Sverrir Jakobsson  
Deildarforseti

Faculty of Philosophy, History and Archaeology at the University of Iceland  
has declared this dissertation eligible for a defence  
leading to a Ph.D. degree in History

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*Net-works: the technological development and economic significance of the pelagic trawl*

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Reykjavík 2025

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ISBN: 978-9935-9811-3-4  
ORCID: 0009-0000-2718-7176

## Abstract

Technological change is a crucial but a vastly under-researched aspect of the development of modern fisheries. This is the first study to explore the invention and development of the pelagic trawl, one of the most effective fishing gears in the world. This thesis examines a large and complex network of inventors and organisations from all over the world, including Iceland, each of whom were involved in the innovation process, and how their interactions and influences drove technical change. The innovation process is charted by looking at changes in the design of the pelagic trawl over time in detail and identifying the drivers of change and the impetus behind the new designs and ideas. The invention of the pelagic trawl is an excellent window into the process of how new technologies and ideas are introduced into fisheries. In following the story of inventors and designs, this study also presents the lives of the key individuals and their motivations, as well as the motives of organisations and various government institutions in encouraging the development of the pelagic trawl. Lastly, the economic significance of pelagic trawling is explored by looking especially at its effects on fish catch and productivity.

## Ágrip

Tæknibreytingar eru lykilþáttur í nútímaþróun fiskveiða en hafa lítt verið rannsakaðar. Í þessu verkefni er í fyrsta sinn tekin til rannsóknar uppfinning og þróun flotvörpunnar, eins afkastamesta veiðarfæris í heiminum. Við könnum stórt og flókið net uppfinningamanna og stofnana í mörgum löndum, þ. á m. Íslandi, sem unnu að þróun flotvörpunnar og hvernig samskipti þeirra og áhrif knúðu tæknibreytingar áfram. Við rekjum uppfinningannaferlið með því að skoða nákvæmlega breytingar á hönnun flotvörpunnr í tímans rás og metum hvaða áhrifaþættir koma við sögu nýrra hugmynda og hönnunar. Uppfinning flotvörpunnar er ágætur gluggi inn í ferlið sem verður til við að þróa nýja fiskveiðitækni. Með því að fylgja eftir uppfinningamönnunum og framvindu hönnunar kynnumst við starfi frumkvöðlanna og hugmyndunum sem knúðu þá áfram, en einnig þætti stofnana og stjórnvalda í að örva þessa nýju tækni. Loks skoðum við efnahagslega þýðingu flotvörpunnar með því að kanna áhrif hennar á fiskafla og framleiðni í veiðum.

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## Preface

When the subject of the pelagic trawl was first introduced to me, it was as an odd little piece of fishing trivia; that the pelagic trawl was one of only two types of fishing gear with a known inventor. The other is the Danish seine, which was invented by Jens Væver in the mid-nineteenth century. It is another Dane, Robert Larsen, who is credited with the invention of the pelagic trawl, almost exactly a century later. My father, an ex-fisherman and fisheries journalist of many years' experience, told me this – after which he told me of how he had gone to interview a senior fishing gear inventor in Sweden with a different story. This was Stig Rune Yngvesson, who, while discussing his latest fishing innovation, had digressed to tell the story of how his father, Yngve Bernhardsson, had originally invented of the pelagic trawl - and that his idea had been stolen. This story was the inspiration for this thesis.

Yngve Bernhardsson's son Stig Rune started this all, by telling a story to my father. So, I am now telling it to you – albeit in my own way, with references and graphs. I did get to hear it for myself from Stig Rune himself, all while sitting in the house his father and grandfather had lived in, on one of the tiny islands that make up the Öckerö archipelago. He told another story, of how back in the day when Christianity had first come to the islands the old gods had run away – except one particularly stubborn god, who instead hid out on one of islands, an island so small as to be barely more than a rock. This god was trapped there by all the good Christian folk around him and has slowly been going mad over the centuries. It's a fun little story, as Stig Rune told it, and he said that on a quiet night you can hear the god laughing to himself. He pointed to that rocky little island from the window, at which point a massive one-eyed seagull decided to perch on the balcony. He was, it turned out, a longtime visitor to the house who Stig Rune regularly fed treats. I did not think to ask if he, too, was an old god in disguise.

In the course of writing this thesis I must thank Rannís, Hugdok, and Akkur for providing funding. I am also grateful to Tyberøn Trawl Door, Euronete, Vónin, and Brim for their grants. I would be extraordinarily remiss if I did not express my gratitude to Viktor Strange and Hörður Jónsson (of Tor-Net and Veiðarfæragerðin respectively) for teaching me everything a girl needs to know about trawls and netlofts. I must also thank Guðmundur Gunnarsson for his patience in explaining trawl designs and sharing his own research on pelagic trawling in Iceland, as well as my gratitude to Søren Byskov for his advice and assistance during the early stages of this thesis.

# 1 Introduction

The pelagic trawl was first used around the time of the Second World War in the Skagerrak and Kattegat. Here, Swedish fishermen caught herring in relatively shallow waters, usually with bottom trawls. They saw that the herring rose higher in the water column at night. When first introduced, the pelagic trawl was only used at night. This later changed when the same fishermen also used pelagic trawls during the day. Then they ventured further out into the North Sea to use the pelagic trawl there as well. It was popular enough that by the 1950s the pelagic trawl was known to netmakers, fishermen, and fisheries gear technologists around the world.

Despite this, the pelagic trawl was not as initially popular elsewhere as it was in Sweden. Although it was known and used by many, it was almost always outmatched by the purse seine in efficiency and in volume of catches. Part of its ongoing use from the 1950s can be attributed to the systematic experimentation and adaptation of fishing gear, including the pelagic trawl, by NGOs and government-run organisations. The pelagic trawl was developed further by them with the aim of making it a more effective and efficient method of catching herring. In the decades since the Second World War the pelagic trawl has become a specialised tool, often employed when other types of gear (such as the purse seine) are unsuited to the fishing conditions. The development and later use of the pelagic trawl is linked with a steady increase in pelagic catches since the mid-twentieth century.

Currently, there are several analyses of the history of fishing vessels, fisheries biology, and fisheries, all which successfully explore their significance – but none which examine fishing gear. There is currently no detailed study of fishing gear which examines the development of any specific gear type, nor of the innovators who developed it. As a result, fishing gear is a neglected corner of fisheries history and the history of technology. The development of fishing gear, especially in the early to mid-twentieth century, demonstrates great change as organic materials are replaced with synthetic ones. This is matched with a corresponding increase in the size of fishing vessels and the development of onboard preservation and processing equipment.

This thesis demonstrates that within fisheries there were complex relationships between individuals and communities, including a geographically diverse network of inventors and fishermen. This allows for a detailed examination of the environments which produced pelagic trawls and which drove its development. An important aspect of this is exploring the role of new materials and resources, and the techniques that were developed to best utilise them. Together, they form the basis for understanding drivers of change. By making a detailed study of the pelagic trawl, this thesis in effect demonstrates technological change in fisheries as a whole, as the advances in materials and resources were seen throughout the fishing industry of Europe and elsewhere. We get to see how

the complex factors which encourage innovation enable the exploitation of fisheries, as well as the role of individuals and organisations in this. Additionally, this thesis is the first to make a detailed study of the inventors of fishing gear by examining their environments, identifying their resources, and understanding their motivations. It uses written sources as well as the recollections of fishermen themselves to tell their stories. The changes they saw over the course of their working lives demonstrate how they adapted to new challenges, from the introduction of new materials to the implementation of fishing restrictions.

There are three core aims to this thesis. The first aim is to identify key inventors, organisations, and networks. Here, understanding the environments and resources of inventors is a critical step in identifying the drivers of change and how they differ between different individuals as well as institutions. The second aim is to present the technological development of the pelagic trawl and the people behind it. The key design features are identified, along with their materials and components, as well as the approaches and techniques used by inventors in designing, testing, and using the pelagic trawl. The third aim is to explore the economic significance of the pelagic trawl, in how it was used and in its impact. This is achieved by using landing and productivity data as the foundation for analysing its effectiveness and efficiency. Looking at how and why the pelagic trawl continued to be used demonstrates that there were several reasons why it was significant.

In order to pursue these aims, several approaches were utilised, as each aim had its own challenges. Finding the core inventors was accomplished in two stages. The first was to identify them through documentation, such as patents and journal articles. The second was to interview individuals connected to those inventors, such as their children or surviving contemporaries. While the core basis for the first aim relies on printed sources, the oral history (albeit anecdotal) was important in understanding many nuances and details. Presenting the development of the pelagic trawl was possible through the large quantity of printed source material.

While there is a lack of detailed data on early designs, particularly as patent diagrams typically lack the exact detail this thesis required, other sources can help fill the knowledge gap. Later designs were recorded in a standardised format, to the extent that any proficient netmaker could have accurately reproduce the design for themselves. Additionally, these later designs were often described in great detail, especially any adjustments and adaptations made during testing. Testing and use of the pelagic trawl were also described, often with scientific exactness, demonstrating the techniques used by innovators and users. Analysing economic significance was the most challenging aim, as relevant data were frequently unavailable. However, sufficient data were preserved in fisheries statistics for at least three nations, although their scope was often limited.

Nevertheless, this does allow for analysis, which is supported by other source material.

During the early research stages of this thesis, it became clear that key developments occurred between 1930 and 1980. During this timeframe the development of the trawl

changed. Pelagic trawls began as small nets made from organic fibres, reinforced with hemp ropes, using lead weights and glass or cork floats. These trawls were towed by small boats of around 10 to 20 metres long. By the end of the 1960s trawls were made of lighter and stronger nylon, with chain as weights and plastic or aluminium floats. The trawls were also much larger, needing trawlers of 55 metres or more in length to tow not just the trawl but also its catch, often of 60 tonnes or more. Trawlers themselves also developed greatly, with the stern trawler becoming a popular choice for fishermen. These newer trawlers had an array of specialised equipment, from dedicated processing decks to netsounders. This thesis only follows the development of the pelagic trawl up to the 1980s as by this point many the key developments had already been made.

Analysing the significance of the pelagic trawl required an array of statistical data from three countries. These are: Sweden from 1954 to 1969, Scotland from 1965 to the 1990s, and Iceland from the 1990s onwards. These countries and these timeframes are used because finding relevant statistical data are challenging, especially that which specifically applies to the pelagic trawl. Luckily, each of these datasets were of particular relevance to this thesis. The data available for Sweden is from when the pelagic trawl was still in its early pair trawl form and made from organic components. Here the trawl is in its original pair trawl form and in its largely organic form – and without fishing restrictions. The data from Scotland is from time when the pelagic trawl is still being used as a pair trawl by some and as a one-boat trawl by others, but both forms are largely made from synthetic fibres and used with large vessels capable of processing large catches at sea. Here we see the pelagic trawl in a technologically advanced form, but during the time when restrictions and challenges first appear. Finally, the data from Iceland is from when the pelagic trawl was coming into use after decades of technological development. This shows us what the pelagic trawl is capable of when used by those either with considerable experience, or even just access to a wide variety of resources and guidance.

## 1.1 Research Questions

As described previously, there are three core aims: identify key inventors and networks, present the technological development of the pelagic trawl, and explore the economic significance of the pelagic trawl. Each of these aims contains several research questions which shape this thesis. These aims can be considered as looking first at the people, then then the pelagic trawl, and finally significance of the pelagic trawl as part of the wider context in which the people and the pelagic trawl are functioning.

The first and second aim are presented together in the second section of this thesis, while the third aim is explored in the third section. It was not possible to separate the first and second aim when writing about the technological development as they are so closely intertwined.

The first aim, identifying key inventors, organisations, and networks, entails asking the following questions about the people behind the trawl:

- Can the earliest inventor(s) be identified, as well as the problem they wish to solve?
- What are their backgrounds, environments, resources, and motivations?
- What are the drivers of change, as they pertain to these inventors?
- What is the role of networks and organisations and how are they involved?
- What are the relationships between inventors, groups, and networks, and how do they interact with each other?

These questions are focussed on the people and groups behind the pelagic trawl. First, they seek to understand how and why they came about to invent or design a pelagic trawl. Secondly, they establish how individuals and groups interacted with each other and how that in turn affected the development of the pelagic trawl. Part of this is establishing what the invention of a pelagic trawl would solve. This is not a question with a single, easy answer; rather, it is individual to each inventor, environment, and to each of the groups involved. The drivers of change as they relate to individuals are as important as those which affect groups, as events affecting the fishing industry has very tangible effects on those working within it.

The second aim, presenting the technological development of the pelagic trawl, raises a number of questions which focus on the pelagic trawl itself:

- Can a chronological sequence of trawl designs be established?
- What are the key features and materials, and how do they change over time?
- Are there any failed designs, ideas, or approaches?
- How did inventors go about designing, testing, and using their designs?
- How did inventors use new materials and advances in their design?
- How does the actual use of the pelagic trawl differ from its intended use?

Here, looking at the pelagic trawl itself, the focus is largely on the technical aspects. There are sufficient sources to determine the evolution of the pelagic trawl over time, both in design features and in terms of materials and auxiliary advances such as sonar.

Failed designs are important, as they demonstrate to what extent innovation and experimentation was possible by different inventors, as well as the response by a wider community to these attempts. There is also a large body of material that describes testing and using pelagic trawls. It is important to relate these technical aspects back to the questions asked for the first aim, which is why these two aims are dealt with simultaneously.

Testing new ideas and the introduction of new materials are key aspects of invention. Inventors are dependent on having the time and resources to do this. Another aspect of testing and designing is the difference between intended use and actual use. This, too, could be considered an aspect of failure, although any inventor would undoubtedly think it as an unexpected success.

The final aim, to explore the economic significance of the pelagic trawl, means widening the thesis to encompass a wider context:

- In which established (and new) fisheries was the pelagic trawl used?
- Did the development of the pelagic trawl create new fisheries?
- What were the products (and value of the products) of the pelagic trawl?
- How effective was the pelagic trawl in comparison with other fishing methods?
- Does the use of the pelagic trawl provide greater value than other methods?
- Does the use of the pelagic trawl change over time, and if so, how and why?

As data is somewhat limited, an in-depth economic analysis of the pelagic trawl is not possible. Instead, we must determine as much as we can from the data available and piece together a picture of its significance. Identifying the fisheries it was used for, as well as new fisheries that it enabled, is a good start. From this we can attempt determine the extent it was used within those fisheries, as well as the value of its catches. The bulk of that value will derive from the products made from those catches; luckily, there are some data for the products of pelagic fisheries. The effectiveness of the pelagic trawl when compared to other pelagic fishing methods is also an important method of gauging its significance.

Again, there are some data which should allow for a direct comparison with other fishing methods. This will demonstrate an immediate reason for whether – and why – the pelagic trawl was used. This should be taken into consideration with the value of the catch and the products derived from it. This should show us how and why the pelagic trawl was used. Finally, the changing use of the pelagic trawl needs to be addressed. How this changes over time can be charted through the available source material and will be presented as a component of the questions already asked.

Together, these questions help shape the thesis in both approach and structure, with the intention of forming a comprehensive picture of the inventors, their inventions, as well as the wider environment in which the pelagic trawl was being use and developed.

## 1.2 Theory and Methodology

This thesis falls firmly in the study of history of science and technology (HST). HST has as its aim the study of people and technology, ranging from stone age tools to the internet; the political, economic and cultural impact of technology on humanity and the relationship between them. It such shares much with the history of science and science and technology studies. The aim of science and technology studies (STS) is to understand the relationship between technology and society – between innovation, research, culture, politics, and society. Society and culture being key components of STS and HST means sociology is a critical component too; critical theories and social theories are two methods employed in this area and are therefore frequently applied to STS and HST.<sup>1</sup>

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<sup>1</sup> Bijker, 'Technology, Social Construction Of', 135.

As a consequence, STS and HST are rightly considered to be multi-disciplinary fields, requiring an understanding of history, technology and to an extent, sociology and anthropology. For many researchers, this field requires an in-depth knowledge of the specialised technologies and scientific research of their chosen subject, such digital communication, military technologies, mechanical engineering, or medicine. This does mean that the focus of research is often narrowed to the twentieth century.

A large component of HST and STS is focussed on communications technology and the media, with many theories specific to this area of study. They are numerous and are not discussed here as they are not relevant to this thesis. The sociology of scientific knowledge (SSK), and its partner, the sociology of scientific ignorance (SSI), exist as a subset of sociology and technology; its relevance in this thesis is limited but of interest. As a study it focusses on scientific research and is largely descriptive. It aims to understand points at which research could have diverged from its path – the key idea is that of the principle of symmetry, where understanding the ideas that failed is as important as the ones that succeeded.<sup>2</sup> In this it looks to cultural, political, and economic factors. By doing so it prefers to understand the context of the decisions made by key individuals and has no focus on the merits of the scientific research in question, only its progression and context. This, unfortunately, places the focus on key individuals and fails to critique the relevance or importance of the research in question.

Understandably, the philosophy of the relationship between humans and technology is the subject of extensive debate. As a consequence, there are numerous theoretical approaches used within HST, of which several are also methodologies. The theories of relevance to this thesis fall into one or more broad categories of determinist, constructionist, and critical. There are also a number of scholars and writers who have spent their time analysing and deconstructing these various theories and arguing over their philosophical fine print.

The following theoretical and methodological approaches presented here are those that were considered for this thesis. They are those that are used most frequently and are discussed in depth by those in the history of technology. In many instances they are not suited and would require adapting to an extent that would either renders them useless or push them too far outside their original scope. However, this does not preclude certain approaches or the inclusion of key ideas. Instead, it produces something more akin to a Frankenstein approach with components selected from some of the theories and methods discussed here. The core ideas behind the social construction of technology (SCOT) and actor-network theory (ANT) were especially useful in establishing the limits this thesis. Ultimately, the approach of SCOT was the most relevant and useful.

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<sup>2</sup> Bijker, 136.

- Technological Determinism

Technological determinism has its origins in the nineteenth century, with roots in Marxist thinking. It is, for the most part, poorly defined and has several variations<sup>3</sup> - hard, soft,<sup>4</sup> and neutral. In hard determinism, technology is the driving force of social activity and progress, with people organising themselves in order to benefit the technology and its ongoing development. The people, as a society or as individuals, have no choice in this. As function follows form, the use of technology is determined by its structure, which in turn determines the behaviour of the user. Soft determinism argues that there is a degree of control exerted by the user or society, however, this control is limited and the outcome inevitable. Neutral is the stance of technology is neither good or bad, only its use determines its role. Neutral determinism exists in partnership with technological instrumentalism, which goes further in stating that technology is neutral when the cultural and social conditions under it which it was produced can be ignored.

If technological determinism were to be applied to this thesis, it would in effect apply to all fisheries technology – and the history of fisheries would itself contradict the basic tenements of determinism. While technological developments in fisheries could initially be considered deterministic, the later imposition of controls and restrictions is incompatible with these ideas. Controls have been in place in since the mid twentieth century, such as when mesh sizes were regulated in Britain<sup>5</sup> and when Norway initiated a complete prohibition on pelagic trawling in the 1970s.<sup>6</sup> Additionally, these restrictions serve humanity in an indirect manner; fish stocks are preserved or fished sustainably not only in order to benefit humanity as a direct resource, but also to conserve the maritime environment for its own sake. Both hard and soft determinism would be hard pressed to make any argument, although a neutral stance could be argued - if the point of this thesis was to argue whether the pelagic trawl was 'good' or 'bad'.

- Actor-Network Theory (ANT)

Actor-network theory (ANT) was the product of Bruno Latour, Michel Callon, and John Law in the 1980s.<sup>7</sup> It functions as much as a methodology as well as a constructionist theory, focussing on describing the connections between individuals, artefacts, and concepts. Latour has continued to update ANT over the subsequent decades, clarifying and defining various aspects. This seems to entail ongoing reflective musings on terminology and semantics within ANT as ANT moves more into the realms of anthropology and philosophy than history.<sup>8</sup>

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<sup>3</sup> Hughes, 'Technological Momentum', 102.

<sup>4</sup> Héder, 'AI and the Resurrection of Technological Determinism', 123.

<sup>5</sup> Great Britain, Convention for the Regulation of the Meshes of Fishing Nets and the Size Limits of Fish.

<sup>6</sup> Norway, Act No. 57 of 1972 regulating the participation in fishery.

<sup>7</sup> Muniesa, 'Actor-Network Theory', 80.

<sup>8</sup> Latour, An Inquiry into Modes of Existence.

There are a number of specialised terms and ideas within ANT. This includes the idea of generalised symmetry, where human and non-human actors are treated as equal entities within a network. A network is itself comprised of a number of components; actants, actors, intermediaries, and mediators.<sup>9</sup> Intermediaries have no influence or impact on the network, while mediators do. Their impact cannot be gauged by input alone, only output. Networks are themselves constantly being reworked and kept alive by the constant interaction of all these components.<sup>10</sup> ANT suffers from three core issues. Firstly, it does not explain how the network came to exist in the first place. Secondly, it does not have the capacity to compare networks. Thirdly, it suffers from punctualisation. Punctualisation is the idea within an idea; to use ANT would be to consider a trawl not just an actor, but also as an assembly of components which is also comprised of many other actors.

ANT is not suited to this thesis as it fails to explore and understand the how and why of a network's origin. It also fails to account for the wider context of politics and culture that influence decision making. This is especially important in this thesis, where many netmakers are somewhat disparate and exist within a series of small networks rather than within a large single network. ANT seems more apt for the study of a large, cohesive network, such as an organisation or socially integral industry. There are, however, parts of ANT that can be brought to this thesis. The importance of both concepts and materials as actors is a useful of understanding the resources available to inventors, as is the exploration of scientists as forming a network. Scientists (as opposed to inventors) create a forum of experts providing feedback and resources, even when not directly collaborating. New materials in fisheries changed fisheries technology radically. They were adopted swiftly and often with little resistance or preference to tradition. The adoption of new concepts goes hand in hand with new materials, as the introduction of new materials created new ideas and facilitated pre-existing ones.

- Social Construction of Technology (SCOT)

The social construction of technology (SCOT) was created in the 1980s as a way to examine the social context of technology. The primary scholars were Wiebe Bijker, Trevor Pinch,<sup>11</sup> with contributions from Thomas Hughes. It functions as a methodology as much as a theory. The intention is to understand the greater social context of a technology and the meaning which that technology holds for society. It draws on the SSK idea of the principle of symmetry.<sup>12</sup> By utilising the principle of symmetry, SCOT was deviating from a linear model of progression for technology, instead placing each design as a nexus in series of designs, something more akin to a network than a family tree. It goes further by

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<sup>9</sup> Latour, *Reassembling the Social*, 37–42.

<sup>10</sup> Muniesa, 'Actor-Network Theory', 82–83.

<sup>11</sup> Bijker, Hughes, and Pinch, *The Social Construction of Technological Systems*.

<sup>12</sup> Bijker, 'Technology, Social Construction Of', 135.

introducing interpretative flexibility, which draws on social constructionism by understanding how the same technology has a different meaning to different groups involved in the creation and development of a technology. This in turn leads to the identification of different social groups;<sup>13</sup> these are typically the producers or designers of the technology. Primary groups are users and producers, but other groups can include manufacturers, politicians, and salespeople.

When using SCOT as a methodology there are clear steps that can be followed. While these steps are not defined in exact terms, they allow some degree of flexibility from the user. They can be set out as: identifying relevant social groups; identifying design flexibility and design problems; linking problems, designs and groups; understanding conflict; and looking at closure, whether rhetorical or redefinition. Rhetorical closure is when a successful design negates the need for further development, as the problem is seen as solved. Redefinition of the problem is when a new problem is invented whose solution renders the old problem irrelevant (or part of the solution for the new problem). Key concepts include understanding that as society changes and develops the definition of the problem and technology changes (the reintroduction of interpretative flexibility), and that the technology should be related to a wider contemporary context.<sup>14</sup>

The downside of SCOT is that when it proceeds to the final part, the wider context, it fails to elaborate on what this should entail.<sup>15</sup> In doing so it ignores by omission the significance of the technology in later timeframes. Langdon Winner specified that this could be perceived as social determinism.<sup>16</sup> Social determinism in this instance would suggest that only social interactions account for all human behaviour, omitting any other influence. There was further criticism from Winner,<sup>17</sup> who listed a number of concerns. They include: the omission of the consequences of technology; the omission of the 'invisible' social groups who are affected by, but have no role in, the development process; the omission of deeper cultural, economic, or intellectual origins of social choice; the amoral approach in preferring not to judge technology; and its role in human affairs.

For this thesis SCOT appeared ideal as it considered equally the designs which failed and succeeded, as well as relating the groups and designs to a wider contemporary context. Winner's criticisms, however, are too pointed to be dismissed and would entail adapting SCOT significantly. Instead, what is of particular use in this thesis is the identification of key designs as nexus points in a cobweb of inventions rather than a single linear progression, as well as the concept of redefining the problem when it appears to have been solved. This is an interesting idea for fisheries technology, where fishing gear

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<sup>13</sup> Klein and Kleinman, 'The Social Construction of Technology', 29.

<sup>14</sup> Klein and Kleinman, 30.

<sup>15</sup> Klein and Kleinman, 30.

<sup>16</sup> Winner, 'Upon Opening the Black Box and Finding It Empty', 364.

<sup>17</sup> Winner, 'Upon Opening the Black Box and Finding It Empty'.

must be repeatedly adapted for different fisheries and fishing grounds. Approaching different sets of inventors as distinct groups helped form a greater understanding of different types of inventors and inventions. The criticisms, as per Winner, are also very useful in identifying potential weaknesses within this thesis. As a result, this thesis looks much closer at the greater context of inventors with an eye to their resources, influences, and drivers of change.

In summary, these theories fall into one of three categories: technological determinism, social constructionism, and critical theory. Technological determinism is the oldest of the theories, and states unequivocally that technology drives human society, with humanity having little or no choice in future outcomes. Technological determinism is an area which appears to be poorly defined and explored, despite being easily and frequently the subject of derision and rebuttal. Social constructionism is the opposite, stating that it is people who drive technology and thus determining the outcome. Social constructionism is a social theory and as such is rooted in sociology, designed to examine the nature of social interactions and create paradigms of social relationships and behaviours. Specifically, it is based on the theory of shared ideas and constructs – the definition of ideas and identities of which members of a society agrees upon. In effect, the agreement of a group of people as to what constitutes reality.

Critical theories are focussed less on the technology and more on the society that has created it. As an approach it has a more application in the philosophy of technology than in HST, however it is recognised and has its uses as a reflective tool in understanding how the society that created a technology came to be. Critical theories are by definition multi-disciplinary, utilising data from history, science, technology, anthropology, culture, politics, and psychology. The downside of critical theory is that it focusses too greatly on a specific point in time; tracing changes over an extended timeframe in culture, technology, politics, and economics may be too demanding.

SCOT has been the strongest influence on this thesis. The second section of this thesis (technological development) examines the pelagic trawl as an artefact which has different meanings to different people and social groups. It presents the story of the trawl using a chronological narrative of inventors and inventions while simultaneously exploring what the trawl meant to those inventors. This section also examines the relationships between inventors and networks in order to understand who the relevant social groups were and how they interact with each other. Closure is also explored, where a problem is seen to be solved; this is expanded upon when looking at how the problem (seen to be solved) is redefined. ANT, while not used in this thesis, was useful in realising that it was important to consider the agency of new materials and their influence in inventors, as well as in considering the role played by a forum of scientists working on fisheries gear, which is particularly applicable given the role played by ICES and the FAO. In the third section (the greater context: economic significance) it was important to assess significance (one of

Winner's criticisms of SCOT). This is achieved by understanding the role played by the pelagic trawl in commercial fisheries, including that of the consequences of the pelagic trawl. In some parts of this section, understanding the use of the pelagic trawl meant resolving another of Winner's criticisms, of understanding if there were deeper cultural, economic, or intellectual choices made in the design and use of the pelagic trawl.

### 1.3 Sources

There were numerous primary sources available for this thesis, although some were more challenging to obtain than others. A large number of sources on pelagic trawls and pelagic trawling were found in contemporary publications. This included conference proceedings, the most prominent being *Modern Fishing Gear of the World*, with volumes 1, 2, and 3 published in 1959, 1963, and 1971 respectively. Additional articles and data were found in magazines and journals such as the *Commercial Fisheries Review*, *Fisheries Newsletter*, *Fishing News International*, and *Science et Pêche*.

Almost all of these sources are in English, although significant amount of source material was also found in Iceland, as well as Swedish, French, and German. Many sources originally written in other languages were later published in English, often in an abbreviated form, or as part of reports or articles. In Canada, many Russian and German papers were made available in English by the Fisheries Research Board of Canada Translation Series. In the case of fisheries statistics, many nations included introductions, alternate data headings, and footnotes in English (although in earlier years this was in French). In this thesis the majority of sources used are those either in English (or translated into English) or Icelandic, with the exception of the Swedish fisheries statistics.

The *Modern Fishing Gear of the World* series was published by the Food and Agriculture Organisation (FAO) in conjunction with Fishing News Books Ltd., and were but a small sample of the publications they produced from the 1950s onwards. They published a large variety of books and manuals on fishing and fisheries, from *Commercial Fishing Methods: an introduction to vessels and gear* (1971), *The Stern Trawler* (1972), the *FAO Catalogue of Fishing Gear Designs* (first published in 1965), to *How to Make and Set Nets* (1986). Each of these books has been useful to this thesis. The core focus of these publications is practicality – they provide information geared primarily to the fisherman, not the scientist. As such, they are invaluable in that they present ideas and information in clear and direct language, in the manner of an instruction manual. This is almost always accompanied with an array of clearly labelled diagrams. Often there is also a glossary, sometimes in multiple languages. In 1964 the FAO and Fishing News Books Ltd. also published *Fish Catching Methods of the World* (and its many subsequent editions). This particular book contained several chapters and articles written by those involved in pelagic fisheries research and gear development.

The International Council for the Exploration of the Sea (ICES) also produced a large number of documents and reports on fisheries research. However, most of their reports focus on marine biology and ecology. They were very scientific and too often omit any technical or practical information on fishing gear or techniques. There were numerous committees which include – to name but a few – the Pelagic Fish (Northern) Committee, the Fishing Technology Committee, the Gear and Behaviour Committee. They published numerous reports which contain important details concerning pelagic fisheries and the state of research being conducted.

A core source are historical and recent statistical data. The FAO has FishStatJ,<sup>18</sup> software with several data sets for global production in fisheries. Likewise, ICES has two sets of historical catch statistics for Europe from the early twentieth century onwards. While these are very useful by themselves, the original data contained in annual fishing statistical reports produced by countries such as Sweden, Norway, Britain, Scotland, and Iceland contain much more detailed data for pelagic fisheries. In several instances this included detailed data for pelagic trawling and pelagic fishing methods, as well as data on the value of catches and fishing gear.

## 1.4 Literature Review

At present there is no historical research on pelagic trawling. Very few studies to date have looked at technological change in fishing gear. There have been studies of technological change in trawlers and fishing vessels, as well as the development of processing equipment aboard vessels. None discuss the nature of the change in fishing gear in any detail, at least not in regard to the specifics of the technological development. There are numerous studies regarding individual fisheries, which typically discuss the social, economic, or political role of fishing or fishing communities.

There is one book which discusses the technological development of one type of fishing gear. Thomson's *The Seine Net*<sup>19</sup> (published 1969) has an introductory chapter (of 33 pages, with a great many pictures) in which the invention of the seine net is described, although it is almost entirely anecdotal and devoid of primary sources. Nevertheless, it is the only other text which describes the invention and development of a type of fishing gear. It should be noted, however, that at the time the seine net was the only type of fishing gear with a known – and celebrated – inventor. The other chapters of Thomson's book (the remaining 150 or so pages) are a practical guide to the contemporary design, manufacture, and use of the seine net, in keeping as a publication of Fishing News Books Ltd.

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<sup>18</sup> FAO, 'FishStatJ - Software for Fishery and Aquaculture Statistical Time Series'.

<sup>19</sup> Thomson, *The Seine Net*.

Broader approaches to fisheries frequently appear; one example of this is Smylie's *Herring: A History of the Silver Darlings*.<sup>20</sup> As a history, it presents a wide swathe of information from the earliest known herring fishery to the modern day, frequently interspersed with recipes and personal observations. As an overview it is an interesting and entertaining read, but it is intended for general readership and thus lacks specificity or analysis that would be expected of an academic work. A more specific text would be Robinson's *Trawling: The Rise and Fall of the British Trawl Fishery*,<sup>21</sup> which is more specific and detailed in its account of British trawling with a strong focus on the political and social affairs and impacts. As a result, it rarely mentions fishing gear and when so only in passing. *Contested and Dangerous Seas: the North Atlantic Fishermen, Their Wives, Unions and the Politics of Exclusion*<sup>22</sup> by Davis delves into the impact of and relationship between fisheries and communities, exploring the significance of fisheries specific to the people who were directly impacted by their exploitation. With a focus on individuals and movements, its focus on technology is narrowed to the necessity of safety at sea, rendering discussion on types of fishing gear absent – and largely irrelevant.

Many of these works are largely discussions on changes in fishing communities, often over fairly large timeframes. Works which focus on narrow timeframes, such as *British Trawlers in Icelandic Waters: History of British Steam Trawling off Iceland, 1889-1916*, and *the Anglo-Icelandic Fisheries Dispute, 1896-1897*<sup>23</sup> by Thór, show a snapshot of the development of trawling in Iceland and has the added benefit of describing different fishing methods in detail, as well as background material on the individual Icelanders involved. Further discussion on Icelandic fisheries during the key time period for this thesis can be found in Jóhannesson's *Troubled Waters: Cod War, Fishing Disputes, and Britain's Fight for the Freedom of the High Seas, 1948-1964*.<sup>24</sup> This article appears in the *Studia Atlantica*, a particularly useful publication series published by the North Atlantic Fisheries History Association, featuring articles by many authors already mentioned and whose works are frequently referenced in this thesis.

*Studia Atlantica* volume 3, *Technological Change in the North Atlantic Fisheries*,<sup>25</sup> is of particular relevance to this thesis as they contain several articles discussing technology relating to twentieth herring fisheries. One of these articles is Byskov's *Esbjerg's Fishmeal Industry: Competition, Conflict and Cooperation*<sup>26</sup> on the processing and demand for herring and other pelagic fishes. It explores the role of processing for non-human consumption and its significance to pelagic fisheries. Another article, by Karlsdóttir, is also of interest, and is expanded upon in her book *Fishing on Common Grounds: The*

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<sup>20</sup> Smylie, *Herring*.

<sup>21</sup> Robinson, *Trawling*.

<sup>22</sup> Davis, 'Transatlantic Danger'.

<sup>23</sup> Thór, *British Trawlers in Icelandic Waters*; Davis, 'Transatlantic Danger'; Davis, *Contested and Dangerous Seas*.

<sup>24</sup> Jóhannesson, *Troubled Waters*.

<sup>25</sup> Holm and Starkey, *Technological Change in the North Atlantic Fisheries*.

<sup>26</sup> Byskov, 'Esbjerg's Fishmeal Industry: Competition, Conflict and Cooperation'.

*Consequences of Unregulated Fisheries of North Sea Herring in the Postwar Period.*<sup>27</sup> It explores in greater depth the exploitation and over-fishing of herring in the mid-twentieth century. Both Byskov and Karlsdóttir present technological change as one of the drivers for change within pelagic fisheries, although they do not explore the technical detail of this change, focussing instead on its impact.

Technological change is presented by Bornmalm and Lagerqvist by way of fishing vessels in *From Rustic Fishing Boats to Steel Trawlers: The Development of Fishing Vessels on the West Coast of Sweden, 1850–1980.*<sup>28</sup> They do not discuss fishing gear, however the requirements for gear are mentioned when discussing engine power and hold capacity. Heidbrink also explores the development of fishing vessels, in particular when discussing the adoption and development of onboard processing in *From Sail to Factory Freezer: Patterns of Technological Change.*<sup>29</sup> This is particularly important in understanding the how fishing vessels adapted to both technological change and to economic demand, a subject that is further explored in *A Second Industrial Revolution in the Distant-Water Fisheries? Factory-Freezer Trawlers in the 1950s and 1960s.*<sup>30</sup> Most works describing technological change or development in fisheries frequently focusses on trawlers, not fishing gear, with great attention paid to the adoption of sonar, increased engine power, hold capacity, onboard processing equipment, or fishing power.

Fishing power or productivity is examined by several authors, including Walden et al. in *Productivity Change in Commercial Fisheries: An Introduction to the Special Issue.*<sup>31</sup> The role of technology and its development over time is considered a clear fact, rather it is the ways in which it can be measured that is challenging and in need of further study. This is also a challenge acknowledged by Engelhard in *One Hundred and Twenty Years of Change in Fishing Power of English North Sea Trawlers*<sup>32</sup> and again in *On the Need to Study Fishing Power Change: Challenges and Perspectives.*<sup>33</sup> Both explore the changes to fishing technology – but largely focus in the trawlers and fishing vessel, not the type of gear used. This, too, is seen in Finley's *The Industrialization of Commercial Fishing, 1930–2016.*<sup>34</sup> The importance of technological development of fishing vessels, which are assuredly a major factor in both the increase in catches and in the development of fishing gear, is emphasised by Palomares and Pauly's *On the Creeping Increase of Vessels' Fishing Power.*<sup>35</sup> This is explored further in Whitmarsh et al's *Natural Resource Exploitation and the*

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<sup>27</sup> Karlsdóttir, *Fishing on Common Grounds.*

<sup>28</sup> Bornmalm and Lagerqvist, 'From Rustic Fishing Boats to Steel Trawlers'.

<sup>29</sup> Heidbrink, 'From Sail to Factory Freezer: Patterns of Technological Change'.

<sup>30</sup> Heidbrink, 'A Second Industrial Revolution in the Distant-Water Fisheries?'

<sup>31</sup> Walden et al., 'Productivity Change in Commercial Fisheries'.

<sup>32</sup> Engelhard, 'One Hundred and Twenty Years of Change in Fishing Power of English North Sea Trawlers'.

<sup>33</sup> Engelhard, 'On the Need to Study Fishing Power Change'.

<sup>34</sup> Finley, 'The Industrialization of Commercial Fishing, 1930–2016'.

<sup>35</sup> Palomares and Pauly, 'On the Creeping Increase of Vessels' Fishing Power'.

*Role of New Technology: A Case-History of the UK Herring Industry*<sup>36</sup> where the role of technological change is placed within a wider context.

A regular editor of the *Studia Atlantica* series is Holm, whose article *World War II and the "Great Acceleration" of North Atlantic Fisheries*<sup>37</sup> also discusses technological change as driver of change in fisheries, particularly the increase in catches, as well as the demand for fish. Environmental impact is a core recurring theme in fisheries history, in particular exploitation and over-fishing. This is almost always tied to technological change in the mid-twentieth century. Garrido et al (ed.) discuss the issue of overfishing extensively in *Too Valuable to Be Lost: Overfishing in the North Atlantic since 1880*<sup>38</sup>. While containing several articles, Reid's *Underutilization, Undersupply, and Overfishing in the Herring Industry 1930–1980: A Case Study in the Evolution of Britain's Productivist Fisheries Policy*,<sup>39</sup> is of particular interest, comparing the catching ability of different types of pelagic fishing gear, including the pelagic trawl. It demonstrates that the adoption of new fishing methods contributed to overfishing through historical statistical data, although it does not discuss the nature or use of these different fishing methods.

There are several works which catalogue known fishing methods past and present in near-encyclopaedic fashion. The earliest of these is the Hasslöf's *Svenska västkustfiskarna: Studier i en yrkesgrupps näringsliv och sociala kultur*,<sup>40</sup> which, despite its impressive size, is limited to only the west coast of Sweden for a relatively short time period. Sadly, it mostly pre-dates the invention of the pelagic trawl. Another, more detailed guide is von Brandt's *Fish Catching Methods of the World*,<sup>41</sup> which has enjoyed several reprints over the last sixty years. It has more detailed information regarding fishing gear past and present (including a detailed section on the pelagic trawl), describing both historical and contemporary use. Von Brandt also presents how fishing gear was used, although these examples are often specific to a particular group or fishing vessel type. A more recent attempt is *A History of Fishing*<sup>42</sup> by Sahrhage and Lundbeck, which, while fairly comprehensive, lacks the detail found in von Brandt.

Finally, there are a series of ethnographic works where everyday routines and typical fishing practises are presented and discussed. Several works by Byron focus on fisheries, including the Swedish west coast fisheries. These include *Portraits of the past: Bohuslän society in the twentieth century*,<sup>43</sup> which presents a variety of individuals' oral histories of fishing and their community in the mid-twentieth century. Byron also explored the practical

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<sup>36</sup> Whitmarsh et al., 'Natural Resource Exploitation and the Role of New Technology'.

<sup>37</sup> Holm, 'World War II and the "Great Acceleration" of North Atlantic Fisheries'.

<sup>38</sup> Garrido and Starkey, *Too Valuable to Be Lost*.

<sup>39</sup> Reid, 'Underutilization, Undersupply, and Overfishing in the Herring Industry 1930–1980: A Case Study in the Evolution of Britain's Productivist Fisheries Policy'.

<sup>40</sup> Hasslöf, *Svenska västkustfiskarna: Studier i en yrkesgrupps näringsliv och sociala kultur*.

<sup>41</sup> Brandt, *Fish Catching Methods of the World*.

<sup>42</sup> Sahrhage and Lundbeck, *A History of Fishing*.

<sup>43</sup> Byron, *Portraits of the Past*.

aspects of fishing in *Skippers and Strategies: Leadership and Innovation in Shetland Fishing Crews*.<sup>44</sup> This discusses not only the importance of human interaction with technology, but also how new technology and new approaches are adopted and used by fishermen. This is also a focus in *Old and Trusted, New and Unknown: Technological Confrontation in the Shetland Herring Fishery*<sup>45</sup> by Goodlad. These works are perhaps the most consistent and detailed, in that while they rarely discuss the technical detail of fishing gear, they do explore in detail the way in which it was used and handled. This is an aspect that is rarely seen in the historical examination of fisheries but can be found in anthropological or ethnographic works, such as Löfgren's *Resource Management and Family Firms: Swedish West Coast Fishermen*<sup>46</sup> and Hasslöf's *Customs, Laws and Organization in Nordic Fishing*.<sup>47</sup> This approach is not limited to Sweden or Scotland, as demonstrated in *Icelandic foremen and skippers: the structure and evolution of a folk model*<sup>48</sup> by Pálsson and Durrenberger and the twenty-first century study "*Little kings*": *community, change and conflict in Icelandic fisheries*<sup>49</sup> by Chambers et al.

Despite the numerous works regarding fisheries, fishing technology, and the ways in which fishing technology is used, there are none which specifically discuss or explore the use or technological development of the pelagic trawl, or of the impact or significance of the use or technological development of the pelagic trawl.

## 1.5 Structure

The structure of this thesis is based around the three aims described previously, with the first and second aim merged into one section. As a result, this thesis is divided into three sections. The first section is the introduction. The second section combines the technological development of the pelagic trawl with the story of its inventors. This is so that a chronological narrative of inventions is presented while simultaneously exploring their inventors and their lives. This also allows us to explore this network of individuals and their connections, as well as their personal motivations and networks. The third section is on the significance of the pelagic trawl, examining its importance within the larger context of national and international pelagic fisheries and markets, drivers of change, and the overall performance of the pelagic trawl as compared to other types of fishing gear.

The second section, the development of the pelagic trawl, is divided into three chapters: the pair trawl, the one-boat trawl, and variations on the pelagic trawl (the interchangeable trawl, the semi-pelagic trawl, and the combination trawl). While the overall structure is roughly chronological. Here it is shown that each of these designs are a

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<sup>44</sup> Byron, 'Skippers and Strategies'.

<sup>45</sup> Goodlad, 'Old and Trusted, New and Unknown: Technological Confrontation in the Shetland Herring Fishery'.

<sup>46</sup> Löfgren, 'Resource Management and Family Firms: Swedish West Coast Fishermen'.

<sup>47</sup> Hasslöf, 'Customs, Laws and Organization in Nordic Fishing'.

<sup>48</sup> Pálsson and Durrenberger, 'Icelandic Foremen and Skippers: The Structure and Evolution of a Folk Model'.

<sup>49</sup> Chambers, Helgadóttir, and Carothers, "'Little Kings'".

response to a specific problem, one which is very straightforward: make a trawl to catch these fish, in this place, and at these depths. Because of this, each inventor in their own environment is creating a solution tailor-made to that environment, even as they were constrained by the available resources while simultaneously interacting with other inventors their environments.

The first chapter begins with the very first pelagic trawls, pair trawls, which were developed in the 1930s. Early designs were limited in three ways: the lack of effective trawl doors (which necessitated the use of two boats), the use of organic fibre netting, and the size of the fishing boats which towed the trawl. These factors limit the size of the trawl, which in turn limits the quantity of herring than can be caught. The inventors of these early pair pelagic trawls were independent fishermen and netmakers who ran their own businesses. The two key inventors at this time were Yngve Bernhardsson and Robert Larsen. While Bernhardsson was originally based in Sweden and Larsen in Denmark, they were only 60km apart across the Kattegat. This is further explored in how their upbringing, environment, and career paths influenced their decision making, especially the importance of belonging to a larger fishing community designed to support its members. Their personal experiences were a key element of their careers, from decades spent fishing at sea to illness so severe as to induce a vision from God. It also explores their rivalry and the importance of their inventions as a source of income and pride.

The second chapter of this section examines the one-boat trawl, which was made possible due to the development of suitable trawl doors. The nature of the problem has changed; now it is how to make the pelagic trawl more efficient and suitable for catching fish in a variety of environments. Inventors diversified in the 1950s to include engineers and fisheries scientists, although fishermen and netmakers were still involved. There is a stark contrast between the designs of Ponte Sterne Persson, a fisherman, and Karl-Hugo Larsson, an engineer. Persson's design was successful although Persson himself had no apparent contact with the growing community of fisheries scientists. Larsson, however, appears to have been an enthusiastic participant in the conferences, which first started in the 1950s, despite the fact that his design was widely regarded as unsuccessful. Alongside their work were the research projects led by the members of a new profession: the fisheries gear technologist. They were Dr. Joachim Schärfe in West Germany, W. W. Johnson in Canada, and Richard McNeely in the USA. They were either part of an established network of scientists created by ICES, and later on, the FAO. They met, exchanged data and ideas, and on occasion used each other's designs. Unlike the other inventors before them, they operated as employees of organisations which dedicated research and funding into fishing gear development. This was an advantage they had over the inventors of the previous decades, as their salary was not dependant on success. Their resources were far more reliable and their funding secured.

Fisheries gear technologists were also working with the benefits of a suitable trawl door, larger and better equipped fishing vessels, and newly available synthetic fibres. It was the fisheries gear technologists who determined that the use of synthetic materials was a must, as well as the need for accurate measuring and recording equipment. In one instance this resulted in the netsounder, which became an invaluable tool for fishermen so as to go on to use the pelagic trawl more effectively.

Schärfe and McNeely both emphasised the importance of practical testing and the involvement of fishermen. Johnson had himself been a fisherman with several decades' experience before taking on the task of designing a pelagic trawl. The approach employed by each of these men was methodical, with great attention to detail. They conducted frequent, repeated, and closely-monitored practical experiments. Each would go on to successfully develop their own version of an effective one-boat pelagic trawl.

The third chapter examines the variations on the pelagic trawl: the interchangeable trawl, the semi-pelagic trawl, and the combination trawl. The only two known interchangeable trawls were designed by Bernhardsson and Persson. They were intended to be used either as a pair pelagic trawl or a bottom one-boat trawl depending on fishing conditions. They demonstrate a need for a trawl which could be adapted quickly on demand. Both designs were used by fishermen catching herring with bottom trawls during the day and with pelagic trawls at night. This idea solved a very specific problem but its use was very short-lived. The semi-pelagic trawl is also discussed in this chapter, in particular the design as created by A. G. Breiðfjörð in Iceland. This design was also short-lived, as it was towed just above the seabed in order to catch bottom fish. While this design seems to only have been used for few years, it helped inspire the development of semi-pelagic trawls in France a few decades later. Here, the semi-pelagic trawl was created to target specific fish species in certain areas that were not suitable for traditional pelagic or bottom trawls. Finally, the idea of the combination trawl is explored. Schärfe and others would try and develop a trawl which could operate on the bottom and at any depth a fishermen could desire; this was intimately unsuccessful, yet unlike previous failures, was the subject of dedicated and systematic research.

The third section of this thesis analyses the significance of the pelagic trawl in five chapters, each addressing a distinct aspect. These are: the intensification of fisheries; the output of those fisheries and their value; productivity; what effect the use of the pelagic trawl had on employment; and the technological advances in boats and equipment. These different aspects demonstrate that the role of the pelagic trawl varied greatly depending on time and location. Relevant statistical data for the fisheries of three countries is available: Sweden, Scotland, and Iceland. Analysing these data shows that for Sweden, the pair pelagic trawl was the most efficient tool for catching herring in the 1950s and 1960s, but those catches were of a lower value than those caught with the herring bottom trawl. For Scotland, the pelagic trawl was initially very successful during the 1960s,

but was systematically out-performed by the purse seine starting in the 1970s. In Iceland, the pelagic trawl was systematically used from late 1990s. However, it was the dominant method for little more than a decade before the use of the purse seine resumed.

In the first chapter, *Intensification of Pelagic Fisheries*, we see how pelagic fisheries increased steadily over the twentieth century, demonstrating a great demand for pelagic fish. The collapse of the herring stocks in the 1960s did not curtail demand for pelagic fish, rather, pelagic fisheries instead focussed heavily on capelin instead. One consequence of the herring stock collapse was how nations viewed ownership of fishing grounds. The subsequent expansion of territorial waters can be linked directly to the need to protect fisheries and restrict access to them. Another consequence was the regulation of fisheries in Europe and elsewhere, including the introduction of quota systems. Limiting the volume of fish caught changes how fishermen approach fisheries. It was no longer a matter of catching enough fish to make a profit. Instead, the value of the limited volume of fish caught must be maximised, placing importance on quality over quantity.

The value of the catch is seen in the second chapter, *Output*. The volume of pelagic catches made in Sweden, Scotland, and Iceland is shown, as well as the volume of catches made with the pelagic trawl and their value. The pelagic fisheries for each of these nations are explained alongside the products made from those catches. This is then expanded further by examining relationship between catches, products, and the pelagic trawl. Much of the pelagic catch in the twentieth century was low value because it was rendered into oil and meal. The reduction industry was particularly strong in Norway and Denmark, with fishermen of many nations landing pelagic fish there to sell, often of very low quality fish.

The market for fishmeal and fish oil had grown steadily since the mid-twentieth century, but fish oil had strong competition from agricultural products. This meant that large catches were needed for fishermen to make pelagic fishing profitable. The pelagic trawl in Sweden was an improvement over alternative methods as it was better at catching large volumes of low-quality fish for reduction. This was initially the case in Scotland as well, however the introduction of restrictions saw the purse seine dominate when catching large volumes of low value fish. In contrast, the pelagic trawl caught small volumes of fish of high value intended for human consumption, not reduction. This is also partly seen in Iceland, with the value of fish caught with pelagic trawls was higher than those caught using other methods.

The third chapter, *Productivity*, uses catch per unit of effort (CPUE) to understand if the pelagic trawl was more efficient than other fishing methods. This reveals that while the pelagic trawl in Sweden was the more effective fishing method, in Scotland and Iceland it was not nearly as efficient as the purse seine at catching fish. This entails a more detailed examination of the data, demonstrating that there were multiple factors that explain the continued use of the pelagic trawl. These include seasonal changes, different fishing grounds, weather conditions, fish behaviour, and the expenses of operating a fishing

vessel. When these factors are taken into account, it is clear that the pelagic trawl became one tool out of many which fishermen could use as and when needed. By analysing CPUE this thesis demonstrates that the use of fishing gear was not restricted to that which was most efficient. There were a number of factors determining the effectiveness of fishing gear which can vary considerably depending on season and location.

The penultimate chapter, *Employment*, examines whether it is possible to determine if the use of the pelagic trawl had an effect on employment. From the mid-twentieth century employment in fisheries decreased due to mechanisation and advances in shipboard technology. The introduction of fishing restrictions was another factor. Labour demands differed between different types of fishing gear, from its use to its maintenance, as well in its manufacture. When considering fishing gear, crew size (and their experience) is one of many factors that must be factored by fishermen. The experience and knowledge of the crew can have a significant impact on the how effective the fishing gear is.

The final chapter, *Boats and Gear*, demonstrates how the trawlers became the technologically advanced platform required by the pelagic trawl. The development of vessels large enough to use the pelagic trawl was important for deep-water fishing. If a trawler can catch a large volume of fish quickly, then its operating costs are reduced. Onboard processing and preservation facilities to handle the catch were also a key development. For the pelagic trawl to be appealing to fishermen, it must also be easy to use and cheaper to operate in comparison with other fishing methods. The advent of the stern trawler, shipboard mechanisation, synthetic materials, and electronic aids changed how pelagic trawling was carried out.

This thesis strives to present a comprehensive story of the pelagic trawl, from its early years to the variations that developed within a few decades, from the netmakers and fishermen who put their heart and soul into their work to the fisheries gear technologists who make it their careers. It will demonstrate not just where and how the pelagic trawl was used, but where and why and what for. The pelagic trawl was not the most popular nor the most effective fishing method and yet it continued to be developed and continues to be used into the twenty-first century.

## 2 Technological Development

This section seeks to explore and understand the technological development of the pelagic trawl. But inventions do not spring to life without inventors and so a narrative approach to development is used, describing both inventors and their inventions, chronologically from the 1930s through to the 1980s. This approach is critical to explaining how – and why – the pelagic trawl developed. By interweaving these two aspects it is possible to see how the trawl developed as well as the processes and factors that affected this development. The lives of these inventors tell of their purpose and their limitations, those that impelled them to invent and those that inhibited their intentions.

In the introductory section various theoretical frameworks and were discussed, with a particular emphasis on the social history of technology (SHOT). SHOT is the core influence for this thesis, as here the emphasis is equally on individuals as on the inventions. SHOT's emphasis on determining the ways in which inventors and other groups or individuals shape technology is the approach used in this thesis. Another influence was actor-network theory (ANT), which helped in discerning the limitations placed on the inventors by their resources. One aspect of SHOT is understanding why an invention was considered successful or important – which means also understanding the role of failure. An extension of this is also considering the concept of redefining the problem. As a result, several visible but unsuccessful inventors are explored, as well as the variations on the pelagic trawl that were needed to adapt to new environments or fisheries.

Technical details are frequently explored when discussing pelagic trawl designs. These technical details are important for two reasons. Firstly, they demonstrate the limitations placed on early trawl designs in terms of materials and fishing boats. This changes as new materials and new fishing vessels are developed, the progression of which is presented in this thesis. Secondly, they show the features that trawl designs had in common, as well as those which were unique to individual inventors. Here the technical details show how difficult it is to produce truly unique or innovative design features successfully. The terminology used in this thesis, along with a glossary, is provided in the appendices.

Two primary phases of technological development are identified: the pair pelagic trawl and the one-boat pelagic trawl. There is a third chapter, which is can be considered an epilogue of technological development in pelagic trawling. In the first chapter the pair trawl is explored, focussing on the inventors and their environments. This entails understanding their motivations, knowledge and resources. For each invention and inventor, there is a problem that they are trying to solve. In the second chapter the one-boat trawl is discussed, focussing on the important organisations and systematic research-driven approach to technological development. There are inventors here too, but they have very different roles and backgrounds, which are also explored. In this chapter the role of other advances, such as trawl door design, synthetic fibres, and electronic equipment

are put into the context of the pelagic trawl and its development. The third chapter discusses the interchangeable trawl, the semi-pelagic trawl, and the combination trawl. These demonstrate how the problem these inventors were trying to solve came to be redefined even before it was fully solved.

There were many variations of the pelagic trawl. Each was response to a problem that needs solving, with the problem evolving and changing as the trawl developed. The solution to these problems was limited by the available technology of the period and each phase can be characterised by the resources and technology available. The available technology and resources limit the solution and in some cases these solutions are largely ineffective as a result, in turn demonstrating another problem that is yet to be solved. The problem is usually straightforward: make a trawl to catch these fish, in this place, and at these depths. Sometimes this is because the target fishery has changed or was newly identified, but typically it was because the fishing gear already in use became ineffective. As a result, we will see that each inventor in their own environment is creating a solution tailor-made to that environment, while they are also interacting with other inventors and exchange ideas.

The first phase of the pelagic trawl, the pair trawl, was in the 1930s and 1940s. The pair trawl was developed to catch herring in the North Sea and in the Kattegat and Skagerrak at night, when it rose from the seabed. During the day herring could be caught with bottom trawls and the first pair trawls clearly take their form from the bottom trawl. It was limited in three ways: the lack of effective trawl doors (hence the use of two boats), the organic fibre netting used in the trawl, and the size or power of the fishing boats towing the trawl. This limited the size of trawl, which limited the size of the catch.

In the second phase, the one-boat trawl, the problem evolved. Now the problem is twofold: how make the existing pelagic trawl more efficient and suitable for multiple fisheries. Initially the development of the one-boat trawl was hindered as the pair trawl had been, although this did not prevent multiple attempts to create one. Many one-boat trawls were attempted in the 1950s. Over the course of that decade, they benefitted immensely from the development of effective trawl doors, synthetic fibres, and increasingly larger fishing boats. Development was further aided by the introduction of the stern trawler and advancements in sonar and netsounders.

The inventors of the pelagic trawl are explored alongside its technological development. First were the independent fishermen and netmakers who developed the pair trawl. They were business owners and dependent on fishing for their livelihoods. Yngve Bernhardsson, the earliest pair pelagic trawl inventor, was born into an established fishing community near Gothenburg and was part of an extended family of Swedish fishermen. This is a key factor in understanding his later role as a netmaker, as he could draw not only his own experience, but that of a large network of experienced fishermen. The circumstances that led to the creation of the pelagic trawl were unique, however, as

few inventions can be attributed to a vision from God. His contemporaries did not claim divine inspiration for their inventions, but they too had decades of experience in fishing and were embedded in traditional fishing communities. From contemporary newspaper articles we learn that Yngve Bernhardsson had an ongoing patent dispute with a Danish netmaker, Robert Larsen. Larsen, unlike Bernhardsson, actively promoted his designs and engaged with new potential customers. As a result, Larsen would be remembered by many as the inventor of the pelagic trawl.

The one-boat pelagic trawl was the subject of intense development even as the pair trawl continued to be used. The one-boat trawl appears initially to be the domain of engineers and naval architects. Ponte Sterner Persson, however, was a fisherman. While Bernhardsson and Larsen had the background and experience to run their own netlofts, Persson licensed his designs rather than making and selling trawls himself. Little is known of this man, yet his designs were unique and became well-known. His contemporary was Karl-Hugo Larsson, an engineer and naval architect. Larsson also licensed his designs, but had little commercial success. Unlike the other inventors mentioned so far, Larsson interacted regularly with an emerging international forum of scientists and researchers in the 1950s. They were part of the already established networks created by ICES and the FAO. In this forum, fisheries gear development became dominated by a new profession: the fishing gear technologist. In most cases the gear technologist was a scientist, usually with an academic background, although there were instances where they came from a commercial fishing background. They were always employees of a national agency or an NGO (like the FAO). They had very different motivations and resources than the fishermen, netmakers, and independent engineers who were also creating new trawl designs.

One set of fisheries gear technologists developing a successful one-boat trawl were based in West Germany. This was centred around the work of Joachim Schärfe, Andres von Brandt, and the FAO department for fisheries. It was they who determined that the use of synthetic materials was a necessity, as well as the need for accurate measuring and recording equipment. One result of this was the netsounder, which became an invaluable tool for fishermen to effectively use the pelagic trawl. Schärfe also determined that the best trawl doors were a design that had been patented almost twenty years previously, by Franz Süberkrüb, another denizen of West Germany. He was a naval architect and his trawl doors design became an industry standard for pelagic trawls for decades to come.

These men came from academic backgrounds. In contrast, their direct contemporary in Canada, W. W. Johnson, had been a commercial fisherman for many years. Johnson and several of his co-workers had practical industry backgrounds which informed their approach to developing a pelagic trawl. Yet Johnson's approach was much the same as his academically trained contemporaries – methodical, with great attention to detail, and precise record keeping. Johnson, like Schärfe and others in the USA, would successfully develop an effective one-boat pelagic trawl.

Once these successful one-boat pelagic trawls were created they were subject to further experimentation and development. In France, the semi-pelagic trawl was created to target specific fish species which could not be caught with traditional pelagic or bottom trawls. Despite not being considered true pelagic trawls, their development was discussed by the same scientists and gear technologists who worked on pelagic trawl design.

Pelagic trawls would also be altered and adapted to address new problems. Typically, these attempts involved making the pelagic more, yet also less, specialised. The pelagic trawl was a specialised tool which had to be carefully monitored and adjusted when in use in order to be truly effective. Now it needed to be a universal tool, one which could also be used in place of non-pelagic fishing methods. Schärfe and others would go on to try and develop combination trawls in order to maximise their effectiveness – and they were not successful. This was often intended for herring fisheries, when herring stayed close to the seabed during the day.

The final phase in the technological development of the pelagic trawl not in its use, but in the way its primary components and materials were arranged. The dense wall of netting at the front of the trawl was replaced with large open meshes up to 34 metres long. The big-mesh trawl, hexamash trawls, as well as rope trawls (or spaghetti trawls), were a significant development that was also reflective of the need to continue to understand how the trawls interacted with the environment they were used in. Like the development of the one-boat trawls that preceded them, these trawls were the subject of discussion among a wide array of scientists, gear technologists, and researchers in fishing technology.

Development of pelagic trawls are ongoing and will no doubt continue into the future. In this thesis, the development of the trawl is only explored as far as the early 1980s. To continue after this date would entail delving into a substantial body of work which would result in a thesis far longer than limits allow. The key phases in the development of the pelagic trawl take place prior to the 1980s; the leap from organic to synthetic materials, the application of systematic scientific testing and experimentation, the development of sonar and netsounders, the changes in fishing boat size and layout, and the emergence of a specialised profession dedicated to the development of fishing gear.

For the sake of the reader the appendices contain a list of principle inventors, a timeline of inventions, a guide to terminology, and a glossary.

## 2.1 The Pair Trawl

The earliest pelagic trawls were pair trawls, designed and used in Sweden and Denmark. A pair trawl is a trawl towed by two boats in order to keep the mouth of the net open. Operating a pair trawl is challenging, as the boats must maintain excellent communication with each other in order to coordinate handling and using the trawl.

This chapter presents the two earliest pair trawls, their inventors, and their lives. We begin by examining their designs by briefly looking at the technical aspects. Their similarities and differences are presented, as well as the longevity of these designs and how they changed over time. The lives of the two netmakers are also presented, with a focus in the events and experiences that shaped their lives as fishermen and netmakers. This is followed by a discussion on the resources available to them, including the importance of their professional experience and of their communities. This is concluded by examining further the relationship between these rival netmakers and the role played by concept of ownership, patents, and the nature of their rivalry.

The earliest versions were invented by Yngve Bernhardsson and Robert Larsen, successful businessmen who owned and operated their own netlofts in Sweden and Denmark. They were both fishermen turned netmakers, with experience and backgrounds in fishing and fisheries. They were working around the time of the Second World War, using organic materials such as cotton, although both later adopted synthetic fibres. Sources show that their relationship was adversarial as they fought over the patent rights to the pair pelagic trawl in Sweden. Their designs were very similar, utilising the same core concepts with small differences. They could have each arrived at the same solution for the same problem independently. But while Larsen became recognised internationally as the inventor of the pair pelagic trawl, Bernhardsson's contribution was all but forgotten.

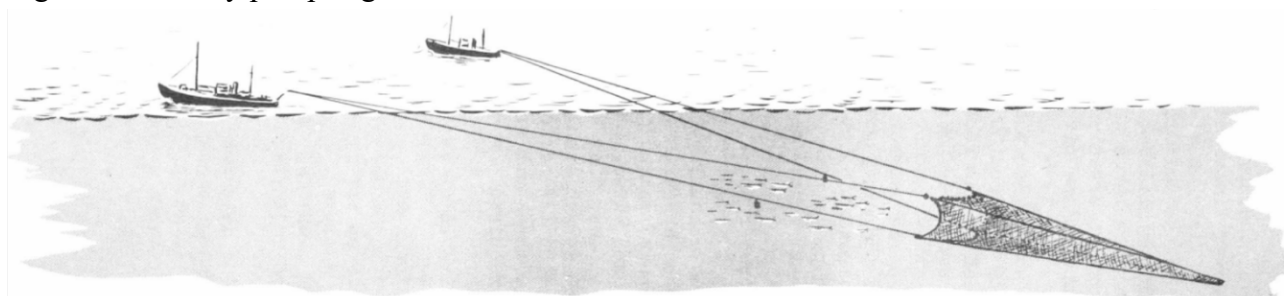
### 2.1.1 The First Pair Trawls

At a glance, the design of the bottom trawl and the pelagic trawl are clearly related. Given that the pair pelagic trawl was invented by fishermen using bottom trawls, it is clear that one inspired the other. A bottom trawl is a bag of netting, the mouth of which is held open vertically by weights and floats. Keeping it open horizontally is more difficult. Until the late nineteenth century this was achieved with a beam of wood – hence the beam trawl. In the 1880s the trawl door was introduced. A pair was needed; one for each side of the trawl, attached with a cable to the vessel towing it. When towed the shearing force of the water forced them to separate. The lower edge of the trawl door was dragged along the seabed, which gave it stability. This was lost when the trawl door was raised above the seabed, as the trawl doors twisted and tangled the warps that attached them to trawl to the boat, fouling the gear. This made a pelagic trawl impossible, or at least extremely difficult. The easy solution was to use two boats instead of trawl doors, one for each side of the trawl.

The size of the early trawls was also limited. This was principally due to the materials the trawl was made from. Netting was typically made from cotton, which breaks easily. A trawl could burst if the volume of fish caught was too great; for this reason, the mesh size was small, but this made the trawl heavier with the added weight of denser netting. The trawl could not be too heavy for the boats to tow it, especially when it began to fill with fish. Finally, there had to be sufficient space on board to store the catch. The fishermen of Sweden had a good reputation for packing herring catches efficiently, preserving them for over week at a time.<sup>50</sup> This was important as fishing in the North Sea meant a trip of at least a week and bad weather could extend this to several weeks.<sup>51</sup>

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Figure 1. An early pair pelagic trawl



Sources: Krason, William S. 'Floating Trawls'. Fishery Leaflet. United States Department of the Interior Fish and Wildlife Service: Bureau of Commercial Fisheries, June 1949.

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A pair trawl removes the need for trawl doors entirely. Instead, the warps from each side of the trawl were attached to different boats. The boats had to be careful to stay just far enough apart to keep the mouth of the trawl open, but not so far as to damage it. This method required excellent communication and coordination between the two boats. A pair pelagic trawl is shown in figure 1. The four warps are clearly seen, two for each side, going to each boat. The lower warp has an extra part, where a weight had been added to separate the warps and keep the mouth of the net open vertically. The trawl corners extend out to a point, providing a reinforced point to which the warps can be attached. This also puts the tension on the selvages (the reinforced seam joining panels together) instead of the netting.

A critical factor in pair trawling was the need for clear and consistent communication between the two boats towing the trawl. For this, the radio was essential to maintain coordination. Failure to do so would result in a poor catch at best and at the very worst the loss of a boat, or even a life. In the Kattegat and Skagerrak, fishermen had found that their radios had too few channels – leading to confusion when there were too many trawlers trying to communicate at the same time.<sup>52</sup> Dedicated fishermen could invest in a radio telephone system which provided a private channel between the two boats to aid them, although experience was also important for using a pair trawl.

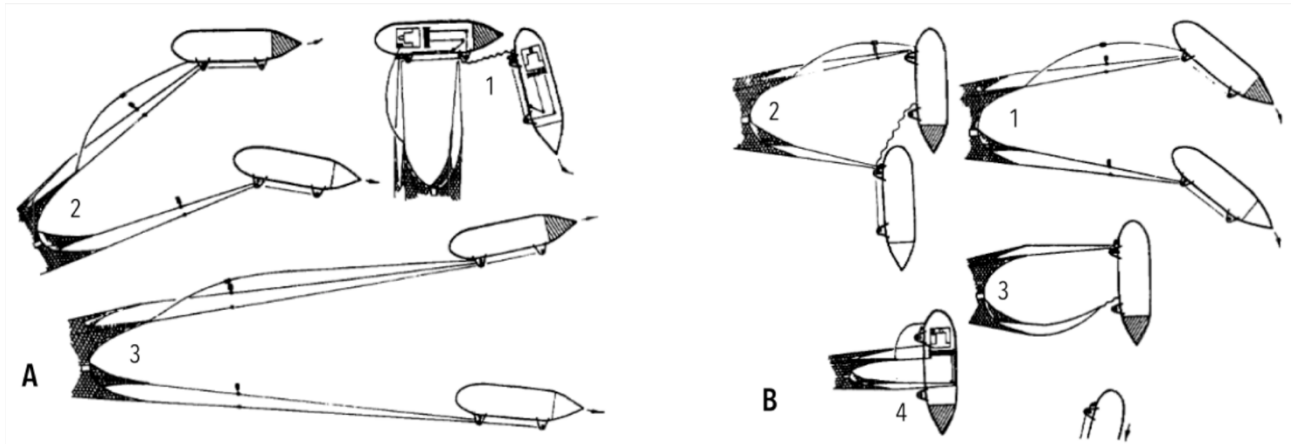
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<sup>50</sup> Johnson, 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966', 8.

<sup>51</sup> Byron, *Portraits of the Past*, 163 & 166.

<sup>52</sup> Byron, 171.

Figure 2. Pair trawling: shooting (A) and hauling (B) in the gear



Sources: Brandt, Andres von. *Fish Catching Methods of the World*. Third. Farnham, Surrey, England: Fishing News Books, 1984.

Pair trawls were also a challenge for small side trawlers. The sequence of shooting, and then hauling, the trawl is shown in figure 3. Despite these challenges, the pair pelagic trawl was mainly used at night.<sup>53</sup> A publication from the 1970s stated that Swedish fishermen were considered “a world leader” in the use of the pair pelagic trawl due to their “skill and technical advances.”<sup>54</sup> There was also a belief that boats passing directly overhead a shoal of fish would frighten the fish and cause them to disperse.<sup>55</sup> That the two boats of the pair trawl would pass either side of a shoal, rather than above it, was seen as an advantage.

The earliest documented pair trawl was by Yngve Bernhardsson, in a patent application made in 1944 (figure 3). It was made of four panels, symmetrical, with narrower side panels. The headline has small floats attached to it and the groundrope has small weights. Each corner of the trawl has a wire, and the two wires on each side then join together, at which point a single warp for each side of the trawl would each attach to a boat. This design has two additional elements: the wires on each side were also joined together with another wire (marked as “5” within figure 3). At the bottom this formed a point where a weight was hung (marked as “4” within figure 3) and from which more weights could be added if needed by threading them onto the warp (marked Fig. 2 within figure 3). A float was attached at the top by more wires (marked as “3” and “10” within figure 3). The length of the warps could be adjusted to control the depth of the trawl.

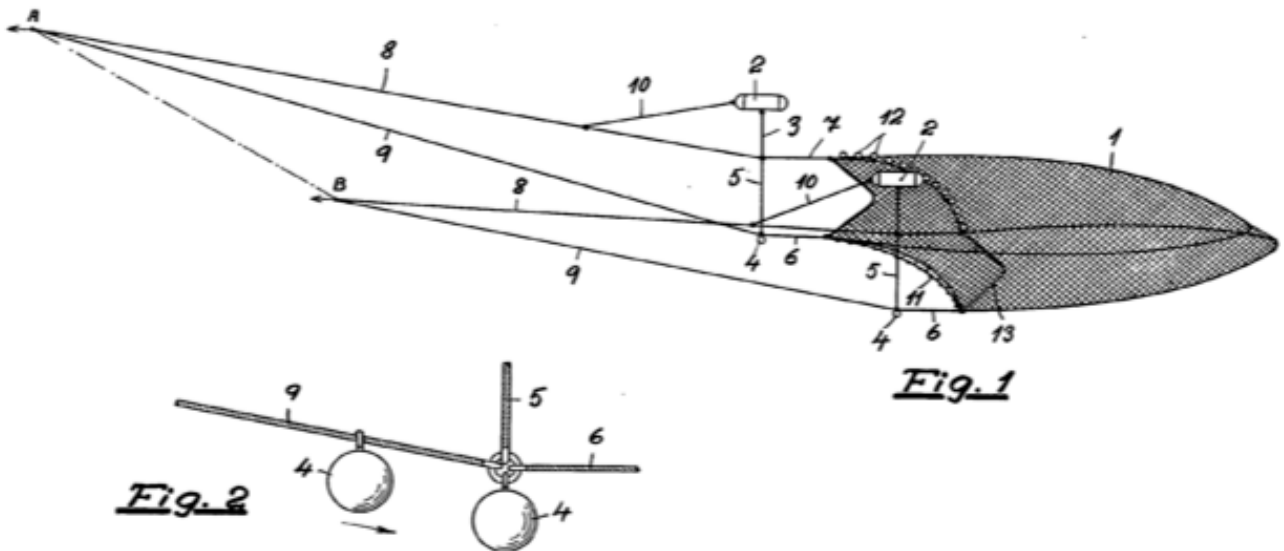
The description specifies a rectangular mouth and the use of floats and weights. It further specifies the absence of trawl doors. Bernhardsson’s design looks like it is missing a codend and the description has no mention of one. On a modern trawl the codend gives the trawl the appearance of a funnel, with the codend being the narrowest part. While Bernhardsson’s design is lacking in some details, it is clear that it was quite small.

<sup>53</sup> Thomson, *Pair Trawling and Pair Seining*, 79.; Byron, *Portraits of the Past*, 169.

<sup>54</sup> Thomson, *Pair Trawling and Pair Seining*, 99.

<sup>55</sup> Thomson, 78–79.

Figure 3. Bernhardsson's pair trawl, 1944

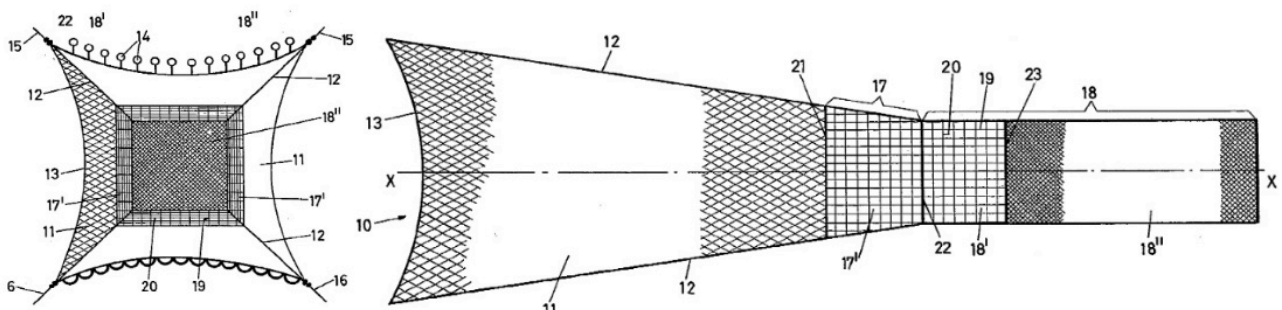


Sources: Bernhardsson, K. Y. T. Trål. Patent- och Registreringverket SE119930. Göteborg, filed 20 March 1944, and issued 7 August 1947.

A later patent from the 1960s shows a trawl with a codend,<sup>56</sup> however, this was almost twenty years later. From the 1944 patent diagram some aspects are clearly not to scale and there is no indication of scale anywhere in the document. It may be that he simply did not bother to depict the codend as it was not relevant to the patent. If deliberate, the omission of a codend and other details could also have been an attempt to protect his design from being copied by other netmakers.

There are no sources which demonstrate how his pair trawl developed over the next few decades, if at all. From later patents we can see that he experimented with other types of pelagic trawl, as well as different ways of using netting. A later patent of 1964<sup>57</sup> shows that he made a square-mouthed trawl with a codend. It had different mesh sizes throughout the body of the trawl, including a section of netting turned 45 degrees from the usual way (figure 4).

Figure 4. Bernhardsson's trawl design, 1964



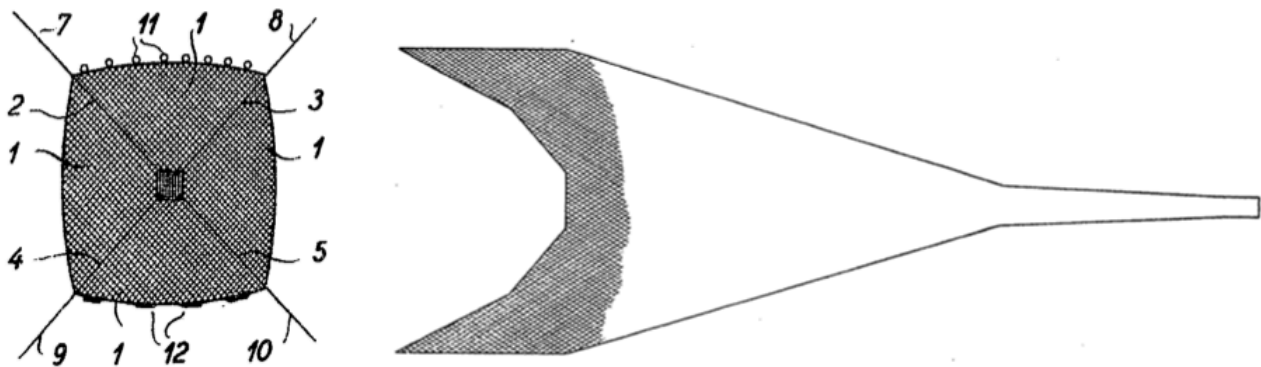
Sources: Bernhardsson, K. Y. T. Trälliknande nät. Patent- och Registreringverket SE216940C1. Donsö Nätfabrik, Bröderna Nyfeldt, Donsö, Sweden, filed 18 December 1964, and issued 1 June 1967.

<sup>56</sup> Bernhardsson and Donsö Nätfabrik, Anordning vid trålnät.

<sup>57</sup> Bernhardsson, Trälliknande nät.

Bernhardsson was interested in using new materials, such as nylon, from an early date,<sup>58</sup> with many of his later patents in conjunction with a netting manufacturer and netmaker based on the nearby island of Donsö. He struggled with synthetic twines to begin with as early nylon twine was too elastic and once stretched the meshes would not return to their former size,<sup>59</sup> distorting the trawl. This made the trawl impossible to reuse. Bernhardsson also worked on knotting techniques once he realised that the knots in hand-sewn meshes slipped when synthetic fibres were used,<sup>60</sup> which would also distort the trawl.

Figure 5. Larsen's pair trawl, 1948



Sources: Larsen, Robert Emil. Flydetrawl. Direktorat for Patent- og Varemærkevæsenet DK76017C. Skagen, Denmark, filed 1 December 1948, and issued 8 June 1953.

Robert Larsen's pair trawl was made of four identical panels and the patent diagram (figure 5) shows that it had a codend. His patent focussed on the shape of the trawl, the arrangement of floats and weights, and the warps. There was a warp from each corner of the trawl, with a weight attached to the bottom warps. The two warps for each side lead directly to a boat. Like Bernhardsson's design, the length of the warps determined the depth of the trawl when it is being towed. This early design was made of cotton netting with a small gauge and the same small mesh size throughout. Weights were made of lead, although by the mid-1950s many floats were made from either metal or plastic.<sup>61</sup> By the 1950s Larsen had added a hydrophone,<sup>62</sup> an underwater listening device. Exactly how Larsen used it is not known, but it was used to detect shoals of fish and their movements.

The only significant difference between the patent and a 1956 article describing Larsen's trawl is the presence of a rope attached between one corner of the trawl and the codend.<sup>63</sup> Commonly called a lazy deckie,<sup>64</sup> this was used to haul up the codend alongside the boat. Doing this meant that the codend could be accessed directly and the catch unloaded without having to haul the entire trawl onboard first. Hauling the entire trawl onboard without the aid of a net drum or a hydraulic winch was difficult, often dangerous,

<sup>58</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>59</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>60</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>61</sup> Glanville, 'The Larsen Mid-Water Trawl', 119.

<sup>62</sup> Anonymous, 'Ýmislegt', 190.

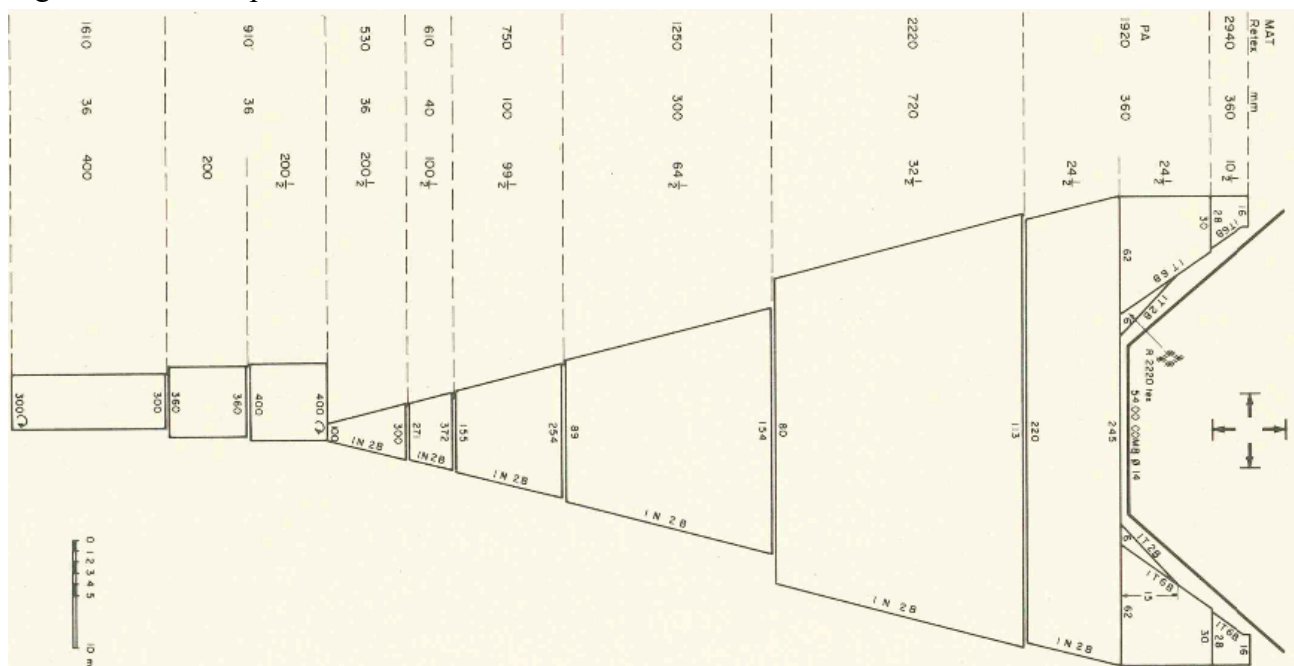
<sup>63</sup> Glanville, 'The Larsen Mid-Water Trawl', 113.

<sup>64</sup> An abbreviation for deckhand.

and hard work. Net drums were not standard on herring fishing boats in Sweden until the mid-1960s,<sup>65</sup> although by the mid-1950s Swedish and Danish fishing boats had winches to haul in the warps.<sup>66</sup> While the 1956 article neglects to specify whether or not the trawl was made from synthetic netting, a later 1959 article describing the trawl states that it can be made of either cotton or synthetic twine; it also omits the lazy deckie.

Larsen's pair trawl continued to be successful into the 1970s, with relatively few changes, as seen in a later version from the *FAO Catalogue of Fishing Gear* (figure 6). There were two editions, the first in 1963 and the second in 1972, with Larsen's pair trawl appearing in both. The design is almost exactly the same for both.

Figure 6. Larsen's pair trawl, 1972



Sources: FAO. *FAO Catalogue of Fishing Gear Designs*. 2nd ed. Rome: FAO, 1972.

The detail in the 1972 catalogue shows us that by the 1970s the pair trawl was over 170 metres long, not including the warps. This version specified polyamide netting, such as nylon, with plastic floats for the headline. More importantly, it specified that each section has netting of a different gauge and a different mesh size. The largest mesh sizes were at the front part of the trawl, while the smallest were in the codend. The core concept was still present with the same arrangement of weights, floats, and warps. There were still four identical (symmetrical) panels, although the codend was now constructed of a tube of netting. While the pair trawl was eventually replaced by the one-boat trawl, the use of the pair pelagic trawl persists to the current day. Larsen and Bernhardsson's designs were the earliest, and inspired others, such as the British Leggatt brothers in the 1950s. The Leggatt brothers created their own pair trawl for inshore sprat fishing, although their design was for much smaller boats and a total crew of only 4 or 5 men.

<sup>65</sup> Bornmalm and Lagerqvist, 'From Rustic Fishing Boats to Steel Trawlers', 79.

<sup>66</sup> Glanville, 'The Larsen Mid-Water Trawl', 115.

The 1965 Catalogue had a pair trawl from the well-established fishing gear company Joseph Gundry and Co.<sup>67</sup> which was sold internationally in various sizes,<sup>68</sup> much like Larsen's design. The 1972 edition also had other pair pelagic trawl designs, including a Scottish design not unlike Larsen's (complete with a lazy deckie) from another long-established fishing supplier, Cosalt Ltd. A French design featured in the catalogue used very large meshes in the front of the trawl, beginning at 160 centimetres and decreasing gradually in size down to 8 centimetres in the codend. This trawl was for catching sea bream and whiting, a departure from the original pair pelagic trawls, which focussed on herring and sprat. The pair trawl continued to be used and was updated with new materials and used in more fisheries. The original Atom Trawl became a classic design, one whose development stagnated and was not developed further, at least not sufficiently enough to deter serious competition.

## 2.1.2 Netmakers

The earliest documented – and successful – design for a pair pelagic trawl was created by Yngve Bernhardsson<sup>69</sup> in Sweden, in a patent application in 1944. There are few written sources for his ideas. Bernhardsson was born in 1917 on Fotö, an island part of the Öckerö archipelago, near Gothenburg. It was a long-established fishing community, one of many on Sweden's west coast. The youngest of several children, he was part of a large extended family of fishermen. He began as a fisherman at the age of fifteen and worked on his uncle's boat until his early twenties. In his early twenties he caught tuberculosis and was hospitalised at a specialised sanatorium in the mountains, away from the coast, for several years. This took him away from his family and fiancée until the early 1940s.<sup>70</sup>

It was during his treatment that he became certain of his impending death. It was at this moment, on his deathbed, that the idea of the pair pelagic trawl came to him as a vision from God.<sup>71</sup> While he did recover and return home, his health was not sufficient to work at sea. Instead, he became a netmaker and set about creating the pelagic trawl. The driver for Bernhardsson was his desire to make the trawl as his way to contribute back to his community, to repay their kindness in supporting him and his family financially during his time away.<sup>72</sup> This was a common feature of this small fishing community, where the working population would each contribute a small amount to ensure the welfare of a member or family group temporarily unable to earn sufficient money to survive. Eventually, in March of 1944, he applied for a patent simply titled "Trål"<sup>73</sup> (figure 2).

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<sup>67</sup> FAO, FAO Catalogue of Fishing Gear Designs, 1965, 102.

<sup>68</sup> Bridport-Gundry Ltd., 'MIDWATER TRAWLS', 42.

<sup>69</sup> His full name was Klas Yngve Torvald Bernhardsson, but he went by Yngve.

<sup>70</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>71</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>72</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>73</sup> Bernhardsson, Trål.

A vision from God is a somewhat unusual source of inspiration for fishing gear. It is certainly an interesting driver of technological change. It was an extreme situation for Bernhardsson; the treatments for tuberculosis in the 1940s were brutal and at best deeply unpleasant, as much as the disease itself. An effective antibiotic treatment was not available until 1944.<sup>74</sup> This was too late for Bernhardsson, who had already received treatment. This was a surgical procedure where part of the affected lung was deliberately collapsed and removed: a patient might receive this treatment for an affected lung on multiple occasions.<sup>75</sup> An invasive and traumatising experience, this would have permanently restricted his lung capacity and his ability to work. The recovery period was no doubt extremely painful and being so far from home would have made it a lonely and isolating experience. Recovering from such a procedure could have felt like a deathbed.

The inspiration for the pair pelagic trawl was more likely a subconscious one, rooted in his upbringing and environment. Bernhardsson was born and raised within a community of fishermen, and began his working life as a fisherman while still in his teens. The main fishing methods were either bottom trawls for demersal fish, or a type of bottom trawl for catching herring called a sillbottentrål. As an experienced fisherman using this type of trawl, he would have become very familiar with this gear and how it worked.

When he applied for his first patent, he did so jointly with relatives. He needed help to test out his design, especially as this was a pair trawl needing two boats instead of one. There were numerous trips to test the trawl, mostly to Iceland.<sup>76</sup> While Sweden was officially neutral during the Second World War, the waters of the North Sea and the Skagerrak and Kattegat were heavily mined, making any fishing trip in these waters dangerous. Bernhardsson is mentioned by name in a very short newspaper article of 1947<sup>77</sup> which briefly describes his participation in a rescue. A fishing boat had strayed into a heavily mined area about 15km from Fotö and was blown up, leaving two men dead. Two others survived and were rescued by two local fishermen in a rowing boat, assisted by Bernhardsson in his fishing boat.

Prior to the Second World War fishing boats were manned by family groups; fathers, sons, brothers, uncles, cousins. This was a huge risk if an accident was to occur, as the primary breadwinners for entire families could be lost. It took a handful of accidents during the Second World War for this to change and many fishing boats deliberately broke apart family groups to create new crews in order to mitigate any potential loss of life.<sup>78</sup> Whether or not Bernhardsson tested his new gear without the practical assistance of his relatives is unknown, but the two young men who also helped rescue the survivors did not appear to have been close relatives. Of course, he may have taken the risk when testing the trawl in

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<sup>74</sup> Daniel, 'The History of Tuberculosis', 1868.

<sup>75</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>76</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>77</sup> Anonymous, 'Tidigare bragd av räddarna på samma plats', 4.

<sup>78</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

waters far from home. While Bernhardsson could test his pair pelagic trawl in waters far from danger, Swedish fishermen still had to land their catches in somewhere, typically either Sweden, Norway, or Denmark. Most preferred Denmark, as the prices were better there. Following a successful trip with the pair pelagic trawl, Bernhardsson and his crew returned to land their catch in Denmark, in the port of Skagen.

Figure 7. Yngve Bernhardsson in 1981 (left) and Robert Larsen in 1978 (right)



Sources: Left: image provided courtesy of Skagens Kunstmuseer. Right: Anonymous. 'De tar ifrån oss patentet!' GT, 9 March 1981.

When Bernhardsson landed his successful test catch in Skagen in the early 1940s, he spread out the trawl to dry on the dockside. At this point any sufficiently observant passer-by could take note of the construction and design, of which Robert Larsen is accused in this instance.<sup>79</sup> The port of Skagen was home to Larsen, a successful netmaker, whose netloft was located in the harbour. This story does rely on Bernhardsson taking the time to spread the trawl out to dry in Skagen instead of waiting until he had reached home, 64km almost directly due east across the Skagerrak. It also relies on Larsen taking a well-timed stroll around the harbour and recognising what the pair pelagic trawl for what it was. Any version of this story is, of course, unprovable.

Robert Larsen did not come from a fishing family or fishing background despite growing up in Skagen, a fishing town. Born in 1901, he started working as a fisherman in

<sup>79</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

1923 and bought his own cutter in 1929.<sup>80</sup> He was a fisherman in England and later in Denmark for fifteen years before starting a netloft in 1938 in partnership with Ottinus Sørrig,<sup>81</sup> a netmaker. Sørrig died in 1949, at which point Larsen took over and renamed the netloft from Sørrig og Larsen to Robert Larsen Vodbinderi.<sup>82</sup> There no evidence that Sørrig was involved in developing the pair pelagic trawl.

Larsen began working on a one-boat pelagic trawl in 1931<sup>83</sup> but it was not successful. By 1936 he had decided to try making a pair pelagic trawl instead. As a working fisherman the trawl could only be worked on when he had the time and money to do so. He also worked on the pelagic trawl after opening the netloft, but had to stop during the Second World War as the materials needed were not available.<sup>84</sup> When he resumed development in the late 1940s, he used his fishing boat to trial several versions. Each ended in failure when the netting tore under either the strain of towing or burst from too large a catch.<sup>85</sup>

Larsen's pair trawl was, when finalised, immensely successful, to the extent that it was frequently credited as the first pair pelagic trawl. Larsen called his design 'the Atom Trawl,' although this name is used somewhat inconsistently. His first patent application was in 1948<sup>86</sup> and was the first of over two dozen patents for the same design in different countries.<sup>87</sup> Patents allowed Larsen to licence his designs abroad,<sup>88</sup> including Iceland<sup>89</sup> and Israel.<sup>90</sup> While he did not open another netloft, he did move to new premises in 1956 and then expanded the building several times<sup>91</sup>. In 1949 it was estimated that there were over 500 Atom Trawls in use in Denmark alone,<sup>92</sup> as well as the rights to the patent in Sweden (which had not yet been contested). It was reported that the demand was so great that fishermen wanting to buy an Atom Trawl were working in Larsen's netloft to help him complete orders quicker.<sup>93</sup> The price was a selling point as much as its efficiency, as the pair trawl was about half the price of a purse seine.<sup>94</sup> Unlike the purse seine, however, Danish fishermen found that it worked best in conjunction with sonar in order to locate shoals of fish before towing.<sup>95</sup>

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<sup>80</sup> Anonymous, 'Fisker ærgrede sig - opfandt flydetrawlen', 18.

<sup>81</sup> Anonymous, 'Vodbinderi fylder 50', 3.

<sup>82</sup> Anonymous, 3.

<sup>83</sup> Anonymous, 'Stadig retssag om en 25 år gammel opfindelse', 3.

<sup>84</sup> Anonymous, 'Fisker ærgrede sig - opfandt flydetrawlen', 18.

<sup>85</sup> Anonymous, 'Danska flotvarpan "stærsta uppgötvun í fiskiveiðum í 200 ár"', 7.

<sup>86</sup> Larsen, Flydetrawl.

<sup>87</sup> Anonymous, 'Stadig retssag om en 25 år gammel opfindelse', 3.

<sup>88</sup> Anonymous, 3.

<sup>89</sup> Krason, 'Floating Trawls', 1.

<sup>90</sup> Anonymous, 'Danir kenna fiskiveiðar', 1.

<sup>91</sup> Callesen, 'Flydetrawlet kom fiskeri-ministeren til hjælp!', 10–11.

<sup>92</sup> Anonymous, 'Danska flotvarpan', 13.

<sup>93</sup> Anonymous, 'Atomnótin', 3.

<sup>94</sup> Anonymous, 'Danska flotvarpan', 13.

<sup>95</sup> Anonymous, 'Nýja sildarvarpan danska', 1.

Larsen received an award for his work, a gold medal in 1949<sup>96</sup> from Dansk Arbejde,<sup>97</sup> an organisation which promoted Danish products and recognised Danish inventors and manufacturers. Larsen was mentioned frequently in the print media in Scandinavia and Iceland, with many articles emphasising the effectiveness of the trawl and its ease of use. This success culminated in 1961, when he was made a knight in the Order of Dannebrog<sup>98</sup> for inventing the pelagic trawl.<sup>99</sup>

Bernhardsson also thrived and expanded his business with another netloft in Denmark, called Y-Trawl,<sup>100</sup> in Hirtschals. There was also a netloft in Rönnäng, on the island of Tjörn, about 20km north of Öckerö.<sup>101</sup> He felt that the netloft in Denmark was a better location for some of his Swedish customers,<sup>102</sup> many of whom were landing catches in Denmark. Unfortunately, his netlofts did not survive the collapse of the herring stocks in the 1960s, as he had extended credit to many of his customers who were then themselves bankrupted by the collapse.<sup>103</sup>

Bernhardsson returned to Fotö and started a new company called X-Net in partnership with Harry Nyfeldt. Harry Nyfeldt and his brother Folke owned and ran a netloft, Donsö Nätfabrik, on the island of Donsö, in the Gothenburg archipelago, about ten kilometres as the crow flies from Fotö. Bernhardsson had collaborated with them on several patent applications in the 1960s and they clearly had a longstanding relationship. Bernhardsson had bought netting and components for making his first trawls from the Nyfeldt brothers, as the local netloft on Öckerö had refused to sell him these supplies, fearing the competition.<sup>104</sup>

Larsen's business survived the collapse of the herring stocks, likely due to the income from licensing his designs abroad. Robert Larsen died in 1982 at the age of 81. Yngve Bernhardsson died in 1988 at the age of 70. Both left sons who carried on the family business in some form. Robert Larsen's son Knud Erik worked in his father's netloft from at least the 1960s,<sup>105</sup> running it after his father's death until its eventual closure in the early 1990s. Bernhardsson's son, Stig-Rune, was also a prolific and successful inventor of trawls and fishing gear until his death in 2017.

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<sup>96</sup> Anonymous, 'Larsen fær gullverðlaun fyrir flotvörpuna', 1.

<sup>97</sup> Dansk Arbejde Guldmedaille.

<sup>98</sup> Anonymous, 'Familienyt', 4.

<sup>99</sup> Communication with Kongehuset, Det Gule Palæ, Copenhagen. November 2022

<sup>100</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>101</sup> Johansson and Lindquist, 'Svenska Fiskeriförsök Med Enbåtsflyttrål', 1.

<sup>102</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>103</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>104</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>105</sup> Johnson, 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966', 43–44.

### 2.1.3 Environment and Resources

As the earliest documented date for the pair pelagic trawl is 1944, this design is firmly from in the era of organic components, primarily cotton netting. As Denmark did not see the introduction of synthetic polyamide netting until the early 1950s,<sup>106</sup> the same is likely of Sweden. Norway, too, saw the introduction of synthetic fibres in the same decade.<sup>107</sup>

Polyamide was sold under several trade names, including nylon. Cotton netting was favoured for herring nets, while heavier and more robust material like sisal and hemp were used for bottom trawls. These were also frequently tarred, which reduced damage from abrasion, although it did not significantly extend the lifespan of the netting.<sup>108</sup> Organic netting rarely lasted beyond a year without care and preventative measures.<sup>109</sup> While this was far from ideal, and expensive, it did present an opportunity to introduce changes regularly, if not annually. Even incremental alterations over the course of a sufficient period of time can result in significant changes. By the 1970s Swedish fishermen demonstrated a preference for fine synthetic twine that did not stretch, such as polyester or terylene, or low stretch nylon.<sup>110</sup> While this was lightweight, it was more vulnerable to damage from abrasion or bursting if the trawl was over-filled with fish.

The updated Larsen design in the 1972 *FAO Catalogue of Fishing Gear Designs* demonstrates that the core concept of Larsen's pair trawl could be successfully updated with newer materials, such as nylon netting and plastic floats. He had also adapted his design with larger mesh sizes in the front part. Larsen was then one of many netmakers who embraced these new materials, although we do not know at what point he decided to do so. Bernhardsson was interested in synthetic netting from an early date and experienced the challenges of working with this new material before it was fully developed. He struggled initially with nylon, as early versions would stretch under tension but not return to its original shape when released.<sup>111</sup> He also had to develop new knotting techniques when assembling sections of nylon netting as traditional knots would not stay in place, as synthetic twine was more slippery than its organic predecessors.<sup>112</sup> Slipperiness was also a problem for netting manufacturers, who would not fully resolve this issue until the late 1950s.<sup>113</sup> Without additional sources it is not possible to ascertain whether or not this changed his pair trawl design significantly. It does not appear to have had a significant

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<sup>106</sup> Søndergaard, 'The Introduction of Synthetic Fibres in Denmark's Fisheries, c. 1945-1970', 17–18.

<sup>107</sup> Martinussen, 'Nylon Fever: Technological Innovation, Diffusion and Control in Norwegian Fisheries during the 1950's', 29.

<sup>108</sup> Søndergaard, 'The Introduction of Synthetic Fibres in Denmark's Fisheries, c. 1945-1970', 18–19.

<sup>109</sup> Søndergaard, 18.

<sup>110</sup> Thomson, *Pair Trawling and Pair Seining*, 89.

<sup>111</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>112</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>113</sup> Martinussen, 'Nylon Fever: Technological Innovation, Diffusion and Control in Norwegian Fisheries during the 1950's', 39.

impact on his design. As we have seen, there was little change between the original 1950s version of the Atom Trawl and the version in the 1972 Catalogue.

Robert Larsen worked on his trawl design for more than a decade. He made a trawl and tested it when he had the opportunity, making alterations and adjustments as he did. He began working on a one-boat design in 1931 and continued to work on it, applying for a patent in 1948. There were three reasons for this long delay. First, he simply did not have the money to work continuously on his ideas.<sup>114</sup> Second, he did not have the time; he was a full-time fisherman. Third, there was a shortage of materials during the Second World War,<sup>115</sup> although this must have been a minor challenge compared with the difficulties of fishing in mined waters patrolled by armed vessels. His experience as a fisherman was critical in his attempt to make a pelagic trawl. Knowledge and experience not only created the idea and formed how it would be shaped, but provided the opportunity to test it, as Larsen had his own fishing boat and the experienced crew to assist him.

Time and experience are also resources, which both Yngve Bernhardsson and Robert Larsen had. Larsen was sixteen years older than Bernhardsson, which gave Larsen a decade's head start on his design. When Larsen began working on his design in 1931, he was already thirty years old, with nearly a decade of fishing experience. By the time he applied for his patent in 1948, he had been working on it for more than fifteen years. He also had the benefit of experience working abroad, in Britain, as well as later in Denmark.

Bernhardsson began working on his design in his mid-twenties, in the early 1940s, leading up to his 1944 patent. He had spent a short but significant amount of his adult life working as a fisherman, followed by several years in hospital, away from the coast. He had only fished in Swedish waters until he tested his designs in Icelandic waters. He did have the enormous benefit of being raised in a fishing community where the majority of his male relatives were fishermen and actively fishing for a living. This is seen in his patent for the pair pelagic trawl, where he is credited as inventor and co-applicant with two relatives. Later he makes applications in collaboration with another netloft in Sweden. Bernhardsson was making the most of the people around him and their experience, as well as crediting them for their contribution. He had the encouragement and financial support of an extended family of fishermen when he switched to netmaking. Of course, Bernhardsson also had the benefit of divine inspiration, although experimentation and experience would have shaped the development of the trawl over the following years.

In contrast, Larsen is the lone inventor and applicant on his patents and he never mentioned collaborators. It was only in an interview with Larsen's son for the netloft's 50<sup>th</sup> anniversary, after Larsen's death, that Sørrig is mentioned.<sup>116</sup> None of Larsen's patents predating Sørrig's death in 1949 reference Sørrig in any way, so he was not a contributor.

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<sup>114</sup> Anonymous, 'Fisker ærgrede sig - opfandt flydetrawlen', 18.

<sup>115</sup> Søndergaard, 'The Introduction of Synthetic Fibres in Denmark's Fisheries, c. 1945-1970', 18.

<sup>116</sup> Anonymous, 'Vodbinderi fylder 50', 3.

While Sørrig did not contribute to the Atom Trawl, as his business partner he would have played a role in setting up and financing the netloft to begin with. As there is no evidence of his involvement, it must be assumed that his role was minimal. If Sørrig did not contribute to the creation of the Atom Trawl, it is hardly unusual that he was not mentioned by Larsen himself in relation to it.

The question remains: who came first? Bernhardsson or Larsen? Documentation supports Bernhardsson, by several years, regardless of anecdotal evidence. But the concept was hardly novel when the extensive use of bottom trawls for herring by Swedish and Danish fishermen is taken into account. The conflict arising from this question is explored in greater depth in the next chapter. However, their knowledge and resources were key to their success as trawl designers and netmakers. This is important, as they were very much comparable not only in the problem they were trying to solve, but also had the same challenges and limited array of resources. With a very similar knowledge and experience they are equally likely to have stumbled upon the same answer to the same problem, independently of one other. An Icelandic article of 1950 stated that the original pair pelagic trawl was Swedish – but that Larsen’s design was better, to the extent that Swedish fishermen preferred it.<sup>117</sup>

#### 2.1.4 Competition and Conflict

The customer base for Bernhardsson and Larsen differed. Larsen was based in Skagen. He sought a large customer base outside of Denmark, with established customers in France and the Netherlands by the mid-1950s.<sup>118</sup> While his sales catalogue does not use the term, his design was frequently referred to as the ‘Atom Trawl’ or the ‘Atomic Trawl.’<sup>119</sup> His sales catalogue (figure 8) was in both English and Danish; most likely it is from the mid-1950s. The English text is dominant throughout with the smaller Danish text underneath. The illustrations are simplistic and would not have allowed the reader to replicate the designs.

Bernhardsson’s early customers were his extended family and community, limited initially to the Öckerö island group and later the Gothenburg archipelago. His customer base was principally Swedish fishermen,<sup>120</sup> many of whom landed catches in Denmark. Later, Bernhardsson opened a second netloft in Hirtshals, about 40km west of Skagen. Both were thriving fishing ports in the 1950s and 1960s, so there is little reason to assume that Bernhardsson chose Hirtshals to avoid Larsen’s netloft in Skagen. In 1949 Bernhardsson is referenced as allowing a netloft in Gothenburg to manufacture his design.<sup>121</sup> Whether this was because he could not meet demand or was selling a licence to manufacture within Sweden is unclear, but clearly there was a demand early on.

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<sup>117</sup> Thorsteinsson, ‘Danska flotvarpan’, 56.

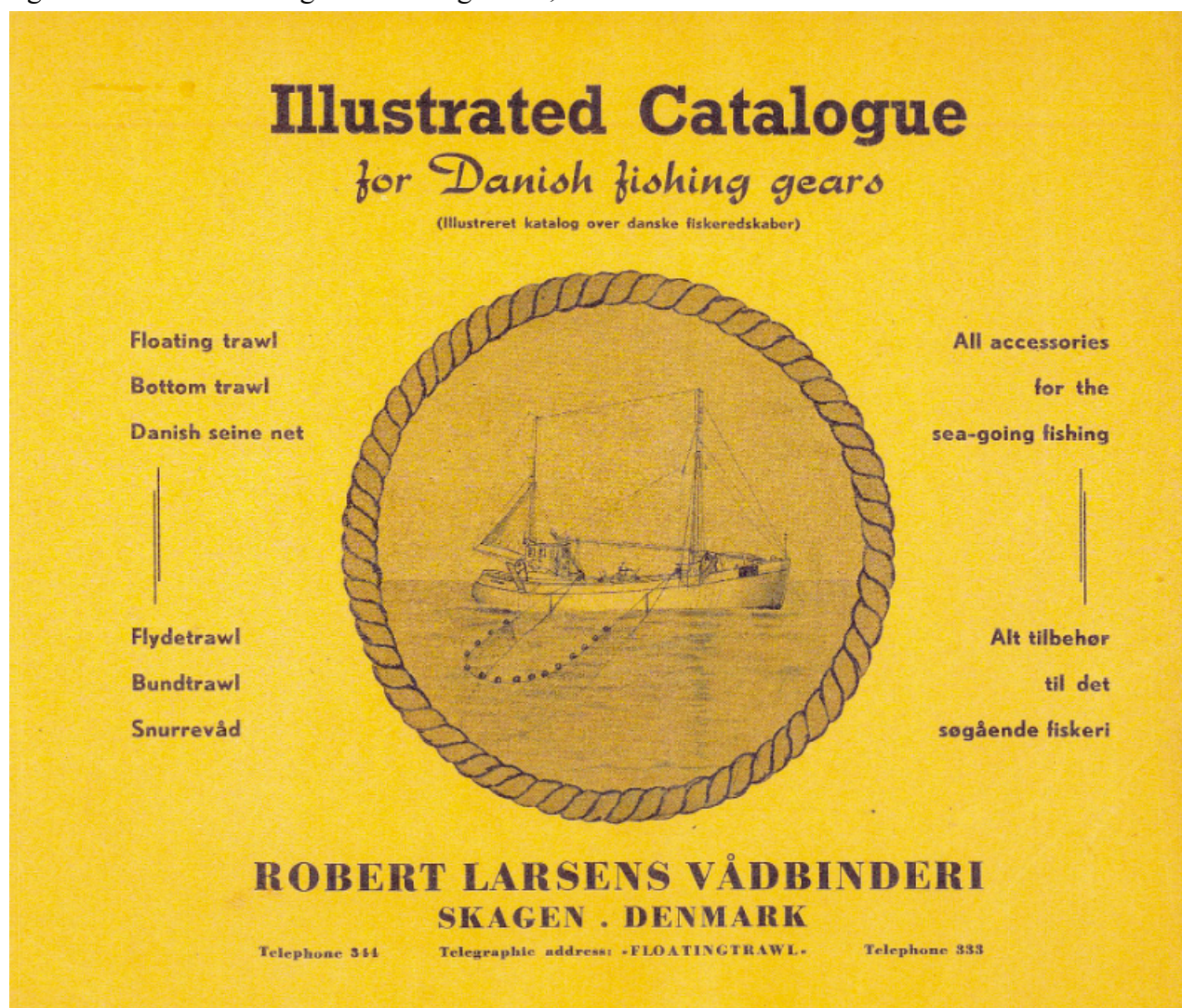
<sup>118</sup> Anonymous, ‘Mid-Water Trawl Report: Fishing Herring 3 Ways’, 11 & 22.

<sup>119</sup> Anonymous, ‘“Atomic” Pilchard Trawl’.

<sup>120</sup> Personal communication with Stig Rune Yngvesson, son of Yngve Bernhardsson.

<sup>121</sup> Anonymous, ‘Bernhardsson på Fotö konstruerat och Stranne & Oresten bundit’, 1.

Figure 8. Larsen's Catalogue of Fishing Gears, unknown date



Sources: Larsen, Robert Emil. 'Illustrated Catalogue for Danish Fishing Gears'. Unknown publisher or date. Document provided courtesy of Skagens Kunstmuseer

Bernhardsson and Larsen both applied for Swedish patents. However, Larsen's application was rejected when Bernhardsson contested it, with Larsen losing the subsequent appeal at great financial cost to himself. In Danish newspaper articles of 1971 and 1974 Larsen dismissed the legal challenges as a nuisance created by disgruntled Swedish west coast fishermen.<sup>122</sup> He never refers to Bernhardsson or any other Swedish fishermen or netlofts by name. He goes on to state that he only stopped his counter-challenge as it was too expensive to continue, and that another Swedish netloft now had the patent rights to 'his' design.<sup>123</sup> He went on to say that this Swedish netloft was still pursuing him through the legal system for compensation for copyright infringement.

Bernhardsson and Larsen both held patents in Britain in the 1940s but this was not a source of conflict. No ready reason is available for this. It may be that Bernhardsson was either unaware of Larsen's application, or was too late in challenging it. Given the high

<sup>122</sup> Anonymous, 'Fisker ærgrede sig - opfandt flydetrawlen', 18.

<sup>123</sup> Anonymous, 'Stadig retssag om en 25 år gammel opfindelse', 3.

cost of challenging Larsen's Swedish patent application, it would have been prudent to refrain from filing another challenge, especially as the market for pelagic trawls in the UK was relatively small until the late 1960s.

Bernhardsson worked for Donsö Nätfabrik (owned by the brothers Harry and Folke Nyfeldt) after the collapse of the herring stocks bankrupted his own business, collaborating with them on several patent applications. One of these patents was the subject of a legal dispute with another netloft, Fotö Trålbinderi. The dispute began in the 1960s when they made pelagic trawls from Bernhardsson's design without paying licensing fees. This was further complicated when Bernhardsson's patent expired in the mid-1960s. After this Bernhardsson and Harry Nyfeldt began working on an updated pelagic trawl design, based on the 1944 original, making a successful patent application in 1975. The ensuing court case against Fotö Trålbinderi resulted in this patent being rescinded on the basis that the design did not contain sufficient original or unique features.<sup>124</sup> The court costs, substantial to begin with, ended with Bernhardsson ordered to also pay his opponent's court costs. One of Fotö Trålbinderi's comments following this verdict was that it had all been pointless, as Bernhardsson's design concept was outdated and no longer being manufactured.<sup>125</sup>

In 1981<sup>126</sup> Larsen stated that he allowed his other patents to expire without renewing them.<sup>127</sup> This suggests that by the late 1960s and early 1970s this income was no longer as important as it had been. Perhaps this was due to the drastic decline in herring fisheries, or to the increase in popularity of other types of pelagic trawls, such as the one-boat trawl. Most likely the potential for legal entanglements and associated costs may have deterred him from pursuing renewing existing patents or taking out new ones. Later, in 1978, he stated that there was no point in taking out new patents, even though he and his son had developed a newer version of the pelagic trawl.<sup>128</sup>

Clearly, Larsen had ceased to concern himself with patents and licensing by the early 1970s, perhaps partly in the realisation that his design had become outdated and partly in recognition of the high costs and effort involved in trying to hold on to patent rights. At this point he had retired, with a successful business still in operation. Bernhardsson did not have that advantage and needed to ensure financial security for his family as well as his prospective retirement. The loss of his 1975 patent and subsequent financial losses must have been devastating. No doubt this, along the loss of his business in the collapse of the herring stocks, and with his long-standing poor health from tuberculosis and its treatment, contributed to his death less than a decade later.

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<sup>124</sup> Anonymous, 'De tar ifrån oss patentet!', 7.

<sup>125</sup> Anonymous, 7.

<sup>126</sup> Anonymous, 7.

<sup>127</sup> Anonymous, 'Fisker ærgrede sig - opfandt flydetrawlen', 18.

<sup>128</sup> Anonymous, 'Flydetrawl kom', 10–11.

Bernhardsson in particular appears to have had a strong attachment to his work, based in his upbringing in a fishing family and community, as well as the strong emotional and religious link to his near-death experience. Larsen, however, had the relative luxury of a successful business and the knowledge that he was widely acknowledged as the inventor of the pelagic trawl. This allowed him to step back and assess his relationship to his patents, especially following the changes in fisheries and fishing gear.

Larsen was acknowledged as the inventor of the pelagic trawl starting in the 1950s. While a Swedish origin was occasionally alluded to, or Swedish skill or experience in pair pelagic trawling mentioned, Bernhardsson himself was almost completely omitted. An Icelandic article of 1961 that simply states that Robert Larsen was the inventor of the pair trawl and that this fact was disputed by the Swedes who believed that Yngve Bernhardsson was the inventor.<sup>129</sup> This fact is repeated in a later article in 1971.<sup>130</sup> There is a later source from 1978, where he was briefly mentioned as the inventor of the pelagic trawl, but is sadly mis-named as “Yngves Berntsson.”<sup>131</sup> In both instances, Bernhardsson was mentioned, but the text instead emphasises the significance of Larsen’s Atom Trawl. By not engaging with a larger audience, Bernhardsson effectively made himself invisible. His design survives in only patents, where the bare minimum of detail was provided. This limits our understanding of how and to what extent his designs were significant. Larsen’s designs are preserved through numerous articles with detailed descriptions and diagrams which make the trawl easy for others to replicate.

This early phase of the pelagic trawl is one characterised by conflict. Part of SCOT’s approach, as discussed in section 1, entails understanding conflict. In SCOT, conflict occurs when members of a social group do not agree that a solution had been attained. Bernhardsson and Larsen could be considered part of the same social group based on their profession (be it netmaker, fisherman, or fisherman-turned-netmaker), their shared customer base (Danish and Swedish fishermen fishing in the North Sea and in the Kattegat and Skagerrak), or their immediate environment (homes in established fishing ports and communities). While they are, from a modern perspective, working on the same problem, we do not know enough to truly know if they thought this was the case. It is possible that they did not consider it to be quite the same problem, even if they thought their solution to be near-identical. So, although Bernhardsson and Larsen were part of the same social group, their conflict arises when they dispute the ownership of that solution.

Drivers of change for these men, as individuals, is obvious; they were using the skills and knowledge they had acquired to ensure their livelihoods. For Bernhardsson, faith also played a large role. On a larger scale, they were trying to catch unreachable fish, fish that could not be caught with existing methods. This was a necessity in that it allowed their

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<sup>129</sup> Anonymous, ‘Sænsk flotvörpuveiði’, 1 March 1961, 53.; Anonymous, ‘Sænsk flotvörpuveiði’, 21 February 1961, 9.

<sup>130</sup> Thorsteinsson, ‘Flotvörpur og Flotvörpuveiðar: önnur grein’, 12.

<sup>131</sup> Thomson, Pair Trawling and Pair Seining, 77.

customers, fishermen who used the pair pelagic trawl, to supply the reduction industry. The reduction industry demanded high volumes of pelagic fish but paid low prices, which in required fishermen to make larger catches in order to profit from pelagic fisheries. The reduction industry and the greater context of pelagic fisheries is explored further in section 3. This also explains how their paths crossed; Bernhardsson landed a catch in Skagen, Larsen's home town. The Danish reduction industry paid higher prices for fish than the Swedish factories.

Both men continued to work on their designs, updating them over the next few decades. In Larsen's case this entailed updating it with new materials and for bigger boats. In one sense this is rhetorical closure, as no substantive changes were made to the form of the design. And yet the problem has also been redefined, as the parameters have changed: better materials are available and the boats are bigger. For Bernhardsson the problem was redefined and his other designs are discussed further in the next chapters.

### 2.1.5 Summary

The pelagic trawl began as a pair trawl, needing two boats to tow it as it had no trawl doors. Its size was initially small, as it was constructed using cotton netting, typically with glass floats and lead weights. Radio was essential to ensure that the boats towing it could communicate. The size of the trawl increased when synthetic materials became available in the 1950s. There were two inventors, Yngve Bernhardsson and Robert Larsen. They each produced a pair trawl within the same timeframe, in largely the same geographical area.

While there are similarities between them, there are also key differences. Their role as inventors was firmly intertwined with that of their livelihoods as fishermen and netmakers. They were both protective of their inventions, taking legal steps to protect those inventions. However, while Bernhardsson relied on a consistent pool of repeat customers in Sweden, Larsen made efforts establish an international customer base. It was this that led to Larsen being recognised as the inventor of the pelagic trawl.

Bernhardsson's choice of occupation was partly enabled by way of a vision from God. His primary motivation in developing the pair pelagic trawl was a desire to repay the support his community had extended to his family during his illness. His netloft was also a means to continue as a productive member of his community. Netmaking was also a logical occupation for a fisherman who could no longer work at sea, one that allowed him to remain a part of his family profession and his community. For Larsen, netmaking was safer than fishing, something that also allowed him to maintain regular working days instead of being away from home for weeks at a time. He began working on his trawl long before he set up as a netmaker, but it was not completed until almost a decade after his netloft was established, largely due to a lack resources. He identified the problem and worked over several decades to find a solution, one which he successfully promoted and

sold. Unlike Bernhardsson, he came from outside of a fishing community, but he clearly adapted and integrated himself into one over the course of his lifetime.

The personal drivers of their inventiveness are a combination of necessity and opportunity. They both had the desire to secure a reliable income to support themselves and their families. They both chose netmaking over that of fishing. Larsen's Atom Trawl remained a four panel, symmetrical trawl, one which would go on to be considered a classic and ground-breaking design. Bernhardsson also developed his trawl, although it is hard to tell exactly what effect new advances had on his designs due to the lack of surviving source material. The drivers of change, on a bigger scale, was the reduction industry demanding large volumes of pelagic fish (see section 3). Bernhardsson and Larsen were responding to the desire to exploit existing pelagic fisheries to a greater extent by catching fish at times otherwise unreachable by other fishing methods.

## 2.2 The One-Boat Trawl

The one-boat pelagic trawl was not a new concept in the mid-twentieth century. The bottom trawl – itself a one-boat trawl – had been in use since the 1880s, when trawl doors were first effectively used in sea fisheries in Britain. Trawl doors work by keeping the mouth of the trawl open horizontally. However, the trawl doors of the early twentieth century were only effective for bottom trawls. It was not until the late 1930s that an effective trawl door for pelagic trawls was invented. But trawl doors were just the first problem; the second was horsepower. Most fishing vessels of the immediate post-war period did not have sufficient horsepower to tow a one-boat pelagic trawl.

Neither were trawl doors the first advance to aid the development of the one-boat pelagic trawl. Originally developed in the 1920s, synthetic fibres such as nylon were introduced into fisheries as netting in the 1950s. Synthetic netting, plastic floats, the widespread use of sonar, and the introduction of the stern trawler made the one-boat pelagic trawl possible. Many of these developments were also made possible by the systematic research of industry specialists who had the resources to experiment.

There had been unsuccessful attempts to create a one-boat pelagic trawl. Previously fishermen and netmakers had driven development. In the 1950s the one-boat trawl was the focus of a diverse array of individuals, including engineers, naval architects, businessmen, scientists, as well as fishermen and netmakers. And a new occupation was created: the fisheries gear technologist. Some of these individuals were independent, while some worked for governments or NGOs. Their motivations and purpose were no longer in the realm of business, profit, or even just recognition. Many were professionals tasked with improving productivity and efficiency in fisheries by increasing catches or by identifying new fisheries. Their designs were published in great detail so that they could be easily replicated by others. Many of these individuals met and communicated frequently, often as participants of organisations such as the FAO or ICES. They shared data, formed research groups, organised conferences, and published their work.

### 2.2.1 Trawl Doors

A trawl needs trawl doors to keep the mouth of the trawl open while it is being towed through the water. A pair of trawl doors are needed, one for each side of the trawl, and are considered part of the trawl rigging. The cable that attaches the trawl door to the trawl is called a bridle, and the cable that attaches the trawl door to the trawler is called a warp.<sup>132</sup> If rigged correctly, the flow of water against the trawl doors will create a shearing effect and push them in the desired direction. In this case they are pushed apart, in order to open the mouth of the trawl. This shearing effect was a known concept in line fishing<sup>133</sup>

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<sup>132</sup> The names for fishing gear can vary greatly, both by region and over time. See appendix for a glossary.

<sup>133</sup> Brandt, *Fish Catching Methods of the World*, 248.

and trawl doors were first adopted for commercial bottom trawling in the late nineteenth century.<sup>134</sup> Opening the trawl vertically is achieved much more easily by using floats on the headline and weights on the groundrope. The exact arrangement of bridles, warps, trawl doors, floats, and weights, and other components can vary immensely depending on the fisherman using it. The whole arrangement can be altered and adapted depending on the fishing conditions.

A one-boat trawl cannot function effectively without trawl doors and the one-boat pelagic trawl requires a different kind of trawl door to a bottom trawl. The bottom trawl doors of the 1930s and 1940s were roughly the size and shape of a door, but oriented horizontally. One edge of the trawl door rested on the seabed and was reinforced with metal sheathing, or a shoe. These trawl doors were constructed from an iron frame onto which wooden planks were attached horizontally. Some trawl doors had planks of denser, heavier wood planks at the bottom, above the shoe, and lighter wood planks at the top. This, along with the shoe, helped keep the trawl door upright while it was in the water.

A trawl door that fell over while being towed fouled the trawl, resulting in lost time, no catch, and extra work for the crew to untangle and reset it. This happened frequently when bottom trawl doors were used with pelagic trawls. Bottom trawl doors remain upright because they rested on the seabed – lose contact and they quickly tangle and foul the trawl.<sup>135</sup> If it could not achieve (or maintain) speed then the trawl doors would foul, even if resting on the seabed. Techniques such as using the shoe as a weight, or using wood planks of different densities, could help keep the doors upright. In West Germany, glass floats were attached to bottom trawl doors to help keep them upright.<sup>136</sup> This was also done with pelagic trawls to keep trawl doors at the right depth.<sup>137</sup>

This does not mean that it was impossible to use bottom trawl doors with a pelagic trawl. A pelagic trawl designed by Ponte Sterner Persson clearly shows that it was entirely possible to use bottom trawl doors successfully with a one-boat pelagic trawl. His 1958 patent application for a six-wing pelagic trawl (figure 11) has trawl doors clearly oriented the same way as bottom trawl doors. But it must have been difficult and time-consuming; sadly, the techniques to make them work were not recorded.

The most successful pelagic trawl door was invented before the first one-boat trawls, in 1938.<sup>138</sup> The patent applicants were Hamburg residents Franz Süberkrüb, Ernst Roscher, and Kurt Hansing. The inventor was Süberkrüb, a naval architect, while Roscher and Hansing were co-applicants. Süberkrüb's co-applicants were also naval architects (operating as the company Roscher & Hansing) and most likely Süberkrüb's employers. This trawl door design (figure 9, left), was oriented vertically, unlike bottom trawl doors.

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<sup>134</sup> Brandt, 248.

<sup>135</sup> Süberkrüb, 'Otter Boards for Pelagic Trawling', 359.

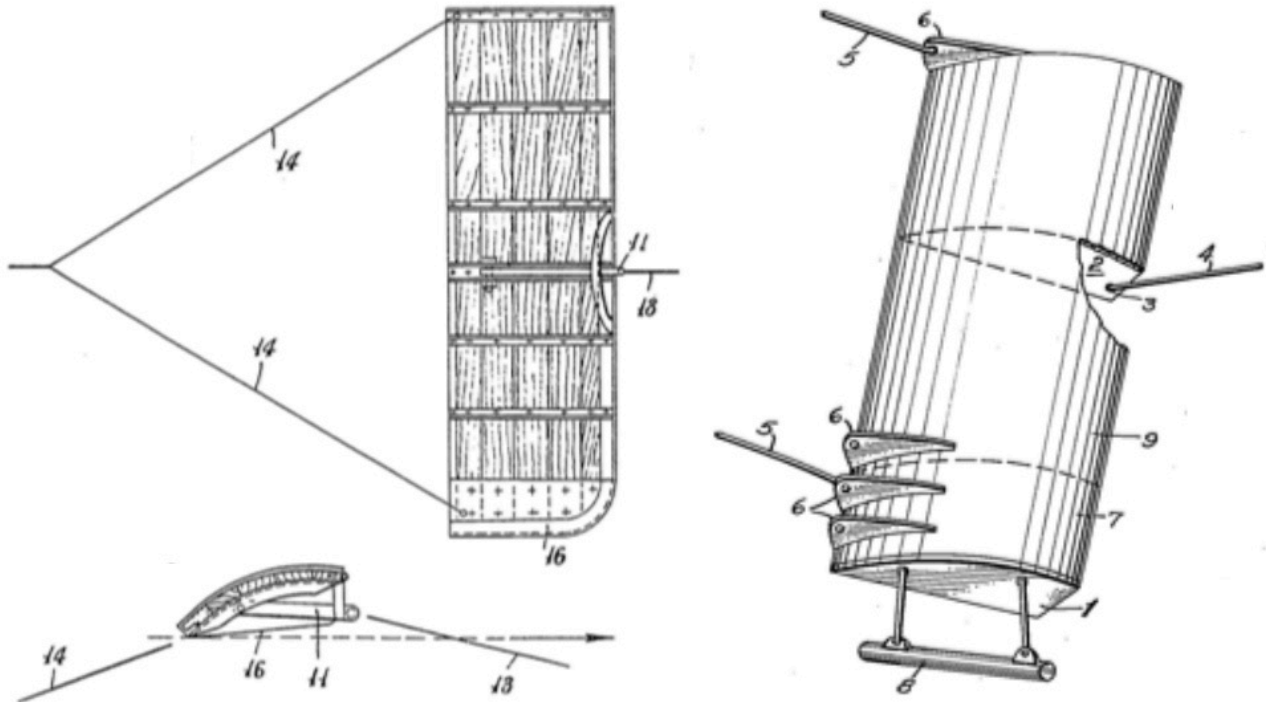
<sup>136</sup> Schärfe, 'German Cutter Trawling Gear', 303.

<sup>137</sup> Anonymous, 'New Type One-Boat Mid-Water Trawl Gear', 23.

<sup>138</sup> Süberkrüb, Roscher, and Hansing, Improvements in or relating to Trawl Boards.

The trawl door was at least twice as tall as it was wide, as well as curved in order to be more hydrodynamic.<sup>139</sup> The original trawl door of the late 1930s had a metal frame with wooden planks attached. It also had a metal shoe which acted as a weight to keep the trawl door oriented upright when in the water. This trawl door, and those of its type, would be known (and are still referred to) as Süberkrüb doors.

Figure 9. Süberkrüb's trawl doors, 1938 (left) and 1959 (right)



Sources: Left: Süberkrüb, Franz, Ernst Karl Ludwig Roscher, and Kurt Jaeger Hansing. Improvements in or relating to Trawl Boards. Patent Office GB523452. Filed 9 December 1938, and issued 15 July 1940. Right: Süberkrüb, Franz. Scherbrett zum seitlichen Offenhalten von Schlepptnetzen. Deutsches Patentamt DE1096108B. Filed 22 January 1959, and issued 29 December 1960.

Süberkrüb had also applied for a number of patents in Europe in the 1920s and 1930s, all pertaining to ship propulsion. In the 1930s he was working with (or for) Roscher & Hansing, as many of their joint patents have them or their company as co-applicants (but not co-inventors). The patent for the pelagic trawl door was first made in Britain and does not cite priority for any preceding applications made in other countries. The application was made in 1938 and approved in 1940. Presumably they were unaware that their patent was successful until after the end of the Second World War. The firm of Roscher & Hansing did not survive the Second World War. Available records indicate that neither did Hansing. Available records show that Roscher continued to work as a naval architect in the USA post-war. As a co-applicant he was presumably entitled to a share of the proceeds from any licensing agreements for the trawl door.

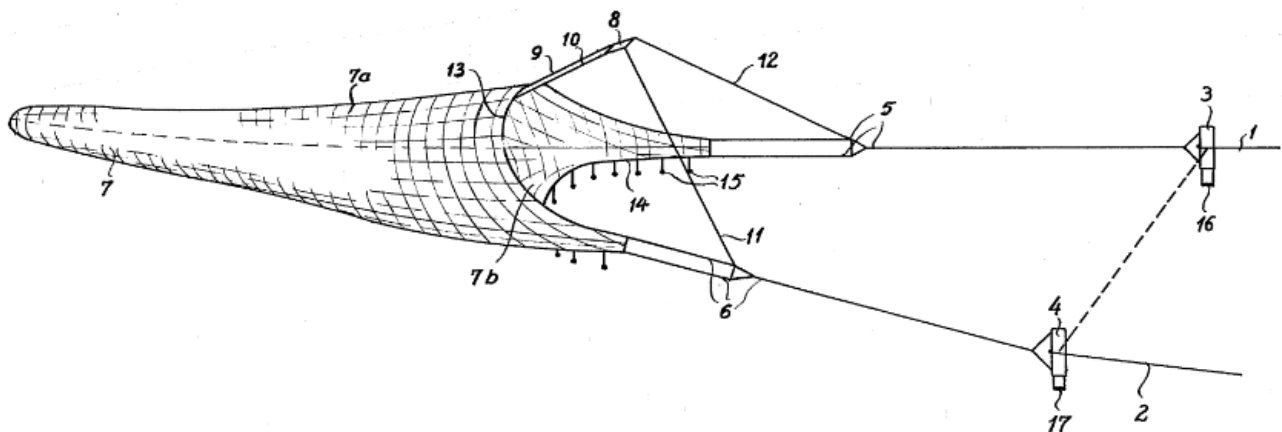
Süberkrüb continued to work as a freelance naval architect in Hamburg after the Second World War. He applied for several other patents related to boats and propulsion, without any co-applicants. He also updated and extended his patents for existing

<sup>139</sup> In modern terminology, the orientation makes it a high aspect trawl door and the curve makes it a hydrofoil door.

inventions – in particular the trawl door. This updated application cited him as the sole inventor and applicant. In the new 1959 patent, the form remained the same, as it remains upright and curved (figure 9, right). However, it was now constructed from a large single curved piece of steel with brackets and a separate weight (instead of a shoe).

In 1959 Süberkrüb applied for a one-boat pelagic trawl<sup>140</sup> (figure 10). This trawl had additional third door, or kite, on the headline (marked as “8” within figure 10), which aided in keeping the mouth of the net open. The drawing indicates that the trawl used netting turned 45° to form open squares, instead of the flexible diamonds created by standardly used netting. The reason is not specified, but would have reduced towing resistance. There is no indication that this trawl was widely used, if at all.

Figure 10. Süberkrüb’s one-boat trawl, 1959



Sources: Süberkrüb, Franz. Fischnetz. Deutsches Patentamt DE1114668B. Hamburg 1, Chilehuas C, Hamburg, Germany, filed 21 September 1959, and issued 5 October 1961.

Franz Süberkrüb died in 1960. His patent applications of July 1960 had his wife, Emma, as the applicant and himself as the inventor.<sup>141</sup> The patent application of November 1960 had the same, but in this case the document indicates that the inventor is deceased.<sup>142</sup> Neither of these patents were for trawling gear. His final patent for trawl doors, published in 1964, credits him posthumously as the inventor and his widow as the applicant.<sup>143</sup> A later source of the mid-1960s confirmed that Süberkrüb was deceased and that his widow held the rights to his patents.<sup>144</sup> The trawl doors were patented in at least six countries, mainly northern Europe and the USA.

Süberkrüb trawl doors became the most common type of trawl doors for fishermen using pelagic trawls for some time.<sup>145</sup> This was because they were definitively the best type of trawl door for pelagic trawling for several decades due to their design. When ordering a pelagic trawl, some netmakers included Süberkrüb doors as a package deal. There was

<sup>140</sup> Süberkrüb, Fischnetz.

<sup>141</sup> Süberkrüb and Süberkrüb geb. Joedicke, Vorrichtung zum Verdrehen der Flossen von ein- und ausfahrbaren Schlingerdaempfanlagen bei Schiffen.

<sup>142</sup> Süberkrüb and Süberkrüb, Schlingerdaempfanlage fuer Schiffe.

<sup>143</sup> Süberkrüb, Scherbrett zum pelagischen Fischen.

<sup>144</sup> Johnson, 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966', 3.

<sup>145</sup> Brandt, Fish Catching Methods of the World, 267.

also a considerable amount of information about Süberkrüb doors available. Combined with a growing body of fishermen who used them and were willing to recommend them, this would make them an easy choice for those interested in one-boat pelagic trawling.

Multiple industry publications of the 1970s and 1980s which describe pelagic trawling refer specifically to the Süberkrüb trawl door. It was both known by name as a specific brand of trawl door<sup>146</sup> and as a style of trawl door,<sup>147</sup> suggesting that there were many imitators. The predominance of Süberkrüb and Süberkrüb-style trawl doors in West Germany were noted in the mid-1960s.<sup>148</sup> They also inspired early attempts by the U.S. Fish and Wildlife Service when they made their own one-boat pelagic trawl in the early 1960s.<sup>149</sup> The popularity of this trawl door was sufficient to prompt government leaflets aimed at fishermen, such as the leaflet entitled "Choosing the Size of Suberkrub (sic) Trawl Board to Suit a Pelagic-Type Four-Panel Trawl", which was published by Fisheries Scotland in the early 1980s.<sup>150</sup> Even in the 1980s Süberkrüb trawl doors were still considered the best for pelagic trawling.

## 2.2.2 Fishermen and Netmakers

Ponte Sterner Persson leaves little record of his personal life or achievements outside of his patents. His profession as stated on his patents was "fisker" (fisherman). He was born in 1902 and lived his entire life on the island of Smögen, part of an archipelago about 50 km north of Gothenburg (and Öckerö), until his death in 1974. Smögen was an established fishing community by the twentieth century, so it is likely that he came from a fishing family, although he himself was unmarried and had no children. His final patents were granted in 1961, after which there is no indication of his continued involvement in trawl design.

Persson's earliest patent application was in 1949 for a one-boat pelagic trawl,<sup>151</sup> which had an unusual arrangement of bridles and warps. This was followed by another patent application for a one-boat design with a kite in 1950.<sup>152</sup> These were not successful designs, and may be the unsuccessful attempts later referred to by AB Stranne & Oresten in a short letter which was published as part of a report by Johansson and Lindqvist in 1967.<sup>153</sup>

Many of Persson's patents were made in conjunction with a netloft in Gothenburg called AB Stranne & Oresten. Founded in the 1936 by Olaf Wedel Stranne and Johan

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<sup>146</sup> Bridger et al., *Glossary of United Kingdom Fishing Gear Terms*, 67.

<sup>147</sup> Garner, *How to Make and Set Nets*, 93.

<sup>148</sup> Johnson, 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966', 3.

<sup>149</sup> Rathjen and Fahlen, 'Progress Report on Midwater Trawling Studies Carried out off the New England Coast in 1961 by M/V Delaware', 4.

<sup>150</sup> Ferro, *Choosing the Size of Suberkrub Trawl Board to Suit a Pelagic-Type Four-Panel Trawl*.

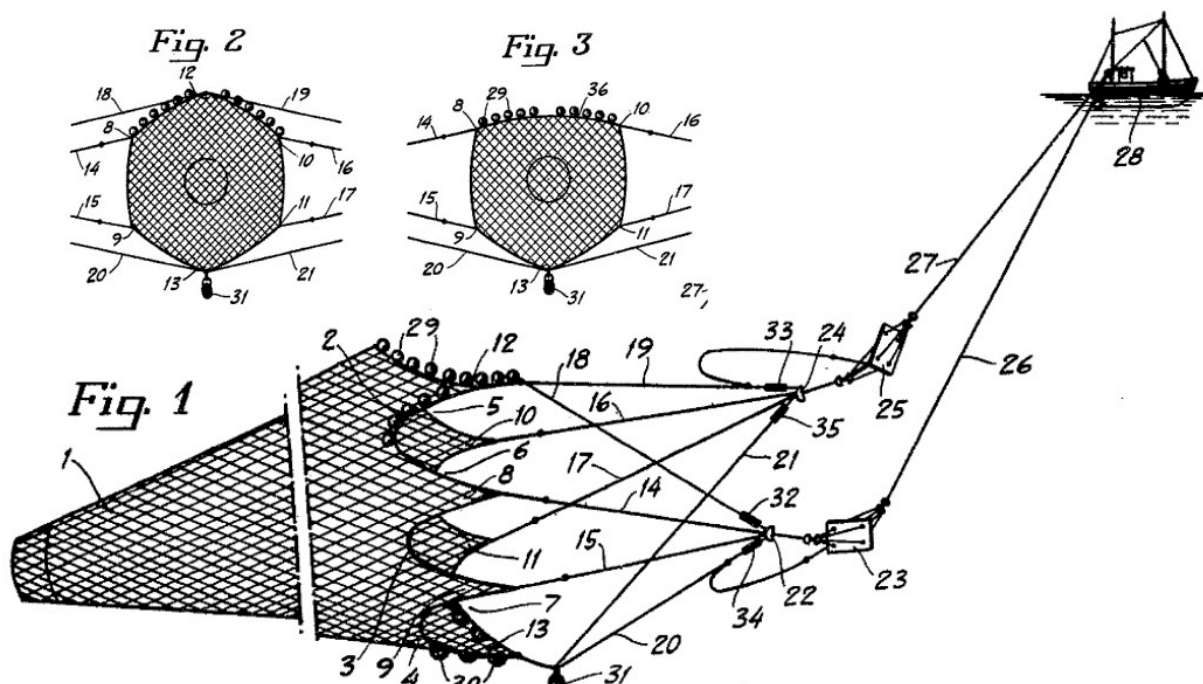
<sup>151</sup> Persson, *Anordning ved trawl*.

<sup>152</sup> Persson, *Improvements in Trawl Nets for Fishing*.

<sup>153</sup> Johansson and Lindqvist, 'Svenska Fiskeriförsök Med Enbåtsflyttrål', 12–13.

Henry Lambert Oresten in Gothenburg,<sup>154</sup> they manufactured and sold fishing equipment, including glass floats marked with the company name. There is no indication whether Persson was an employee, a partner, or that he had simply licensed them to manufacture his designs. When Johansson and Lindqvist sought information on Persson's design for their report, it was AB Stranne & Oresten who responded.<sup>155</sup> Their response, printed in the report, stated that attempts in the early 1940s to make a one-boat pelagic trawl had failed. This would suggest that this partnership of Persson with Stranne and Oresten had existed since at least the early 1940s. There is pattern where Persson alone patents an initial design concept, followed by further patents with Stranne and Oresten (as individuals, not as a netloft), suggesting that they were involved in developing these designs further. This was likely as a result of either feedback from fishermen, or of Stranne and Oresten's involvement in constructing and testing the trawls. As a business they ceased to operate in the 1970s, perhaps as a consequence of the collapse of the herring stocks in the 1960s.

Figure 11. Persson's stjärntrål, 1958



Sources: Persson, *Ponte Sterner. Trawl. Direktorat for Patent- og Varemærkevæsenet DK90665C. Smögen, Sweden, filed 13 October 1958, and issued 27 March 1961.*

According to the 1967 report the six-wing trawl was made from terylene netting with a mesh size of 85mm in the wings. It states that the trawl has increased in size due to fishing boats also increasing in size and was undergoing continual development in response to other advances in fishing technology. The trawls were used by boats as small as 15 metres with 75 horsepower and as large as 32 metres with 800 horsepower. The six-wing trawl could therefore not have been a one-size fits all product, but one that was commissioned to suit the trawler using it. It was used in variety of locations including Iceland, the west

<sup>154</sup> Anonymous, 'Årgång Nittioett', 590.

<sup>155</sup> Johansson and Lindqvist, 'Svenska Fiskeriförsök Med Enbåtsflytrål', 12.

coast of England, and the Baltic Sea. Clearly popular, the letter proudly states that 140 trawls had been ordered that year alone. It also states that results were variable, with poor results in the Skagerrak and Kattegat and in the North Sea, but that it performed well in the Irish Sea, the Baltic Sea, and around the Hebrides.

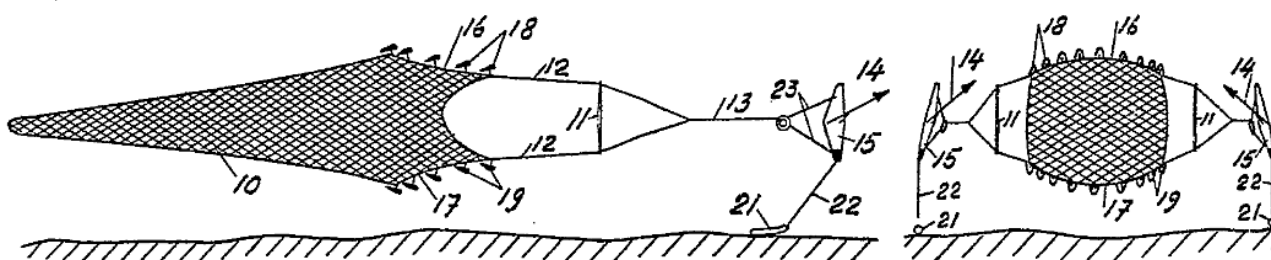
A follow up report of 1970 shows that Persson's six-wing trawl was used in fishing trials with good results.<sup>156</sup> However, after the collapse of the herring stocks the six-wing trawl disappears. This was followed by the death of Persson in the mid-1970s, as well the apparent demise of AB Stranne & Oresten as a company. The six-wing arrangement is not seen again, despite its apparent success and its disappearance is most likely due to the complexity of its construction and use.

### 2.2.3 Engineers

Karl Hugo Larsson was an engineer, living and working in Stockholm, Sweden with his wife. Born in 1898, he worked as an engineer for various shipyards from 1924 until 1940 and began working as a consulting naval architect in 1936.<sup>157</sup> His patents of 1949 state his occupation as civil engineer, but by 1959 he is referred to as a consulting naval architect.<sup>158</sup>

Larsson began working on a one-boat pelagic trawl in 1943.<sup>159</sup> He was part of an effort to make a paravane in conjunction with the Swedish Royal Navy which involved testing scale models in a flume tank.<sup>160</sup> A paravane is a mine-sweeping device which is towed behind a ship. Its design requires it to be hydrodynamic so as to maintain the correct depth while it is being towed. In this respect the design of paravanes has a great deal in common with trawl doors. Larsson tested 15 different types of "hovering trawlboards"<sup>161</sup> for the purpose of removing mines from harbours. He included his own design, as well as several sizes of Süberkrüb trawl doors and a trawl door designed by the U.S. Fisheries and Wildlife Service for the Cobb Trawl.<sup>162</sup>

Figure 12. Larsson's Phantom Trawl, 1940s



Sources: Larsson, Karl-Hugo. Flydevod. Direktorat for Patent- og Varemærkevæsenet DK79354C. Stockholm, Sweden, filed 22 November 1949, and issued 23 May 1955.

<sup>156</sup> Lindquist, 'Årsberättelse', 6.

<sup>157</sup> Harnesk, *Vem Är Vem?* Stor-Stockholm 1962, 754.

<sup>158</sup> Kristjonsson, 'List of Contributors', 1959, xix.

<sup>159</sup> Johansson and Lindquist, 'Svenska Fiskeriförsök Med Enbåtsflyttrål', 10.

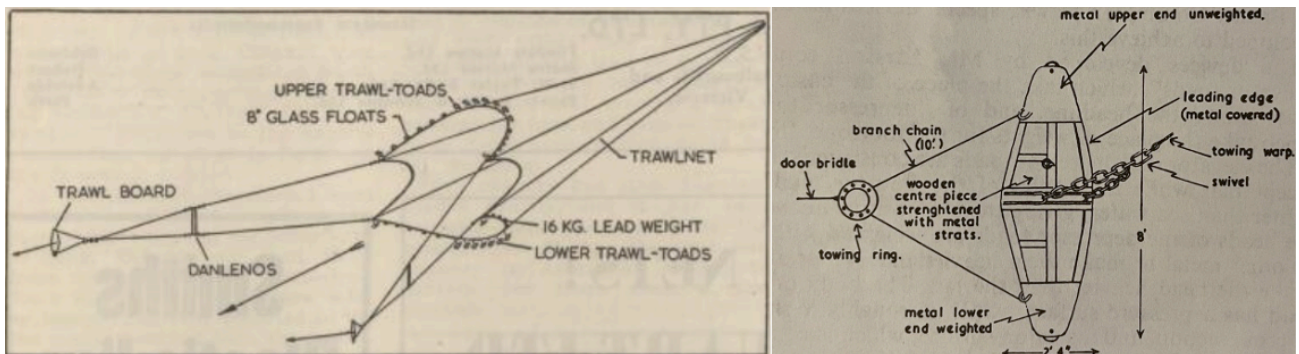
<sup>160</sup> Schärfe, 'Discussion on Midwater Trawling', 258.

<sup>161</sup> Johansson and Lindquist, 'Svenska Fiskeriförsök Med Enbåtsflyttrål', 10.

<sup>162</sup> Johansson and Lindquist, 10.

In 1949 Larsson applied for a patent for the Phantom Trawl (figure 12).<sup>163</sup> This application was for the entire trawl assembly, including trawl doors. The patent has very little information about the trawl itself, focussing instead on the trawl doors and rigging arrangements. Larsson referred to his trawl door as wing boards (figure 13, right).

Figure 13. Larsson's Phantom Trawl, 1950s



Sources: Left: Anonymous. 'Swede's "Phantom Trawl" Claim'. *Fisheries Newsletter*, 4 April 1954. Right: Parrish, B. B. 'Midwater Trawls and Their Operation'. edited by Hilmar Kristjónsson, 1:333–43. Farnham, Surrey, England: Fishing News Books, 1959

The wing boards were originally attached to the trawl with a single bridle and two inner footrope legs, which were kept separate with a danleno. A paper presented at a conference by Larsson in 1957 shows he abandoned this arrangement in favour of two bridles attached to the wing door,<sup>164</sup> although another paper at the same conference used the design shown in the patent.<sup>165</sup> However, this paper is the only other source which described the physical construction of the trawl and there is no reason to think it is outdated or inaccurate in its description of the Phantom Trawl. It specifically states that until 1959 the Phantom Trawl was mainly made from cotton netting with manila ropes. Any changes were then perhaps limited to the rigging, not to the body of the trawl. From this paper we also learn that the Phantom Trawl was a symmetrical four-panel design, where the side panels were narrower than the top and bottom panels. This gave the trawl a rectangular mouth. The largest mesh size was 120mm in the wings, decreasing throughout to the smallest, 34mm, in the codend. Later versions of the Phantom Trawl from the late 1950s would include elevator and depressor devices called trawl-toads (figure 13, left), which he had previously patented as part of a bottom trawl in 1949.<sup>166</sup>

In the 1950s and 1960s Larsson applied for numerous patents in Europe, Iceland, and North America, all for fishing gear. The Phantom Trawl was the most successful, winning Larsson the silver medal at the International Inventor's Fair in Paris in 1956.<sup>167</sup> His trawl appears to have been well known, but perhaps not popularly used. Larsson was one of the few independent inventors to regularly interact with the growing scientific community that

<sup>163</sup> Larsson, Flydevod.

<sup>164</sup> Larsson, 'Scandinavian Experience with Midwater Trawls', 346.

<sup>165</sup> Parrish, 'Midwater Trawls and Their Operation', 341.

<sup>166</sup> Larsson, Skæreplan, navnlig til fisketrawl.

<sup>167</sup> Anonymous, 'Larsson Floating Trawl Wins Award'.

appeared in the 1950s. Süberkrüb, too, had engaged with this community until his death in 1960. Süberkrüb had presented a paper at the 1957 International Fishing Gear Congress organised by the FAO, which was then published in the proceedings.<sup>168</sup> Larsson was also involved with the Congress of 1957, contributing a short yet detailed overview of pelagic trawling in Scandinavia. He described Robert Larsen's pair trawl, Persson's six-wing trawl, and his own Phantom Trawl. Here he refers to these three pelagic trawls as "the best known types used in Scandinavian waters."<sup>169</sup> The most detailed description is of his own trawl and trawl doors. Larsson was quick to tout the wing door as having "twice the shearing ability of an ordinary board of the same area"<sup>170</sup> although he does not state whether the ordinary board is a Süberkrüb-style trawl door or the kind typically used for bottom trawling.

The lack of construction detail on the Phantom Trawl was discussed by a Canadian report. They stated that when they conducted their experiments in the 1950s their "...next step was to research all the trade journals for detailed information on ... Karl-Hugo Larsson's one boat "Phantom" midwater trawl, but such details were sadly lacking."<sup>171</sup> What little they knew indicated that the Phantom Trawl was effective for catching Baltic herring, but not for the faster-swimming North Sea herring. A Canadian fisherman who had used the wing doors had concluded that they were no more effective than any other type of trawl door for catching herring.<sup>172</sup> The Canadians were forced to go to the U.S. Fish and Wildlife Service who were also testing a Phantom Trawl. They learned that thus far experiments with it had been inconclusive – and that there were significant difficulties in handling the Phantom Trawl. However, it seems that only the U.S. Fish and Wildlife Service found the wing doors useful, albeit not in the intended manner.

The U.S. Fish and Wildlife Service had tested the Phantom Trawl, complete with wing doors and elevator toads. Elevator toads were meant to replace the floats and were designed to shear upwards when travelling through the water. Depressor toads, replacing weights, did the opposite, shearing downwards. Their experiments found that the wing doors with the toads caused significant drag, which in turn caused the cotton netting of the trawl to tear under strain, especially if the boat was moving too quickly.<sup>173</sup> This meant that the mouth of the trawl did not open far enough as sufficient speed could not be achieved without damaging the trawl. They also pointed out that the Larsson wing door was partially constructed from plywood, which caused buoyancy issues at certain depths – problems which were solved by using metal doors. Later the U.S. Fish and Wildlife Service

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<sup>168</sup> Süberkrüb, 'Otter Boards for Pelagic Trawling', 359–60.

<sup>169</sup> Larsson, 'Scandinavian Experience with Midwater Trawls', 346.

<sup>170</sup> Larsson, 347.

<sup>171</sup> Johnson and Rycroft, 'The Management of Innovation in the Field of Fishing Gear in Canada', 32.

<sup>172</sup> Johnson and Rycroft, 32.

<sup>173</sup> Sand, 'Midwater Trawl Design by Underwater Observations', 209–10.

carried out experiments of their own trawl design using Larsson's wing doors in addition to metal doors of their own design (albeit made partly of plywood).<sup>174</sup>

Another Canadian researcher, writing in 1954,<sup>175</sup> stated that at that time the Phantom Trawl was entirely experimental – and only in use by two fishing vessels in Sweden and one in Norway. He went to describe the trawl as tested by the Marine Laboratory in Aberdeen, Scotland, as well as by research vessels in England and Denmark – all without success, as they caught no herring. The Marine Laboratory found that the opening of the mouth was smaller than Larsson claimed and that netting was prone to tearing – sometimes caused by the fins of the elevator toads, or when the boat changed direction. Tearing of the netting “often occurred without any apparent cause and under ideal weather conditions.” The report described a discussion with Larsson's manufacturer, Gunnar Albrechtson (of Jul. Albrechtson & Company, based in Gothenburg). Albrechtson plainly shared his belief that the danleno arrangement was unnecessary and should be removed, also recommending stronger manila netting. But this could only be found in Sweden at great expense, as it would have to be handmade. Ultimately, the Canadian researcher concluded that the trawl was not strong enough to withstand the strain of being towed. Even with more work on the design it could only have a limited application. Despite this, the researcher further stated that “most people who have used this gear agree that the wing doors and trawl toads are excellent in design.”<sup>176</sup> This statement indicates that to most people the theory that was sound, not the execution.

In the late 1950s Larsson was still using cotton and manila. Many others had already defaulted to nylon and polyamides for netting. The production of the metal trawl toads was a problem, beset by manufacturing difficulties which he thought could be alleviated by using plastic instead.<sup>177</sup> While the trawl toads appear to have been tested by various institutions, none recommended them, and they do not appear to have been actually manufactured in plastic. Given his interest in plastics for the elevators/depressors, Larsson must have at least considered updating the netting to synthetic fibres for his later designs, but there are no sources which demonstrate this. Similarly, the wing doors must have been updated. Plywood was not unusual material for pelagic trawl doors in the 1950s; it was used for trawl doors experiments in Canada<sup>178</sup> and America, as mentioned previously.

Larsson attended the second and third International Fishing Gear Congress, in 1963 and 1970 respectively. While he did not contribute any papers, he was an active participant in the discussions, which were transcribed in the published proceedings. His contributions to each International Fishing Gear Congress show that he was well-read on contemporary

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<sup>174</sup> McNeely, 'Development of the John N. Cobb Pelagic Trawl - A Progress Report', 19 & 21.

<sup>175</sup> Tibbo, 'Herring Fishing and Research Methods in Europe (Report on Trip to Europe July 13 to February 25, 1954)', 5 & 9.

<sup>176</sup> Tibbo, 9.

<sup>177</sup> Schärfe, 'Discussion on Midwater Trawling', 259.

<sup>178</sup> Parrish, 'Midwater Trawls and Their Operation', 342.

fisheries research. In the 1970 Congress he iterates his 45 years of experience as a naval architect and ship's surveyor, and refers to his new "Phantom Trawl model 1970."<sup>179</sup> Unfortunately, the design of this updated Phantom Trawl does not appear to have survived. He did not present this design at the conference, nor did he patent it.

This new design had paravanes attached to lines or extra net panels at the mouth of the trawl, however the exact arrangement is unclear from his brief description. He goes on to say is that to "...handle the paravanes which, by the way, is a question of seamanship. I am ready to instruct anyone who wants to know how."<sup>180</sup> Reading tone into such a short statement is questionable, but the reader cannot help but feel a note of frustration has crept in; the question of seamanship in particular feels suspiciously as if Larsson felt the fault lay with the user, not the product. There were multiple reports and articles which described unsatisfactory tests of the Phantom Trawl. No doubt Larsson was not happy with his work being so thoroughly dissected.

Another potential frustration of Larsson's can be found in his contribution to the Discussion on Midwater Trawling at the 1963 conference, when he stated that he "...would recommend, however, research organisations not to forget about those funny people called inventors. They very often have good ideas and like most other people, they want to be paid for their work."<sup>181</sup> It is impossible to know whether this spoke of genuine concern or was just a good-natured reminder to his fellow participants to look outside of their respective organisations; regardless, there is a note of frustration. It must have been difficult to actively create new fishing gear without the support and funding to conduct research and testing. Larsson himself had previously benefited from the resources of the Swedish Navy in the 1940s when testing paravanes. Other independent inventors often had to pause their experiments due a lack of funding or resources. Of course, the statement may also reflect a feeling of being shut out of a professional community populated by specialists who spent considerable time testing trawls at sea, gaining valuable experience as well as data. There is no evidence as to how much time Larsson spent actively testing his gear, or analysing feedback from fishermen. When describing his trawl, he did not describe how the trawl should be used. Unlike his contemporaries, he provided no detailed written instructions on handling, tactics, or best use.

The note of frustration is also seen in the phrase "they want to be paid for their work." It is likely that independent inventors like Larsson thought that their intellectual property was not respected. Süberkrüb-type trawl doors were mentioned frequently, so copies already existed for fishing gear, regardless of patent rights. Given that the designs created by the FAO and government research departments were effectively free, Larsson was perhaps dismayed at the sheer amount of competition. Larsson would have been in his 70s

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<sup>179</sup> Brandt, 'Discussion: Materials, Design, Construction and Selection of Gear', 375.

<sup>180</sup> Brandt, 375.

<sup>181</sup> Schärfe, 'Discussion on Midwater Trawling', 258.

by the third Congress. He likely retired around this time as there was no new work or involvement from this point on. He died in 1988. While his Phantom Trawl has left a significant footprint in contemporary written sources, it seems to have left little lasting impact on fishing gear design. Most of the source materials originate from industry professionals involved in testing and experimenting with trawl gear, with no evidence that it was actually used by fishermen regularly or successfully. Despite his strong presence, Larsson's Phantom Trawl did not have the same success as enjoyed his contemporaries.

#### 2.2.4 Fisheries Gear Technologists

The principal individual who drove the development the one-boat pelagic trawl was Dr. Joachim Schärfe, who mostly worked in West Germany. Another key individual involved in the development of the trawl was Andres von Brandt, who was the director of the Institut für Netz-und Materialforschung of the Bundesforschungsanstalt für Fischerei (Institute for nets and materials research, of the Federal Research Centre for Fisheries), based in Hamburg. Schärfe initially worked under von Brandt in the early 1950s before moving to the Fisheries Division of the FAO in 1957 as a fisheries gear technologist.<sup>182</sup> Schärfe would later take on the role of Chief in the Gear Technology Section of the Department of Fisheries at the FAO, replacing Hilmar Kristjonsson by 1971.<sup>183</sup> Von Brandt spent several decades in the position of director of the Institut für Netz-und Materialforschung. Later he was the Emeritus Professor of Fish Catching Techniques at the University of Hamburg.<sup>184</sup>

Von Brandt demonstrated an interest in pelagic trawling in 1950 after conducting tests on Süberkrüb trawl doors.<sup>185</sup> This report had a descriptive account of pelagic trawling in Scandinavia and West Germany, including the Larsen Atom Trawl. He also described several pair pelagic trawls used by West German fishing vessels in the Baltic, contrasting one made with cotton and one made with perlon, stating that they only used the pair trawl at night as the herring was higher in the water at night. In his report he noted that keeping the trawl at the right depth during towing was difficult. He goes on to describe how a steam trawler could use a one-boat pelagic trawl if the Süberkrüb trawl doors were properly used, and that this had been demonstrated by Süberkrüb himself. While von Brandt familiarised himself early on with pelagic trawling and the ways in which it was conducted in northern Europe, he had other professional interests. This included research on synthetic materials for netting, as well a classification system for fishing gear, which eventually resulted in the 1964 publication *Fish Catching Methods of the World*.

Subsequent testing of one-boat pelagic trawls began in the early 1950s. Fishing vessels were chartered by the Institut für Fangtechnik, who paid the vessel the average

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<sup>182</sup> Schärfe, 'The Use of Echo-Sounding as a Means of Observing the Performance of Trawling Gear', 241.

<sup>183</sup> Kristjonsson, 'Notice to the Reader', 1971, xii.

<sup>184</sup> Kristjonsson, 'List of Contributors', 1971, xiii.

<sup>185</sup> Brandt, 'The Floating Trawl', 15.

profit expected of a successful fishing trip – minus the value of the catch, which was sold by the captain and crew.<sup>186</sup> From 1963 the purpose-built research vessel Walther Herwig was used, although commercial trawlers were occasionally still chartered as well. Early testing by Schärfe involved equipping a small rubber dinghy with an echosounder to monitor the trawl while it was being towed.<sup>187</sup> This arrangement led to the development of the netsounder, in the years 1958-1959.<sup>188</sup> Clearly, progress was swift; an Atlas “netsonde” was referenced in a 1960 Icelandic article, listed as a part of a newly built (in Bremerhaven) vessel’s array of electronic equipment.<sup>189</sup> Improvements were ongoing, however, with advances<sup>190</sup> and new models emerging over the course of the 1960s.

The advantage of using a dinghy was that it could be manoeuvred above different parts of the trawl. This was ideal until the motor broke, leaving the dinghy and its occupants behind.<sup>191</sup> Without a radio they simply had to wait several hours until the trawler realised what had happened and returned for them.<sup>192</sup> This led to mounting the sonar device onto the trawl itself. This was not necessarily a simple solution, as it entailed attaching an additional cable carrying an electric current to the headline of the trawl, where the headline transducer was placed. It had to be durable enough to endure prolonged immersion in the sea, avoid becoming tangled in the warps and cables, and withstand potential rough handling. The benefit was that the netsounder relayed data back to the trawler, providing real-time information as to the depth of the trawl. It also showed shoals of fish as they entered the trawl, providing not just confirmation of a catch but also a rough estimation of its size. Schärfe later pointed out that while the netsounder had been refined and made a commercial success by German companies, it was originally developed in Britain, in Lowestoft.<sup>193</sup>

Jelly bottles<sup>194</sup> were also used by Schärfe in early trawl tests, although by 1957 they had been replaced with the angle of attack meter.<sup>195</sup> This purpose of the jelly bottles was to calculate the angle and shape of the headline of the trawl while it was being towed in the water. The jelly bottle technique worked by putting warm gelatin solution into a bottle with a small compass. Von Brandt specified that the gelatin could be mixed 1:1 with machine oil, which helped equalise the pressure when immersed, with the bottles kept in a basin of hot water until the last minute.<sup>196</sup> Several bottles were attached along the headline, so that as the gelatine cooled down and solidified, the angle was preserved along with the

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<sup>186</sup> Schärfe, ‘The German One-Boat Mid-Water Trawl’, 2–3.

<sup>187</sup> Schärfe, ‘The Use of Echo-Sounding as a Means of Observing the Performance of Trawling Gear’, 241–42.

<sup>188</sup> Schärfe, ‘One-Boat Midwater Trawling from Germany’, 221.

<sup>189</sup> Anonymous, ‘Skip og vélar: Nýr 1000 lesta togari’, 270.

<sup>190</sup> Schärfe, ‘The German One-Boat Mid-Water Trawl’, 20.

<sup>191</sup> Bates, ‘Engel Netze’.

<sup>192</sup> Personal communication with Hans Hermann Engel.

<sup>193</sup> Craig, ‘Discussion on Fish Detection’, 418.

<sup>194</sup> Jell-o in North America.

<sup>195</sup> Schärfe, ‘The Use of Echo-Sounding as a Means of Observing the Performance of Trawling Gear’, 244.

<sup>196</sup> Brandt and Steinberg, ‘Experiments with Floating Trawls in the Region of Egersund’, 57.

direction indicated by the compass.<sup>197</sup> These measurements were then used to calculate the angle of the headline. When Schärfe used jelly bottles for trials on chartered fishing vessels large quantities of gelatine had to be produced by the ship's cook,<sup>198</sup> who was not at all happy to find out what it was being used for.<sup>199</sup> Despite more advanced equipment, a version of the jelly bottle – The Jelly-Filled Directional Rolling Inclinometer – was still in use in the 1960s.<sup>200</sup>

The FAO organised the first International Congress of World Fishing in 1957, the year Schärfe moved to the FAO. The proceedings were published in 1959 and Schärfe was credited in the front matter as a significant contributor to its compilation and editing. However, there is an absence of papers on one-boat pelagic trawling in West Germany, despite multiple papers by Scandinavian, Canadian, and British contributors. Instead, there were numerous articles describing research methods, such as depth telemeters, netsounders, jelly bottles, and scale models. This suggests that experiments with pelagic trawls were in some way unsatisfactory, with only the methods used in those tests of sufficient interest. Schärfe later specified the period of significant research and development as starting in 1959.<sup>201</sup>

When von Brandt discussed pair pelagic trawling in 1957, he stated that cutters were manoeuvrable enough for pair trawling but lacked the engine power for large trawls, while steam trawlers had the engine power but lacked the manoeuvrability needed for pair trawling.<sup>202</sup> The one-boat pelagic trawl had to be suitable for smaller fishing vessels with less horsepower as well as for larger trawlers. Schärfe intended his one-boat pelagic trawl as an economical alternative for small deep-sea trawlers which could not reach distant fishing grounds off the coasts of North America and Greenland.<sup>203</sup> The trawl was adopted by the newly introduced stern trawlers and factory trawlers.<sup>204</sup> Schärfe also intended for the one-boat pelagic trawl to be able to catch species other than herring, including semi-pelagic species (those near, but not on, the bottom).<sup>205</sup>

There were numerous trials and fishing trips, with forty-three organised by Schärfe between 1958 and 1969.<sup>206</sup> Von Brandt also led trial fishing trips during this time. The one-boat pelagic trawl initially based much of its design on pair trawls.<sup>207</sup> While it was effective at catching cod and spawning herring, it was far less effective for catching shoals of fish

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<sup>197</sup> Carruthers, 'Simple Devices for Studying the Geometry of Various Gears and for Relating Some Commercial Fishing Operations to the Existing Water Movements', 254–55.

<sup>198</sup> Bates, 'Engel Netze'.

<sup>199</sup> Personal communication with Hans Hermann Engel.

<sup>200</sup> Carruthers, 'Trawl Studies and Currents', 518–21.

<sup>201</sup> Schärfe, 'The German One-Boat Mid-Water Trawl', 2.

<sup>202</sup> Brandt and Steinberg, 'Experiments with Floating Trawls in the Region of Egersund', 66–67.

<sup>203</sup> Anonymous, 'One Boat Midwater Trawl Passes Tests', 23.

<sup>204</sup> Schärfe, 'The German One-Boat Mid-Water Trawl', 5–6.

<sup>205</sup> Schärfe, 'One-Boat Midwater Trawling from Germany', 228.

<sup>206</sup> 'International Conference on Design, Construction, and Operation of Commercial Fishing Vessels - Proceedings', 7.

<sup>207</sup> Schärfe, 'The German One-Boat Mid-Water Trawl', 3.

that were more active and spread out over a large area. By 1962 it became apparent that significant changes needed to be made,<sup>208</sup> which included switching to a four-panel trawl, making the mouth of the trawl larger and more rectangular.<sup>209</sup> This, along with changes in the trawl doors and rigging, almost immediately resulted in consistently good catches of North Sea non-spawning herring.<sup>210</sup>

Trials were also carried out on stern trawlers, which had been swiftly adopted in West Germany. Schärfe thought the one-boat pelagic trawl was best suited to stern trawlers.<sup>211</sup> Stern trawlers made handling trawls and large catches much easier as the trawl and catch could be hauled onboard using hydraulic gear and then processed below decks. Schärfe specified the use of Atlas-Werke sonar and fish-finders in his trials. Atlas-Werke sold netsounders by 1966, as reported by a visiting Canadian gear technologist.<sup>212</sup> Netsounder sets included a transducer board, recorder, and over thousand metres of coaxial cable.<sup>213</sup> Other companies, such as Simrad, Furuno, Elac, and Marconi quickly developed these units for commercial sale. By the 1970s the netsounder had developed further to include the multi-netsonde<sup>214</sup> which was used in place of multiple netsounder devices on the trawl.

Some testing used scale models instead of full-size trawls, which were observed and recorded by divers. At a scale of 1:4, they were helpful in ensuring that the modifications needed would be effective.<sup>215</sup> Despite the effectiveness of models, Schärfe expressed as early as 1959 that he preferred to use real-size trawls over scale models because then the fishermen onboard could see it working for themselves.<sup>216</sup> This made it more likely that they would buy and use the gear outside of the trials, having gained experience handling and using the gear at no cost to themselves. It also lent them greater credibility in communicating the success of the trawl to other fishermen.

Schärfe commissioned trawls of his own design from several netlofts in West Germany, with netmakers participating in trials. These netlofts then made and sold pelagic trawls based on their own and Schärfe's designs. Two of these netlofts were H. Engel in Kiel and Itzehoer Netzfabrik in Itzehoe. Itzehoer Netzfabrik, founded in the nineteenth century, also manufactured monofilament.<sup>217</sup> The netloft H. Engel was started in 1951 by Hans Engel in 1947 after he fled to Kiel after the Second World War. The netloft relocated to Bremerhaven in 1969, where it was eventually taken over by his son, Hans Hermann Engel and renamed Engel-Netze. Hans Hermann Engel was involved in the trawl trials on board

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<sup>208</sup> Schärfe, 'One-Boat Midwater Trawling from Germany', 222–23.

<sup>209</sup> Schärfe, 'The German One-Boat Mid-Water Trawl', 17.

<sup>210</sup> Schärfe, 7.

<sup>211</sup> Schärfe, 11.

<sup>212</sup> Johnson, 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966', 20–21.

<sup>213</sup> Johnson, 20–21.

<sup>214</sup> Horn, 'New Types of Multi-Netsonde Equipment', 389–95.

<sup>215</sup> Schärfe, 'The German One-Boat Mid-Water Trawl', 5.

<sup>216</sup> Truang, 'Discussion on Rational Design of Fishing Gear', 269.

<sup>217</sup> Carrothers, 'Monofilament Nylon Web for Salmon Gill Nets - 1959', 1.

the research ship *Anton Dorn*,<sup>218</sup> observing the trawls' performance – including on the dinghy that was left behind with the netsounder. He was later involved a joint German-Thai fishing initiative in the 1960s,<sup>219</sup> aimed at modernising Thai commercial fisheries.<sup>220</sup> They were advertised and sold worldwide in the 1960s and 1970s.<sup>221</sup>

Schärfe used synthetic twines exclusively for his trawls, polyamides such as perlon or nylon.<sup>222</sup> These early one-boat trawls were designed with these stronger and more durable synthetic fibres specifically so that they could handle larger catches. While early synthetic fibres were much more expensive than their organic counterparts, they were significantly stronger and far more durable. Von Brandt carried out extensive research demonstrating the superiority of synthetic netting and ropes in the 1950s. The first International Fishing Gear Congress in 1957 dedicated a significant amount of time (and subsequent publication space) on the discussion of synthetic and organic fibres. Von Brandt was also a leading member of a Working Party on Terminology and Numbering Systems and headed a Working Party on Testing Methods at this conference.<sup>223</sup>

Von Brandt described the requirements for a one-boat pelagic trawl in 1962:

- “1. A high specific strength of the netting material so that it could hold, if necessary, large catches without damage to it;
2. Good flow-through of water to keep down any possible return swell in front of the net;
3. A large opening height to be able to fish as large a range as possible;
4. Easy manoeuvrability in order to be able to shift the net easily from one depth to another;
5. Good suitability for work.”<sup>224</sup>

Von Brandt, in keeping with his research and role as director of the Institut für Netz- und Materialforschung, dedicated a section of his report to examining the polyamide twine used in the trawls. He discusses their thickness, twist, and the tensile strength of the knots when wet. Unsurprisingly, the key result was that synthetic fibres were much better than organic ones. Synthetic twine is stronger and lighter, which means that the trawl can be bigger and lighter, tolerating more strain and weight before breaking. This fulfils the points made by von Brandt, as each is achieved by the use of synthetic netting. Most of all, the polyamide netting reduced drag, regardless of weight, making it easier to tow.<sup>225</sup> This required less fuel and less horsepower.

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<sup>218</sup> Bates, 'Gear Talk: The Origins of Pelagic Trawling'.

<sup>219</sup> Bates, 'Engel Netze'.

<sup>220</sup> Nagalaksana, 'Thailand Country Experience 1987', 118.

<sup>221</sup> Bates, 'Engel Netze'.

<sup>222</sup> Schärfe, 'The German One-Boat Mid-Water Trawl', 16–17.

<sup>223</sup> Brandt, 'Report on the Working Groups on "Terminology and Numbering Systems" and "Testing the Properties of Twines"'.  
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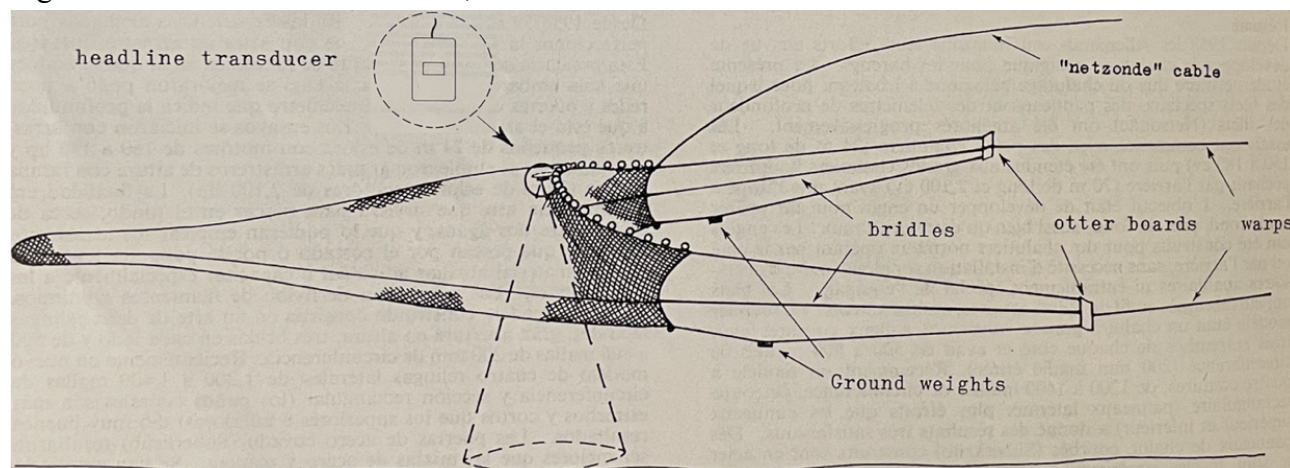
<sup>224</sup> Brandt and Steinberg, 'Experiments with Floating Trawls in the Region of Egersund', 7.

<sup>225</sup> Brandt and Steinberg, 11–12.

Von Brandt soaked the netting with bitumen or pitch to dye it black, which also helped to stiffen the panels. The use of bitumen or pitch to preserve organic netting was a common technique in commercial fishing until synthetic netting was adopted, although here its primary role was as a dye. He did, however, state that this made the trawls harder to for the crew see when the netting was being repaired at night.<sup>226</sup> Dying the trawl was an attempt to camouflage the trawl from the fish. Fish behaviour and response to trawls and fishing gear were a key part of von Brandt's approach, which also included using jelly bottles attached to different parts of the trawl, to see how it was oriented.<sup>227</sup> This data were then compared to netsounder and sonar readings showing how the fish behaved when they approached or were near the mouth of the trawl. s

The original one-boat pelagic trawl design developed by Schärfe in 1957<sup>228</sup> was for a small two-panel trawl (figure 14). It was trialled in 1961 by von Brandt, who took three two-panel trawls out on three trawlers to Egersund, off southwest Norway.<sup>229</sup> The trawls were made by Engel from polyamide netting. Two-panel trawls of the same design were also trialled by Schärfe on two separate trips in 1962 and 1963, along with a four-panel trawl design.<sup>230</sup>

Figure 14. Schärfe's one-boat trawl, 1950



Sources: Schärfe, Joachim. 'One-Boat Midwater Trawling from Germany'. In *Modern Fishing Gear of the World*.

Six trawls in total were made and tested, each of a different size or with a different rigging arrangement. They had a maximum mesh size of 200mm, which was the maximum mesh size that a netting machine could make at the time.<sup>231</sup> This netting was made with braided twine, not twisted, so that the meshes were less likely to distort, as well as being more resistant to abrasion.<sup>232</sup> The maximum mesh size made by netting machines

<sup>226</sup> Brandt and Steinberg, 12.

<sup>227</sup> Brandt and Steinberg, 56–57.

<sup>228</sup> Schärfe, 'One-Boat Midwater Trawling from Germany', 221; Brandt, 'Report on the Working Groups on "Terminology and Numbering Systems" and "Testing the Properties of Twines"', 98–99.

<sup>229</sup> Brandt and Steinberg, 'Experiments with Floating Trawls in the Region of Egersund', 4–18.

<sup>230</sup> Schärfe, 'One-Boat Midwater Trawling from Germany', 221–28.

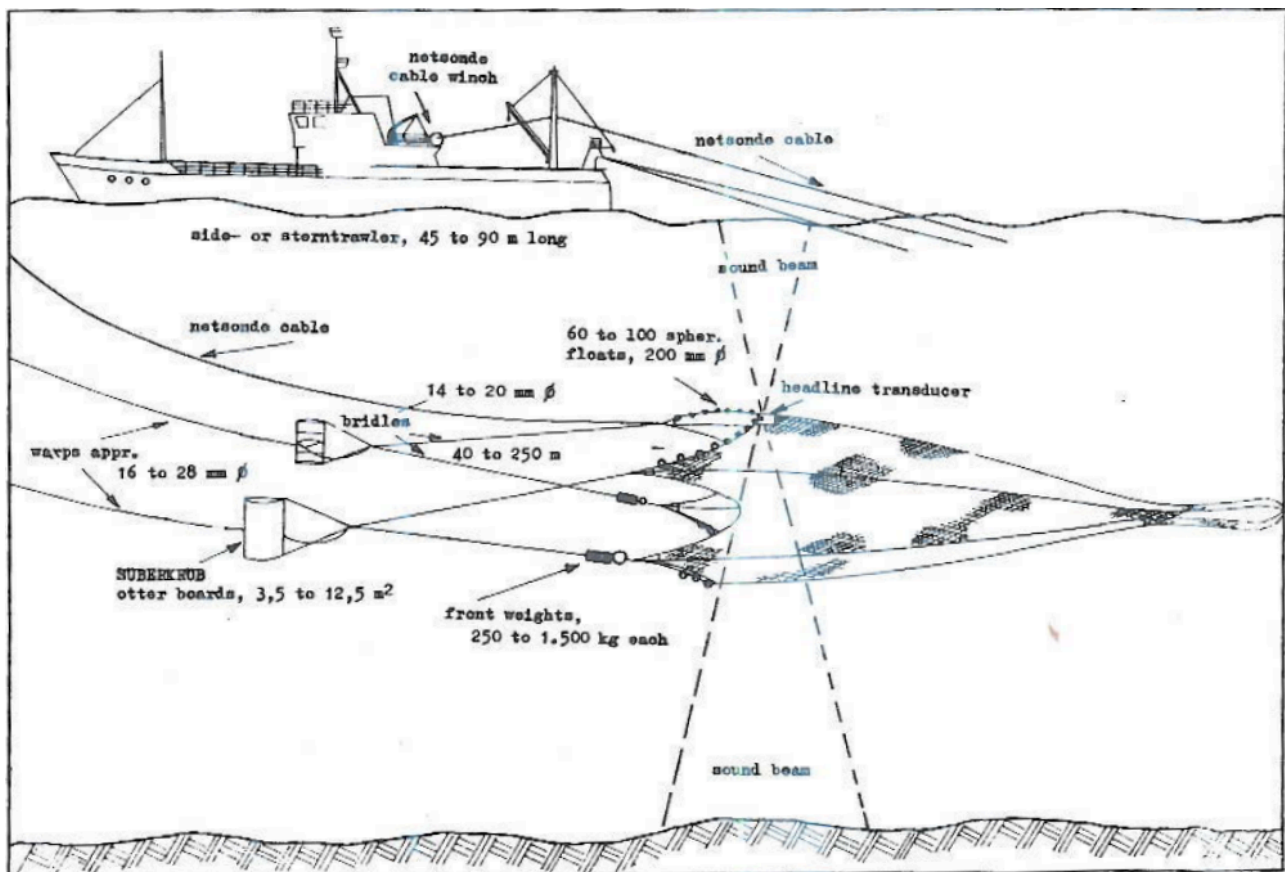
<sup>231</sup> Bates, 'Engel Netze'.

<sup>232</sup> Klust, *Netting Materials for Fishing Gear*, 136.

increased to 560mm<sup>233</sup> in 1968 and then to 800mm in 1971.<sup>234</sup> These trawls were also made by Hans Engel's netloft and Schärfe credited Engel's netloft for their "close co-operation" on the development of the trawls.<sup>235</sup> Both von Brandt and Schärfe used Süberkrüb trawl doors and both had a netsounder mounted on the headline of the trawls. Figure 14, which is taken from Schärfe's report of 1964, is identical to the one used by von Brandt, first published in 1962.

The four-panel trawl quickly replaced the two-panel trawl. The four-panel trawl was symmetrical, changing the shape of the mouth of the trawl from a rectangle to a square. Over the course of the 1960s, as the trawl became bigger, so did the size of the mouth of the trawl, from a width of less than 20 metres to about 55m. This substantially increased its area, from just 250m<sup>2</sup>, to around 1200m<sup>2</sup>. The rigging arrangement also changed, with fewer bridles needed.<sup>236</sup> Figure 15 shows Schärfe's four-panel one-boat pelagic trawl of the 1960s, with Süberkrüb trawl doors and stern trawler specified. Both von Brandt and Schärfe described the trawl dimensions, materials, and rigging in exhaustive detail.

Figure 15. Schärfe's one-boat trawl, 1960s



Sources: Schärfe, J. 'The German One-Boat Mid-Water Trawl PART 3: Fishing Vessels and the Trawl Gear'. Fishing News International, September 1969.

<sup>233</sup> Brandt, 'Discussion: Materials, Design, Construction and Selection of Gear', 376.

<sup>234</sup> Bates, 'Gear Talk: The Origins of Pelagic Trawling'.

<sup>235</sup> Schärfe, 'One-Boat Midwater Trawling from Germany', 223.

<sup>236</sup> Schärfe, 228.

Over the 1960s various trials were carried out in a number of locations, including south west Norway, south west Iceland, and west Greenland.<sup>237</sup> There were mixed results, some of which could now be attributed to the impending decline of herring stocks. Nevertheless, these trials established that the size of the trawl was more important than the towing speed, leading to a substantial increase in the size of the trawls over the next decade. By the early 1960s Schärfe and von Brandt had arrived at the same conclusion: that the one-boat pelagic trawl was best used with ancillary equipment such as sonar and netsounders. Further, the one-boat pelagic trawl had to utilise adaptive techniques in order to be effective.<sup>238</sup> These would vary depending on the location, the species targeted, and the fishing conditions. Schärfe refers specifically to “outwitting” the fish, especially as the gear was often slower than the fish it was trying to catch.<sup>239</sup>

This approach was referred to as ‘aimed trawling.’ Sonar was used to locate a shoal of fish, which was then approached by the trawler. The speed and depth of the trawl was then adjusted in anticipation of how the shoal would respond; speed and timing were critical in ensuring a catch.<sup>240</sup> This was necessary with herring, which typically dove in response to oncoming trawls. The netsounder would then confirm that the shoal of fish had passed through the mouth of the trawl. This was not necessarily straightforward, as the netsounder could record the fish at the mouth of the net, only to have the fish change direction and evade the trawl at the last moment. This was a particular concern if the trawler had insufficient horsepower to tow the trawl it was attempting to use.

Schärfe’s successful one-boat pelagic trawl was not one single design. Rather, it was a series of design concepts and tactics which could be adapted to the fishing vessel using it. The trawl was made according to the size and horsepower of the trawlers, while the tactics depended on the target species and fishing conditions. Key features were synthetic fibres, large meshes, Süberkrüb trawl doors, and the support and guidance in how to best use the trawl. This approach also made Engel-Netze a highly profitable company, as it tailored each trawl it sold to the trawler using it and, if necessary, went as far as to send a representative to guide novice skippers in setting up and using the trawl.<sup>241</sup> Trawls could also be bought as a package, complete with Süberkrüb trawl doors and rigging included – all with the aim of making the purchase and use of an Engel trawl an easy and straightforward process.<sup>242</sup>

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<sup>237</sup> Schärfe, ‘The German One-Boat Mid-Water Trawl’, 4.

<sup>238</sup> Schärfe, 25.

<sup>239</sup> Schärfe, 25.

<sup>240</sup> Brandt and Steinberg, ‘Experiments with Floating Trawls in the Region of Egersund’, 48 & 51.

<sup>241</sup> Personal communication with Hans Hermann Engel.

<sup>242</sup> Personal communication with Hans Hermann Engel.

## 2.2.5 Scientists and Ex-Fishermen

In 1950 skipper Nels Nelson constructed a one-boat pelagic trawl for his fishing boat *Combat*, in British Columbia, off the Pacific coast of Canada. Having previously experimented with pelagic trawls in the late 1940s, he went on to catch a few tons of herring after repurposing a cotton salmon seine net. The trawl was constructed by a Danish fisherman, Anker Kjerside, who had joined Nelson's crew after emigrating to Canada following the Second World War.<sup>243</sup> Kjerside had the details for making a Larsen pair trawl, although he pointed out that Nelson's previous attempts had failed because the mesh size was too small throughout the trawl – there had to be bigger mesh in the front. Kjerside also went on to adapt the Larsen trawl into a one-boat version for use on *Combat*.

However, catches with the trawl were small and Nelson eventually gave up and converted to purse seining as it was more profitable.<sup>244</sup> Other fishermen in the area also attempted pelagic trawling for herring in the early 1950s, wanting to catch herring that were too deep for purse seines. The herring off the coast of British Columbia stayed in deeper water during the night, almost on the bottom, and rose higher in the water column during the day. They also spread out during the day, instead of being a concentrated shoal of fish. However, their attempts were at best mixed and many stopped experimenting.

The fishermen of British Columbia quickly recognised that they lacked the time and resources to conduct systematic tests by themselves. In 1953 Captain Rupert Prince wrote to request help from the Fisheries Research Board of Canada,<sup>245</sup> which led to the formation of an advisory committee comprised of fishermen and Fisheries Board representatives. One member of the fishermen's committee was then employed by the Fisheries Research Board to design and make a pelagic trawl,<sup>246</sup> as well as train a crew in its use.<sup>247</sup> This was Wesley W. Johnson, an experienced commercial fisherman who went on to work for the Department of Fisheries as a gear technologist<sup>248</sup> and eventually became the Chief of the Fishing Operations Division.<sup>249</sup> Johnson, with his father, had made an unsuccessful attempt to make a pelagic trawl in the late 1940s.<sup>250</sup> Johnson began by working with William E. Barraclough, a scientist for the Fisheries Research Board, alongside Captain David Moore and his boat *Prince Rupert* (not to be confused with the aforementioned skipper Rupert Prince). Moore had previously constructed a pair of Larsson trawl doors, which he had found no better than conventional trawl doors of the 1960s.<sup>251</sup>

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<sup>243</sup> Johnson and Rycroft, 'The Management of Innovation in the Field of Fishing Gear in Canada', 19.

<sup>244</sup> Johnson and Rycroft, 20.

<sup>245</sup> Johnson and Rycroft, 20.

<sup>246</sup> Barraclough and Johnson, 'A New Mid-Water Trawl for Herring', 1.

<sup>247</sup> Johnson and Rycroft, 'The Management of Innovation in the Field of Fishing Gear in Canada', 31.

<sup>248</sup> Johnson, 'Midwater Trawling in Canada', 1.

<sup>249</sup> Johnson and Rycroft, 'The Management of Innovation in the Field of Fishing Gear in Canada', 2.

<sup>250</sup> Johnson and Rycroft, 8.

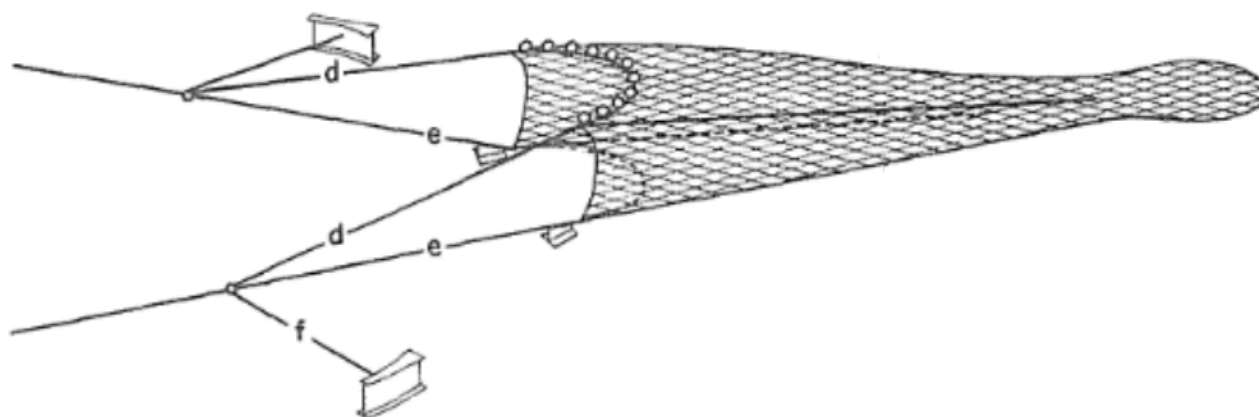
<sup>251</sup> Johnson and Rycroft, 32.

Johnson began by experimenting with existing gear. A one-boat version of the Larsen Atom Trawl was tested, as was the Larsson Phantom Trawl. He already had a plan for the Atom Trawl and a plan for the Phantom Trawl was obtained from the U.S. Fish and Wildlife Service.<sup>252</sup> While Robert Larsen never patented his design in Canada, Karl-Hugo Larsson had in 1955.<sup>253</sup> However, Johnson found both their designs lacking. Testing by the U.S. Fish and Wildlife Service on the Phantom Trawl had demonstrated its failings and he also had negative feedback from fishermen, including his own family. Instead, he began to design a new one-boat pelagic trawl suitable for the Pacific herring fishery.

By 1956 Johnson had designed and tested a one-boat pelagic trawl with trawl doors (figure 16). It was a symmetrical four-panel design, where each panel was identical. It was used with fishing vessels that fished from the stern, but without stern ramps. It was bigger than the Phantom Trawl,<sup>254</sup> made possible by Johnson's deliberate use of nylon netting. Nylon reduced towing resistance as the fibres were smoother than cotton, as well as being thinner, and it absorbed less water.<sup>255</sup> Nylon's strength meant that the trawl could be designed to make catches up to 60 tonnes. Towing resistance was also reduced through the use of large mesh sizes; larger meshes were requested by the fishermen's advisory committee for this reason. Four different sizes of mesh were used throughout with the largest in the wings (127mm) with the smallest in the codend (32mm).<sup>256</sup>

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Figure 16. The British Columbian trawl, 1965



Sources: FAO. FAO Catalogue of Fishing Gear Designs. Rome: FAO, 1965.

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Key features included pennants as part of the trawl door rigging and a zipper placed in the codend. The pennants (figure 16, marked as 'f') were extra cables which attached to the point where the warps met the bridles. At this point there would typically be a trawl door, but instead there was a link point where a pennant (a steel wire rope) was attached. The trawl door was attached to the end of the pennant.

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<sup>252</sup> Johnson and Rycroft, 19 & 32.

<sup>253</sup> Larsson, Trawl Nets.

<sup>254</sup> Parrish, 'Midwater Trawls and Their Operation', 340.

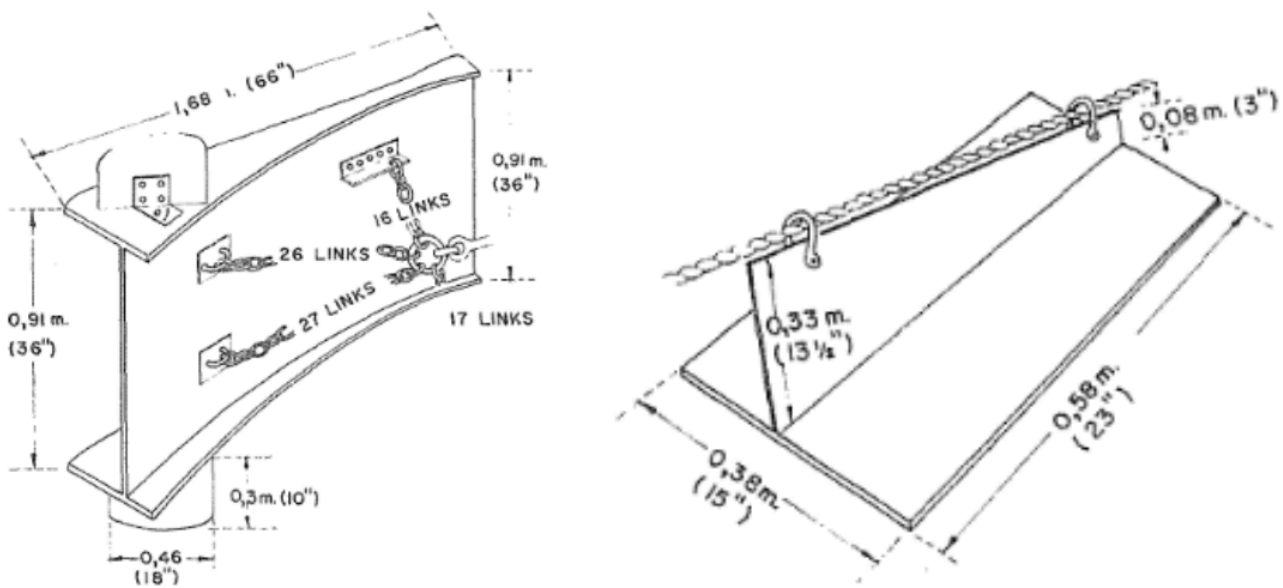
<sup>255</sup> Barraclough and Johnson, 'A New Mid-Water Trawl for Herring', 3.

<sup>256</sup> Parrish, 'Midwater Trawls and Their Operation', 340.

The zipper was a short section of one of the codend seams, which allowed it to be opened and the herring extracted using a brailer (a large scoop made of netting, typically used on purse seiners). This was necessary as the trawlers had no stern ramp and the catches were too large to be hauled over the side (a dangerous procedure in itself). Johnson reported that the weight of the catch brought close to the side of the trawler helped steady it in poor weather.<sup>257</sup>

Barracough, Johnson, and Moore also designed their own trawl door (figure 17, left). Initially, it was made almost entirely of laminated plywood.<sup>258</sup> Plywood was lightweight, cheap, and easy to mould into a curved shape. There were also depressors (figure 17, right) made from steel plate, designed by David Moore.

Figure 17. Johnson & Barracough's trawl door (left) and Moore's depressor (right), 1965



Sources: FAO. FAO Catalogue of Fishing Gear Designs. Rome: FAO, 1965.

This pelagic trawl was a success, with the final report stating that they "...anticipate that similar nets, with different dimensions and different mesh sizes, would be successful in taking other commercial species in British Columbia (sic) waters."<sup>259</sup> The report was very detailed, including full construction details, how to rig the trawl doors, and the exact operation of the trawl. Operating the trawl required the use of sonar to locate a school of herring and that the trawl was deployed before reaching it. The depth of the trawl was managed by calculating the length and angle of the warps; the netsounder was not yet known in Canada. A depth telemeter was used to record the depth of the trawl, but the device had to be sent down and then retrieved while the trawl was in the water. The level of detail in this report was such that any fisherman could easily replicate the design for themselves. This trawl was also described in great detail in a patent<sup>260</sup> filed by Canadian

<sup>257</sup> Johnson, 'Midwater Trawling in Canada', 56.

<sup>258</sup> Johnson, Moore, and Barracough, Mid-Water Fishing Trawl for Herring and the Like, 9.

<sup>259</sup> Barracough and Johnson, 'A New Mid-Water Trawl for Herring'.

<sup>260</sup> Johnson, Moore, and Barracough, Mid-Water Fishing Trawl for Herring and the Like.

Patents and Development Limited, a Canadian government agency which patented inventions made through government run departments<sup>261</sup> – such as the Fisheries Research Board. This patent, approved in 1960, acknowledges Johnson, Barraclough, and Moore as inventors, however, the patent applicant was the Canadian government.

In 1956 the U.S. Fish and Wildlife Service and the Canadian Fisheries Research Board conducted a series of joint trials off the coast of Washington as part of the International North Pacific Exploratory Fishery Program, of which the USA and Canada were both members. An exploratory fishing vessel belonging to the U.S. Fish and Wildlife Service, *John N. Cobb*, was used over the course of six weeks to test several types and sizes of pelagic trawl<sup>262</sup> including two designed by Johnson; cotton trawls were also tested, likely the Phantom Trawl. Testing had mixed results; large quantities of hake and other species were caught, including some herring. However, on many occasions they also caught nothing but jellyfish and plankton<sup>263</sup> despite the use of sonar to locate shoals of fish.

The U.S. Fish and Wildlife Service also conducted a separate series of tests off the Atlantic coast in 1955 and 1956, specifically near Maine, close to Nova Scotia. The charter vessel *Metacomet* spent several weeks searching for herring with sonar, with the aim of locating herring and then testing different types of gear.<sup>264</sup> Gill nets, a lampara seine, and a pelagic trawl designed by Johnson were tested; the pelagic trawl was satisfactorily towed from the stern of the vessel, but the trawl doors did not function as expected.<sup>265</sup> This pelagic trawl successfully caught small herring<sup>266</sup> so the trawl did work outside of Canada, even if the trawl doors did not.

The exploratory cruises of the *John N. Cobb* used a number of techniques which included divers recording the gear as it was being towed, as well as the use of depth telemeters<sup>267</sup> and sonar. Like the Canadians, at this time the US did not have netsounders depth telemeters. A commercial depth telemeter was almost a possibility in the US in the mid-1950s. The company Minneapolis Honeywell, based in Seattle, began experimenting and developed a prototype netsounder device which was tested, in Canada, by Johnson in 1957. It was, however, abandoned due to a perceived lack of market.<sup>268</sup> A depth telemeter was designed and developed by the U.S. Fish and Wildlife Service in 1957 for their pelagic trawl trials.<sup>269</sup> This device, attached to the trawl and then to the fishing boat with a cable, allowed the fishing boat to see the real-time depth of the trawl in relation to the bottom and thus adjust it to prevent contact with the seabed.

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<sup>261</sup> Kretz, 'Inventions for Industry. Canadian Patents and Development Limited and the Commercialization of University Research in Canada', 1.

<sup>262</sup> Anonymous, 'North Pacific Exploratory Fishery Program', July 1956, 47–48.

<sup>263</sup> Anonymous, 'North Pacific Exploratory Fishery Program', August 1956, 39–40.

<sup>264</sup> Anonymous, 'North Atlantic Herring Research', July 1956, 46–47.

<sup>265</sup> Anonymous, 'North Atlantic Herring Research', August 1956, 37–38.

<sup>266</sup> Anonymous, 'North Atlantic Herring Research', September 1956, 25–26.

<sup>267</sup> Anonymous, 'Electronic Devices Utilized in Fishery Research and Management', 20–21.

<sup>268</sup> Johnson and Rycroft, 'The Management of Innovation in the Field of Fishing Gear in Canada', 43.

<sup>269</sup> McNeely, 'A Practical Depth Telemeter for Midwater Trawls', 363.

Other trawls design quickly followed. In 1960 another report by the same authors describes Trawl No. 3, through to Trawl No. 6, as well as the “trouser trawl”<sup>270</sup> (there is no mention of Trawl No. 2). This report also contained the design of a new trawl door, which had been developed as dual purpose, for use on the bottom and for pelagic trawls (discussed further in section 2.3.3). These trawls were not patented by the Canadian government, although the trawl door was. Trawls No. 3 through 6 were adaptations of the original trawl design. No. 3 was designed for operating close to the bottom and is notable for the 250mm meshes in the wings and at the front of the trawl. No. 4 was designed for smaller fishing vessels, while No. 5 was a version of No. 3 with standardised mesh/twine sizes and a combination of single and double knots. Trawl No. 6 was developed to catch small, fast-moving schools of herring. Not all of the trawls were successful, and none were patented. Two further experimental trawls were constructed, each with channel or section where water could flow unobstructed; the aim was to reduce towing resistance. These trawls had a complex construction, with eight panels and an internal channel or tunnel.

In Canada, Johnson’s reports of 1956 and 1960 discussed the commercial use of the one-boat pelagic trawl. They stated that in 1955-56, only seven trawlers used the one-boat pelagic trawl, increasing to nineteen in 1956-57. Both reports also repeatedly state that the purse seine was far more popular and far more efficient; the nineteen trawlers of 1956-57 caught a grand total of 2000 tonnes between them over the entire winter herring season, while the purse seiners caught 40,000 tonnes in less than a month. What the report does not mention is how many purse seiners there were. We do get an idea of the relative benefits of both types of gear – the purse seine caught ‘hundreds of tonnes’<sup>271</sup> at a time, while the pelagic trawl caught herring at depths the purse seine could not reach.

According to Johnson’s report it was not only cheaper to buy a pelagic trawl than a purse seine, it was also cheaper to operate, as the pelagic trawl only required half the number of crew. Although only briefly described, trawlers using the pelagic trawl ranged in size from 11 to 20 metres and from 34 to 175 horsepower. Johnson noted that the “skippers have been able to build their nets to meet the requirements of each vessel and operate the gear on a commercial basis.”<sup>272</sup> Fishermen customised the basic one-boat pelagic trawl to suit the size and speed of their fishing boats in order to catch herring too deep for purse seines. However, their fishing boats had to be adapted to fish from the stern, as well as needing equipment like sonar and depth telemeters. This was a costly up-front investment, regardless of the advantages – which were few, as pelagic trawling caught much smaller quantities of fish compared to purse seining.

In 1961 the Bureau of Commercial Fisheries, part of the U.S. Fish and Wildlife Service, conducted four trials off the coast of Maine, on the eastern Atlantic coast. Their first aim

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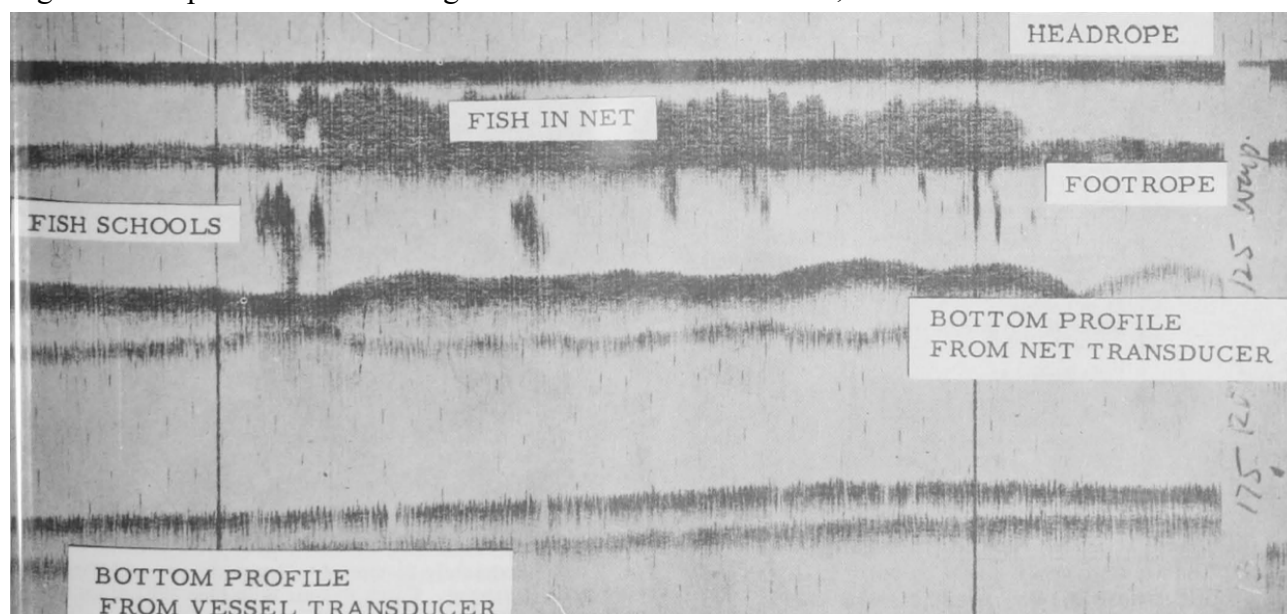
<sup>270</sup> Barraclough and Johnson, ‘Further Midwater Trawl Developments in British Columbia’, 13.

<sup>271</sup> Barraclough and Johnson, ‘A New Mid-Water Trawl for Herring’, 24.

<sup>272</sup> Barraclough and Johnson, ‘Further Midwater Trawl Developments in British Columbia’, 44.

was to search out potential new fisheries and their second was to attempt a one-boat pelagic trawl. To start with they used a two-panel "standard No. 36 eastern otter trawl,"<sup>273</sup> which was a type of bottom trawl. This was adapted for pelagic trawling by turning it upside down. The headline of a bottom trawl usually protrudes further out than the groundrope, so turning the trawl upside down reversed this, making the headline protrude instead. The results were such that "...it [was] obvious that more elaborate gear and equipment was necessary."<sup>274</sup> Planning for future tests, U.S Fish and Wildlife personnel considered Schärfe's two-panel pelagic trawl the most appropriate. It could be accurately controlled when in the water and trawl telemeters could be used to monitor the depth of the trawl, as well as shoals of fish in relation to the trawl.

Figure 18. Depth telemeter readings from the headline of a trawl, 1961



Sources: Rathjen, Warren F, and L. A. Fahlen. 'Progress Report on Midwater Trawling Studies Carried out off the New England Coast in 1961 by M/V Delaware'. *Commercial Fisheries Review* 24, no. 11 (1962): 1-11.

For the next set of trials, the U.S. Fish and Wildlife Service constructed a modified version of Schärfe's two-panel one-boat pelagic trawl complete with a depth telemeter on the headline and Süberkrüb trawl doors. This depth telemeter, created by U.S. Fish and Wildlife Service personnel, was particularly effective (figure 18). It showed the seabed in relation to the trawl and it also showed when fish passed through the trawl. Any potential issues with the power cable were sidestepped by attaching it to one of the warps.

The two-panel trawl was successful, catching over thirty different species of fish over the course of the trials. However, only a handful were caught in quantities of more than 45kg in any one tow. The conclusion was that there was potential for a successful pelagic fishery in the area, but that the "...development of an effective gear system, alone, does

<sup>273</sup> Rathjen and Fahlen, 'Progress Report on Midwater Trawling Studies Carried out off the New England Coast in 1961 by M/V Delaware', 2.

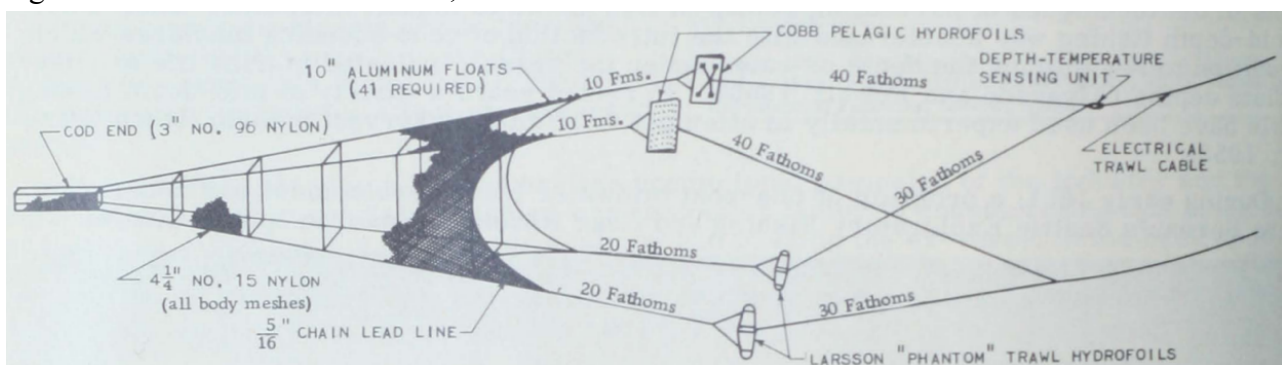
<sup>274</sup> Rathjen and Fahlen, 3.

not assure development of a fishery."<sup>275</sup> The assessment of the trawl was largely positive; it was the lack of an appropriate exploitable fishery which curtailed further experiments.

At the same time a pelagic trawl was designed for the exploratory vessel *John N. Cobb*, operating off the coast of Washington, on the western Pacific coast, with the aim of utilising its horsepower to the maximum extent.<sup>276</sup> The principal investigator was Richard McNeely, a participant of the first and second International Fishing Gear Congress. McNeely had a background as a machinist and a recreational fisherman.<sup>277</sup> It was his mechanical expertise and interest that led him to develop an underwater camera which he later used to observe fishing gear while it was in the water. When he first worked for the U.S. Fish and Wildlife Service in the 1950s it was as an Electronic Scientist.<sup>278</sup> By 1971 he was the Chief of the Harvesting Efficiency Program.<sup>279</sup> In 1977 he was a Supervisory Research Electronic Engineer, when the United States Department of Commerce awarded him a gold medal for his contribution to the development of fishing gear technology, sampling system development, and conservation engineering.<sup>280</sup>

McNeely chose to begin his experiments by using a pair pelagic trawl which had been partially constructed and then abandoned by a local fisherman. The U.S Fish and Wildlife Service completed its construction, only to completely disassemble, redesign, and rebuild it after it performed poorly in tests.<sup>281</sup> This trawl was the Cobb Trawl (figure 19), which used four trawl doors. The lower trawl doors were Larsson wing doors, while the upper pair were a new design made of plywood (figure 20).<sup>282</sup> They were similar to Süberkrüb's design, incorporating a curved outer edge, albeit with regularly placed holes aided the movement of water. Testing in 1961 was often conducted without the use of sonar to locate shoals of fish. These blind tows resulted in poor catches of multiple species.

Figure 19. The Cobb Trawl Mark I, 1963



Sources: McNeely, Richard L. 'Development of the John N. Cobb Pelagic Trawl - A Progress Report'. *Commercial Fisheries Review* 25, no. 7 (1963): 17-27.

<sup>275</sup> Rathjen and Fahlen, 10.

<sup>276</sup> McNeely, 'Development of the Cobb Pelagic Trawl: A Progress Report', 240.

<sup>277</sup> Jenkins, 'Profile and Influence of the Successful Fisher-Inventor of Marine Conservation Technology', 51.

<sup>278</sup> Kristjonsson, 'List of Contributors', 1959, xix.

<sup>279</sup> Kristjonsson, 'List of Contributors', 1971, xvi.

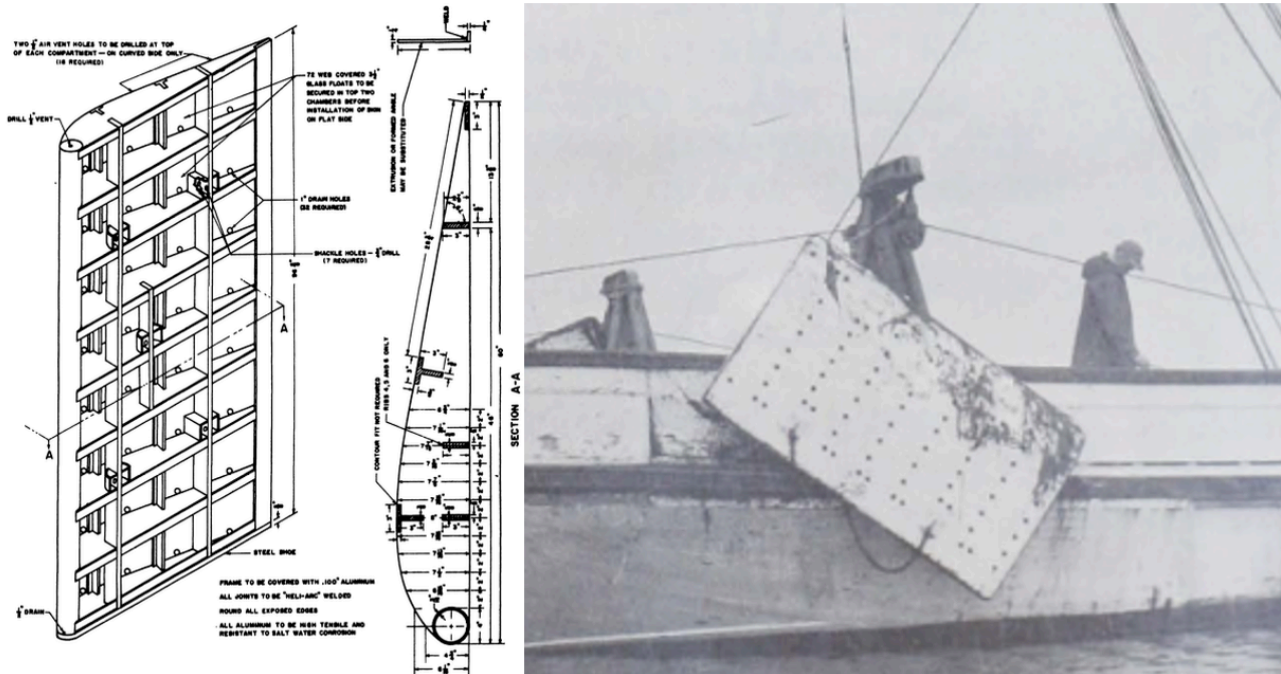
<sup>280</sup> Department of Commerce, 'The Twenty-Ninth Annual Honor Awards Programme', 11.

<sup>281</sup> McNeely, 'Development of the Cobb Pelagic Trawl: A Progress Report', 241.

<sup>282</sup> McNeely, 241.

However, the Cobb Trawl was only partly developed as a commercial trawl; it was also intended for scientific sampling and to determine if there was a potential fishery yet to be exploited. Even as the Cobb Trawl was being tested as a potential commercial trawl, it was also being used to monitor existing fisheries and identify new ones.

Figure 20. The Cobb Trawl door, 1963



Sources: McNeely, Richard L. 'Development of the John N. Cobb Pelagic Trawl - A Progress Report'. *Commercial Fisheries Review* 25, no. 7 (1963): 17–27.

The four trawl door arrangement did not last, replaced in 1964 with just the two hydrofoil trawl doors of aluminium<sup>283</sup> (figure 20). These were clearly inspired by Süberkrüb in their size and shape, although the Cobb doors had holes to aid the flow of water. In 1962 the Cobb Trawl Mark II<sup>284</sup> was developed (figure 21). Both the Mark I and the Mark II were constructed from nylon netting, with braided nylon ropes and aluminium floats. The Cobb Trawl Mark II had several additions; one of these was the addition of "criss-cross rib lines" to better distribute strain across the trawl. Mesh sizes increased in the wings from 114mm to 152mm, but decreased in the body of the trawl from 114mm to 76mm. This was to prevent the "gilling problem," where fish were caught in the meshes.<sup>285</sup> The Cobb Trawl Mark II had four trawl doors, although the plywood hydrofoil doors were replaced with ones of the same size made of aluminium. It had over seventy small glass floats placed inside the upper sections of each trawl door to help it stay upright.<sup>286</sup> Like its predecessor, it was used for sampling, after which it was tested to determine its suitability for commercial use. The report, however, refrained from making any conclusions as to its performance, instead stating that more extensive testing was needed.

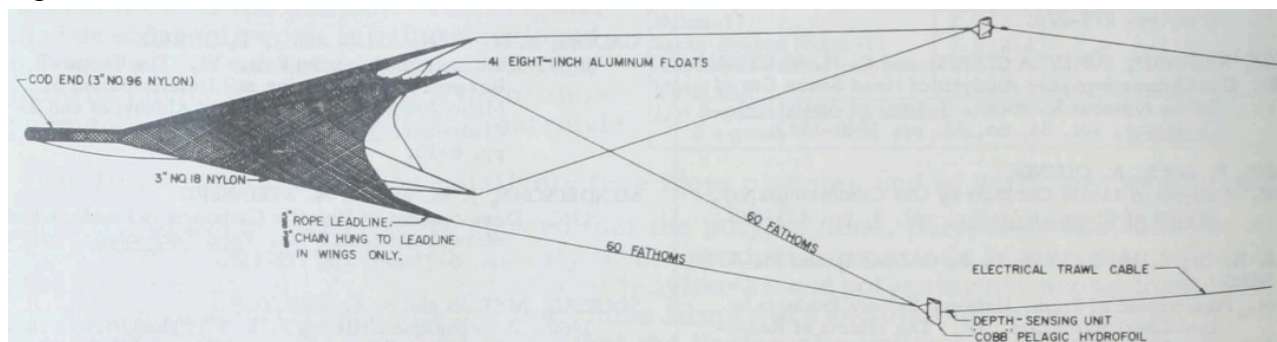
<sup>283</sup> McNeely, Johnson, and Gill, 'Construction and Operation of the "Cobb" Pelagic Trawl (1964)', 12–13.

<sup>284</sup> McNeely, 'Development of the Cobb Pelagic Trawl: A Progress Report', 244.

<sup>285</sup> McNeely, 247.

<sup>286</sup> McNeely, 244.

Figure 21. Cobb Trawl Mark II, 1964



Sources: McNeely, Richard L, Leonard J Johnson, and Charles D Gill. 'Construction and Operation of the "Cobb" Pelagic Trawl (1964)'. *Commercial Fisheries Review* 27, no. 10 (1965): 10–17.

While there were several other versions of the Cobb Trawl, they did not vary significantly from the Mark II design. One of these was almost identical to the Mark II, with the exception that the mesh size was consistent throughout the trawl, of only 76mm. This version was very successful at catching large quantities of hake. The hake was located using sonar and the depth of the trawl was adjusted by using the depth telemeter and altering speed. Large catches were attributed to the use of sonar to locate the fish combined with the use of the depth telemeter to accurately position the trawl. Multiple problems were identified, such as many small fish caught in the trawl, issues with maintaining speed and direction while towing, and damage sustained to the trawl from contact with the seabed.<sup>287</sup> Clearly, much work was still needed in the Cobb Trawl and this was one factor in why it was not successful as a commercial trawl.

The later discovery of a large shoals of hake in Puget Sound while developing the Cobb Trawl did create a short-lived fishery there in 1966, with pelagic trawls were favoured by fishermen.<sup>288</sup> It was not a particularly profitable fishery, as hake was a low-value fish destined for reduction. It was only initially exploited by between two and six local fishing vessels – who had borrowed their Cobb Trawls from the U.S. Fish and Wildlife Service.<sup>289</sup> The borrowed trawls were scale models, at two-thirds size. However, further development on the Cobb Trawl ceased as the discovery of the hake fishery brought Soviet trawlers to the Pacific coast in large numbers from 1967 onwards. While not profitable for the smaller local fishermen, the larger Soviet factory trawlers were able to catch and process large volumes of hake, with 114 Soviet vessels fishing in 1967 alone.<sup>290</sup> This effectively ended the local fishery, despite the negotiation of a 12 nautical mile limit for Soviet trawlers in 1967.<sup>291</sup>

In Canada, interest in the pelagic trawl had waned after 1960. Johnson himself argued that it had never been high to begin with, not least due the sudden success of purse

<sup>287</sup> McNeely, Johnson, and Gill, 'Construction and Operation of the "Cobb" Pelagic Trawl (1964)', 16.

<sup>288</sup> Markham Morton and Millican, 19th and 20th Annual Reports of the Pacific Marine Fisheries Commission for the Years 1966 and 1967, 45–47.

<sup>289</sup> McNeely, 'Recent Developments in Midwater Trawling in the Pacific Northwest of the United States of America', 444.

<sup>290</sup> Markham Morton and Millican, 19th and 20th Annual Reports of the Pacific Marine Fisheries Commission for the Years 1966 and 1967, 45–47.

<sup>291</sup> Markham Morton and Millican, 45–47.

seining in Newfoundland<sup>292</sup> in the 1960s, which focussed on increasing catches in the winter herring fishery,<sup>293</sup> with fish sent for reduction. As a result, prices were low, making high-volume catches necessary to make a profit.<sup>294</sup>

In 1966 the Canadian Atlantic Offshore Fishing Vessel Conference was held, where Dr. Schärfe gave a paper on the one-boat pelagic trawl developed in West Germany.<sup>295</sup> In the same year Johnson visited several European countries on a research trip, resulting in a comprehensive report on herring trawling.<sup>296</sup> It concluded that West Germany “was easily the most advanced in the method.”<sup>297</sup> Returning to Canada, Johnson began a new pelagic trawling project in 1967 on the Atlantic east coast, in Nova Scotia. Until then the pelagic trawl had been developed on the Pacific west coast of Canada, in British Columbia. This move was because Soviet trawlers had appeared off the coast of British Columbia in 1965 fishing for large volumes of hake.<sup>298</sup> This had negative effect on Canadian fishermen, as it later would for their American contemporaries using the Cobb Trawl the following year.

This new Atlantic coast pelagic trawling project used West German pelagic trawls with Süberkrüb trawl doors, designed by Schärfe and manufactured by Engel in Kiel.<sup>299</sup> Trials were undertaken with a small type of fishing boat used for scalloping, for the simple reason that scalloping was not profitable at that time – the idea was to allow fishermen who already owned that type of vessel to successfully diversify.<sup>300</sup> Modifications were necessary as the scallopers were closer in design to the side trawlers. Adaptations were made to the scalloper to tow the trawl from the stern instead of the side as the towing resistance from side trawling was too great. These modifications included adding a zipper to the Engel trawl, as the scalloper could not haul the catch aboard without a stern ramp. Spring catches of spawning herring were often too big for the scalloper to handle, so towing time was limited to only a few minutes, with a release mechanism added to the codend to allow any catch exceeding seventy tonnes to escape the trawl. The results were impressive, and several other scallopers converting to pelagic trawling. There were further trials with Engel trawls in 1968 with other fishing vessels, including stern trawlers, with satisfactory results.<sup>301</sup> It was in Canada that the term “Engel trawl” became synonymous with high opening trawls,<sup>302</sup> demonstrating its popularity.

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<sup>292</sup> Johnson, ‘Midwater Trawling in Canada’, 8.

<sup>293</sup> Day, ‘This Changing World: Revival of the Newfoundland Herring Industry’, 316.

<sup>294</sup> Johnson, ‘Midwater Trawling in Canada’, 34.

<sup>295</sup> Johnson, 3.

<sup>296</sup> Johnson, ‘Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966’.

<sup>297</sup> Johnson, ‘Midwater Trawling in Canada’, 3.

<sup>298</sup> Markham Morton and Millican, 19th and 20th Annual Reports of the Pacific Marine Fisheries Commission for the Years 1966 and 1967, 45–47.

<sup>299</sup> Johnson, ‘Midwater Trawling in Canada’, 9–10.

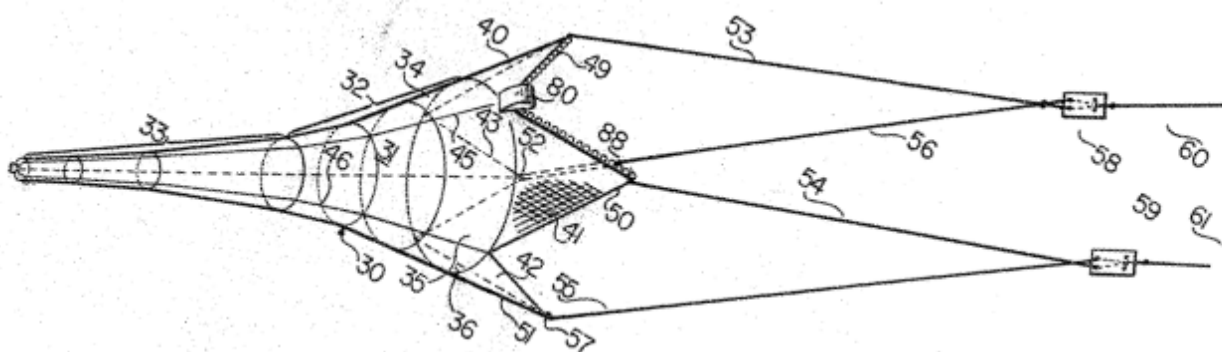
<sup>300</sup> Johnson, 4.

<sup>301</sup> Johnson, 9–26.

<sup>302</sup> Government of Canada, ‘Engel Trawl’.

Many fishing vessels needed shipboard adaptations. Even stern trawlers set up for bottom trawling struggled with underpowered winches which could not tow the trawl at high speed.<sup>303</sup> Towing speed was important, neither too fast or too slow, in response to the behaviour of the herring. Described as having different responses depending on the time of day, herring could be “spooky”<sup>304</sup> or easily frightened, as during the day they dove in response to an oncoming trawl; in the evening they would rise instead. The trawler had to adjust the trawl when approaching a shoal. Johnson stated that “midwater trawling requires far more skill than bottom trawling and perhaps even purse seining” and that “depth control is not a major problem,”<sup>305</sup> as sonar and netsounders solved this aspect of pelagic trawling. From Johnson’s reports, it is clear that a properly equipped trawler should find using the pelagic trawl relatively straightforward. Further, the aim was for fishing vessels to be dual purpose.<sup>306</sup> They had to be able to engage in pelagic trawling and one other method as well, in order to diversify and not rely on one fishery.

Figure 22. Johnson’s Diamond Trawl, 1968



Sources: Johnson, Wesley W. Mid-Water Trawl. Canadian Intellectual Property Office CA776376A. Canada, issued 23 January 1968.

In the mid-1960s Johnson oversaw the development of the Diamond Trawls (figure 22). They were inspired by German trawlers using pelagic trawls used to catch cod and redfish in the deep waters<sup>307</sup> off the coast of Greenland. The Diamond Trawls, of which at least ten versions were developed, were designed to have very large mouths and had netting with a mesh size of up to 80cm. Trawlers needed at least 1200 horsepower to tow them due to their size. Made of four symmetrical panels, each panel was identical and came to a point which formed the wing; this places the wings on the sides rather than on the corners of the trawl. Each panel is then an elongated diamond shape; this also meant that the mouth of the trawl was also a diamond shape, rather than a square. This is different from typical trawl design, where each panel resembles a “V” shape and each wing is formed of two panels with the selvedge running down the middle. The selvedge is the seam where

<sup>303</sup> Johnson and Rycroft, ‘The Management of Innovation in the Field of Fishing Gear in Canada’, 22.

<sup>304</sup> Johnson, ‘Midwater Trawling in Canada’, 27.

<sup>305</sup> Johnson, 26.

<sup>306</sup> Barraclough and Johnson, ‘Further Midwater Trawl Developments in British Columbia’, 28.

<sup>307</sup> Carrothers, ‘Descriptions of Trawl-Gear Used for Demersal Species by the Canadian Fleet in Subarea 5 and Statistical Area 6 during the Period 1969 through 1971’, 2.

panels are sewn together, typically with a rope sewn to it for reinforcement, which then runs the entire length of the trawl. These ropes take the strain when the trawl is towed, preventing the meshes from stretching too far and breaking. The ropes and selvages also help the trawl keep its shape when in the water. The lack of traditional selvages and seam on the Diamond Trawl may have caused the meshes to strain and break.

The 1972 version of the Diamond Trawl had a maximum mesh size of only 200mm and is depicted with Süberkrüb-style trawl doors.<sup>308</sup> By this time larger mesh sizes would be expected. This trawl was also quite small, less than 90 metres long, yet intended for use by a fishing boat of 200 to 380 horsepower. The repeated attempts to develop this design and its modifications indicate that the Diamond Trawl was considered necessary for at least one fishery. However, there is no indication that it was used to any meaningful extent.

The pelagic trawl was one of over a dozen research programmes in Canada which on fishing gear. This included purse seining, which was actively encouraged as an efficient fishing method and directly contributed to the collapse of the herring stocks.<sup>309</sup> Much of this herring was also caught by the large Soviet fishing fleet that had decimated the hake fishery on the Pacific coast. The need for diversity in fishing and fishing gear was noted in a later report of 1974 where it was observed that there was a “trend in the Canadian fleet toward multi-trawl operation, in which each vessel carries both bottom and mid-water gear rigged for rapid changeover.”<sup>310</sup> The pelagic trawl was still being used in Canada in the 1970s, but was only one tool out of many so that fishermen could “take maximum advantage of various fishing conditions.”<sup>311</sup>

## 2.2.6 Collaboration and Communication

There was significant amount of communication and sharing of data between fisheries gear technologists, inventors, and researchers. The FAO organised the first International Fishing Gear Congress in 1957 in Hamburg, which was swiftly followed by another in 1963 in London, and a third in Reykjavik in 1971. Both von Brandt and Schärfe were involved in organising the first congress. Schärfe was credited by his supervisor at the FAO, Hilmar Kristjonsson, for his assistance in compiling and editing the proceedings for publication.<sup>312</sup>

The FAO organised many other meetings and conferences, such as the Congress of Fishing Boat Designers in 1951, which was followed by two more Congresses within a few years.<sup>313</sup> There was the Conference on Stern Trawling<sup>314</sup> organised by the British White Fish

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<sup>308</sup> FAO, *FAO Catalogue of Fishing Gear Designs*, 1972, 94–95.

<sup>309</sup> Pitcher et al., ‘Hard of Herring’, 114.

<sup>310</sup> Carrothers, ‘Descriptions of Trawl-Gear Used for Demersal Species by the Canadian Fleet in Subarea 5 and Statistical Area 6 during the Period 1969 through 1971’, 2.

<sup>311</sup> Carrothers, 2.

<sup>312</sup> Kristjonsson, ‘Notice to the Reader’, 1959, xiv.

<sup>313</sup> Hardy, ‘Fishing Is a Global Business and Vital to Feed the World - Archive, 1960’.

<sup>314</sup> White Fish Authority, *Stern Trawling: A Record of the Stern Trawling Conference at Grimsby, England, in September, 1963*.

Authority, and the Canadian Atlantic Herring Fishery Conference.<sup>315</sup> Then there were also the working groups organised by ICES, such as the Pelagic Fish (Northern) Committee, the Herring Committee, or the Fishing Technology Committee. Many of these conferences and congresses also held working parties and meetings for their participants. There were numerous other conferences and working groups of which many were members.

These are only a handful of examples of the events and organisations which connected a diverse array of individuals. Additionally, there were the events such as the World Fishing Exhibition, which first began in 1963<sup>316</sup> and was aimed at fishermen and those working in the commercial fishing industry, rather than gear technologists or scientific researchers. There were also multiple industry publications aimed at fishermen, netmakers, and shipbuilders. This includes Fishing News Books Ltd., which published many FAO handbooks and conference proceedings.

Magazines and periodicals, either independent or government sponsored, conveyed information in great detail. In some instances, magazines were used to convey information directly to fishermen, such as regular notices stating that free charts could be obtained as to the location of telegraph cables on the seabed (so bottom trawlers could avoid them more easily). They reported a combination of scientific and technical reports, political issues, surveying data, conferences, and advertising for fishing gear. By the 1960s fishermen had an array of potential sources for up-to-date information on new developments. In Iceland, selected presentations from the first International Fishing Gear Congress in Hamburg were written up and published a year before the official publication, (albeit in Icelandic).<sup>317</sup> This was followed in 1963 with two articles on the second International Fishing Gear Congress,<sup>318</sup> where the work of Schärfe and others was discussed in detail. Fisheries and fishing gear were a popular subject for magazine and newspaper articles in Iceland, frequently detailed and with diagrams; technical information on trawls and trawl construction was not hard to come by.

Fishermen and inventors attended these conferences, actively presenting their ideas and observations as well as participating in the subsequent discussions. At the first International Fishing Gear Congress in 1957 many spoke of their experiences and many scientists and gear technologists responded with interest and questions. Many of the fishermen who attended seem to have had established working relationships with scientists and gear technologists. One of these fishermen was Captain Roberts, a British deep sea trawler captain who participated in several of the discussions. Roberts maintained an ongoing interest in fisheries technology, subscribing to publications from at least four countries, some of which were not in English.<sup>319</sup> At the conference discussions he

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<sup>315</sup> Johnson, 'Midwater Trawling in Canada', 3.

<sup>316</sup> Anonymous, 'London Exhibition', 24.

<sup>317</sup> Júlíusson, 'Frá ráðstefnu FAO í Hamborg', 346–53 & 356.

<sup>318</sup> Thorsteinsson, 'Flotvörpur og Flotvörpuveiðar: fyrsta grein'.

<sup>319</sup> Lonsdale, 'Discussion on Terminology and Numbering Systems', 12.

spoke on the financial constraints of testing gear while operating a functioning fishing vessel, as well as the logistical constraints, which included the disruption to the crew work routines.<sup>320</sup> Schärfe was in agreement:

“...it cannot be expected of commercial fishermen to make experiments. Of course, this work has to be done by governmental institutes using research ships. Furthermore, it is not enough to prove the technical superiority of a certain design but it also has to be worked out until it is completely reliable for commercial use.”<sup>321</sup>

Several other scientists and fishermen also agreed with Roberts, citing that the burden of experimentation should fall not just to the organisations that could afford it, but those that would do so with the rigorous and repeated testing that commercial gear required. At the same conference Schärfe expressed the importance of fishermen gaining experience and working knowledge of the pelagic trawl through testing it (at no cost to themselves).<sup>322</sup> The effectiveness of the gear was known and understood by fishermen first-hand, knowledge which could then be passed on to their peers. Johnson, in Canada, also expressed the importance of experience. He praised the fishing experience of his colleagues, including the Chief of the Exploratory Fishing Division, Jack Rycroft:

“Mr. Rycroft speaks the fisherman's language, he is easily able to handle the author's office and similarly the author can handle Mr. Rycroft's projects and office in his absence.”<sup>323</sup>

Prior working experience in fisheries had great value, as it conferred a transferable skillset that academic lacked. Other fishermen came to be employed to work on fishing gear. Johnson clearly thought it easier and quicker to train an ex-fisherman in the rigorous scientific techniques than it was to pass on sufficient fishing experience to a newly-graduated scientist. The issue, from Johnson's viewpoint, was that a great deal of this experience could be gained from the formal training process, if only the traditional education system would recognise its importance:

“For many years, it has been wrongly assumed that a formally qualified professional in any related discipline, no matter how remote, is capable of directing development work on fishing vessels and gear, regardless of whether or not he has actual practical experience in such development, or even in the total fishing operation. In our view, the most effective people to direct and carry out such work are technically adaptable commercial fishermen.”<sup>324</sup>

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<sup>320</sup> Dickson, 'Discussion of Choice of Fishing Gear and Some New Methods', 441.

<sup>321</sup> Dickson, 444.

<sup>322</sup> Truang, 'Discussion on Rational Design of Fishing Gear', 269.

<sup>323</sup> Johnson and Rycroft, 'The Management of Innovation in the Field of Fishing Gear in Canada', 77.

<sup>324</sup> Johnson and Rycroft, 6.

Scientists working for the U.S Fish and Wildlife Service, however, seem to have been mostly academically trained and focussed more on zoology and marine biology. McNeely appears to be the exception. As mentioned previously, he was a trained machinist and keen recreational fisherman, which brought him to fisheries by way of his own curiosity and desire to experiment. Nevertheless, the U.S. Fish and Wildlife clearly had a good relationship with the fishermen of the Pacific coast when they lent Cobb Trawls to fishermen in 1966. Unlike Johnson, who chartered operating fishing vessels for research, the Cobb Trawl was developed on a purpose-built research ship. This would have led to a different kind of relationship with local fishermen, although both were demonstrably successful. Schärfe also chartered fishing vessels, even when a purpose-built research vessel was available. He clearly had a good working relationship with many fishermen, as well as commercial fishing industry professionals in fish processing, netmaking, and the manufacture of electronic equipment.

There was also a good relationship between the institutions conducting gear technology research, or at least the individuals working for them. Johnson in Canada and the scientists of the U.S. Fish and Wildlife Service in the 1950s exchanged information and visited each other's facilities. Johnson also interacted extensively with Schärfe in the 1960s, with Schärfe acting as a guide and intermediary for Johnson's intensive research trip to Europe in 1966. The working groups of ICES also show connections between industry professionals in America, Canada, Iceland, Britain, France, West Germany, Scandinavia, as well as the Soviet Bloc.

FAO publications such as the FAO Catalogue of Fishing Gear Designs required gear designers to submit the plans and details of their work. Two editions of this book, published in 1965 and 1972 respectively, include fishing gear designs by Schärfe, von Brandt, Johnson, Nédélec, Portier, and other gear technologists. It also had designs by netmakers Larsen, Engel, Joseph Gundry and Co., and Cosalt Ltd. However, Bernhardsson, Persson, and Larsson did not contribute. Of these three, only Larsson was an active participant of the large community of gear technologists and scientists working on fishing gear. As importantly, some also studied or worked under each other. Schärfe initially worked under von Brandt's supervision. He was not the only one; Guðni Thorsteinsson studied in Kiel and then worked under von Brandt for several years before returning to Iceland to work as a fisheries gear technologist.<sup>325</sup> There were several also Icelanders working in the FAO in the 1960s,<sup>326</sup> including the Chief of the Gear Technology Section of the Department of Fisheries, Hilmar Kristjónsson. At the same time, Icelander Arni Friðriksson was Secretary General of ICES.<sup>327</sup>

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<sup>325</sup> Thorsteinsson, 'Íslenzk Veiðitækni', 205.

<sup>326</sup> Anonymous, 'Fish - The Big Thing In Iceland', 7.

<sup>327</sup> Anonymous, 7.

The role of the inventor, somewhere between the fishermen and the gear technologists, is not easily quantified. Some, like Larsson, were very active within this larger community. Persson and Bernhardsson did not participate. Although he was a successful business owner, Bernhardsson gained his client base by word-of-mouth and referrals. He does not appear to have advertised or travelled to demonstrate his work. His patents and patent dispute show that he was protective of his work, yet he was largely unknown to the gear technologists. Larsen was known as the inventor of the pair pelagic trawl, which garnered him recognition. Later interviews show that he was tired of the multiple patent disputes he was engaged in. It is not unfeasible that the inclusion of his pair pelagic trawl design in both editions of the FAO Catalogue of Fishing Gear Designs represented a shift in how he wanted to be remembered. Perhaps he decided it was easier to be acclaimed as the inventor of the pair pelagic trawl than it was to fight for the right to own the design.

Larsson interacted directly with gear technologists, but his trawl was not successful and his frustration is discernible, if subtle. In comparison, Persson did not interact directly with gear technologists or researchers, yet his trawl was successful, albeit on a relatively small scale. Larsson's frustration is in contrast to the cordial and seemingly respectful interactions recorded between gear technologists and fishermen at conferences. It is also in contrast to his emphasis on the value of independent inventors while others discussed the burden of fishermen testing new gear. While he was an active participant, there is nothing to suggest that he used these conferences as an opportunity to learn or acquire new information.

Despite the free flow of information, there was little active collaboration on gear development. Rather, each scientist, gear technologist, and inventor worked in their own environments. They communicated, swapped information and data, and discussed in detail the intricacies of their work. When working on committees and working groups, these scientists presented their own work to that group, expecting each to take what they needed from it and use that in their home environments as they saw fit. They had realised that the fishing gear they were trying to develop was tailored to their immediate environment and needs. While certain elements were transferrable, pre-made trawls had to be adapted and used in a way that suited the environment they were being used in. The success of netlofts like Engel's were based on their tailor-made approach in ensuring that each trawl sold was made to fit the trawler, the fishing grounds, and the fishery in which it was to be used. It is a shame that more cannot be learned about the other netlofts that appear in this thesis, particularly those based in Gothenburg. They were involved in the development of early pelagic trawls and must have communicated closely with the inventors whose designs they manufactured and sold. They form a near-invisible group and network whose connections are only hinted in the source material.

Previously, when examining the pair pelagic trawl, the relevant social group was that of the two key inventors, the netmakers-turned fishermen who were long-standing members of established fishing communities. But with the development of the one-boat trawl there were several social groups. Fishermen/netmakers in one, alongside independent inventors, and then there are the scientists/fisheries gear designers. They are all, broadly speaking, working towards the same problem: making a one-boat pelagic trawl. But for some, the problem was more detailed; Johnson was working on a solution tailored to a specific fishery on the west coast of Canada. Others were working towards a multi-purpose solution that could be used in different fishing conditions, like Schärfe was in Europe (see chapter 2.3.3).

Individuals can belong to more than one social group. Most of the individuals discussed in this section also being to another social group. This is one of individuals who were working independently of each other yet corresponded or met to discuss their work. It is they who define this phase in the development of the pelagic trawl as that of collaboration. It was not just designs that were shared – trials and test results were also shared, creating a forum for feedback and commentary. One ongoing aspect of this phase of the pelagic trawl is that the problem is almost never solved; instead, it is deemed sufficient, or development halts due to other factors. Disruptions to fisheries or the lack of uptake from fishermen was an ongoing issue; most of the designers either moved on or were already working on the next version of their design.

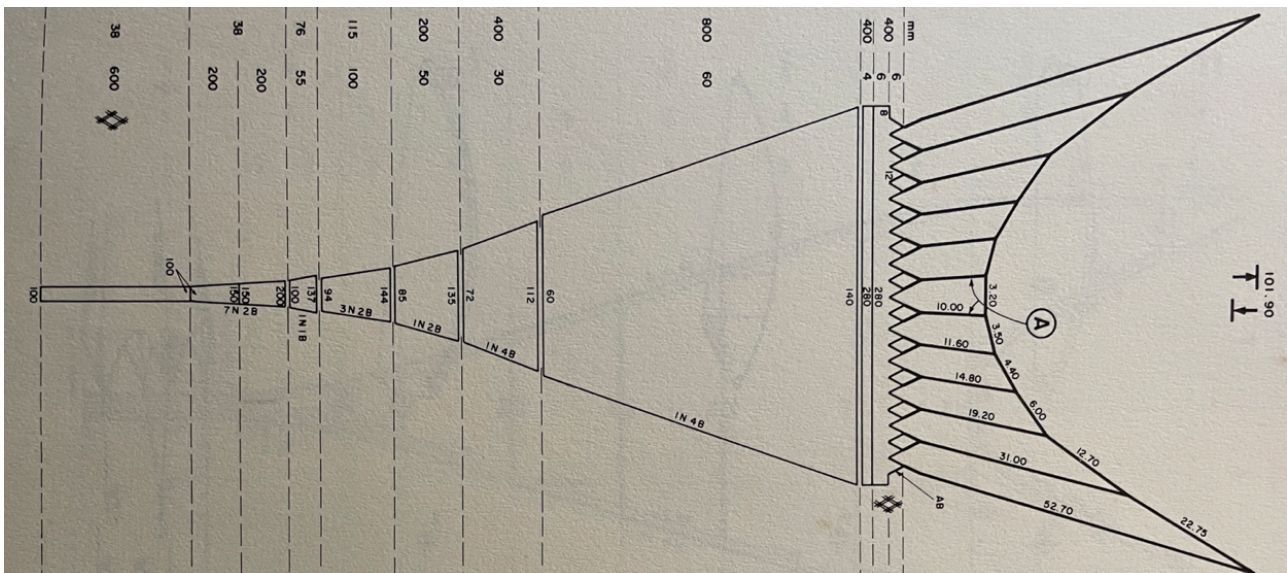
As with their backgrounds, drivers of change vary between these individuals. A personal response is discernible with Larsson, much as was seen with Bernhardsson and Larsen previously. They were using their knowledge and skills to make a living, as was Süberkrüb. These men were independent and unsupported by external funding. This is not the case with the gear technologists, who demonstrate the approach of a scientist tasked with research, although clearly to a high professional standard. Unlike the independent inventors, they are responding to the dictates of their employers, who are NGO's and governments. In this case, their work is the result of a much larger set of directives. This ranges from the FAO's mandate to ensure consistently exploitable global food sources, to the Canadian government's desire to ensure stability for its fishermen.

### 2.2.7 Legacy

There were further developments in the pelagic trawl, in particular increasing mesh sizes in the front of the trawl. Initially there was the rope trawl, which was swiftly followed by the big diamond mesh trawl and then the hexamesh trawl. They were quickly copied and tested by numerous fisheries departments in Europe. Mesh sizes were initially limited by the netting machines. The maximum mesh size they could produce did increase significantly over the decade. However, very large mesh sizes could only be made by hand due to their size and the gauge of rope required. Large meshes were used to reduce the

weight of the trawl and to reduce water resistance, which resulted in lower fuel consumption.<sup>328</sup> Developments in machine-made netting from the 1960s onwards had already allowed the pelagic trawl to evolve significantly, with meshes in the front part growing to 800mm by 1971.<sup>329</sup> This was supported by the discovery that a physical barrier was not the key to preventing fish from escaping the mouth of the trawl. Instead, the fish were frightened by the vibration of the trawl as it was being towed. Smaller meshes were still needed at the end of the trawl, to stop the fish from escaping the cramped codend.

Figure 23. Rope or spaghetti trawl, 1972



Sources: FAO. FAO Catalogue of Fishing Gear Designs. 2nd ed. Rome: FAO, 1972. 96-97

Rope trawls (figure 23) were first used in Poland and East Germany in the early 1970s.<sup>330</sup> The use of large meshes in a relatively small trawl resulted in a 10-20% reduction in drag,<sup>331</sup> which meant that older trawlers with less horsepower could tow it and still save on fuel. The downside was that these ropes easily tangled and were difficult to keep organised, especially if using twisted instead of braided rope. Unsurprisingly, this led to it being nicknamed the spaghetti trawl. It was also called the Jager trawl and East German fishermen used it in the north west Atlantic to catch herring in the early 1970s. Described as 'new' in 1972 when a third of the factory trawler fleet was using it, trawlers reported a 20 to 25% increase in catch volume. In the following year all factory trawlers fishing in this area were using them.<sup>332</sup> The rope trawl was tried in Iceland, however, it was only used at midnight in midsummer, to catch blue whiting when towed near the seabed.<sup>333</sup> Rope trawls were unsuccessfully tested in the Netherlands and quickly dropped in favour of testing

<sup>328</sup> Thorsteinsson, Veiðar og Veiðarfæri, 121.

<sup>329</sup> Bates, 'Gear Talk: The Origins of Pelagic Trawling'.

<sup>330</sup> Thorsteinsson, Veiðar og Veiðarfæri, 119.

<sup>331</sup> Thorsteinsson, 120.

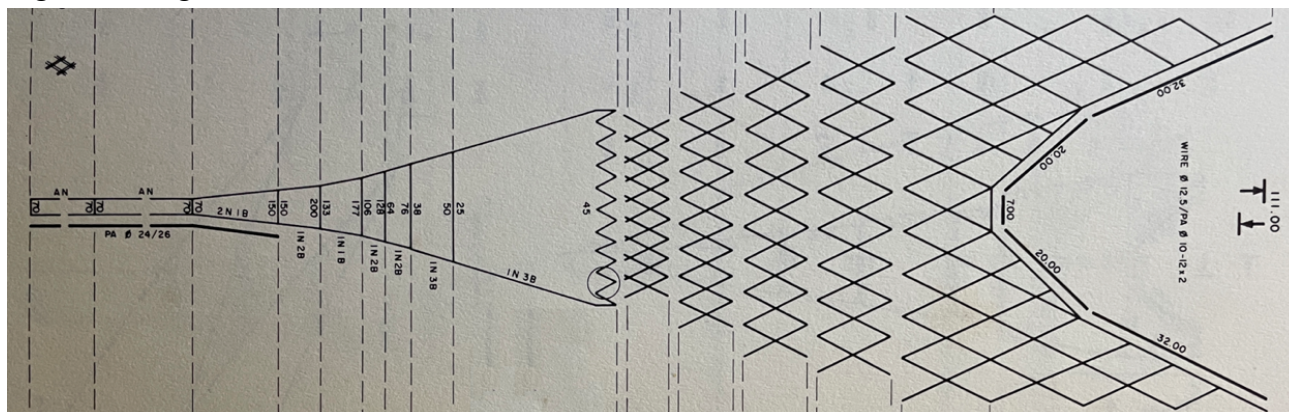
<sup>332</sup> Mahnke, Danke, and Schultz, 'Annual Meeting - June 1974: GDR Research Report, 1973', 8.

<sup>333</sup> Thorsteinsson, Veiðar og Veiðarfæri, 121.

hexamash trawls.<sup>334</sup> Rope trawls were also tried in the UK, where they were also superseded by either hexamash or big diamond mesh.<sup>335</sup>

Big diamond mesh was first seen in France with a mesh size of 16 metres (figure 24),<sup>336</sup> used to catch whiting and bream off the coast of France. This design was a pair trawl and needed two fishing boats of 300 to 500 horsepower to tow it. The largest mesh was the top section, at 16 metres; each mesh decreased in size until 8 metres where it was attached to machine-made netting with a mesh size of 1.6 metre. Braided rope had to be used for the meshes as twisted rope easily distorted and shortened the meshes.

Figure 24. Big diamond mesh trawl, 1972



Sources: FAO. FAO Catalogue of Fishing Gear Designs. 2nd ed. Rome: FAO, 1972.

These large meshes, despite being made of rope, reduced the volume of material in the front of the trawl. This reduced the weight of the trawl. Less material also reduced water resistance, or drag, when the trawl was towed through the water. This in turn reduced fuel consumption. The big meshes were quickly copied in Norway and the Faroe Islands<sup>337</sup> and were successful in catching blue whiting, a pelagic species whose fishery intensified after the collapse of the herring stocks in the late 1960s. These large meshes survive into the twenty-first century and remain a core design feature of pelagic trawls.

Another variation of the large mesh trawl was the hexamash trawl (figure 25). This was first tested around 1979 in several countries, including Sweden,<sup>338</sup> the Netherlands,<sup>339</sup> and Norway.<sup>340</sup> In Norway hexagonal meshes was proven to have less water resistance and stayed open better than the diamond meshes of standard netting.<sup>341</sup> When applied to pelagic trawling, the hexamash was elongated and used to catch blue whiting. In the Netherlands, it was first tested when it was used to catch mackerel off the coast of Ireland.

<sup>334</sup> Marlen, 'Engineering and Comparative Fishing Trials on Trawls with Large Hexagonal Meshes in the Front Part', 3.

<sup>335</sup> Bjordal, 'Report of the Working Group on Research and Engineering Aspects of Fishing Gear, Vessels and Equipment', 34.

<sup>336</sup> FAO, FAO Catalogue of Fishing Gear Designs, 1972, 106–7.

<sup>337</sup> Thorsteinsson, Veiðar og Veiðarfæri, 121–22.

<sup>338</sup> Bjordal, 'Report of the Working Group on Research and Engineering Aspects of Fishing Gear, Vessels and Equipment', 14–15.

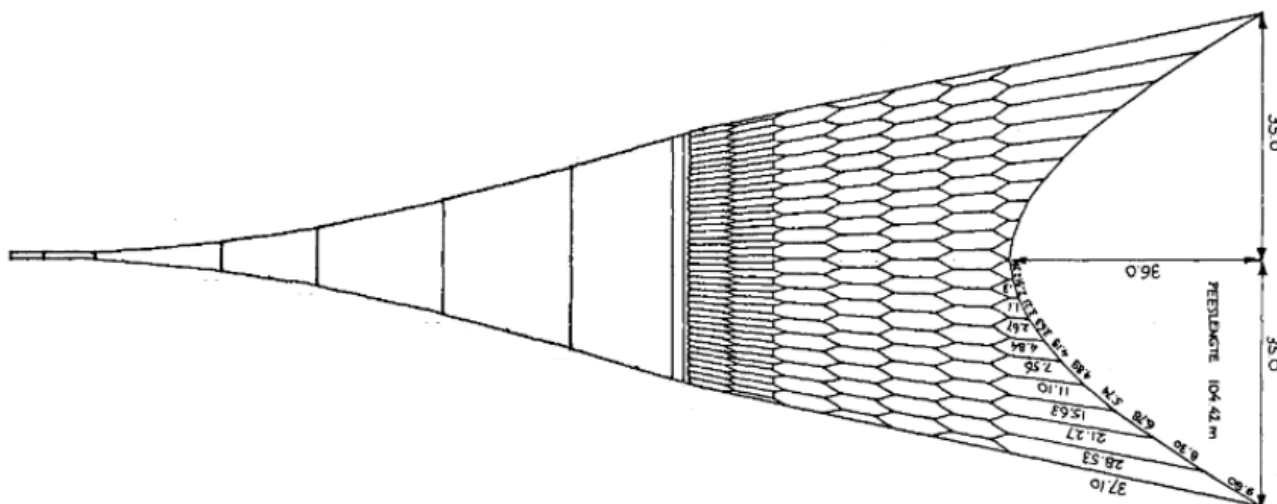
<sup>339</sup> Marlen, 'Engineering and Comparative Fishing Trials on Trawls with Large Hexagonal Meshes in the Front Part', 3.

<sup>340</sup> Bjordal, 'Report of the Working Group on Research and Engineering Aspects of Fishing Gear, Vessels and Equipment', 15–16.

<sup>341</sup> Brandt, Fish Catching Methods of the World, 317.

It was considered successful, as “catches were very well comparable to those of the commercial ships and certainly not significantly less” and this included fishing closer to the bottom for demersal species.<sup>342</sup> Trials in the Netherlands concluded that big meshes were an “valuable concept,”<sup>343</sup> whether they were hexagonal meshes or the big diamond mesh trawls of the French,<sup>344</sup> and that further investigation was required.

Figure 25. Hexamesh trawl, 1981



Source: Marlen, Bob van. ‘Engineering and Comparative Fishing Trials on Trawls with Large Hexagonal Meshes in the Front Part’. Rijksinstituut voor Visserijonderzoek, May 1981.

## 2.2.8 Summary

One-boat trawls were the result of concerted effort by many different people in several countries. Their motivations varied, from ensuring their livelihoods to obeying directives decided by organisations. Drivers of change were, for some, personal. But for others their work was part of a career in a scientific field, directed and funded by the NGO’s and governments. In Canada, this was about providing versatility to fishermen to prevent loss of income. In West Germany, diversity was also driver, as was the optimising the pelagic trawl for multiple fisheries. In Europe the FAO funded research into ensuring that fisheries were fully exploited in order to secure food sources. The fisheries gear technologists had the benefit of this funding and utilised it as employees, not as independent inventors.

These inventors started not long after the pair trawl was developed in the 1940s. This effort was begun primarily by netmakers, fishermen, and engineers. While an effective trawl door had been created in the 1930s by Süberkrüb, it was not used by these early innovators. Either they were unaware of its existence, did not wish to pay to use this design, or did not think the doors suitable. Some designed their own trawl doors, often with limited success. Persson’s six-wing design used the same trawl doors as used by bottom trawls. The unusual six-wing design was successful and used by Swedish fishermen

<sup>342</sup> Marlen, ‘Engineering and Comparative Fishing Trials on Trawls with Large Hexagonal Meshes in the Front Part’, 13.

<sup>343</sup> Marlen, 14.

<sup>344</sup> Marlen, 14.

in the 1950s. In contrast, there is no evidence that Larsson's Phantom Trawl was bought or even manufactured outside of testing. The Phantom Trawl was tested by American and Canadian researchers as part of their research into developing a one-boat pelagic trawl, but with disappointing results. Persson's trawl was discussed by Larsson himself at a later date, in the larger context of trawl development in Scandinavia.

Larsson and Persson were early innovators in the one-boat pelagic trawl, but with limited degrees of success. There is little source material about Persson, a fisherman whose primary residence was on an island that was home to a long-established fishing community. We know is that he licenced his designs to a netloft in Gothenburg and that his designs were most likely the result of decades of fishing experience. Why he chose to invent, and what role that played in his life, is unknown. Whether he relied on an income from his patents or continued to fish are also a mystery. We do know that in the 1960s his six-wing design was commercially sold in large numbers. Larsson's motivations are easier to decipher; he was an engineer and by his own description, an inventor. He had other employment as a freelance engineer to support his experimentation. His trawl, while at least partially wrapped in the guise of scientific enquiry, was created with the aim of commercial success. He does not appear to have achieved this, despite engaging with the scientific community at regular intervals throughout the 1950s and 1960s. Of these early inventors, Süberkrüb was the most successful. A freelance naval architect, his trawl doors became an industry standard for many fishermen internationally using a one-boat pelagic trawl well into the latter part of the twentieth century.

Süberkrüb trawl doors enabled the development of the one-boat trawl designed by Schärfe in the late 1950s and 1960s. Schärfe first worked in West Germany for the Institute for Nets and Materials Research, part of the Federal Research Centre for Fisheries, before moving on the Fisheries Division of the FAO. The directives and resources of these institutions allowed him to research and develop a one-boat pelagic trawl. Schärfe also utilised netlofts and fishing boat crews to construct and test trawls, disseminating not just knowledge but also experience of the trawl to those groups that would make and use pelagic trawls. One of those to benefit from this was the netloft run by the Engels, who ran a successful business making pelagic trawls. Schärfe was working at a time when synthetic fibres were becoming popular and insisted on their use for these trawls. As a scientist he used an array of equipment, such as sonar, to monitor and adjust the trawls, which led in to the development of the netsounder.

Schärfe was not the only fisheries gear technologist; others in Europe and North America were also finding themselves in this new profession. Johnson in Canada later described the advent of the fisheries gear technologist as something new, albeit one best suited to ex-fishermen rather than scientists, as they ideally needed years of experience and training. Johnson and McNeely in the USA worked with a particular directive in mind which, like Schärfe, was aimed at solving a problem. They all worked for governments or

NGOs for whom developing (or improving) fishing gear was one approach to ensuring a supply of fish. The development of the one-boat pelagic trawl did this by increasing the efficiency of fishing boats in catching pelagic fish under certain conditions.

In the 1970s the one-boat pelagic trawl was developed further, taking full advantage of the advances in synthetic materials begun in the 1950s. This was the big-mesh trawl, the rope trawl, and the hexamash trawl. Each succeeded in reducing drag and water resistance while increasing catch volume with each tow. Synthetic fibres were stronger and lighter than their organic predecessors, which allowed trawls to be bigger without being heavier. Replacing areas of small mesh netting with large rope meshes reduced the weight of the trawl even further, which further reduced water resistance. This saved fuel, allowing trawlers with less horsepower to tow the trawl without difficulty. In addition to this, big meshes also demonstrated that removing the physical wall of netting did not reduce catch sizes, as the vibrations of the meshes was sufficient to stop fish from escaping the front part of the trawl. The use of big meshes continues to be used in pelagic trawls into the twenty-first century. This development optimised the trawl further and ensured that it became as efficient as possible.

## 2.3 Variations on a Trawl

The different stages of development for the pelagic trawl have, for the most part, been easy to categorise. They conveniently divide into two core phases: the pair trawl and the one-boat trawl. However, this sidesteps somewhat the issue of what precisely constitutes a pelagic trawl. As a term, pelagic trawl can contain the concepts of interchangeable, semi-pelagic, epipelagic, universal, multi-purpose, and combination trawls. Andres von Brandt, who in the 1960s wrote the definitive catalogue and classification of fishing gear,<sup>345</sup> did not consider semi-pelagic or combination trawls to be true midwater trawls.<sup>346</sup> By his definition, a true pelagic trawl (and its trawl doors) would have zero contact with the seabed. So, these trawls would not, by his definition, be considered pelagic trawls. Yet those who developed them were either involved in developing pelagic trawls, or considered these variations an extension of their work on pelagic trawls.

An interchangeable trawl could be rigged either as a pelagic trawl or as a bottom trawl. Many of the semi-pelagic trawls were one-boat trawls and had design features more typical of bottom trawls, such as a heavily reinforced groundrope or protruding headline panel. Known examples were used to catch cod, a demersal species. Several examples of universal, multi-purpose, and combination trawls were also developed. The intent behind these was a desire to maximise functionality – to have a single trawl that could be used in multiple fisheries. Few were successful as most fishing gear needs to be tailored to the conditions of a specific fishery or fishing grounds and conditions.

Despite not falling under the strict definition of pelagic trawls, these trawls were strongly influenced by, and in turn had an influence on, the design of pelagic trawls. They are a good example of communication and the interchange of ideas between inventors, fishermen, and gear technologists. As von Brandt's statement regarding true pelagic trawls shows, this is also where inventors and designers are themselves classifying their own work. They are creating descriptors and categories, determining what the problems were and identifying new problems.

Those involved in designing and testing pelagic trawls were not all attempting to solve the same problem. Rather, each is trying to solve a problem that they have themselves identified. Each has identified a solution to the original problem – resulting in the one-boat pelagic trawl – and have then redefined the problem. One of these new problems was to make a trawl that can be adaptable in some way in order to be both a pelagic trawl and something else, as and when needed. Redefining the problem is a key phase in technological development. However, as has been demonstrated here, this was a largely futile attempt.

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<sup>345</sup> Brandt, *Fish Catching Methods of the World*.

<sup>346</sup> Brandt, 'One-Boat Midwater Trawling', 263.

### 2.3.1 Interchangeable Trawls

An interchangeable trawl was a trawl that could function either as a one-boat bottom trawl or as a pair pelagic trawl. The body of the trawl remained unchanged, with use being determined by the rigging arrangements. This was the arrangement of warps, bridles, and trawl doors. The core concept was to reduce the amount of gear (and its cost) while simultaneously maximise its functionality. While it is tempting to think of the interchangeable trawl as bridging the gap between the pair trawl and the one-boat trawl, this is not the case. They instead represent a desire to maximise the herring fisheries of the North Sea and the Skagerrak and Kattegat. Traditional herring fishing in these waters was originally done with one-boat bottom trawls, which were at least partially replaced with pair pelagic trawls. The Swedish fishermen using interchangeable trawls were attempting to maximise their fishing potential, as this allowed them to catch herring during the day and at night, without the hassle of carrying extra trawls during a fishing trip. Swedish fishermen in the 1940s and 1950s caught herring with bottom trawls during the day and with pair pelagic trawls at night<sup>347</sup> when the fish were higher in the water column.<sup>348</sup>

There are only two known designs for interchangeable trawls. The first was by Ponte Sterner Persson in 1953 and the second by Yngve Bernhardsson in 1962, both Swedish fishermen/netmakers (who were introduced in chapters 2.1 and 2.2). Both patents present the same concept – a trawl that it can be used as either a pair pelagic trawl or a one-boat bottom trawl and switch between the two by changing the rigging. Both patents specify that the one-boat trawl arrangement is for bottom trawling and that the pair trawl arrangement is for pelagic fishing. For one-boat trawls this also required the addition of trawl doors to keep the mouth the trawl open horizontally. The trawl door shown in these designs is the standard horizontally-oriented trawl door, typically used with bottom trawls of this period. This further supports that the one-boat version was not intended to be used as a one-boat pelagic trawl, as the doors would not have stayed in position when off the seabed. However, fishermen may have attempted to use it as a one-boat pelagic trawl, and perhaps they were successful.

Persson's design (figure 26) was a six-wing trawl, which is perhaps why it is referred to in one source as the stjärntrål (star-trawl).<sup>349</sup> However, no specific reason is given for the wings. There is no information on how the body of the trawl was constructed, but if the trawl had six seams (instead of four) then the intention may have been to distribute the strain from the warps and bridles more evenly throughout the body of the trawl. It was initially developed in 1954 as an unsuccessful pair trawl made from cotton netting. As discussed previously, this design was re-developed and re-patented as a one-boat pelagic

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<sup>347</sup> Byron, *Portraits of the Past*, 169.

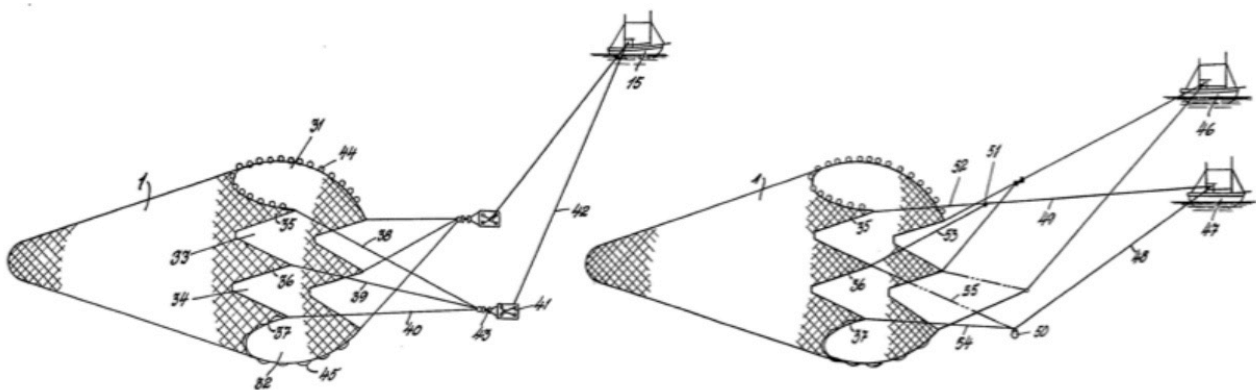
<sup>348</sup> Larsson, 'Scandinavian Experience with Midwater Trawls', 345–46.

<sup>349</sup> Johansson and Lindquist, 'Svenska Fiskeriförsök Med Enbåtsflyttrål', 1 & 14.

trawl in 1958.<sup>350</sup> It was clearly ineffective as a pair trawl or as a bottom trawl, yet sufficiently effective as a one-boat pelagic trawl to warrant further development. There is no indication if redeveloping the trawl into a one-boat pelagic trawl was as a result of Persson's initiative, or whether it was in response to fishermen using it as a one-boat pelagic trawl even though it was not designed that way. The patent diagram for the interchangeable trawl does not indicate different mesh sizes in the body of the trawl, or a distinct codend, but by this point in time it would be very unusual for this not to be the case. The lack of detail was probably a deliberate to protect intellectual property; an Icelandic source of the early 1950s states that the netloft AB Stranne & Oresten (who manufactured Persson's trawls) refused to share or show them any diagrams, although they were happy to sell him a trawl.<sup>351</sup>

The earliest patent application date for this interchangeable design was in Denmark in 1953<sup>352</sup> with at least four other applications made in various countries including Britain, France, Finland, and the USA. The final patent application was in 1956. However, images of the six-wing trawl appeared in numerous other sources in the 1960s, although it was rarely discussed in the accompanying text. Rather, it seems to have been included due to the novelty of the six-wing configuration.

Figure 26. Persson's interchangeable trawl, 1953



Sources: Persson, *Ponte Sterner. Trawl*. Direktorat for Patent- og Varemærkevæsenet DK83071C. Smögen, Sweden, filed 27 June 1953, and issued 25 February 1957.

The effectiveness of the interchangeable trawl is difficult to gauge. A few sources describe its use as a one-boat trawl and none describe its use as a pair trawl. A report by Johansson and Lindqvist in 1967 depicts the one-boat version. They stated that it was most effective when fishing in the Hebrides and the Baltic for herring and sprat, but performed poorly in the North Sea and Skagerrak.<sup>353</sup> They go on to suggest that the pair trawl version would perform better here, as they were deeper waters.

<sup>350</sup> Persson, *Trawl*, filed 13 October 1958, and issued 27 March 1961.

<sup>351</sup> Anonymous, '4. Sænska flotvarpa'.

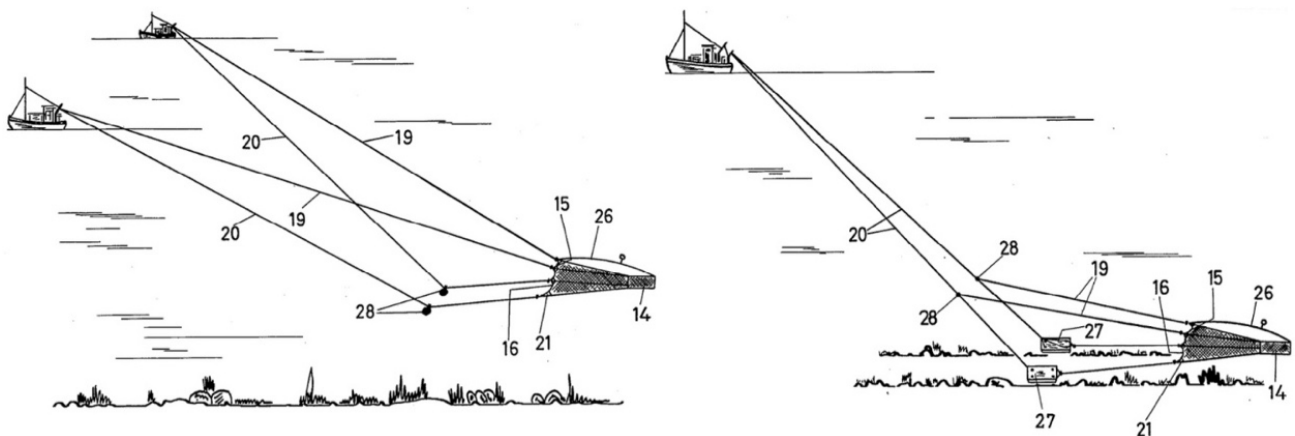
<sup>352</sup> Persson, *Trawl*, filed 27 June 1953, and issued 25 February 1957.

<sup>353</sup> Johansson and Lindqvist, 'Svenska Fiskeriförsök Med Enbåtsflyttrål', 12–13.

Johansson and Lindqvist's report contains letters from the three netmakers whose trawls are depicted. Persson himself did not communicate with Johansson and Lindqvist. However, the netloft he collaborated with, AB Stranne & Oresten, wrote a short letter discussing Persson's trawl in detail. It specifies that work began on its design in the late 1940s, and that since then 140 trawls of this type had been sold. This is supported by an earlier source of 1959 which stated that "a number of these trawls are said to be use in the Baltic, where good catches of Baltic herring ("strömming") have been recorded."<sup>354</sup>

The second interchangeable trawl (figure 27) is by Yngve Bernhardsson. His design is also for an interchangeable one-boat bottom trawl and a pelagic pair trawl. The patent application for this design was made nearly a decade later than Persson's, in 1962.<sup>355</sup> Beyond the patent and Johansson and Lindqvist report of 1967, there are no data on its use or efficiency, and this design is not depicted in other source material. Bernhardsson was not one of the netmakers who communicated with Johansson and Lindqvist, so the report contains no additional information.

Figure 27. Bernhardsson's interchangeable trawl, 1962



Sources: Bernhardsson, K. Y. T. Anordning vid en träl. Patent- och Registreringverket SE185539C1. Göteborgs Bandväveri AB, Göteborg, Sweden, filed 31 March 1962, and issued 16 May 1963.

Bernhardsson's patent discusses the wings of the trawl in detail. They were made of a strong material such as canvas, meant to reinforce them against the strain of the warps and bridles. The trawl had a square mouth, with sections of netting decreasing in size towards a distinct codend. A lazy deckie was added, a feature seen in his earlier pair trawl patents. Johansson and Lindqvist's report contains one image which is clearly drawn from the patent.<sup>356</sup> That Bernhardsson took the time and expense to patent this design suggests that there was a market for this type of trawl. The letter from AB Stranne & Oresten confirms this, demonstrating that there was a thriving customer base in Sweden.

What is missing from these patents and source material is scale: it is very difficult to know how big this trawl was meant to be. The interchangeable trawl had to have been no

<sup>354</sup> Larsson, 'Scandinavian Experience with Midwater Trawls', 347.

<sup>355</sup> Bernhardsson, Anordning vid en träl.

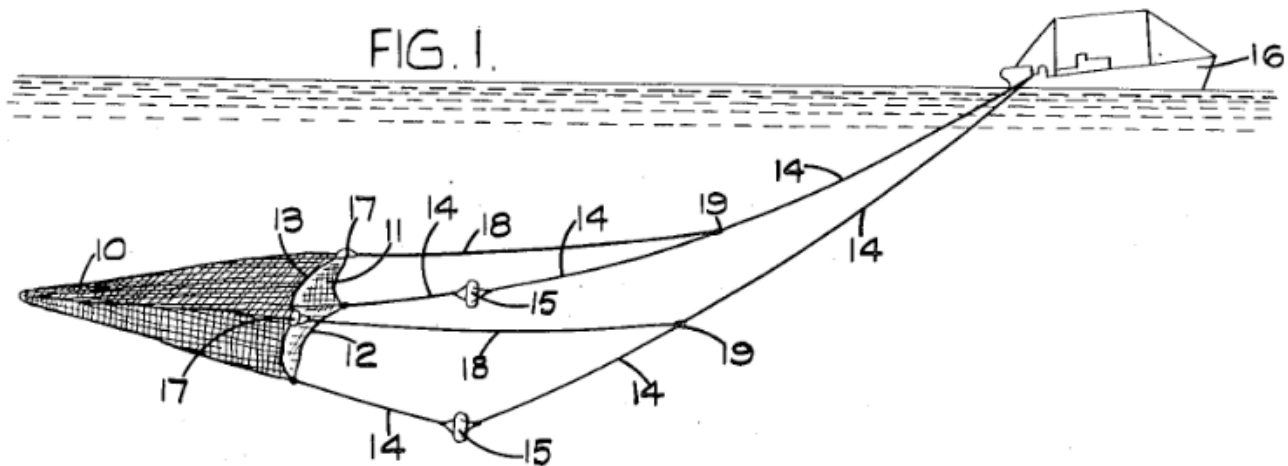
<sup>356</sup> Johansson and Lindqvist, 'Svenska Fiskeriförsök Med Enbåtsflyträl', 14.

bigger than a herring bottom trawl, otherwise a single fishing boat could not have towed it. This meant that even re-rigged as a pelagic pair trawl it was smaller than the typical pelagic pair trawl. This is logical, or even an advantage, as Johansson and Lindqvist's report states that the failure of one-boat pelagic trawls in Sweden was due to small fishing vessels with insufficient horsepower. It is probable that the interchangeable trawl was successfully used as a one-boat pelagic trawl due to its smaller size. Persson, as discussed previously, adapted his interchangeable trawl into an effective one-boat pelagic trawl.

### 2.3.2 Semi-Pelagic Trawls

In early 1950 a series of tests were undertaken in Faxaflói,<sup>357</sup> the large bay where Reykjavík is located. Various pelagic trawls, including one designed by Agnar Guðmundsson Breiðfjörð, were tested.<sup>358</sup> His design is one of the earliest for one-boat pelagic trawls and was known in Britain as early as 1952.<sup>359</sup> It was in 1952, after three years of testing, that Breiðfjörð applied for a patent for his pelagic trawl.<sup>360</sup> However, Breiðfjörð designed his trawl to catch cod, a bottom fish. At that time, the bottom trawls used to catch cod were made from organic fibres and the rough basalt seabed caused significant damage to the them. Breiðfjörð, who ran an aluminium siding factory, had no experience in fishing. But he was aware of this issue and decided that this problem could be solved if the trawl was just above, rather than on, the seabed.

Figure 28. Breiðfjörð's trawl, 1952



Sources: Breiðfjörð, A. G. Fishing Trawls. United States Patent Office US2771702. Reykjavík, Iceland, filed 9 August 1952, and issued 27 November 1956.

Breiðfjörð's patent (figure 28) shows that the trawl had vertical trawl doors, although the orientation is not specified in the patent description. Earlier diagrams indicate horizontal doors, suggesting that he began by using conventional bottom trawl doors.

<sup>357</sup> Anonymous, 'Átta mismunandi veiðarfæri til síldveiða reynd', 16.

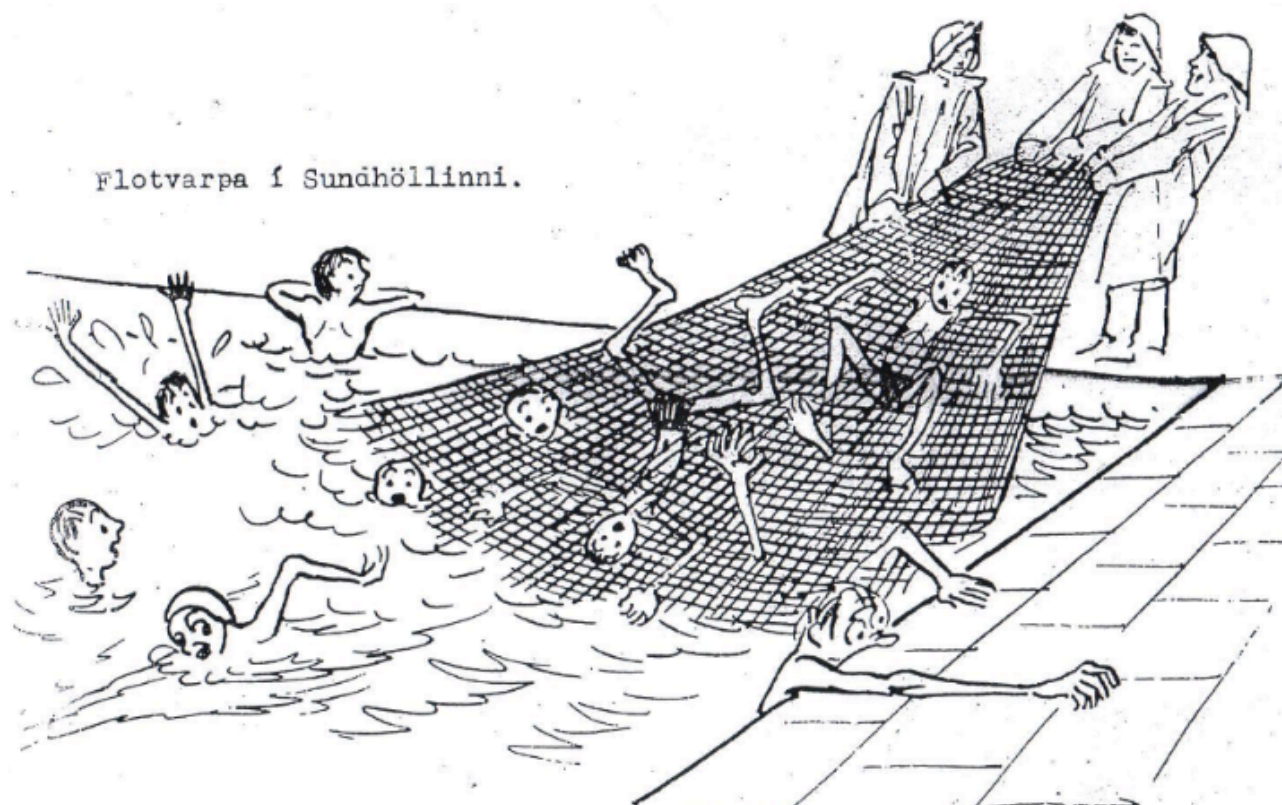
<sup>358</sup> Breiðfjörð was anglicised as Breidfjord outside of Iceland.

<sup>359</sup> Anonymous, 'Íslandstrolli', 1.

<sup>360</sup> Breiðfjörð, Fishing Trawls.

Testing in 1950 resulted in Breiðfjörð making changes to his design<sup>361</sup> prior to his patent application. Another feature of Breiðfjörð's trawl is the orientation of the netting. A sheet of machine-made netting creates a section of netting in which the meshes form diamonds, rather than squares. This allows the netting to expand easily and the trawl to retain its desired shape. Breiðfjörð turned the netting 45° to form open squares instead of diamonds. This was specified in the patent description, but no reason for it was given. In 1952 the Breiðfjörð trawl was equipped with a depth telemeter created by Jón Sveinsson, an electrician working for Breiðfjörð in his factory.<sup>362</sup>

Figure 29. Cartoon depicting testing of the Breiðfjörð trawl, 1952



Sources: Anonymous. 'Flotvarpa í Sundhöllinni'. *Spegillin*, 1 May 1952.

A scale model was also tested in the local swimming pool,<sup>363</sup> as figure 29 shows. There were several short articles about the Breiðfjörð trawl (and other pelagic trawls) in Icelandic print media in the 1950s. Breiðfjörð was awarded a grant from the municipality and the trawl underwent sea trials, many of which were conducted on the trawler *Neptunus*, with the aid of its captain, Bjarni Ingimarsson. *Neptunus* had 1000 horsepower, which was necessary as the trawl doors and rigging were too heavy for smaller fishing boats.<sup>364</sup> In 1952, it was reported that Ingimarsson had used the Breiðfjörð trawl successfully for cod for two months.<sup>365</sup> The same article stated that there were another thirty Icelandic trawlers

<sup>361</sup> Anonymous, 'Flotvörpu reynast vel', 16.

<sup>362</sup> Thorsteinsson, 'Stutt ágríp af sögu togveiða', 193.

<sup>363</sup> Anonymous, 'Togarinn Neptúnus fær goðan afla í flotvörpu af nýrri gerð', 8.

<sup>364</sup> Anonymous, 8.

<sup>365</sup> Anonymous, 'Margar togaranna komnir með flotvörpur', 1.

using pelagic trawls, although it did not say if they were Breiðfjörð trawls. Breiðfjörð made patent applications in Iceland, America, Denmark, and Britain. The Great Grimsby Coal, Salt and Tanning Company bought the licence to manufacture Breiðfjörð trawls in Britain around 1950.<sup>366</sup> Trials in Britain were reported as a success, but that more extensive testing was needed.<sup>367</sup> There is no indication they were manufactured or sold outside of Iceland.

Nylon netting was becoming prevalent in Norway and its superiority was understood in Iceland in 1950.<sup>368</sup> The same year saw an imported Larsen Atom Trawl fail in tests due to the organic netting tearing.<sup>369</sup> Despite this, Breiðfjörð chose to use manila<sup>370</sup> and was not interested in using nylon at that time<sup>371</sup> although he later changed his mind. This led to his trawl falling out of use when more resilient foreign gear from West Germany and France became available.<sup>372</sup>

The Breiðfjörð trawl was discussed in a paper at the first International Fishing Gear Congress in 1957,<sup>373</sup> where it was mentioned as one of the three most prominent one-boat pelagic trawls alongside the Larsson Phantom Trawl and Johnson's British-Columbian trawl. However, there is very little information other than it was designed to catch cod by larger vessels, by side trawlers in the "manner customary for bottom trawls," using "standard plain" trawl doors.<sup>374</sup> More detail was provided in the discussion by Jakob Jakobsson, a fisheries biologist from Iceland. He credited Bjarni Ingimarsson with a significant role in developing the trawl for cod fishing off the south coast of Iceland.<sup>375</sup> He goes on to state that the trawl was used between 1950 and 1954, and only at night.<sup>376</sup> Jakobsson also described the testing of a nylon Breiðfjörð trawl for catching herring, so the trawl must have been updated by the end of the 1950s. He goes on to state that they tried to change the arrangement of bridles and trawl doors so as not to scare the herring but that this caused issues with the opening the mouth of the trawl.

There is no mention of the Breiðfjörð trawl being actively used after 1959. It was known outside of Iceland, as von Brandt included an image of it in *Fish Catching Methods of the World*, although the trawl was not mentioned in the accompanying text.

Claude Nédélec, who was initially at the Institut Pêches Maritimes<sup>377</sup> and later a gear technologist for the FAO,<sup>378</sup> published numerous articles on trawls and trawl gear in *Science et Pêche* starting in 1958. Many of these were published with Marcel Portier, a

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<sup>366</sup> Anonymous, 'Íslandstrolli', 1.

<sup>367</sup> Anonymous, 'New Trawl Report', 24.

<sup>368</sup> Anonymous, 'Endurbættur flotvörpur', 5.

<sup>369</sup> Anonymous, 'Brezkar flörvörpur úr nylon', 1 & 7.

<sup>370</sup> Thorsteinsson, Veiðar og Veiðarfæri.

<sup>371</sup> Anonymous, 'Togarinn Neptúnus fær goðan afla í flotvörpu af nýrri gerð', 8.

<sup>372</sup> Thorsteinsson, Veiðar og Veiðarfæri, 116.

<sup>373</sup> Parrish, 'Midwater Trawls and Their Operation', 337–38.

<sup>374</sup> Parrish, 337–38.

<sup>375</sup> Dickson, 'Discussion of Choice of Fishing Gear and Some New Methods', 443.

<sup>376</sup> Steinberg, 'Discussion: Established Commercial Fisheries', 492.

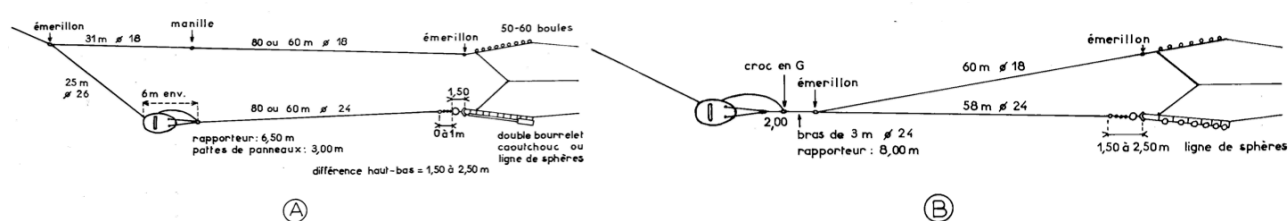
<sup>377</sup> FAO, FAO Catalogue of Fishing Gear Designs, 1965 see Design No. 129.

<sup>378</sup> Kristjónsson, 'List of Contributors', 1971, xvi.

scientist with the Institut Scientifique et Technique des Pêches Maritimes.<sup>379</sup> Nédélec was also a member of several ICES committees in the 1960s, including the Pelagic (Northern) Fish Committee of which Jakob Jakobsson was a member,<sup>380</sup> as well as the Gear and Behaviour Committee of which Andres von Brandt was chair.<sup>381</sup>

In 1959 Nédélec and Louis Libert, also a scientist from the Institut Pêches Maritimes,<sup>382</sup> wrote a two-part article on different trawl types. The first part described in detail the construction of various trawls, including the Breiðfjörð trawl.<sup>383</sup> The article also described Johnson's British-Columbian trawl, the Larsen Atom Trawl, Larsson's Phantom Trawl, an Engel trawl, and many others. Of these, the Breiðfjörð trawl was the only one placed in the section on bottom trawls; the others were all categorised as pelagic trawls.<sup>384</sup> In 1965 Nédélec adapted the rigging arrangement of a Breiðfjörð trawl<sup>385</sup> (figure 30) when testing a semi-pelagic trawl for catching cod in Canada<sup>386</sup> and in the North Sea for herring.<sup>387</sup>

Figure 30. French semi-pelagic trawl rigging arrangements, 1965



Sources: Nédélec, Claude. 'Essais de pêche pélagique de la morue dans la région du Labrador [Tests for pelagic fishing of cod in the Labrador region]'. *Science et Pêche* 137 (April 1965): 1-11.

While von Brandt may not have considered epipelagic trawls to be true pelagic trawls, their design was closer to that of pelagic trawls than bottom trawls. They were made with four panels, where either all four were identical (or at least symmetrical). This would not be the case for a bottom trawl, as the top panel extends much further out than the bottom panel, to prevent fish from fleeing upwards and escaping. The semi-pelagic trawl may have been very close to the bottom, but it was not functioning the same way as a bottom trawl. Von Brandt later described the use of four trawl doors on semi-pelagic trawls where small pelagic trawl doors were placed on the upper bridles, while bottom trawl doors were

<sup>379</sup> Kristjónsson, xvii.

<sup>380</sup> ICES, 'List of Members of the New Committees', 4.

<sup>381</sup> Graham, 'Gear and Behaviour Committee', 1.

<sup>382</sup> Kristjónsson, 'List of Contributors', 1964, xiii.

<sup>383</sup> Nédélec and Libert, 'Etude du chalut 1: Coupe et montage du chalut [Trawl study. 1. Cutting and assembling of trawl]'

<sup>384</sup> Nédélec and Libert, 'Etude du chalut 2: Adaptation du chalut et de son gréement aux différentes pêches [Trawl study. 2. Adaptation of the trawl and its rigging to the various fisheries]', 492.

<sup>385</sup> Nédélec and Libert, 'Le chalut [The trawl]', 154 & 177.

<sup>386</sup> Nédélec, 'Essais de pêche pélagique de la morue dans la région du Labrador [Tests for pelagic fishing of cod in the Labrador region]', 8.

<sup>387</sup> Nédélec, 'Résultats de la campagne de la "Thalassa" en Mer du Nord (octobre 1965) (Essais de chaluts pélagiques et semi-pélagiques) [Results of the campaign "Thalassa" in North sea (october 1965) (pelagic and semi-pelagic trawls tests)]', 1.

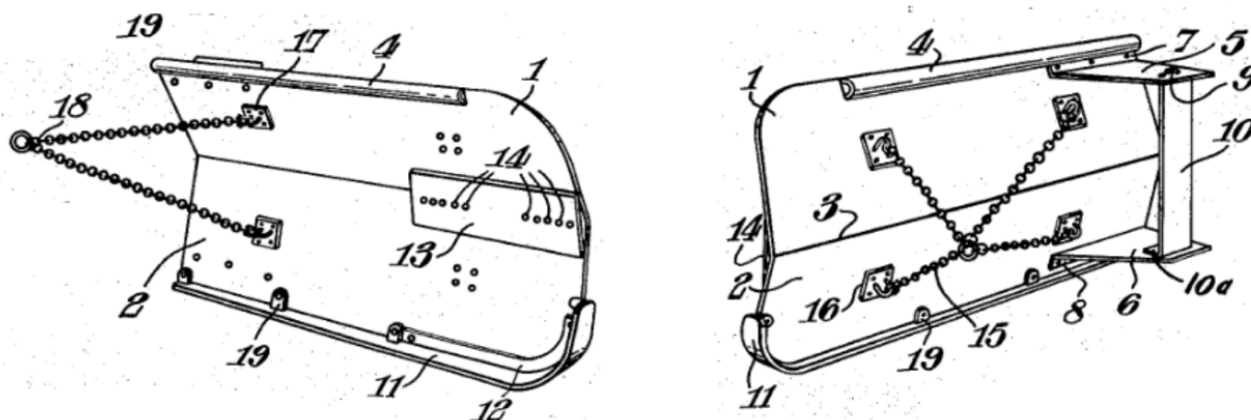
placed on the lower bridles.<sup>388</sup> The bottom doors could rest on the seabed, while the upper doors and the trawl itself were just above it.

In 1970 Portier described the development of the semi-pelagic trawl as the desire to exploit fisheries otherwise unreachable by bottom trawl or conventional pelagic trawls.<sup>389</sup> This meant either herring or cod, depending on the type of semi-pelagic trawl used. They were designed for smaller boats, unlike the Breiðfjörð trawl, and meant to be towed reasonably fast. Like the one-boat pelagic trawls previously described, their success was dependant on the use of sonar and netsounders. Later, Portier commented that the difference between semi-pelagic and high-opening bottom trawls was a matter of rigging, as the trawls were only one or two metres above the seabed when in use.<sup>390</sup>

### 2.3.3 Combination Trawls

The combination trawl was the next stage in the evolution of the one-boat pelagic trawl. Fish behaviour, in particular herring, was the driver for this development. They either dove or rose when frightened and alternated between midwater and the seabed depending on the time of day. Like the semi-pelagic trawl, this type of gear was also useful for catching other fish, such as cod. The idea was that the combination trawl could alternate between bottom trawling and pelagic trawling as required. Unlike the interchangeable trawl, it did not need re-rigging in any significant way to able to do this. Like the interchangeable trawl, this reduced the amount of fishing gear required by fishermen, as well as the cost.

Figure 31. Johnson and Barraclough's trawl door, 1960



Sources: Johnson, Wesley W, and William E Barraclough. Dual-Purpose Midwater-Bottom Otterboard. United States Patent Office US2942371A. Ottawa, Ontario, Canada, filed 25 September 1958, and issued 28 June 1960.

Johnson, in Canada, was interested in the concept of combination gear as early as 1960. He had begun his work on one-boat pelagic trawls by investigating the behaviour of the fish he was trying to catch. He understood early on that the depth of the pelagic trawl

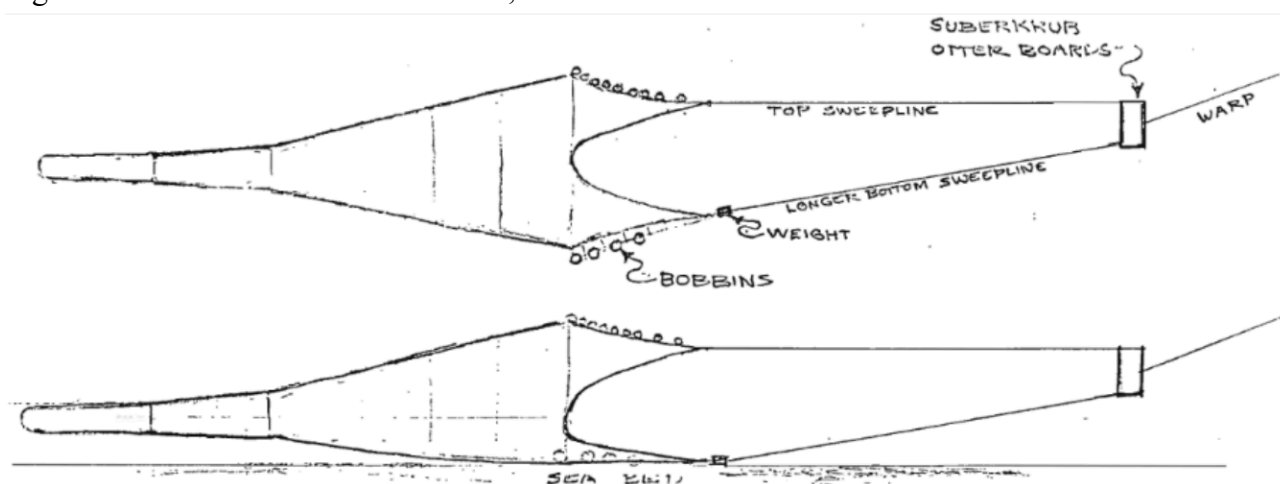
<sup>388</sup> Brandt, *Fish Catching Methods of the World*, 267–69.

<sup>389</sup> Portier, 'Le chalutage pélagique et notes sur ce chalutage avec panneaux Suberkrub [Pelagic trawling and notes about this trawling with Suberkrub doors]', 1.

<sup>390</sup> Brandt, 'Discussion: Materials, Design, Construction and Selection of Gear', 377.

had to be altered during towing to account for the response of the herring. But he decided that the trawl should not be the focus when attempting to create multi-use trawls; rather it was the trawl doors that were the subject of experimentation. Johnson and Barraclough designed combination trawl doors<sup>391</sup> for use with either bottom trawls or pelagic trawls (figure 31). In 1966 Johnson travelled to Europe and Schärfe acted as his guide. Schärfe had completed a prototype of his combination trawl (figure 32) by this time and had conducted a successful trial in the North Sea for catching cod. Johnson was invited to observe trials and was provided with detailed data on the trawl and its testing. Part of Schärfe's design was replicated in Johnson's report, sketched by Johnson himself.<sup>392</sup>

Figure 32. Schärfe's combination trawl, 1966



Source: Johnson, Wesley W. 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966'. Project Report. Ottawa: Industrial Development Services: Department of Fisheries of Canada, 1967.

Schärfe's design began with a pelagic trawl rigged with bobbins on the groundrope.<sup>393</sup> Adaptations were made following the use of scale models and a test run in the North Sea in 1966,<sup>394</sup> including the removal of large areas of netting vulnerable to potential contact with the seabed. The trawl closely resembled a bottom trawl, albeit with Süberkrüb trawl doors. This arrangement required careful control of the warps and bridles to keep trawl doors and the main part of the trawl off the seabed. The bobbins acted in the same way as they did on bottom trawls, allowing the trawl to roll over a rough seabed. Schärfe noted that in order to preserve the netting on the main body of the trawl there had to be a gap between the bobbins and the groundrope, which fish easily escaped through. Schärfe's combination trawl did not appear again; it was not mentioned at the next International Fishing Gear Congress in 1971, in the FAO Catalogue of Fishing Gear Designs, or in any revised reprints of von Brandt's *Fish Catching Methods of the World*. Development may have ceased as a consequence of the collapse of the herring stocks in the 1960s.

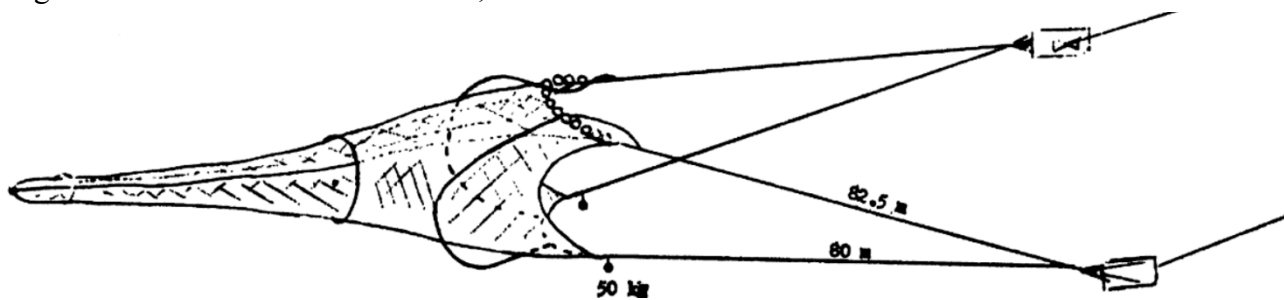
<sup>391</sup> Johnson and Barraclough, Dual-Purpose Midwater-Bottom Otterboard.

<sup>392</sup> Johnson, 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966', 73 & 77–81.

<sup>393</sup> Johnson, 73 & 77–81.

<sup>394</sup> Johnson, 8.

Figure 33. Okonski's universal trawl, 1963



Source: Okonski, S. 'Universal One-Boat Midwater and Bottom Trawl'. In *Modern Fishing Gear of the World 2*, edited by Hilmar Kristjonsson, 229–34. Farnham, Surrey, England: Fishing News Books, 1963.

Another combination trawl was designed by a gear technologist, Stanislaw Okonski, based at the Sea Fisheries Institute in Gdynia, Poland. In 1963 he presented his "universal one-boat midwater and bottom trawl" at the first International Fishing Gear Congress.<sup>395</sup> This trawl (figure 33) used flat horizontal trawl doors, not because it was better than high-aspect or hydrofoil doors, but because it was thought easier for local fisherman to accept a new type of gear if it had recognisable elements that they were already using.<sup>396</sup> It had four identical panels made from polyamide netting, where the bottom panel had double twine to reinforce it against contact with the seabed. It had chain (but no bobbins) on the groundrope. It had been tested in the English Channel the previous year with good results, although it needed a depth telemeter to operate fully. It was described as being very similar in design to pelagic trawls previously used in Iceland, although the Breiðfjörð trawl was not mentioned directly by Okonski.<sup>397</sup> This design does not appear again elsewhere. It is not unreasonable to think that both Okonski and Schärfe later realised that fishermen were opting for something akin to the Canadian approach, where trawlers carried several types of fishing gear and used each as required.<sup>398</sup>

### 2.3.4 Summary

There were many variations on the pelagic trawl. The extent to which they were considered true pelagic trawls is largely arbitrary, as they all involve an element of use that is off the seabed. The semi-pelagic trawl was the most successful, an adaptation which saw the pelagic trawl brought as close as possible to the seabed without coming into contact with it. The interchangeable trawl and the combination trawl were unsuccessful attempts to make multi-purpose fishing gear. They failed because for the same reason the semi-pelagic trawl succeeded. The pelagic trawl, like most fishing gear, works best as a highly specialised tool, either for a particular fishing area or fish species.

<sup>395</sup> Okonski, 'Universal One-Boat Midwater and Bottom Trawl'.

<sup>396</sup> Okonski, 229.

<sup>397</sup> Jakobsson, 'Nýjungur í veiði- og veiðarfærartækni', 43.

<sup>398</sup> Carrothers, 'Descriptions of Trawl-Gear Used for Demersal Species by the Canadian Fleet in Subarea 5 and Statistical Area 6 during the Period 1969 through 1971', 2.

Interchangeable trawls were the earliest to try and create a trawl that could be a one-boat bottom trawl and a pair pelagic trawl. Bernhardsson had created his pair pelagic trawl over two decades previously, while Persson had created an interchangeable trawl before his successful six-wing one-boat pelagic trawl. However, looking at the source material for Persson, we can see that this later design was derived from his interchangeable design to the extent that the same images were used to illustrate both. The motivation behind this development was an attempt to capitalise on the herring fisheries of the North Sea and the Kattegat and Skagerrak, where herring stayed close to the bottom during the day and rose higher at night. There is no data on how successful the interchangeable trawl was and there are no other examples. They are not discussed (and rarely mentioned) by contemporary fisheries gear technologists outside of their apparent novelty value. However, they do demonstrate the desire to fully and more efficiently exploit the herring fisheries in the 1950s and 1960s.

The combination trawl is another design that had little impact, despite the effort and resources dedicated to it. The idea was to have a one-boat trawl that could be used as a bottom trawl or a pelagic trawl depending on how it was set up and towed, again to catch herring in the North Sea. Schärfe's design does not appear to have survived the 1960s, as it was not published. This design was likely abandoned as the herring fisheries had collapsed by the end of the 1960s. This does suggest that it was not as efficient, or perhaps even as versatile, as a conventional one-boat pelagic trawl. In Poland, Okonski had developed a combination or universal trawl, but this too did not get much attention and does not appear in again.

Semi-pelagic trawls were developed to target mostly demersal fish living either on or just above the seabed. Breiðfjörð developed his to catch cod, based not on fish behaviour, but because the seabed was so abrasive as to damage conventional bottom trawls. The French scientists who developed a similar trawl twenty years later, inspired by Breiðfjörð, did not have the same problem. Instead, they were responding to fish behaviour. They went on to develop their own semi-pelagic trawls, although their use during the 1970s appears limited to French waters.

The purpose of these trawls was to fully exploit fisheries to the greatest extent permissible. For the interchangeable and combination trawls, this meant creating a type fishing gear that was versatile and inexpensive. Having one trawl that could be used in multiple situations was desirable. It could also save time, as the trawl did not have to be disengaged from the trawler, packed away, and swapped for another while at sea. The semi-pelagic trawl had a different approach, as it was a specialised trawl, rather than a multi-purpose one. It was created to catch fish that could not be caught with either bottom or pelagic trawls. It retained many features of the pelagic trawl even though it was used very close to the seabed. Retaining its features, rather than losing them, made it more effective.

The motivations of these inventors here are very different. Where the combination trawl was attempting to improve on the pelagic and bottom trawls by taking a multi-tool approach, the semi-pelagic trawl took the pelagic trawl and made it an even more specialised tool. By SCOT's approach, this is very much the case of re-defining the problem. A solution has been achieved – one-boat pelagic trawls were successfully designed, manufactured, and sold by numerous designers and netlofts. Despite this, new ways to define the pelagic trawl were made and new problems made. Some of these were specific to a fishery, such as in France, while others, such as the combination trawl, were attempts to bring a greatly degree of versatility to an existing solution.

## 2.4 Discussion

The technological development of the pelagic trawl has two distinct phases. The first was the pair trawl, which began as the innovation of netmakers and fishermen. The pair trawl was first made with materials and components that could be regarded as pre-industrial, if it were not for the powered fishing boats towing them. The second was the one-boat trawl, which was developed primarily by fisheries gear technologists. They used new materials such as synthetic fibres, plastics, and developed monitoring devices for the trawls. They also had access to larger and more powerful fishing boats. But materials and components are only one facet of technological change. Another is understanding how the trawls were developed: examining the network of fishermen, engineers, and fisheries gear technologists who invented and developed the trawls.

When the pair trawl was invented and developed their inventors were adversarial, in direct competition as rival business owners. They went on to develop a personal conflict over the pair trawl, one which resulted in legal action. They had to self-finance their inventions and did so despite lacking much in the way of resources besides that of experience and determination. As a result, they were protective of their work and the income it provided. This is direct contrast with the one-boat trawl, where fisheries gear technologists were part of a much larger network of scientist and researchers who were working in fisheries. They did not lack experience or determination and they proceeded with the benefit of funding. Most importantly, the scientific approach they utilised entailed publishing their results. They formed conferences and working groups, creating international networks of organisations and individuals.

They did all this in search of a solution to a fairly straightforward problem: how to catch more fish, more efficiently. This problem, in its earliest iteration, was how to catch the herring that could not be caught with bottom trawls or purse seines. The problem was later redefined and narrowed to the immediate needs of the inventors. This can, almost always, be distilled the problem of how to catch these fish, in this location, under these fishing conditions. In some instances, this required specialised versions of the pelagic trawl, while for others a more generic pelagic trawl design was sufficient. Of course, most fishing gear was adapted to a significant extent by the purchaser, and is often ordered tailor-made to the fishing boat that is meant to be using it. This also explains why a new development did not render its predecessors obsolete: the pair trawl continues to be used into the twenty-first century. Specific fisheries, fishing conditions, traditions, and personal preferences are all important factors in deciding what kind of fishing gear should be used.

The pair trawl was a solution to the problem of catching herring higher in the water column, usually at night. Using two boats was necessary as an effective trawl door had not yet been discovered, although it had been invented in Germany just prior to the Second World War. Pair trawls, while effective in the 1940s, were limited to smaller boats and used

organic components in its construction. The netting was made of cotton, with lead weights, glass or cork floats. Moreover, it was used without the assistance of sonar or other devices to monitor the trawl while it was being towed. No doubt there were numerous netlofts that made pelagic trawls of their own design; Larsen and Bernhardsson are the two made visible by their patents and other source material. Newspapers and oral history reveal a decades-long conflict between the two men, one which had little in the way of resolution. Larsen would go on to be remembered as the inventor of the pelagic trawl, while Bernhardsson was largely forgotten. It's not really possible to say who invented the trawl first, as both had extensive backgrounds and a deep understanding of netmaking and trawling. Bernhardsson's patent was earlier than Larsen's, but Larsen claimed he started working on the trawl much earlier. Bernhardsson, who landed a catch in Larsen's hometown of Skagen, suspected that Larsen saw and copied his idea. Of course, all of these things could be true. The design of the pair pelagic trawl is very similar to that of the bottom trawl and is an obvious source of inspiration for both Bernhardsson and Larsen. It is entirely plausible, and highly likely, that they created a functioning pair pelagic trawl independent of each other.

The world of commercial fishing was small, even in the pre-digital age. Fishermen frequently landed their catches in foreign ports, or needed to find a netloft to repair gear made elsewhere. Netlofts sourced their netting and materials, either from local merchants or from abroad. There were also numerous commercial fishing publications aimed at fishermen and fishing communities. A new or novel method of fishing would have been the subject of attention, even if the exact details were kept secret. New concepts and ideas could travel fast, especially when the people using it were themselves mobile and travelling.

Perhaps, instead of debating which inventor got their first, we should instead try to understand how it is that one inventor gained recognition over all the others. From the available source material it is clear that Larsen had an eye for self-promotion. He travelled to promote his trawl and spent time and effort to increase his customer base outside of Denmark, while Bernhardsson focussed on maintaining his existing customer base. Larsen also benefitted from the schemes created to promote Danish goods and advances; this is apparent by his later recognition and awards. Both Larsen and Bernhardsson found themselves defending their inventions in court. Ownership and recognition of the idea of the pair pelagic trawl was important, be it for honour, pride, or financial gain.

While Larsen and Bernhardsson were establishing ownership of their work, other inventors were working on making a one-boat trawl. Two Swedes, Larsson and Persson, had created their own designs, but with very different results. Their trawls were not so different in concept, as the one-boat trawl still had a very similar form to the pair trawl. Instead, it was their success and interactions that were different. Persson, a fisherman, licensed his six-wing design to a netloft which manufactured and sold this trawl to Swedish

fishermen. It was popular, with over a hundred sold in one year alone. Larsson, an engineer, created his trawl in the midst of testing mine clearing equipment for the Swedish Navy. He emphasised his scientific approach in creating his trawl, claiming that when tested it was the superior trawl. Despite this, he does not seem to have had any success commercially, despite engaging with the growing community of fisheries gear technologists. Larsson's gear was impressive enough to be tested by scientists, with mixed results, but never good enough to be used by itself.

Another early inventor was Süberkrüb, whose trawl door design would remain undiscovered for nearly two decades before being discovered and utilised with great success in West German pelagic trawl experiments. The trawl doors were one of a number of technological developments that made the one-boat pelagic trawl possible. Sonar and the netsounder made it possible for the pelagic trawl to be an efficient fishing method in mid-twentieth century Europe. Sonar became more commonly used in the late 1940s and was commonly found on fishing boats by the mid 1950s. Another development of the early 1950s was synthetic netting, which was much stronger than netting made from organic fibres. This allowed trawls to be bigger and lighter, yet still catch and contain catches of tens of tonnes without breaking. This in turn was enabled by changes in fishing boats. Larger trawlers, with more horsepower, could tow these larger trawls and have the space onboard to process their catch. The stern trawlers and factory trawlers had the capability to handle large trawls and large catches.

These innovations were at the same time as Johnson and Schärfe were creating their own pelagic trawls. Both opted for synthetic netting, foreseeing that organic fibres would be obsolete within a decade or so. Johnson had been a fisherman for many years, while Schärfe was academically trained. Nevertheless, Schärfe gained considerable practical experience with fishing gear in the 1950s by participating in trials of fishing gear and experimenting with new types of fishing gear. Scientists working in the USA also experimented with pelagic trawls, although their work was more of a collaborative effort; Richard McNeely presented their work. Unlike Bernhardsson and Larsen they had the financial resources to dedicate time and energy to research and experimentation. As part of their experiments, they created or adapted equipment to monitor the trawl in the water, such as the netsounder and the depth telemeter. These quickly became indispensable, not just in testing the trawl, but using it. The need to create a new trawl had also created the means to observe it, and this in turn became the necessary equipment to ensure its proper use. They also looked ahead and chose to use synthetic materials, as well as encouraging fishermen to upgrade their boats or gear. Schärfe, Johnson, and those in the USA worked on their one-boat trawl between the mid-1950s and the late 1960s. They did so with the benefit of new materials, such as synthetic netting, plastic floats, and in sonar. Both Schärfe and Johnson made a deliberate choice to take full advantage of some of these, which benefitted their work immensely.

Schärfe favoured the Süberkrüb trawl door, as did many others, although Johnson preferred to design his own. The trawl door that the US Fish and Wildlife Service invented were very similar to Süberkrüb's in concept. The US Fish and Wildlife Service also had a different reason from the Schärfe and Johnson for designing a pelagic trawl in the first place. Schärfe and Johnson wanted to make gear for existing fisheries, in order to better exploit them. The US Fish and Wildlife Service invented a pelagic trawl which was used to determine if there was a potential new fishery, one which the trawl could then be used to exploit. Both the US Fish and Wildlife Service and Johnson found that their gear could be used to catch hake, although Johnson had intended for his design to be used for herring. Regardless, both abandoned their efforts despite the effectiveness of their trawls when a large and well-equipped Soviet fleet dominated the fishery they hoped to exploit.

The development of the one-boat pelagic trawl was characterised by collaboration and communication. Schärfe, Johnson, and the US Fish and Wildlife Service were active participants in conferences and freely shared very detailed designs and methods. They all also made efforts to test out each other's gear and were candid regarding the results. The efforts were overall intended to be of benefit to everyone, with no regard to making a profit. Their work was published frequently and in enough detail for anyone with sufficient knowledge to replicate the trawls for themselves. They met, discussed, and evaluated each other's ideas, and took the ideas they needed to improve their own gear.

There were also other versions of the pelagic trawl, some of which predate the one-boat developments of the late 1950s. These include the semi-pelagic trawl, the interchangeable trawl, and the combination trawl. There are only two examples of the interchangeable trawl, one by Persson and another by Bernhardsson. By changing the rigging arrangement, they could alternate between a pair pelagic trawl and a one-boat bottom trawl. Both of these examples are Swedish and reflect the desire to fully exploit the herring stocks around Sweden in the 1950s and 1960s. There is very little mention of these designs outside their patents. Persson's later one-boat pelagic trawl is clearly derived from his interchangeable trawl.

The semi-pelagic trawl was first invented in Iceland in the early 1950s and it could be argued that the Breiðfjörð trawl was the earliest functional one-boat pelagic trawl. Its use appears short lived, although it went on to inspire the development of the French semi-pelagic trawls of the 1960s. It was well-represented in the literature of the 1950s and 1960s and was discussed at the International Fishing Gear Congress in 1957 and again in 1963.

The combination trawl was first seen in the mid-1960s but it was not commercially used. It was intended to be a one-boat trawl that could be used either as a bottom trawl or pelagic trawl by altering its depth while in use, without having to make alterations to its rigging. It was developed by Schärfe, and another version was attempted in Poland a few years earlier. Why it was not developed further is unknown, but as the herring stocks collapsed in the 1960s and this probably halted further experimentation.

This early phase of the pelagic trawl is one characterised by conflict. Part of SCOT's approach, as previously discussed, entails understanding conflict. In SCOT, conflict occurs when members of a social group do not agree that a solution had been achieved. Bernhardsson and Larsen could be considered part of the same social group based on either their profession, their shared customer base, or their home environment. From our perspective they were working on the same problem. It is possible that they did not consider it the same problem, even if their solution was almost identical. So, although Bernhardsson and Larsen are part of the same social group, their conflict arises when they dispute the ownership of that solution. They both continued to work on their designs, updating them. This typically entailed using new materials and bigger boats. In one sense this is rhetorical closure, as no substantive changes were made to the form of the design.

It is unfortunate that there are so few substantive sources for the many Swedish netlofts of Gothenburg and surrounding areas. Their names and occasional snippets of information do frequently appear, but details are too often sadly lacking. From the few sources available there seems to have been a network of netlofts which did business with each other and with the independent inventors discussed in this thesis. Their relationships, friendly and adversarial, are hinted at and could add a great deal to this thesis.

The relevant drivers for change can, like the technological development of the pelagic trawl, be divided into two phases. In the first, where netmakers and fishermen dominate, the drivers of change are particular to a handful of individuals. Yngve Bernhardsson had the benefit of divine inspiration and was also prompted by the ties of obligation and reciprocity that bound his small and tight-knit fishing community together. He also had the burden of securing an income when he was no longer fit to go to sea with a family to provide for. His idea for a pelagic trawl was equally driven by the need for financial security. His experience as a fisherman, coupled with the decades of experience his family had in fishing, informed him of a problem, to which he felt God had provided a solution. It was the same basic problem as identified by other inventors – of how to catch fish that could not be caught by other fishing methods. All of these men saw this problem as an opportunity for financial gain, with their solutions marketed and sold as products to a market receptive to being able to catch more fish. They were all, in turn, protective enough of their trawl designs to patent them and some of them defended the rights to their patents fiercely.

At this time, there were few restrictions on fishing and none of these men were concerned with quotas or trespassing in territorial waters. The herring that they were targeting could, in fact, be caught by other means – but only during the day. The pelagic trawl was first used only at night, when the herring rose in the water column. To use to pelagic trawl was to either only fish at night, or to fish using more than one type of gear. Using only a pelagic trawl meant the fishermen were confident that they could catch more fish with the pelagic trawl than they would with another method. If they were using both,

then they were trying to maximise the quantity of fish they could catch in a single fishing trip. Either way, the opportunity to catch more fish, is a strong driver for the development of the pelagic trawl. This goes hand-in-hand with the men who were themselves driven by the desire for financial security.

The second phase was very different. The one-boat trawl was successfully developed by fisheries gear technologists, some of whom were ex-fishermen. Fisheries gear technologists such as von Brandt, Schärfe, Johnson, and McNeely, as well as those working for government departments and NGOs, were all employees. They answered to a higher power within their organisations, one which directed or approved research. Many of them did eventually take on roles within their organisations where they themselves were in a position to identify and approve of potential areas of research. The drivers here are perhaps loftier than those of the pair trawl; to either create new fishing gear or to make existing fishing gear more efficient for the purpose of improving the lives of fishermen and be ensuring economic stability. Ensuring fishermen had stable and diverse array of fisheries to exploit would bring stability to the everyday lives of fishermen. More importantly, this would also ensure stability in the fishing industry with a consistent supply of fish for the various industries that needed it.

Later on, the pelagic trawl was developed further; the driver here was a continuation of phase two. As controls and restrictions were brought into fisheries, the pelagic trawl needed to be adapted in order to maximise the permissible catch with the least amount of effort. Again, it was about ensuring that the fishermen using it could continue to fully exploit a resource with the least possible cost to themselves.

Throughout these various phases of development, the original problem is repeatably redefined. This too is a driver, albeit one of ongoing technological development. We must also entertain the possibility that one of the reasons some of these developments were pursued was because they opportunity was there – some scientific endeavours are explored because they present a challenge and the possibility of new discoveries, not a solution. This is certainly a factor that should not be discounted. In previous chapters we have met scientists and individuals whose careers were grounded in curiosity and a desire to explore and discover. Some of them certainly had the resources to do so.

Initially, the problem – as solved by Bernhardsson, Larsen, and Persson – was of catching herring more effectively in waters of the Kattegat and Skagerrak. Fishing grounds were quickly extended to the North Sea, while others tried to transplant the idea to Iceland, the USA, and Canada. Larsson also focussed on this, but to a much less successful extent. The pelagic trawl is, at this stage, a very specific tool for a specific task. Süberkrüb solved the problem of the one-boat pelagic trawl by designing a hugely effective and successful trawl door. This made the work of other inventors much easier by removing one potential obstacle as well as an additional fishing vessel.

When the gear technologists and scientists got involved in trawl design, a decade or so later, the problem was redefined. Now it became one of fishing grounds: how to take an idea that works for herring in largely European waters and make it work in North American waters, around Iceland, or even further afield. Additional refinements make the pelagic trawl suitable for catching pelagic species other than herring, such as redfish, mackerel, blue whiting, or capelin. Fishing grounds were exploited globally, with European-made pelagic trawls sent as far afield as Australia. Each of these resulted in design changes that were entwined with other technological advances such as bigger mesh sizes, trawl monitoring equipment, and improved fish detection. Some of these are very successful, others not so much. The pelagic trawl was still a specific tool, but one that could be adapted and modified depending on the fishing conditions.

Finally, the problem was redefined as the need to adapt to pelagic trawl so that it could function as both a pelagic trawl and something else as well. The aim became to make a multi-tool trawl which required minimal modification and was useable by fishermen without needing to be adapted to a specific fishery. This too, was largely unsuccessful. As will be demonstrated in the next section, the pelagic trawl was a specific tool for a specific job. This made it useful and is the reason its use has persisted into the twenty-first century.

It could also be argued that three major technological advances drove change in fisheries. Synthetic fibres were not intended for fishing nets, yet in the 1950s this was a key contributor to the development of fishing gear. It made gear stronger and lighter, which in turn made it much bigger. The one-boat pelagic trawl depended on it; early designs failed due to the inferiority of the cotton netting. This was followed by the development of electrical equipment: the depth telemeter, sonar, and the netsounder. Developed in the 1950s and 1960s, they allowed the pelagic trawl to be used to its full potential. The final key development was in shipbuilding, where fishing boats became larger, more powerful, and could handle fishing gear more safely and efficiently.

### 3 The Greater Context: Economic Significance

The technological development of the pelagic trawl was explored in the previous section, starting with its small, organic form in the 1930s and following its progression through to the much larger synthetic one-boat version that was ubiquitous by the 1980s. Here the focus was on the trawl itself – its fabric, form, and function – and the people who made it. Their motivations and influences, alongside the resources and knowledge available to them, were critical in shaping the pelagic trawl. In this section, however, the focus is on the greater context of these inventors; the fisheries that their trawls were used to exploit, the ways in which those trawls were used, the effectiveness of those trawls, as well as the effect trawling had on those fisheries. Significance can be assessed in a many different ways but here the focus is on the economic and technological significance of the pelagic trawl. A critical aspect of understanding the pelagic trawl is understanding how and why it was used as a fishing method within a major sector of the fishing industry. The overall goal is to provide an assessment of the wider significance of the pelagic trawl.

To do this, five key aspects have been identified and form five chapters. They are: intensification of fisheries, output, productivity, employment, and boats and gear. The pelagic trawl was often used in conjunction with other fishing methods and when possible, direct comparisons between the pelagic trawl and other types of (typically pelagic) fishing gear are presented.

First, in intensification of pelagic fisheries, exploitation, over-exploitation, the inevitable collapse of pelagic fisheries, as well as the consequences of that collapse are explored. The importance of pelagic fisheries is established and the pelagic trawl is placed within a context of demand and control which spans several decades, from the 1930s through the twenty-first century. As a result, it is possible to determine that the pelagic trawl was an important fishing method and was used to both exploit existing pelagic fisheries and in identifying and attempting to exploit new fisheries.

Second, the output of pelagic catches both in terms of quantity and value are explored. The pelagic fisheries for Sweden, Scotland, and Sweden are examined. This is achieved by determining what proportion of the catch was made with pelagic trawls and the economic value of that catch as compared to other pelagic fishing methods. The products and the value of the products made from pelagic fish is then discussed, as this plays a key role in understanding how and why the pelagic trawl was used, which in turn demonstrates the different ways in which it was significant. This varies greatly over time and in different countries over the twentieth century.

Third, in productivity, the effectiveness of the pelagic trawl is calculated using catch per unit of effort (CPUE). CPUE is a means of calculating how much fish was caught and how fast. This can be expressed as tonnes per day, per hour, or per fishing trip. This is then compared to the CPUE of other pelagic fishing methods, in particular the purse seine and

the herring bottom trawl. The factors which could affect the productivity of fishing gear is discussed, which is especially important given the importance of seasonality and the introduction of quotas. Examining productivity demonstrates that the pelagic trawl became more specialised over time, making it a valuable tool regardless of its efficiency.

Fourth, in employment, the decline in the number of fishermen is discussed in relation to the fishing methods available. While reduced employment is acknowledged to be a direct consequence of technological advancement, there are other factors. Different types of gear have different requirements and thus affect how many people may be employed on any one fishing boat. Some of these requirements are the direct result of mechanisation and some a result how the fishing gear is operated and stored.

Finally, in boats and technology, how the pelagic trawl gained the technologically advanced platform it needed in order to make its use easier (and relatively cheap) is explored and compared to other fishing methods. Two sets of statistical data are used, the first of which is from Sweden, the second from Scotland. The first demonstrates how quickly and to what extent sonar and other “special equipment” was adopted by fishermen of all kinds over the course of the 1960s. The second demonstrates that there was a thriving second-hand market for fishing vessels. There are also a number of other sources which describe the relative costs of materials, electronic instruments, and fishing gear in the latter half of the twentieth century.

Statistical data are found in the form of national annual fisheries reports, data which form the basis for this section. Reports for Sweden, Scotland, and Iceland are easily found. Statistical data that directly refers to the use for the pelagic trawl in Sweden is only available from 1954 to 1963, although there is other data outside this time period for pelagic fisheries. For Scotland, relevant data were recorded primarily between 1961 and 1981, with other data on pelagic fisheries continuing after this time frame. In Iceland statistical data for the pelagic trawl only begins in the 1980s. Each of these countries demonstrates a different snapshot of when and how the pelagic trawl was used, supported by other source material describing the use of the pelagic trawl and its importance.

These three countries have been chosen for several reasons. The availability – and accessibility – of data being the first. Annual statistical reports for Sweden, Scotland, and Iceland are free to view and readily accessible online as pdf reports. At the time of writing, statistical data for Denmark was not available as reports have not yet been digitised. Some data was not relevant; Norway was not included as a review of historical Norwegian fishery statistical reports showed that the purse seine dominated over pelagic trawling almost exclusively. This section also uses sources other than statistical reports which describe the use of the pelagic trawl; here material from Norway, Canada, America, West Germany, France, the USSR, and Poland supplement the statistical data.

These countries were also chosen as they represent different timeframes and stages in the development and use of the pelagic trawl. Sweden was the first country to use the pair

pelagic trawl and has some statistical data for its use, albeit for a limited timeframe. Nevertheless, it is enough to provide a window into the early use of the pair pelagic trawl in the North Sea and Baltic Sea, as well as the Skagerrak and Kattegat. Scotland was chosen as it adopted the pelagic trawl on large scale very quickly, alongside the purse seine. This allows for a direct comparison of productivity and output, as well as an assessment of external factors that affect the use of these fishing methods after they were adopted. Finally, Iceland was chosen as a late-comer to pelagic trawling, despite the method being well known in Iceland for several decades prior (and its prior role as a niche fishing method). There is sufficient statistical data which can be used to compare the pelagic trawl to other fishing methods and to determine the extent of its use compared to those established fishing methods. With this, it is possible to examine the factors that prevented it being used on a larger scale earlier and what changed in Icelandic fisheries.

Many of the scientists and gear technologists from these countries shared their experiences and experiments, either by publishing or participating in larger community of individuals and organisations dedicated to fisheries gear technology. They are valuable sources on the use of the pelagic trawl, despite lacking the data that would allow for meaningful quantitative analysis. This allows insight into the factors that affect the use of the pelagic trawl. Of course, these supplemental sources should be considered in the context of the time. East Germany and Poland were part of the Soviet Bloc until the late 1980s and their economic model was vastly different. The economic significance of the pelagic trawl to these nations was therefore very different. As a result, this section is heavily focussed on western Europe and western economies, supplemented with additional information from other countries.

### 3.1 The Intensification of Pelagic Fisheries

Examining the intensification of pelagic fisheries is the first stage in understanding the context in which the pelagic trawl was used, and if it was successful – or not. The first known use of a pelagic trawl was in the herring fisheries of Sweden, of the North Sea and the Kattegat and Skagerrak. The European herring fisheries were one of the first systematically over-exploited fisheries, leading to near total stock collapse. The pelagic trawl enabled overfishing in the North Sea during the 1950s and 1960s. The ensuing collapse of the herring stocks in the late 1960s and early 1970s changed fisheries in two ways. Firstly, in the search for a replacement fishery, and secondly, in implementing measures to ensure stock collapse was not repeated. Stock collapse and the need to adapt as a consequence also changed how nations viewed the ownership of fishing grounds. The subsequent expansion of territorial waters can be linked directly to the need to protect fisheries and, as importantly, restrict access to them.

The technological advances of the 1960s and 1970s, combined with stock collapse and newly formed restrictions on fishing grounds, saw changes in how and where fishing took place. These restrictions brought fishermen either much closer to home or pushed them further out into international waters. There was a need to replace the herring fisheries, which was largely achieved with the abundant capelin stocks which were caught in the same fishing areas with the same fishing gear. Atlantic redfish and blue whiting continued to be fished but these catches were dwarfed by the volume of capelin caught. Capelin was, and still is, the replacement fishery for herring. Herring was fished for again when the stocks were assessed and deemed sufficiently recovered to allow commercial fishing, with catches increasing since the 1990s. Despite recovering, herring is still subject to strict regulation and, like all fish stocks, is closely monitored by the countries that exploit them.

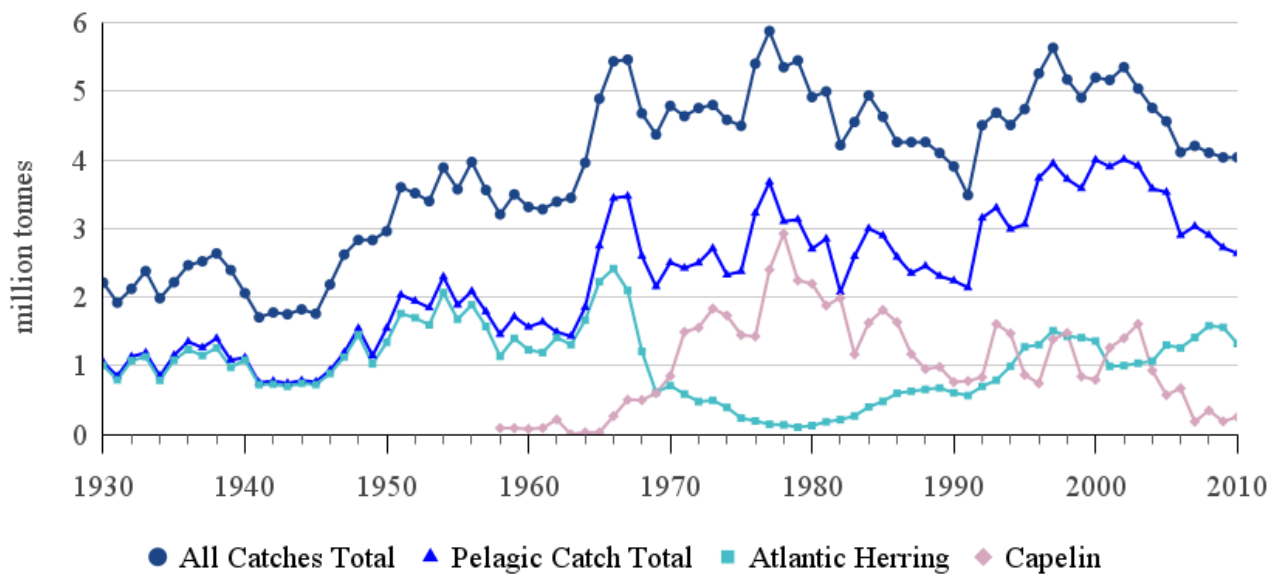
This chapter examines the pelagic fisheries in northern Europe before focusing on the herring fisheries. Herring was overwhelmingly the most dominant all of the pelagic fisheries until the 1960s. The redfish fishery around Iceland, for which there is little qualitative data, is also explored. This is followed by a discussion on overfishing, in particular that of the herring stocks, and of the consequences of that overfishing. These consequences include the implementation of strict quota systems and regulations on fishing gear, as well as the expansion of territorial waters, both of which had a serious impact on how fishermen would approach the surviving pelagic fisheries. These consequences are key to understanding the significance of pelagic fisheries and the role of the pelagic trawl. Limitations placed on fishing affected the value of the catch, so maximising catches by seeking multiple alternatives, such as capelin and blue whiting, became important. The value of pelagic fisheries is explored further in the chapter on output, which discusses the products that were derived from pelagic fisheries.

### 3.1.1 Intensification

Selected catches made by West Germany, Iceland, Norway, Sweden, and Scotland are shown in figure 34. It presents their combined catch for all species (all catches total), the combined pelagic species (pelagic catches total), herring, and capelin. What is clear is that until the mid-1960s almost all of their pelagic catch was comprised of herring. Between the mid-1970s and the early 1990s herring was replaced with capelin. While other pelagic fish species were also caught, they were not as important as herring and capelin.

Fishing intensified in the decades following the Second World War, with intermittent slumps in catches as fish stocks became increasingly overexploited. This is seen in the Norwegian approach to herring fisheries. Large catches were made at the start of the fishing season, followed by a short period of recovery, before even larger catches were made in the same season. This led to an inevitable collapse of fish stocks. A similar pattern is seen with capelin in Iceland (this is discussed further later on). However, in Iceland a well-timed intervention in the 1980s prevented a collapse of the capelin stocks.

Figure 34. Pelagic fish catches in FAO area 27 for selected countries, 1930–2010



Notes: Catch total are for the countries Iceland, Norway, Scotland, Sweden, West Germany (1945-1990), and Germany (1930-1945 & 1990-2010).

Pelagic Catch Total comprises of herring, capelin, sprat, mackerel, blue whiting, Atlantic redfish.

Sources: ICES historical landings dataset, 1904-1949; ICES historical landings dataset, 1950-2010.

Increase in catch volume over the twentieth century is attributed to two factors. Firstly, the need to identify and exploit reliable food resources, and secondly, the swift development of fisheries technology. Identifying reliable food sources was a core mission of the Food and Agriculture Organization (FAO), which was founded in 1946.<sup>399</sup> The Fisheries Department of the FAO was also established in 1946, with three branches:

<sup>399</sup> Shaw, World Food Security, 3–4.

fisheries biology, fisheries technology, and fisheries economics.<sup>400</sup> By 1970 this had evolved into several new divisions, including the Fishing Industries Division, whose responsibilities included dealing with fishing gear and fishing boats.<sup>401</sup> In these decades the FAO provided the means to investigate fishing gear and to undertake research and experiments into making improvements. One of the types of gear to benefit from this was the pelagic trawl. In the decades following the Second World War improvements in fisheries technology, including fishing gear, increased efficiency. Additionally, there were few restrictions and no quota systems for catches.

In the 1950s fishing boats were modernising. New boats were often built with the capability to use multiple fishing gears, depending on the target species or fishing conditions. They used pelagic trawls to mainly catch herring and sprat. Swedish fishermen lagged behind, using smaller boats and staying close to home, fishing in the North Sea and in the Kattegat and Skagerrak. They did use the purse seine to fish for herring in Icelandic waters, although the annual statistical reports from Statistiska Centralbyrån<sup>402</sup> show that their participation in the Icelandic herring fishery declined to almost nothing over the 1950s (and they never used the herring bottom trawl or pelagic trawl there). This decline is mirrored by the rising popularity of the pelagic trawl in the North Sea and the Kattegat and Skagerrak. The statistical data shows that large volumes of herring were caught with pelagic trawls.

In Scotland, the pelagic trawl was widely adopted alongside the purse seine as part of a well-funded scheme between 1961 and 1980 to modernise the fishing fleet. Both types of gear seem to have been equally popular, although the purse seine became the gear of choice by the end of the 1970s. Herring was primarily caught with either the purse seine or the pelagic trawl and it is clear that their adoption made large catches possible. However, they were subject to restrictions and quotas from an early date.

In Iceland, the pelagic trawl was known and occasionally used from the 1950s onwards, although the purse seine dominated pelagic fisheries in Iceland until the 1990s. Icelandic fishermen did use pelagic trawls to catch some sub-species of redfish which could not be caught by other means. However, this was a small fishery. From the mid-1990s, the pelagic trawl was used to catch blue whiting, capelin, and herring in Iceland, although it did not replace the purse seine. Other nations, including West Germany and other nations in Eastern Europe, also participated in this fishery using pelagic trawls. Iceland instituted quotas and fishing restrictions following the collapse of the herring stocks in the 1960s. This has restricted the volume of fish caught with pelagic trawls in Iceland.

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<sup>400</sup> Phillips, FAO, Its Origins, Formation, and Evolution, 1945-1981, 133.

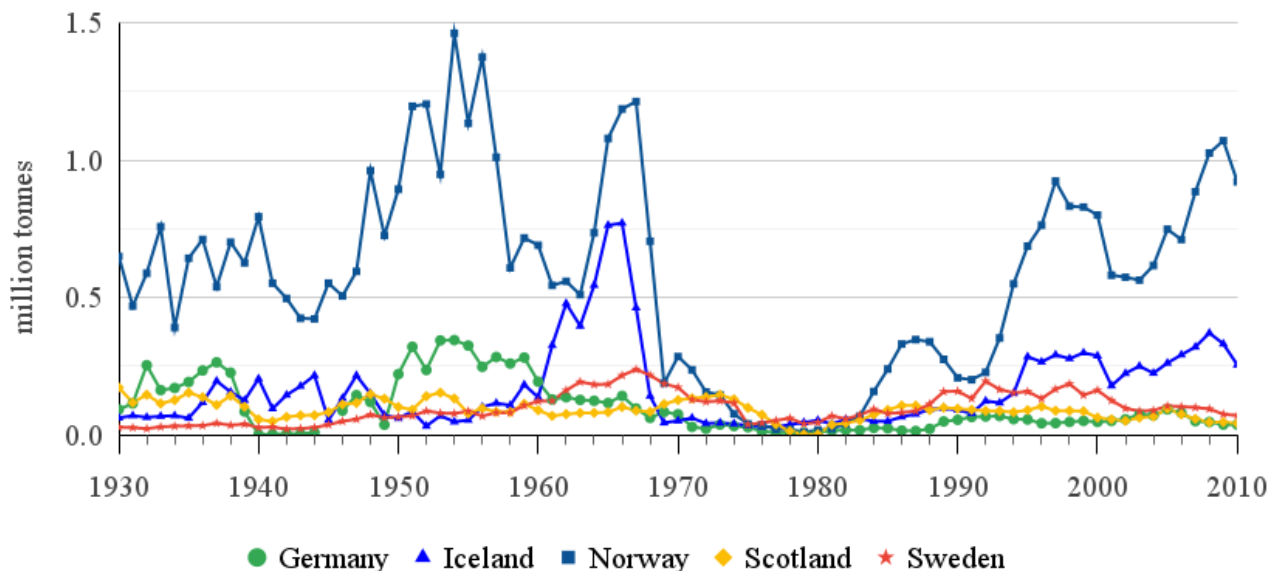
<sup>401</sup> Phillips, 133.

<sup>402</sup> SCB or Central Bureau of Statistics

### 3.1.2 Herring

Herring was the dominant pelagic fishery until the late 1960s. There were several separate herring stocks and fishing grounds; herring was fished in the Baltic Sea, the North Sea, the Skagerrak and Kattegat, around Iceland, the Norwegian Sea, the Barents Sea, as well as inshore waters around Denmark, Iceland, and the UK. The biggest herring stocks were the Atlantic-Scandian stock (also called the Norwegian herring stock) and the North Sea stock. Most herring stocks migrate; the Atlanto-Scandian herring migrate from Norway to Iceland annually, although this was not proved until the 1950s.<sup>403</sup> The same Atlanto-Scandian herring stock was fished in Norway during the winter months, and then in Iceland during the summer months. North Sea herring migrated north to south over the summer months, from the islands of northern Scotland, heading down to the British Channel.

Figure 35. Herring catches in FAO area 27, 1930-2010



Notes: Catch data for Germany comprises of West Germany (1930-1989) and Germany (1990+).

Sources: ICES historical landings dataset, 1904-1949; ICES historical landings dataset, 1950-2010.

Herring catches from 1930 onwards are shown in figure 35. While there are minor fluctuations year to year, there are two significant points that require explanation. The first significant point corresponds to the Second World War, which had a considerable effect on fisheries in Europe. Many fishing boats were requisitioned, although the fishing fleets of Nordic nations largely escaped requisition<sup>404</sup> and continued to fish. Those that attempted to fish were hampered by mines in the North Sea, the Baltic Sea, and the Skagerrak and Kattegat. Norway and Denmark, which Germany occupied during the Second World War, were key sources of fish products for Germany<sup>405</sup> during this time, although their catches were clearly not as high as pre-war. This temporary cessation in fishing did allow fish stocks

<sup>403</sup> Østvedt, 'Catch, Effort and Composition of the Norwegian Winter Herring Fishery', 109.

<sup>404</sup> Holm, 'World War II and the "Great Acceleration" of North Atlantic Fisheries', 70.

<sup>405</sup> Holm, 73-74.

to recover.<sup>406</sup> The second significant point is the decline of the herring stocks from the mid-1960s and its eventual collapse in 1969, which affected all countries participating in the herring fisheries. This was due to the failure of the winter Atlanto-Scandian herring, following intense fishing post-war.

Overall, there was an increase in catches in the herring fisheries from the end of the Second World War onwards, despite the decreased catches in Norway from 1958 to 1963. Overfishing was considered a factor as early as the inter-war period when increased fisheries productivity was connected to the four-year cessation of fishing during the First World War.<sup>407</sup> The ICES Herring Committee, which reported the research of its members, speculated as early as the 1950s that there could be a potential decline in herring catches due to changes in environment, behaviour, or migratory patterns of the fish.<sup>408</sup> However, overfishing was not specifically mentioned as a potential cause at this time.

How much of this can be attributed to the pelagic trawl is unknown and unlikely to be known definitively. Norway, the single biggest exploiter of Atlantic herring, preferred to use purse seines and drift nets,<sup>409</sup> although pelagic trawling was undertaken in rare instances. The same was true of Iceland, where the purse seine was the predominate fishing gear for herring until the 1990s. Sweden used the pelagic trawl and while the proportion of the total catch caught with specific gear types is not recorded, about half of Swedish herring catches in the late 1950s were made with pelagic trawls.<sup>410</sup>

Similarly, no catch volume by gear type is available for West Germany. Pelagic trawling for herring was undertaken in the northwest Atlantic, around Iceland, and around Greenland from the mid-1970s.<sup>411</sup> This was following trials of new big-mesh trawls. One third of West German trawlers were using it in 1972 and in 1973 all of them were.<sup>412</sup> Denmark was reported by one observer as mostly using pelagic trawls for herring by the late 1960s,<sup>413</sup> but there are no statistical data to support this. Scotland used the pelagic trawl for herring and sprat from the mid-1960s onwards. However, annual statistical reports show until the 1990s that the most caught by pelagic trawls in any one year was a little less than 84,000 tonnes. The pelagic trawl was initially popular but quickly replaced by the purse seine. The pelagic trawl was used extensively, but never exclusively.

There was an increase in the use of the pelagic trawl from the late 1940s onwards. By 1960 the pelagic trawl was well known to the major fishing nations of Europe, and the use of the pelagic trawl was established in many. Between 1950 and 1970 it is reasonable to suggest that at least 50% of herring in the North Sea was caught with a pelagic trawl. The

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<sup>406</sup> Gemert and Andersen, 'Challenges to Fisheries Advice and Management Due to Stock Recovery', 1865.

<sup>407</sup> Holm, 'World War II and the "Great Acceleration" of North Atlantic Fisheries', 68–69.

<sup>408</sup> Devold, 'Scandinavian Herring Periods. No. 69', 2–3.

<sup>409</sup> Østvedt, 'Catch, Effort and Composition of the Norwegian Winter Herring Fishery', 111.

<sup>410</sup> Karlsdóttir, *Fishing on Common Grounds*, 104.

<sup>411</sup> Mahnke, Danke, and Schultz, 'Annual Meeting - June 1974: GDR Research Report, 1973', 8.

<sup>412</sup> Mahnke, Danke, and Schultz, 8.

<sup>413</sup> Johnson, 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966', 34.

pelagic trawl was mainly used in the North Sea at this time. It saw far less use in the North Atlantic as the nations which dominated these herring fisheries used purse seines almost exclusively. By reviewing available statistical records for northern Europe, it can be reasonably estimated that between 15% and 25% of the herring caught in the North Atlantic were caught with pelagic trawls.

### 3.1.3 Redfish

There are numerous sub-species of Atlantic redfish, also called ocean perch or sea perch. Redfish can be either demersal or pelagic. The golden redfish (*Sebastes norvegicus*) and the beaked redfish (*Sebastes mentella*) are fished commercially. Acadian redfish (*Sebastes fasciatus*) was considered endangered by the 1990s due to overfishing, but has since recovered. It is also difficult to visually distinguish beaked redfish from Acadian redfish. There was a marked increase in redfish catches in the 1930s, attributed to the development of freezing techniques which allowed for it to be preserved and marketed.<sup>414</sup> There was a high demand for redfish in West Germany as it was a popular Friday meal.<sup>415</sup> It was sold in a variety of forms, including frozen, fresh, smoked, and salted.<sup>416</sup>

Golden redfish is a demersal fish, although it does ascend in the water column during daylight hours to feed. The beaked redfish is found in three distinct populations, of which two are pelagic. Of these two pelagic beaked redfish populations, one occupies shallower waters of less than 500 metres<sup>417</sup> and the other occupies deep pelagic waters far deeper of up to 1000 metres deep.<sup>418</sup> This area of very deep waters, off the continental shelf between Iceland and Greenland, is the Irminger Sea. These fishing conditions make the pelagic trawl the only effective fishing method for redfish.

Figure 36 shows all redfish catches for FAO area 27 (which includes the Irminger Sea). There is a serious issue with these data, however, as for much of the twentieth century many nations did not differentiate between the sub-species of redfish.<sup>419</sup> Pelagic redfish were known in the late 1940s<sup>420</sup> and the beaked redfish was identified in 1951.<sup>421</sup> Further research was conducted in the 1960s to understand the ecosystem and fish populations of the northwest Atlantic, including the waters off Iceland, Greenland, Canada, and the Irminger Sea. It was then that the various sub-species and populations of redfish were fully identified, defined, and studied.

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<sup>414</sup> Kelly et al., 'Fishery Facts-1', 16–18.

<sup>415</sup> Hjaltason, 'Iceland and the German Fish Market 1950-1990: Did Germany Get the Fish It Needed after the 200-Mile Extension?', 278.

<sup>416</sup> Kelly et al., 'Fishery Facts-1', 16–18.

<sup>417</sup> Baranowska et al., 'NWWG 2021: Full Report', 1.

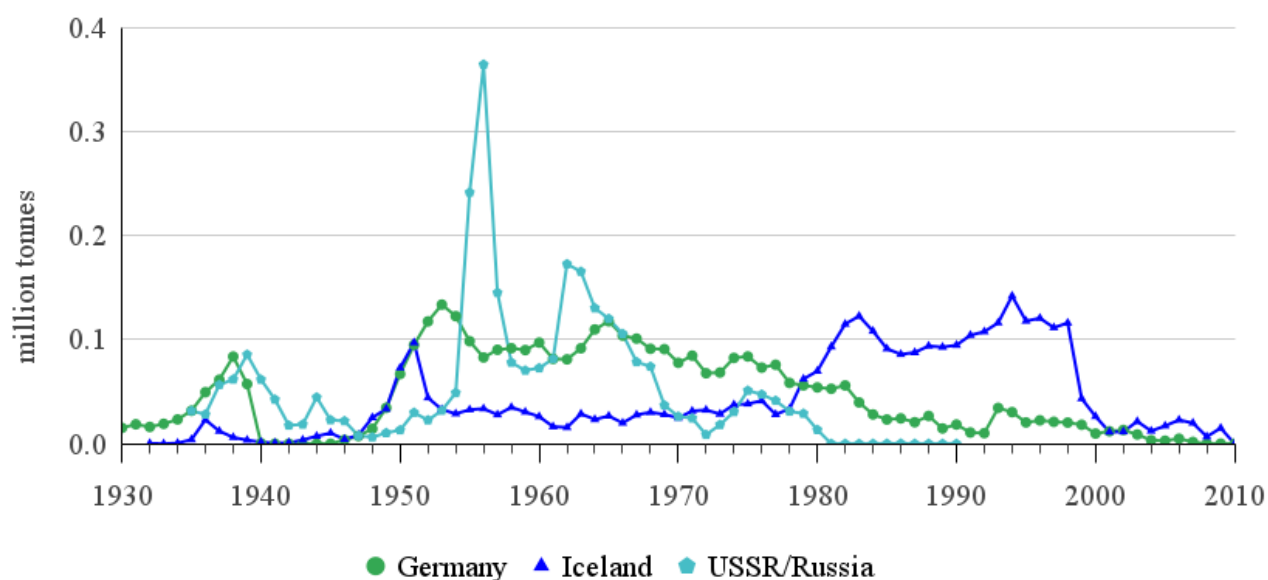
<sup>418</sup> Sigurðsson et al., 'The Fishery for Pelagic Redfish (*Sebastes Mentella*) in the Irminger Sea and Adjacent Waters', 729.

<sup>419</sup> Kelly, Barker, and Westheim, 'Racial Comparisons of Redfish from the Western North Atlantic and the Barents Sea', 28.

<sup>420</sup> Tåning, 'On the Breeding Places and Abundance of the Red Fish (*Sebastes*) in the North Atlantic', 95.

<sup>421</sup> Travin, 'A Brief Survey of Soviet Investigations in Redfish (Genus *Sebastes*)', 90.

Figure 36. Atlantic redfish catches in FAO area 27, 1930-2010



Notes: Atlantic Redfish includes *Sebastes mentella*, *Sebastes norvegicus*, *Sebastes fasciatus*, and *Sebastes marinus*.

Nations with catches of less than 60,000 tonnes are omitted.

Catch data for Germany comprises of West Germany (1930-1989) and Germany (1990+).

Catch data for Russia comprises of the USSR (1930-1991) and the Russian Federation (1992+).

Sources: ICES historical landings dataset, 1904-1949; ICES historical landings dataset, 1950-2010.

Separate catch statistics for redfish sub-species were not recorded immediately. When examining the raw data in the ICES historical catch dataset, the largest category was still 'redfishes nei' up until the late 1990s.<sup>422</sup> Poland began recording sub-species separately in the 1970s. There are some West German records for different sub-species starting in the 1980s. Icelandic catches of beaked and golden redfishes were only recorded separately starting in 1994<sup>423</sup> while the USSR and Norway did not differentiate catches until 2000. The identification of beaked redfish created a new fishery, one that could only be exploited by pelagic trawls. However, as explained previously, it is a fishery impossible to distinguish in the catch statistics. As a result, the redfish catches shown in figure 36 are for all redfish – all sub-species, pelagic and demersal, combined. Norway and Sweden are not represented in figure 36, as Norway consistently caught fewer than 20,000 tonnes annually until the late 1980s. Sweden caught only a few tonnes annually, most likely bycatch.

ICES catch statistics also show catch by zones within area 27. They show that catches by Icelandic fishermen were largely made in Icelandic waters. Catches by the USSR were largely made in and around the Irminger Sea. West Germany fished in Icelandic waters until 1977, when Iceland expanded its territorial waters.<sup>424</sup> West German fishermen began fishing for redfish in the Irminger Sea in the late 1950s and around the Faroe Islands in 1965. However, these catches were much smaller than those made in Icelandic waters.

<sup>422</sup> see various country entries for redfish in ICES, 'DATASET COLLECTIONS: Catch Statistics'.

<sup>423</sup> Jakobsson, 'Deep Water Fisheries at Iceland', 7.

<sup>424</sup> Kristinsson and Sigurdsson, 'Review of the Fishery, Biological Research, Assessment and Management of Golden Redfish (*Sebastes Marinus*) in Icelandic Waters', 3-4.

There is no data for the type of fishing gear used prior to 1990. American<sup>425</sup> and Canadian<sup>426</sup> fishermen used bottom trawls for redfish, at least in the 1950s, although they considered pelagic trawls as a possibility for the future.<sup>427</sup> It is unlikely that other nations were using different methods in the same waters; therefore, it is highly unlikely that anyone was using pelagic trawls to catch redfish in the 1950s or early 1960s. However, by the late 1950s research was being carried out to determine the extent and location of pelagic populations of redfish.<sup>428</sup>

The use of pelagic trawls for redfish began in the 1960s, with records from the International Commission for the Northwest Atlantic Fisheries showing that West Germany was using pelagic trawls for redfish in 1970.<sup>429</sup> Their reports are focussed on the waters of and around the Labrador Sea, which are outside of the ICES catch areas which form the basis for the ICES catch statistics. Sadly, their reports do not differentiate between bottom and pelagic trawling before this date – bar the year 1961 – so it is uncertain if they were used earlier. For the year 1961, the only recorded use of the pelagic trawl is by the USSR for catching herring.<sup>430</sup> The reports of the 1970s show that East Germany and the USSR did not begin to use the pelagic trawl in the Labrador Sea until 1973<sup>431</sup> and 1974<sup>432</sup> respectively, and that they continued to use the bottom trawl as well.

However, whether this preceded or followed the use of the pelagic trawl in the Irminger Sea is unknown. From the 1961 report, we know that the USSR was using pelagic trawls, albeit for herring. For the USSR, pelagic trawls were appealing as they allowed older boats to continue to operate. Older boats struggled, lacking the power required to tow bottom trawls but could cope with pelagic trawls, as they had less drag. Additionally, large volumes of redfish could be caught in relatively short tows using a pelagic trawl.<sup>433</sup>

The pelagic populations of beaked redfish (*Sebastes mentella*), when identified, created a new fishery. Trials around Iceland in 1968 (with a specially designed bottom trawl) suggested that a pelagic fishery for redfish was feasible.<sup>434</sup> This was followed by several West German trawlers fishing commercially in 1969 but their total catch was only about 3400 tonnes<sup>435</sup> and subsequent catches made by West German and Soviet fishermen declined from the mid-1960s onwards. This can be attributed to a combination of overfishing for Acadian redfish and the expansion of Iceland's territorial waters in the late 1970s. In contrast, Iceland's catches of redfish increased in the 1970s and remained

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<sup>425</sup> Kelly et al., 'Fishery Facts-1', 14.

<sup>426</sup> Templeman, 'Redfish Distribution in the North Atlantic', v.

<sup>427</sup> Kelly et al., 'Fishery Facts-1', 15–16.

<sup>428</sup> Kelly et al., 3.

<sup>429</sup> International Commission for the Northwest Atlantic Fisheries, 'Statistical Bulletin Vol. 20 for the Year 1970', 103.

<sup>430</sup> International Commission for the Northwest Atlantic Fisheries, 'Statistical Bulletin Vol. 11 for the Year 1961', 82.

<sup>431</sup> International Commission for the Northwest Atlantic Fisheries, 'Statistical Bulletin Vol. 23 for the Year 1973', 233–34.

<sup>432</sup> International Commission for the Northwest Atlantic Fisheries, 'Statistical Bulletin Vol. 24 for the Year 1974', 242–43.

<sup>433</sup> Cadigan et al., 'Northwest Atlantic Redfish Science Priorities for Managing an Enigmatic Species Complex', 1579–80.

<sup>434</sup> Schärfe, 'The German One-Boat Mid-Water Trawl', 10.

<sup>435</sup> Schärfe, 6.

high until the late 1990s. Statistical data shows that the pelagic trawl was one of two types of gear used in the 1990s, although it was not as popular as the bottom trawl and was subsequently replaced by it. The pelagic beaked redfish population was not as productive a fishery as the demersal population.

The introduction of quotas in 1984 applied to a several species,<sup>436</sup> including redfish. Pelagic trawls made by Engel in West Germany were used by Icelandic research scientists in the 1960s<sup>437</sup> and 1980s.<sup>438</sup> Advertisements in Icelandic magazines for Engel pelagic trawls (ordered via Icelandic netlofts) begin in 1973,<sup>439</sup> although they did not state the species that could be caught with them. In the late 1980s the Icelandic netloft Hampiðjan developed the Gloria trawl to catch beaked redfish in order to compete with Engel.

Iceland has no statistical data for fishing by method or types of fishing gear prior to the 1990s. However, from the 1990s onwards they show that pelagic trawls were not the primary fishing gear. In the 1990s, only around a third of the total redfish catch was caught with pelagic trawls, with the rest caught with bottom trawls.<sup>440</sup> In the twenty-first century bottom trawls were used almost exclusively.

### 3.1.4 Capelin and Blue Whiting

Capelin and blue whiting were not caught in large numbers before the 1960s. This changed following the collapse of the herring stocks, when a replacement fishery was needed to supply the reduction industry.<sup>441</sup> While capelin is now appreciated as a fish for human consumption it was initially fished for reduction. Capelin roe was favoured as a foodstuff and classified separately in Icelandic fisheries statistics. Blue whiting was only fished for reduction. Capelin catches are shown in figure 37. The USSR used both purse seines and pelagic trawls. Iceland favoured the purse seine, with the pelagic trawl used from the 1990s onwards. Norway preferred the purse seine almost exclusively, as there was an idea among Norwegian fishermen that pelagic trawls could damage capelin eggs during spawning.<sup>442</sup> Norway and the USSR caught capelin in the Norwegian Sea and the Barents Sea. Iceland caught capelin mostly in its own waters with the purse seine and banned capelin fishing between 1982 and 1983.<sup>443</sup> There was a stock collapse in the Barents Sea in the early 1990s due not to overfishing but to other environmental factors.<sup>444</sup>

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<sup>436</sup> Pálsson and Helgason, 'Figuring Fish and Measuring Men: The Individual Transferable Quota System in the Icelandic Cod Fishery', 4.

<sup>437</sup> Magnússon, 'Redfish Larvae in the Irminger Sea in May 1961', 1.

<sup>438</sup> Jakobsson, 'The Irminger Sea Oceanic Stock of Redfish "Spawning" and "Spawning" Area.', 2–3.

<sup>439</sup> Sandfell hf, 'Sandfell HF', 3.

<sup>440</sup> Hafrannsóknastofnun, 'Djúpkarfi: *Sebastes mentella*', 13.

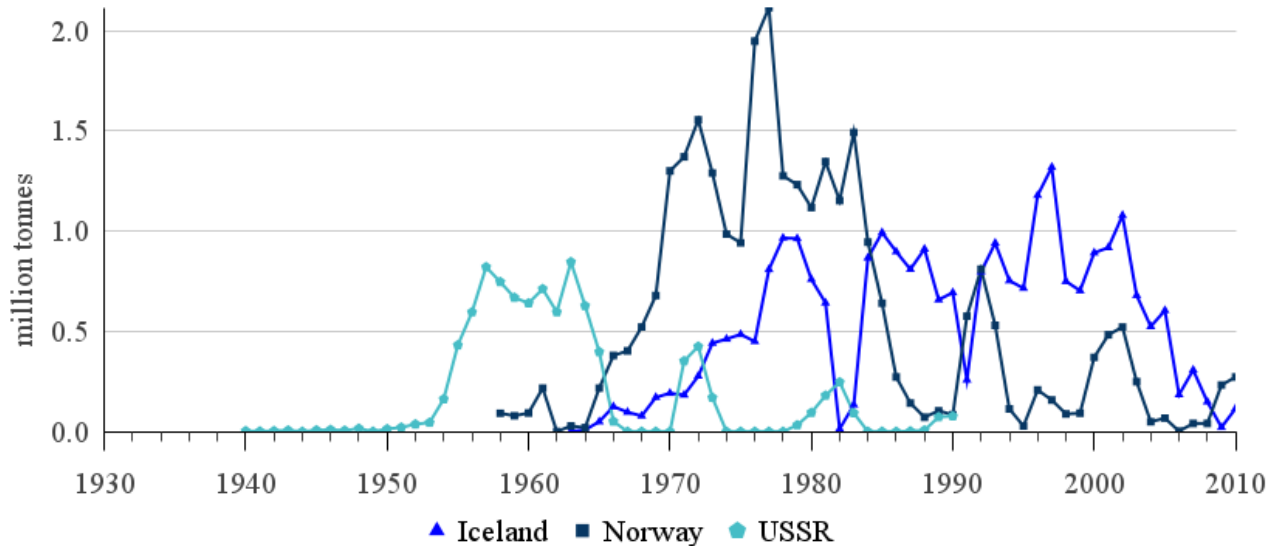
<sup>441</sup> Bailey, 'The Population Biology of Blue Whiting in the North Atlantic', 258.

<sup>442</sup> Bakke and Bjørke, 'Diving Observations on the Barents Sea Capelin at Its Spawning Grounds off the Coast of Northern Norway', 6.

<sup>443</sup> Vilhjálmsson, 'Biology, Abundance Estimates and Management of the Icelandic Stock of Capelin', 153.

<sup>444</sup> Gjøsæter, 'Pelagic Fish and the Ecological Impact of the Modern Fishing Industry in the Barents Sea', 277.

Figure 37. Capelin catches in FAO area 27, 1930-2010



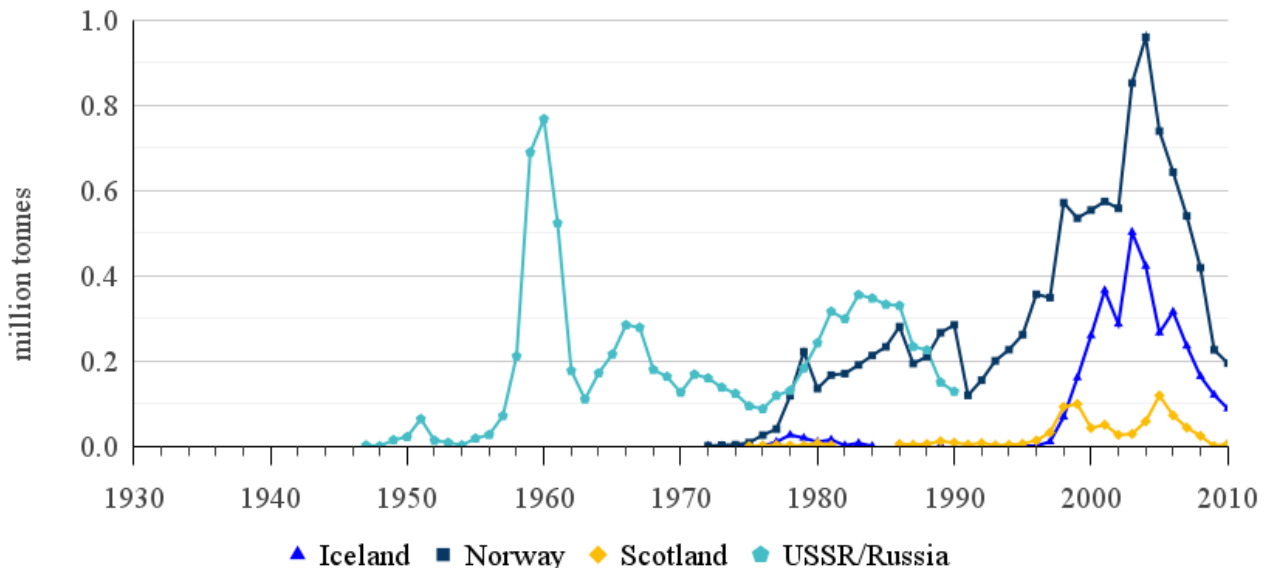
Notes: Nations with catches of less than 60,000 tonnes are omitted.

Catch data for Russia comprises of the USSR (1930-1991) and the Russian Federation (1992+).

Sources: ICES historical landings dataset, 1904-1949; ICES historical landings dataset, 1950-2010.

The blue whiting fishery was exploited by the USSR before Norway and Iceland began to catch large volumes, as shown in figure 38. Norwegian fishermen ventured to a variety of fishing grounds to catch blue whiting, initially in the areas to the west of Britain. Later, Iceland and the North Sea were fished. Pelagic trawls were used in Norway for catching blue whiting in the 1970s<sup>445</sup> but the purse seine was still preferred.<sup>446</sup> Iceland focused on its own fishing grounds, where the purse seine dominated the fishing industry overall.<sup>447</sup>

Figure 38. Blue whiting catches in FAO area 27, 1930-2010



Notes: Nations with catches of less than 60,000 tonnes are omitted.

Catch data for Russia comprises of the USSR (1930-1991) and the Russian Federation (1992+).

Sources: ICES historical landings dataset, 1904-1949; ICES historical landings dataset, 1950-2010.

<sup>445</sup> Karlsten, 'Development and Testing Rope and Large Meshed Midwater Trawls in Norway', 1.

<sup>446</sup> Olsen, 'Some Results of the Norwegian Capelin Investigations 1960-1965', 18.

<sup>447</sup> Hagstofa Íslands.

### 3.1.5 Overfishing and Regulation

The collapse of the herring stocks created an economic recession in Iceland and caused significant economic hardship for many fishermen in Europe. In the 1970s fishing for Atlanto-Scandian herring was either banned or subject to a strict quota system. Iceland and Norway sought alternative fisheries, one of which was capelin. While herring was caught for reduction and human consumption, initially capelin was only caught for reduction. Capelin catches quickly exceeded those of herring, with Norway catching over two million tonnes in 1977 and Iceland catching a little less than a million tonnes in 1979.

By the early 1980s overfishing was recognised as a threat to capelin stocks. Regulations regarding capelin were instituted by Iceland, Norway, and the USSR by the end of the decade.<sup>448</sup> It was overfishing that led to the collapse of the herring stocks in the 1960s and almost certainly to the near collapse of capelin stocks in the early 1980s. A decline in herring stocks had been noted by the late 1950s, becoming the subject of research by the early 1960s<sup>449</sup> by a number of scientists, many of whom contributed research to the ICES Herring Committee. Until the 1960s, the nature of research conducted on herring hampered the ability of scientists to adequately assess the extent or cause of decreasing herring stocks.<sup>450</sup>

Overfishing was recognised as an obvious factor in the decline of herring stocks as early as the First World War. However, a 1965 ICES Herring Committee report on Icelandic herring stocks mentions this idea only in passing<sup>451</sup> and predicts that the stock will recover. In early 1969 an ICES report from Iceland discussed the regulations that were introduced in the mid-1960s to prevent herring smaller than 25cm<sup>452</sup> from being caught. However, this same report of 1969 clearly states that 'overfishing' has not yet occurred, as the herring stock was still considered sustainable. As the drop in catches from the mid-1960s demonstrates (see figure 35), this was clearly not the case. Studies at this time were keen to investigate whether environmental factors were to blame rather than overfishing, showing that there was some significant uncertainty and debate over the matter. This uncertainty was further compounded by the collapse of other herring stocks at the same time. In the 1970s fishing for herring was either banned or subject to a quota system<sup>453</sup> as agreed by the principal nations involved: Iceland, Norway, the USSR, and the UK.

The exploitation of pelagic species was driven by demand from the reduction industry. Much of the pelagic fish caught were reduced into oil and meal, which were relatively cheap products. Large quantities of unprocessed fish are required for reduction. It takes

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<sup>448</sup> Hopkins and Nilssen, 'The Rise and Fall of the Barents Sea Capelin (*Mallotus Villosus*)', 535–36.

<sup>449</sup> Federov, Truskanov, and Yudanov, 'On the Stock Size of the Atlanto-Scandian Herring', 1–2.

<sup>450</sup> Karlsdóttir, *Fishing on Common Grounds*, 21–24.

<sup>451</sup> Jakobsson and Vilhjálmasson, 'Some Remarks on the Icelandic Herring Stocks', 1 & 5.

<sup>452</sup> Jakobsson, 'On the Icelandic Herring Stocks and Their Exploitation', 6.

<sup>453</sup> Arnason and Runolfsson, 'The Effects of Introducing Transferable Property Rights on Fleet Capacity and Concentration of Ownership of Harvesting Rights in the Iceland's Fisheries', 33.

approximately 4.5kg of fish to produce 1kg of meal,<sup>454</sup> an average yield of about 22%,<sup>455</sup> and at least 21kg of fish is needed to produce 1kg of fish oil. Herring and other pelagic fish have a high oil yield and are ideal for reduction. Oil can be obtained from the same volume of fish which can then be processed into meal. Additionally, offal and other waste material from fish processing can also be reduced. While the reduction industry demanded large volumes of fish, it was highly processed and so the quality of the catch was largely irrelevant.

Iceland recognised the imminent danger of overfishing with capelin<sup>456</sup> and instituted a quota system in 1980,<sup>457</sup> which became transferrable in 1986. Norway and the USSR, in joint agreement, closed the capelin fishery in the Barents Sea in 1987 and 1988<sup>458</sup> to protect the stock; the decline in capelin catches for Norway started in the early 1980s. Norway also legislated restrictions on fishing in Norwegian waters in 1972.<sup>459</sup> This can be interpreted as a ban on some pelagic trawling. Anecdotal sources state that this was a direct result of German boats using pelagic trawls in Norwegian waters too successfully, resulting in the ban.<sup>460</sup>

In 1976 Iceland successfully extended its borders to 200 nautical miles, the result of several decades of intermittent dispute which was largely premeditated by Iceland's desire to control access to fish stocks in its waters. In 1982 the UN Convention on the Law of the Sea formally adopted the 200nm limit as an exclusive economic zone (EEZ)<sup>461</sup> for all countries, ending the conflict in Iceland's favour and giving other nations the opportunity to restrict fishing in their waters to the same effect.

The pelagic trawl enabled overfishing in the North Sea considerably, as the pelagic trawl caught large quantities of herring more quickly than the bottom trawl; the greater efficiency of the pelagic trawl as compared to the herring bottom trawl will be discussed further in the following chapters. At least 50% of herring catches by Swedish fishermen in the North Sea were made with pelagic trawls. It must be noted, however, that the Atlanto-Scandian herring was also overfished leading to collapse, but was caught almost exclusively with purse seines. These two different types of fishing gear were used in each environment respectively because they were the optimal type of gear to catch fish in those environments, even though they were both catching herring.

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<sup>454</sup> Boyd, 'Overview of Aquaculture Feeds', 8.

<sup>455</sup> 'The Production of Fish Meal and Oil'.

<sup>456</sup> Hopkins and Nilssen, 'The Rise and Fall of the Barents Sea Capelin (*Mallotus Villosus*)', 544.

<sup>457</sup> Arnason and Runolfsson, 'The Effects of Introducing Transferable Property Rights on Fleet Capacity and Concentration of Ownership of Harvesting Rights in the Iceland's Fisheries', 40.

<sup>458</sup> Hopkins and Nilssen, 'The Rise and Fall of the Barents Sea Capelin (*Mallotus Villosus*)', 538.

<sup>459</sup> Norway, Act No. 57 of 1972 regulating the participation in fishery.

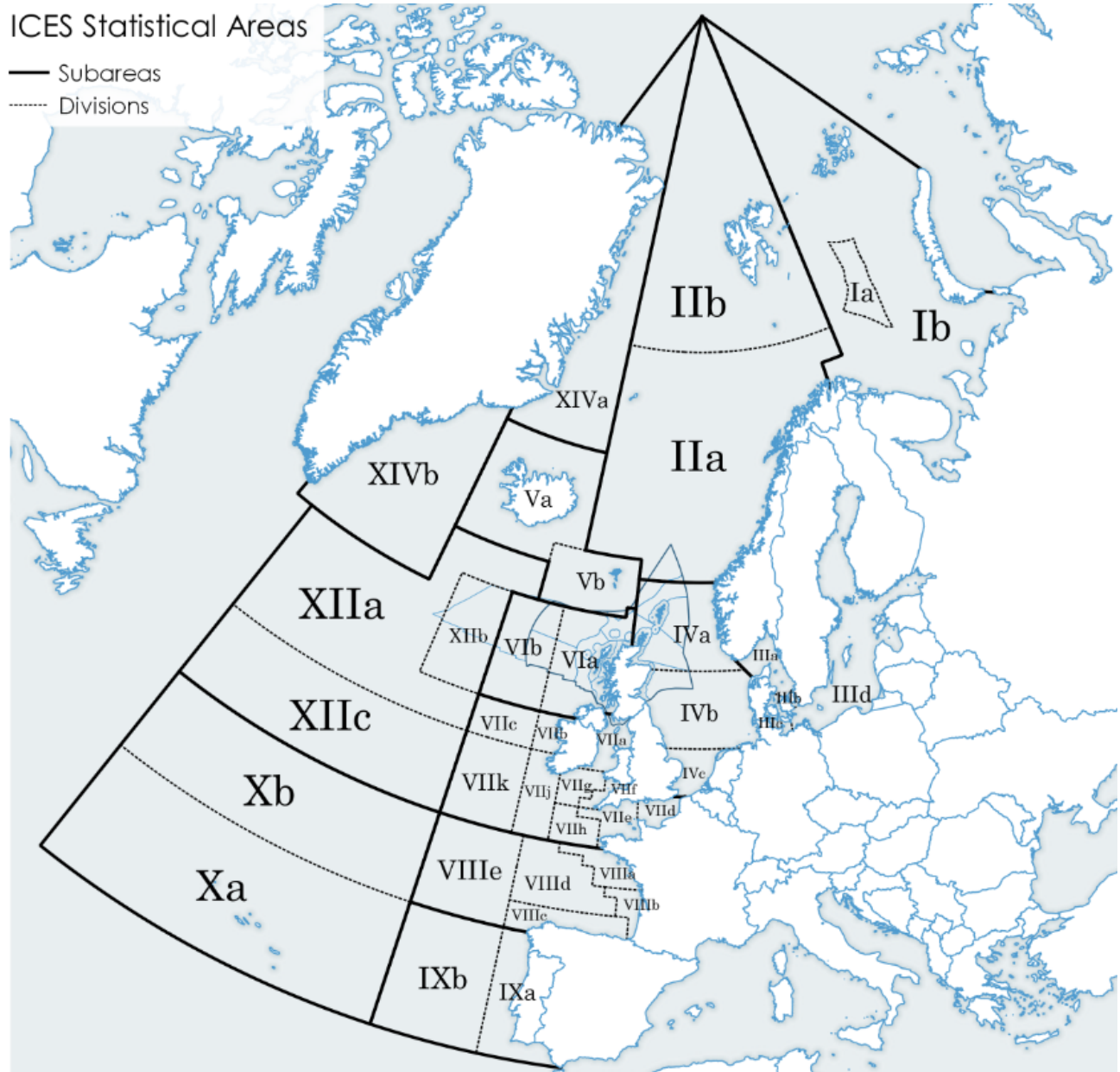
<sup>460</sup> Personal communication with Quentin Bates

<sup>461</sup> Gullestad et al., 'Changing Attitudes 1970–2012', 175.

### 3.1.6 Fishing Grounds

Many nations fished in multiple areas before establishing of the 200nm limit, often participating in seasonal fisheries of other countries, where they also landed catches. The Icelandic summer herring season is one example, with fishermen from Norway, the Faroe Islands, and other European nations participating. Reported landing figures from before 1970 are considered more accurate than those of later years, as earlier catches were not subject to quota restrictions, while later figures may suffer from under-reporting. Earlier figures are, however, less accurate in regards to fishing areas. Fishing areas were frequently amalgamated or were inconsistently tallied from year to year.

Figure 39. FAO Area 27

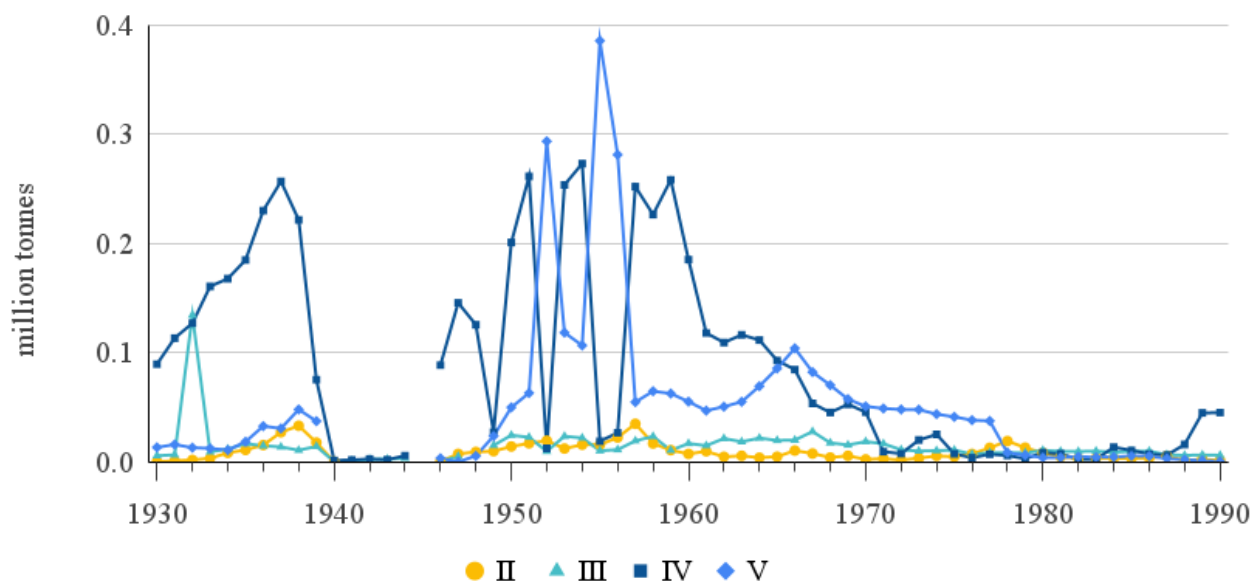


Sources: Marine Scotland, <https://marine.gov.scot/sma/assessment-theme/international-networks>

FAO area 27 (figure 39) was sub-divided into zones I through XIV, each of which was further sub-divided. Catch data is available by zone and this shows the location of certain fisheries, as well as the preferred fishing grounds of each nation. For Iceland, almost all catches were made in Icelandic waters (areas Va and Vb). Norwegian catches were made in the North Sea (area IV) or the Norwegian Sea (area II), with catches made in the Barents Sea (area I) during the 1960s. Scottish fishermen fished in the North Sea (area IV) or off the west coast of Scotland (areas VIa and VIb), with some catches made in Iceland in the 1950s. Sweden made significant catches in the North Sea (area VI), Kattegat and Skagerrak (areas IIIa and IIIb), and the Baltic Sea (area III), but the decade or so between 1965 and 1975 when they primarily focussed on the Kattegat and Skagerrak.

It is possible to see patterns in catches using fishing areas. This is shown in figure 40, which shows the fishing areas for pelagic fish landed in Germany. The main fishing area was the North Sea (IV) until the 1970s, which was largely for herring. There was a spike in catches in the Norwegian Sea (II), again for herring, in the late 1940s. The other main area for fishing was around Iceland (V) until the 1970s, mainly for Atlantic redfish and some herring. Overall, there is a steady decline in fishing for pelagic species from the 1970s onwards, although catches in the Baltic Sea (III) continue. Fishing increases in other areas such as the Baltic Sea, which while not new, saw an increase in the 1970s and 1980s.

Figure 40. German pelagic catches by FAO zones within area 27, 1940-2010



Notes: Zones with catches of less than 30,000 tonnes annually are omitted.

Catch data for Germany comprises West Germany (1930-1989) and Germany (1990+).

Sources: ICES historical landings dataset, 1904-1949; ICES historical landings dataset, 1950-2010.

While Norway favoured the purse seine, drift nets and pelagic trawls were also used. Annual statistical data show negligible catches were made with pelagic trawls, although there are reports of pelagic trawls used around the Faroe Islands to catch blue whiting in the late 1970s.<sup>462</sup> In Iceland, the pelagic trawl was not used systematically until the 1990s.

<sup>462</sup> Isaksen, Jensen, and Olsen, 'Recent Developments on Blue Whiting Trawls in Norway', 1-2.

Fishing almost always within Icelandic waters, Icelandic fishing boats were not able to handle pelagic trawling until this later date. The fishing fleet was comprised of bottom trawlers and purse seiners. The trawlers, which included stern trawlers, were not equipped to handle the large catches made by pelagic trawls as they did not have either the processing capability or hold space. Just as importantly, bottom trawlers did not get a share of the quotas for pelagic fish. The increase in pelagic trawling in the 1990s began when quotas became saleable to bottom trawlers. This was also at the same time as the fishing fleet began to consolidate, with older boats scrapped or sold and replaced with new or second-hand boats capable of handling pelagic trawls.

Sweden mostly fished the North Sea, the Baltic Sea, and the Kattegat and Skagerrak. They used the pelagic trawl extensively to fish in those waters for herring, although it was not as popular in the Baltic Sea. The pelagic trawl was later used by fishermen to catch Baltic herring after the collapse of the other herring stocks, either by those already fishing there or by the west coast fishermen<sup>463</sup> seeking new fishing grounds.

Scotland, fishing in the North Sea and around Scotland, used the pelagic trawl to catch herring. They abandoned it in favour of the purse seine by 1980, at least until the early 1990s. Iceland's response to the collapse of the herring stocks was to expand its territorial waters, as discussed previously.

### 3.1.7 Summary

Catches for pelagic species increased over the course of the twentieth century, except when halted by stock collapse or restrained by the introduction of quotas. This was enabled by the pelagic trawl, particularly in the North Sea for herring. An estimate based on the available data suggests that between 1950 and 1970 as much as 50% of herring in the North Sea was caught using pelagic trawls. Outside of the North Sea, however, the use of the pelagic trawl was much lower, to the point of being negligible. From the 1970s the available statistical data demonstrates a more accurate picture of how, where, and to what extent the pelagic trawl was used.

The pelagic trawl was one tool used to exploit the herring fishery in the North Sea to the fullest extent, to the point of overfishing. However, it was not the cause of overfishing. Rather, it enabled overfishing in the North Sea. The overfishing of herring in the Atlantic was enabled by purse seines and lack of regulations, coupled with a high demand for pelagic fish. Following the implementation of regulations and quota systems, the pelagic trawl was still used, but usually alongside the purse seine.

At least 50% of Sweden's catches of herring in the North Sea were made with pelagic trawls. However, some nations, such as Norway, preferred to use the purse seine almost exclusively. Scotland used the pelagic trawl alongside the purse seine starting in the mid-

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<sup>463</sup> Byron, *Portraits of the Past*, 165–66.

1960s. Here we have definitive data, with the pelagic trawl used for about a decade before being replaced by the purse seine, at least until the 1990s. Iceland was aware of the pelagic trawl and it was used on a very small scale starting in the 1950s, but was not used systematically until the 1970s for pelagic populations of Atlantic redfish. It was only in the 1990s that the pelagic trawl began to equal the purse seine in use for capelin, herring, and blue whiting.

## 3.2 Output

Output is explored in three ways: by examining the proportion of the catch caught with the pelagic trawls, the value of that catch, and the products of the pelagic fishing industry. The volume and value of these catches are compared to other pelagic fishing methods with the intention of understanding the role of the pelagic trawl in pelagic fisheries. The products into which the pelagic catch was processed can be divided into two broad categories; fish intended for human consumption, and fish intended for reduction into oil and meal. The outputs of three countries are presented in detail: Sweden, Scotland, and Iceland. This is largely because they have easily accessible annual statistical reports dating from the nineteenth century onwards. While the ways in which data was recorded (and presented) varied greatly over the years, they typically recorded what happened to catches. This allows us to understand how pelagic catches were utilised and their value.

Herring, sprat, capelin, and blue whiting were all caught in large quantities for reduction from the 1930s onwards. In 1964 over 85% of the Norwegian herring and sprat catch went to reduction.<sup>464</sup> The reduction industry was particularly strong in Norway and Denmark, with fishermen of other nations landing their pelagic fish catches there to sell. One of these other nations was Sweden, whose domestic production of fish oil and meal was typically less than 5000 tonnes each annually over the 1960s – compared to Norway, which produced a peak output of 483,100 tonnes of herring meal and 326,900 tonnes of herring oil in 1967 alone.<sup>465</sup> The market for fishmeal grew steadily over the 1960s and early 1970s due to a demand for livestock feed.<sup>466</sup> Fish oil was used in the manufacture of a wide array of products including lubricants, sealants, printing inks, insecticides, fertilisers, cosmetics, and soap. However, fish oil competed with rapeseed, sunflower, tung, tall, linseed, and soybean oils; it was often used because it was the cheapest.<sup>467</sup> While cod liver oil was historically processed for human consumption,<sup>468</sup> fish oil in the twentieth century was primarily intended for industrial use, and in the twenty-first century, for aquaculture.<sup>469</sup>

Fish intended for human consumption had to be high quality and thus had a higher value than fish intended for reduction. Fish intended for reduction was of a low quality, often damaged or even actively decomposing, with a correspondingly low value. The low value of these catches had the effect of spurring fishermen to make larger catches, to compensate for the lack of value. The lack of quality requirements meant they took little care with these catches. The low value of the fish destined for reduction was not the only reason why large catches were needed; the reduction industry itself demanded them.

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<sup>464</sup> Shapiro, Circular 235: The Fisheries of Norway, 7.

<sup>465</sup> Fiskeridirektøren Director General of Fisheries of Norway, *Fiskeristatistik* 1968, 44.

<sup>466</sup> Fineberg and Johanson, 'Industrial Use of Fish Oil', 228 & 231.

<sup>467</sup> Fineberg and Johanson, 222.

<sup>468</sup> Swann Harding, 'A History of Cod Liver Oil Therapy', 338.

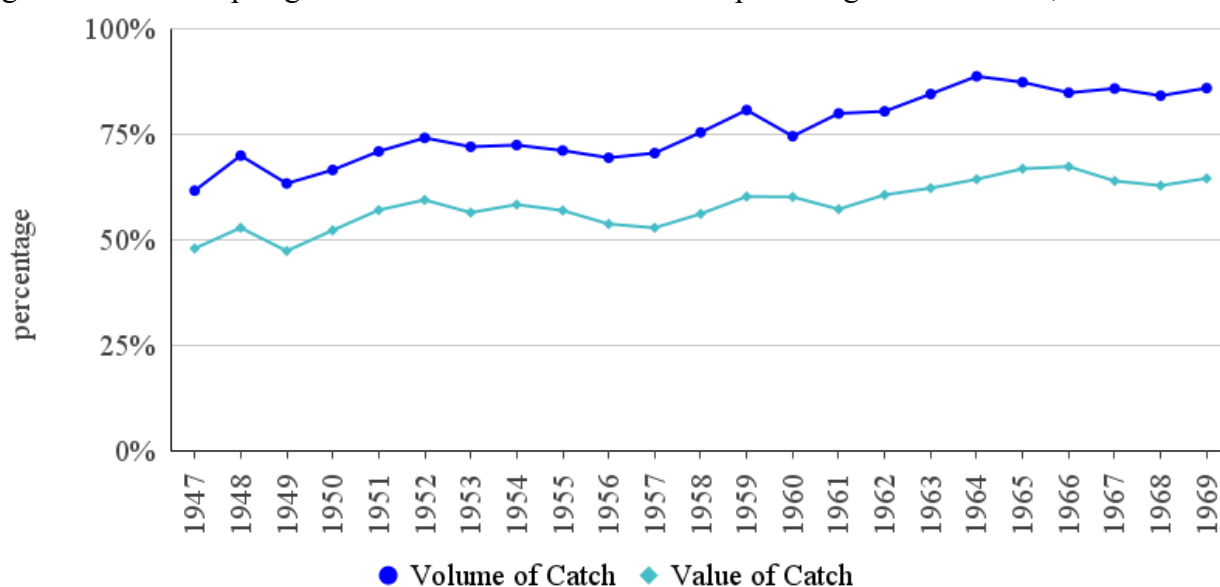
<sup>469</sup> Jackson and Shepherd, 'The Future of Fishmeal and Fish Oil', 189.

It must also be noted that these two types of fish processing have vastly different supply demands. For human consumption, only part of the fish is used. In rendering, however, the entire fish is used. It requires approximately 4.5kg of fish to produce 1kg of fishmeal, a yield of about 22%, whereas it takes at least 21kg of fish to produce 1kg of fish oil.<sup>470</sup> As a result, the rendering industry demanded large volumes of fish.

### 3.2.1 Sweden

Swedish fisheries were centred around herring, which comprised around half of all catches between 1954 and 1963. Figure 41 shows what proportion of the total catch was pelagic, in volume and value. The pelagic catch was comprised of herring, mackerel, sprat, and skrapfisk; together, they made up around three-quarters the total catch in the 1940s, growing to around 85% in the late 1960s. The value of the pelagic catch roughly mirrored the volume, rising over the same time period. However, the value is proportionally lower, reflecting the low value of pelagic species.

Figure 41. Swedish pelagic catches: volume and value as a percentage of all catches, 1930-1969



Notes: Pelagic catch comprises of catches of herring, mackerel, sprat, and skrapfisk.

Sources: Fiske 1947 to 1969.

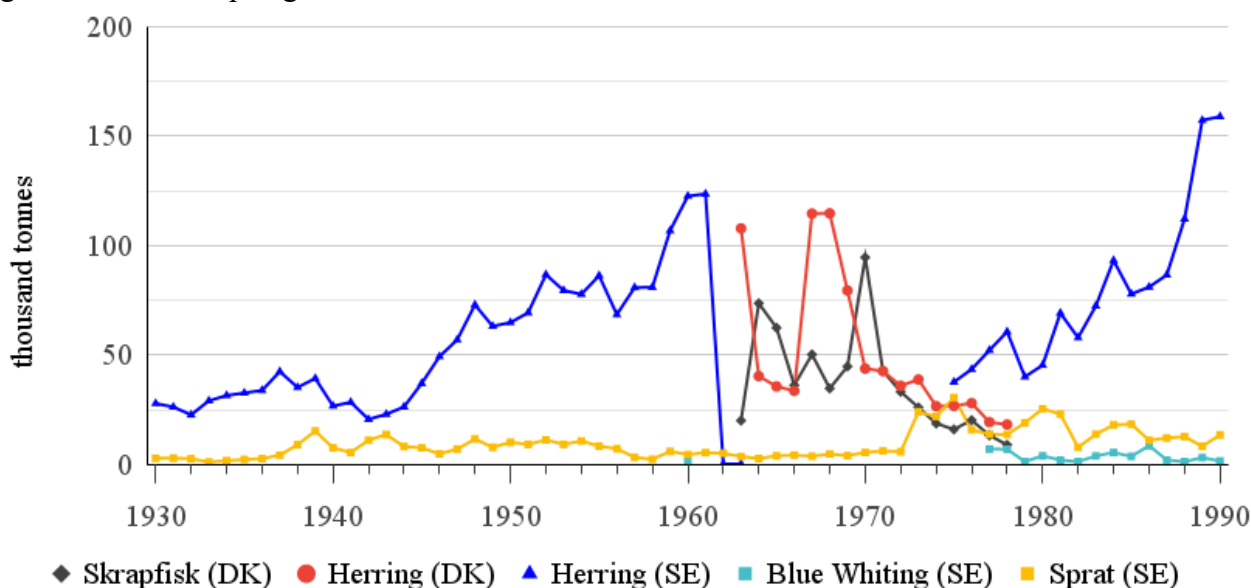
Herring, mackerel, sprat, and skrapfisk were caught by Swedish fishermen, but most catches comprised of herring. Herring accounted for around half of all catches between 1954 and 1963. From 1958 around 75% of all catches were of pelagic fish, including herring, sprat, and skrapfisk.

Figure 42 shows pelagic fish catches made by Swedish fishermen, with separate entries for fish landed in Sweden and Denmark. It shows that very little herring or skrapfisk were landed in Sweden ports between 1963 and 1978. Instead, most of the catch was landed in Denmark, as the Danish rendering plants offered better prices.

<sup>470</sup> Boyd, 'Overview of Aquaculture Feeds', 8.

Most herring and all skrapfisk were destined for the reduction industry, to be processed into meal and oil. Skrapfisk, or 'industrial fish', was fish of no particular species and a single catch (or landing) could comprise of several different fish species, including those that would normally be counted elsewhere, such as herring. It could be intentionally caught for rendering, or it could be fish that was surplus to demand. This fish was often damaged or even actively decomposing, as this did not affect the rendering process. As a result, no care was required in the fishing, storing, preservation, or transporting of catches to the place of landing. Catches destined for reduction were often referred to in Denmark as skidtfisk or trash fish.<sup>471</sup>

Figure 42. Swedish pelagic catches, 1930-1990



Notes: Species with catches of less 30,000 tonnes annually are omitted, as are catches landed in countries other than Sweden or Denmark.

(DK) indicates landings in Denmark, (SE) for landings in Sweden.

Sources: ICES historical landings dataset, 1904-1949; ICES historical landings dataset, 1950-2010; Fiske 1930 to 1969; Fiskestatistik Årsbok 1971 to 1979.

Denmark first established its reduction industry in 1948<sup>472</sup> and was supplied by consistently high pelagic catches in the 1950s and 1960s.<sup>473</sup> Norway also had a large reduction industry. In 1964 over 85% of the Norwegian catches of herring and sprat went to reduction.<sup>474</sup> In the same year a large proportion of mackerel catch was sent for reduction as the market for human consumption was saturated.<sup>475</sup> It is probable that other nations without sizable reduction industries also landed unwanted or low value catches in Denmark and Norway.

<sup>471</sup> Byskov, 'Esbjerg's Fishmeal Industry: Competition, Conflict and Cooperation', 146.

<sup>472</sup> Holm, 'World War II and the "Great Acceleration" of North Atlantic Fisheries', 84.

<sup>473</sup> Holm, 76.

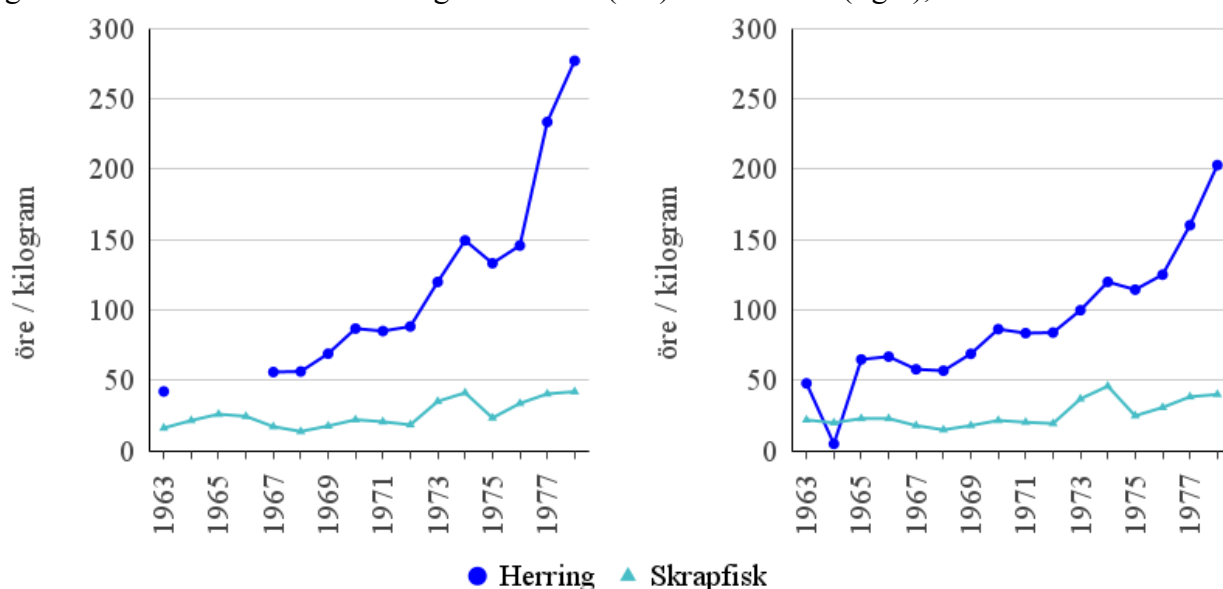
<sup>474</sup> Shapiro, Circular 235: The Fisheries of Norway, 7.

<sup>475</sup> Shapiro, 6.

Sweden did not have a reduction industry capable of competing with its neighbours, nor did it offer competitive prices. The Swedish authorities attempted, unsuccessfully, to encourage Swedish fishermen to land their herring catches in Swedish ports.<sup>476</sup> In 1964 alone it was estimated that 80% of herring landings made in Danish ports were by Swedish fishermen alone,<sup>477</sup> simply because the prices were better there.<sup>478</sup> Between 1963 and 1978 landings of fish by Swedish fishermen in Denmark decreased substantially, from a peak of 197,493 tonnes in 1964 down to 28,453 tonnes in 1978. As shown previously, in figure 42, this is not because these fish are being landed in Sweden (or elsewhere). Rather, they reflect the collapse of the herring stocks starting in the mid-1960s. The impending collapse of the herring stocks is also seen in the fluctuating value of these landings over the 1960s and 1970s.

Figure 43 shows the value of all landings made by Swedish fishermen for herring and skrapfisk, in öre per kilogram. It shows that prices in Denmark were typically higher. While the price for skrapfisk was only marginally higher in Denmark, often only by one or two øre, this price was per kilogram. A catch of several tonnes or more would result in a significantly higher price in Denmark than Sweden. Herring commanded a much higher price – which is unsurprising, given the stock collapse of the 1960s. This herring must have been processed for human consumption instead of rendered, otherwise the price would be the same as for skrapfisk. There is no explanation for the extremely low price of herring in Sweden in 1964.

Figure 43. Value of Swedish landings: Denmark (left) and Sweden (right), 1963-1978



Notes: From 1971 onwards landings in Sweden for herring also include strömming (Baltic herring).

Sources: Fiske 1963 to 1969; Fiskestatistik Årsbok 1971 to 1979.

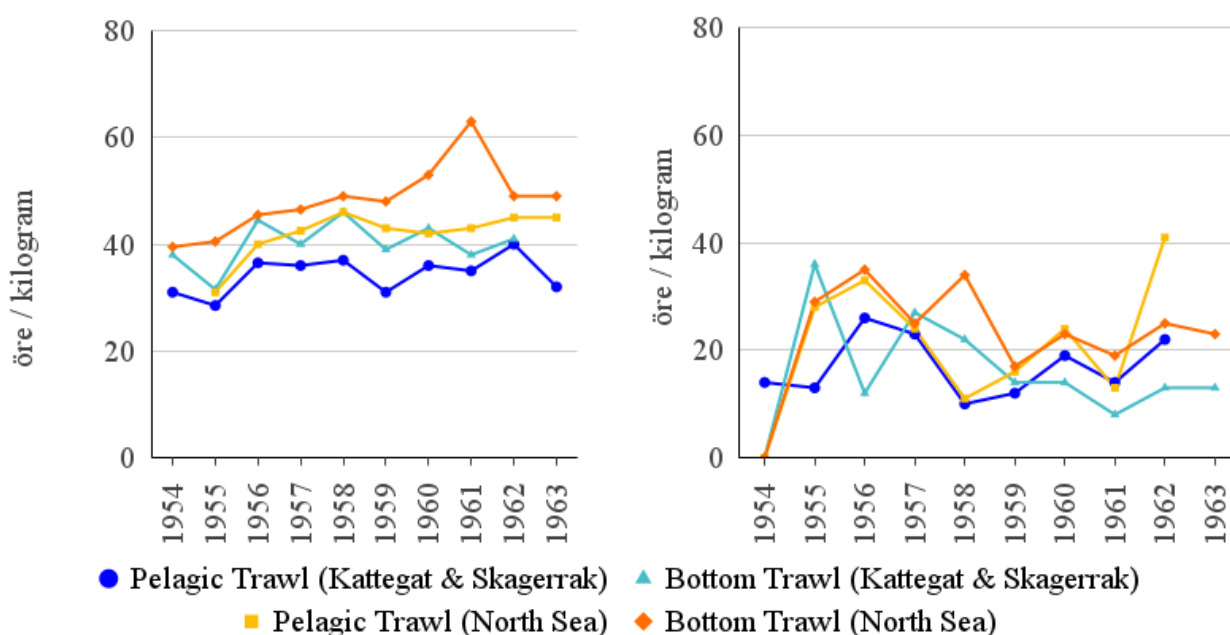
<sup>476</sup> Byron, Portraits of the Past, 168.

<sup>477</sup> Statistika Centralbyrån (Sveriges Officiella Statistik), Fiske 1964-66, 44.

<sup>478</sup> Byron, Portraits of the Past, 168.

This lack of value for herring and skrapfisk is also seen in figure 44, which shows the value of the landings made by Swedish fishermen in the Swedish ports of Gravarne and Smögen. Detailed statistics were recorded regarding the landings made in these ports between 1954 and 1963. Sadly, they do not continue beyond this date. They also record catches made with different types of fishing gear, including the pelagic trawl and the herring bottom trawl. This data was recorded for two different fishing areas, the North Sea and the Kattegat and Skagerrak. The value by type of fishing gear shows that the catches of skrapfisk and herring made with the pelagic trawl were typically worth less than those made with the herring bottom trawl. The price per kilogram is comparable to those discussed previously, in figure 43.

Figure 44. Value of Swedish landings: herring (left) and skrapfisk (right), 1954-1963



Notes: Data is derived from landings made in the ports of Gravarne and Smögen only.

Data for the Bottom Trawl is taken from entries from the *sillbottentrålfisket* (herring bottom trawl) and for the Pelagic Trawl from *flytrålfisket* (pelagic trawl).

Sources: Fiske 1955 to 1969.

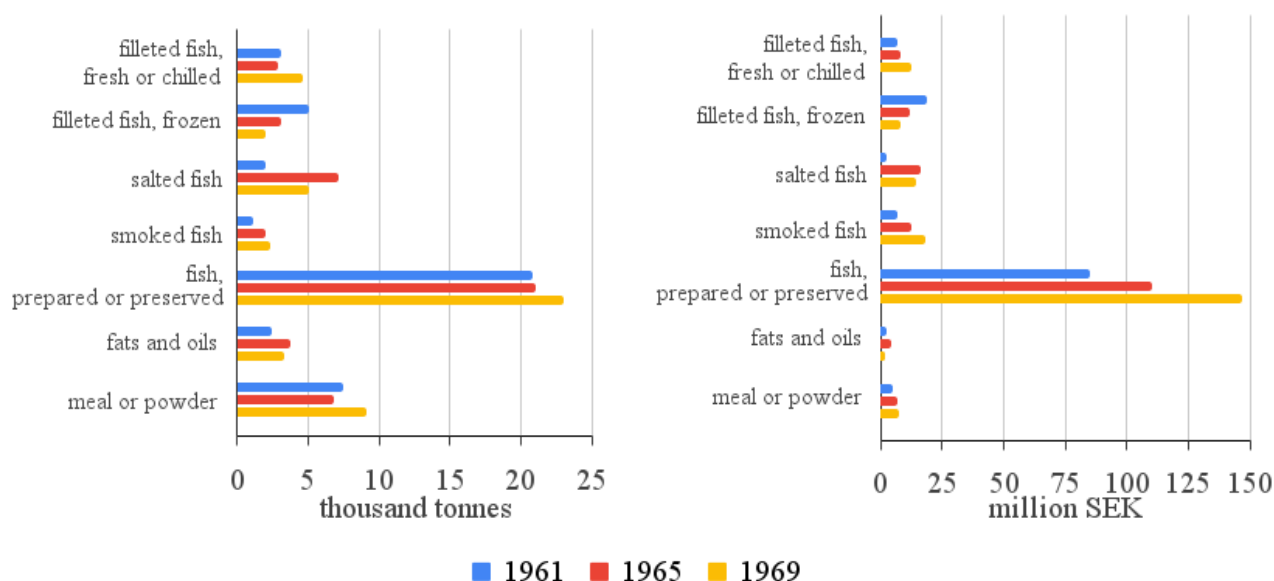
The lower value means that these catches were most likely low quality, or are at least were perceived to be so. Given that the pelagic trawl was a relatively recent invention, it is highly likely there were at least a few flaws in its design and operation. It could also reflect a glut; the pelagic trawl caught more fish than the herring bottom trawl and its use could have saturated the market. It is estimated that by the 1950s about half of all herring in the North Sea was caught with pelagic trawls.<sup>479</sup> Swedish fishery statistics for 1963 estimated that pelagic trawls were responsible for at least 45% of the herring catch from the North Sea alone.<sup>480</sup>

<sup>479</sup> Karlsdóttir, *Fishing on Common Grounds*, 104.

<sup>480</sup> Statistiska Centralbyrån (Sveriges Officiella Statistik), *Fiske 1963*, 39.

The quantity and value of the products of pelagic fisheries in Sweden are shown in figure 45. Unfortunately, these specific data are only available for the 1960s. But even from just this decade it is clear that fish for human consumption was of higher value, with prepared and preserved fish increasing in value over the 1960s. Sweden's rendering industry was very small in comparison to Denmark and Norway. Denmark produced 125,000 tonnes of fishmeal in 1966, which rose to 227,000 tonnes in 1971.<sup>481</sup> Production of meal and oil in Sweden increased to barely 10,000 tonnes in 1972.<sup>482</sup> If the volume of unprocessed fish required for rendering is accounted for, then the volume of unprocessed fish sent for rendering was roughly equal to the volume of unprocessed fish being processed for human consumption.

Figure 45. Swedish herring products: volume (left) and value (right), 1961-1969.



Sources: Fiske 1961, 1965, and 1969.

Pelagic trawls were much larger than herring bottom trawls, taking a larger catch for every tow (discussed further in chapter 3.3). This meant that the catch was crushed under its own weight, either during the tow or when hauled onboard, resulting in a damaged catch. A discussion on Scottish herring fishing methods in the 1950s describes damaged fish as "having the stamp of trawled herring," after they have been "churned up."<sup>483</sup> It also refers to Denmark and Sweden directly:

"In some other countries the increase in trawling has been accelerated by the abandonment of "quality" in favour of "quantity" in the race to fulfil the insatiable demands of the oil and meal factories."<sup>484</sup>

<sup>481</sup> Kolhonen, 'Fish Meal: International Market and Situation and Future', 37.

<sup>482</sup> Kolhonen, 37.

<sup>483</sup> Hodgson, *The Herring and Its Fishery*, 42.

<sup>484</sup> Hodgson, 50.

A contrasting source from the 1960s describes Swedish fishermen as being very good at handling herring on board boat to ensure their high quality – but this refers to the swift packing and preservation of the herring, not the effect of the fishing gear.<sup>485</sup> Quality was not important if selling to a reduction plant, especially if it had no effect on the price.

Of course, damaged fish could be attributed to a lack of skill with the pelagic trawl or to some difficulty in operating it. The pelagic trawl was used mainly at night,<sup>486</sup> which would have been extremely challenging, especially as the early pelagic trawls were pair trawls. Pair trawling requires exacting co-ordination between two boats, which is challenging in the best of conditions. However, the pelagic trawl was not exclusively used at night and this alone cannot account for damaged fish. It is far more likely that the fishermen simply had no reason to care whether the fish were damaged, instead focussing on the larger catches of which the pelagic trawl was capable. Larger catches would compensate for the lower price paid for fish for reduction.

The pelagic trawl enabled high catches of low-quality fish, even though it was likely that it was the trawl itself that compromised its quality. This coincided with ongoing high demand for fish by the reduction industry. This would have further encouraged the use of the pelagic trawl, especially following the collapse of the herring stocks. Yet, despite the high demand for low-quality fish, it had little value. As a result, the pelagic trawl added little to the overall value of pelagic fisheries despite being the more effective fishing method. The effect of the collapse of the herring stocks had a serious effect on landings made by Swedish fishermen in Danish ports, as only 20,000 tonnes of fish were landed in 1978,<sup>487</sup> compared with over 100,000 tonnes landed in 1963.<sup>488</sup> Danish ports started to struggle to meet factory demand in the 1970s. Initially this was due to the collapse of the herring stocks, latterly due to the introduction of quotas.<sup>489</sup>

### 3.2.2 Scotland

Until the mid-1960s the primary pelagic fishing methods in Scotland were ring nets and drift nets. The technique of trawling for herring in the North Sea was already known to Scottish and English fishermen, with a pair pelagic trawl inspired by Robert Larsen's design used on small scale in England from the 1950s.<sup>490</sup> Pelagic trawls and purse seines were introduced in the mid-1960s, although purse seining was already known in Shetland, courtesy of visiting Norwegian fishermen.<sup>491</sup>

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<sup>485</sup> Johnson, 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966', 35.

<sup>486</sup> Byron, *Portraits of the Past*, 163–64.

<sup>487</sup> *Fiske Statistik Årsbok 1978*, 33.

<sup>488</sup> Statistiska Centralbyrån (Sveriges Officiella Statistik), *Fiske 1964-66*, 44.

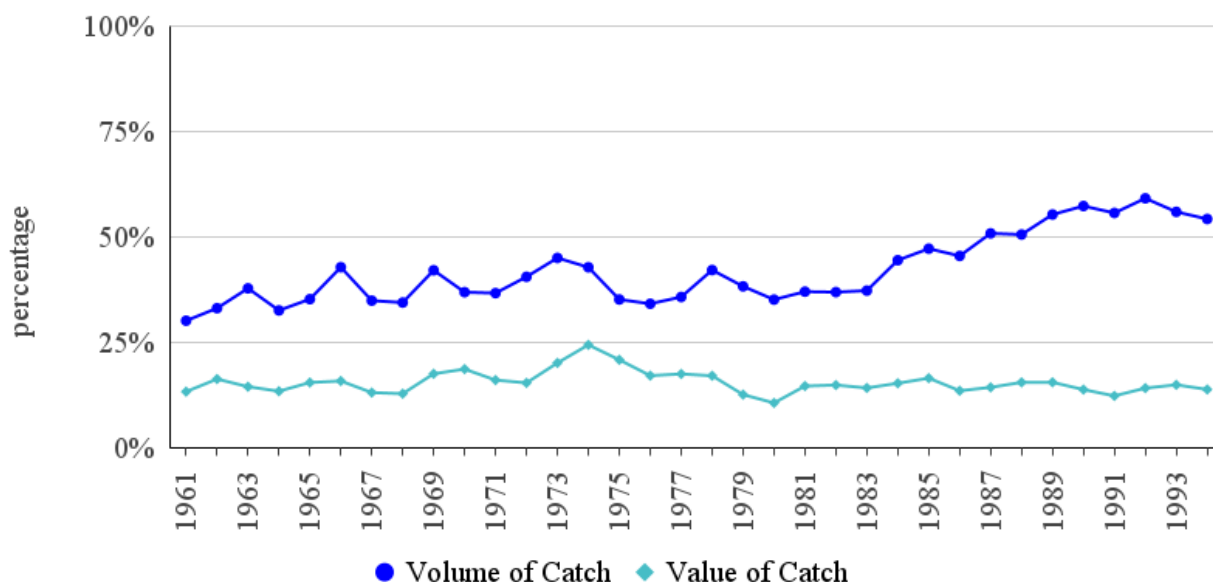
<sup>489</sup> Byskov, 'Esbjerg's Fishmeal Industry: Competition, Conflict and Cooperation', 139–40.

<sup>490</sup> Noel, 'The Thames Floating Sprat Trawl', 348.

<sup>491</sup> Goodlad, 'Old and Trusted, New and Unknown: Technological Confrontation in the Shetland Herring Fishery', 61.

Figure 46 shows volume of pelagic fish as a proportion of the total catch. Pelagic catches range from just over 30% to just under 60% of the total volume of fish caught. This fluctuates over time, although was consistently higher in the 1980s. The value of those catches is also shown in in figure 46. The value of pelagic catches as a proportion of the total catch remains relatively stable, between 10% and 20%, bar a peak during a handful of years in the mid-1970s.

Figure 46. Scottish pelagic catches: volume and value as a percentage of all catches, 1961-1994



Notes: Figures exclude shellfish.

Sources: Scottish Sea Fisheries Statistical Tables 1961 to 1994.

The 1960s was not a good time for herring fishing, as this was when the herring stocks began to collapse. The annual herring catch in Scotland had fluctuated frequently over most of the twentieth century, with catches typically between 75,000 and 150,000 tonnes. When the herring fishery began to decline in the 1970s fishermen switched to catching mackerel instead. Mackerel catches quickly came to exceed 150,000 tonnes annually. Catches of sprat were always very low, never exceeding a one-time high of 13,000 tonnes. Catches of capelin were negligible. Blue whiting was caught from the mid-1970s onwards, but not in any significant quantity until the mid-1990s.

Statistical data for the pelagic trawl began in 1965, followed in 1965 by the purse seine. The pelagic trawl and purse seine were introduced with great encouragement by the Herring Industry Board in the early 1960s.<sup>492</sup> The Herring Industry Board provided loans and subsidies for the purchase of gear and boats, to encourage fishermen to switch to either trawling or purse seining, with the aim of modernising the fishing fleet.<sup>493</sup> The methods they replaced, ring nets and drift nets, were inshore fishing techniques whereas pelagic trawls and purse seines operated further out at sea. This expanded the area in

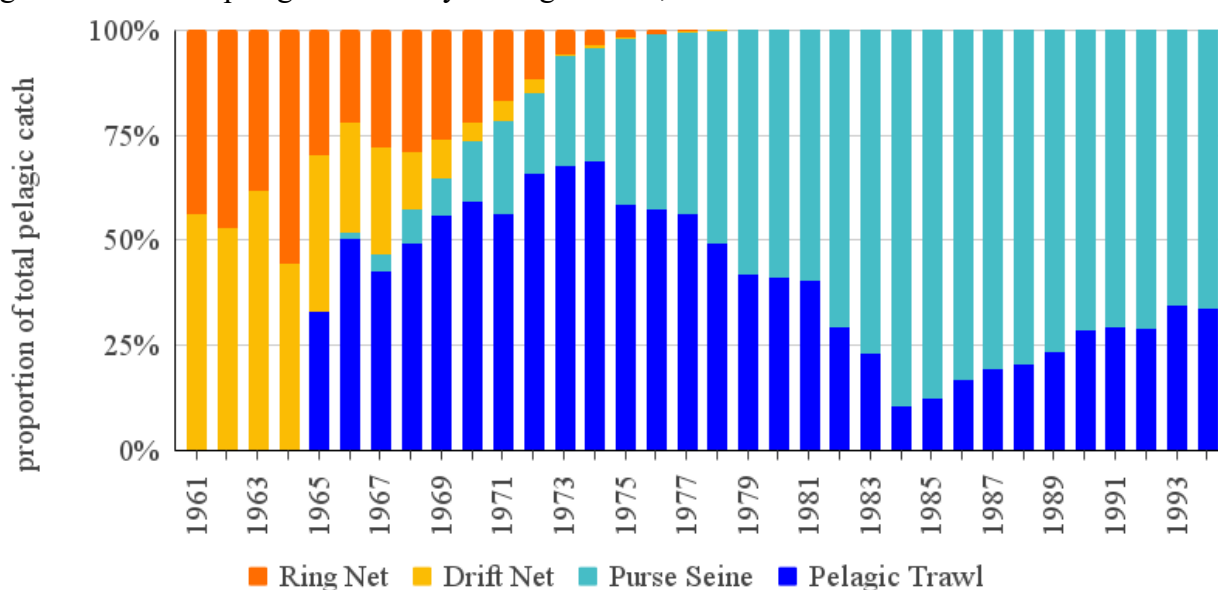
<sup>492</sup> Reid, 'Managing Innovation in the British Herring Fishery: The Role of the Herring Industry Board 1945-77', 284.

<sup>493</sup> Reid, 'Underutilization, Undersupply, and Overfishing in the Herring Industry 1930-1980: A Case Study in the Evolution of Britain's Productivist Fisheries Policy', 90.

which Scottish fishermen could fish. However, Scottish fishermen rarely travelled outside of the waters west of Scotland or the North Sea, bar occasional periods of fishing in Icelandic waters.<sup>494</sup> Pelagic trawls were initially used to catch sprat, but by the end of the 1960s had switched to herring, and in the 1970s to mackerel. Purse seines were initially used to catch herring but from the mid-1970s were mainly used to catch mackerel.

Figure 47 shows the proportion of total pelagic catches made with each type of gear. In 1965, the first year they were used, pelagic trawls made over a quarter of all pelagic catches. The proportion of catches made with pelagic trawls increased every year until 1973, by which point almost three-quarters of pelagic catches were made with the pelagic trawls. However, purse seines swiftly overtook pelagic trawls in volume of fish caught. By 1984 purse seines were responsible for just under 90% of all pelagic catches.

Figure 47. Scottish pelagic catches by fishing method, 1961-1994



Sources: Scottish Sea Fisheries Statistical Tables 1961 to 1994.

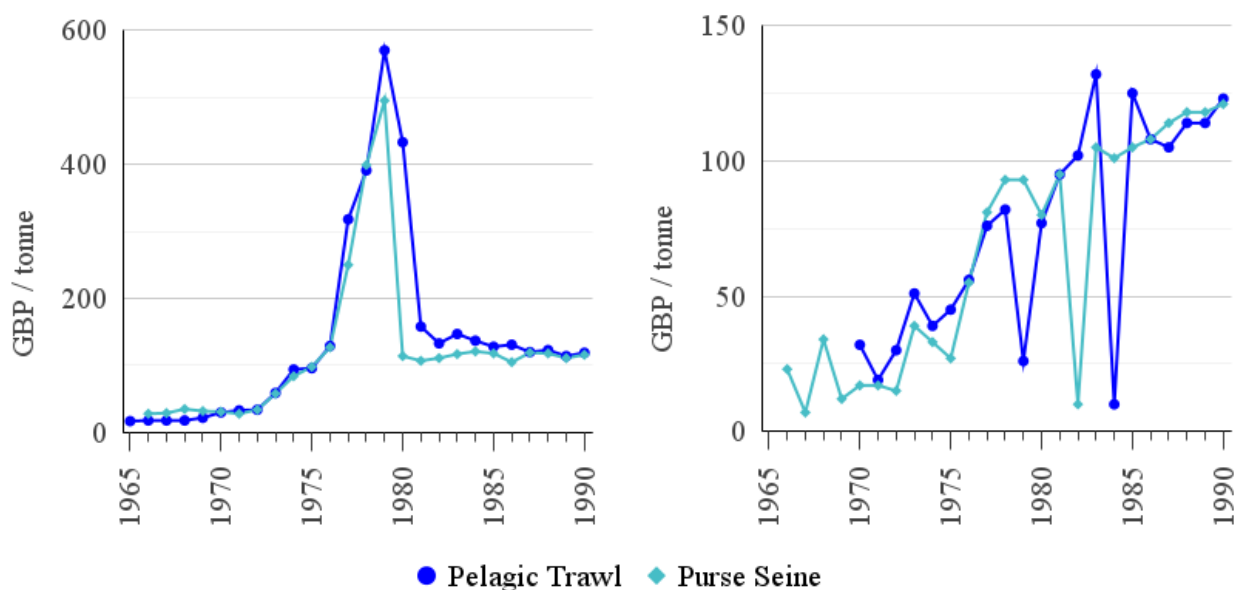
The major factor behind the increase in purse seining was a dramatic increase in fuel prices starting in 1974. Pelagic trawling consumed thousands of tonnes of fuel when actively fishing, unlike purse seining. Additionally, many early pelagic trawls in Scotland were pair trawls, so there were two trawlers requiring fuel, not just one. Purse seining can be accomplished with a single boat and if more than one boat is used then additional boats are much smaller and use less fuel. Despite this, the pelagic trawl continued to be used. One explanation for its continued use is that catches with the pelagic trawl were often of higher value, shown in figure 48. However, this does entail asking why those catches were of higher value, or perceived to be of a higher value.

Figure 48 shows the value of the herring and mackerel catches by year and method. It shows that the value of herring caught with the pelagic trawl was typically higher than herring caught with the purse seine. A similar pattern is seen with mackerel, although are

<sup>494</sup> ICES, 'DATASET COLLECTIONS: Catch Statistics'.

there are two years where the value is significantly lower, and one where it is significantly higher. Overall, this is the opposite of the Swedish fisheries and by that same reasoning would indicate that catches were of higher quality. However, while herring caught with the pelagic trawl may have incurred less damage from the gear than in previous years, purse seining still typically damaged fish much less than trawling, at least until the 1980s. Regardless, the relatively high value of pelagic trawl catches suggests that quality was not the determining factor in the value of these catches. Unfortunately, there is no record of whether these catches were intended for human consumption or for reduction.

Figure 48. Value of Scottish catches: herring (left) and mackerel (right), 1965-1990



Sources: Scottish Sea Fisheries Statistical Tables 1961 to 1990.

If quality was not the determining factor, then seasonal variations may yield an explanation. Monthly catch volume by gear type was not recorded, but a limited dataset on the gross earnings of pelagic trawlers from 1975 to 1980 is available. It shows that they had the highest earnings in the winter months, from around September to February, with very little in earnings in the rest of the year. The North Sea herring fishery was fished roughly between August and January.<sup>495</sup> Unfortunately, there is no similar data for the purse seine, so a comparison is not possible. The available data suggest that pelagic trawls and purse seines were fishing at different times of year, which indicates that the pelagic trawl was catching fish that the purse seine could not reach, or catch effectively. The value of this catch could derive from a seasonal demand, or it could derive from a perceived higher quality of fish as a result of fishing method.

The 1970s saw a substantial increase in the volume of imported seafood products, matched by rising exports and declining catches overall.<sup>496</sup> Scotland (and the UK) caught fish for reduction, with fish oil and meal being exported, while also importing fish products

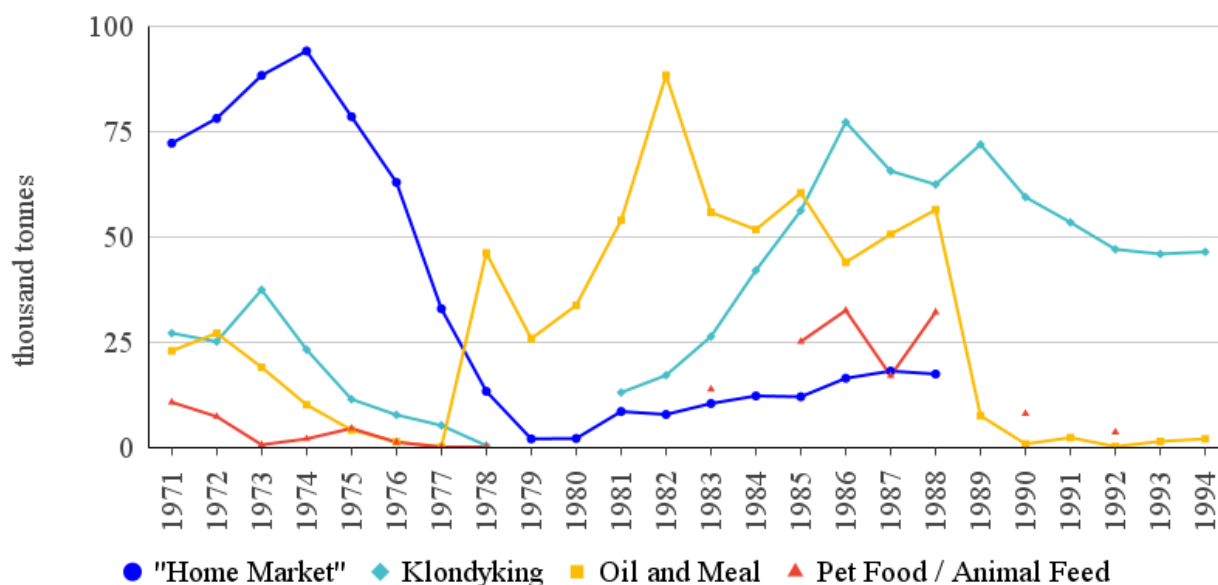
<sup>495</sup> Hodgson, *The Herring and Its Fishery*, 16–17.

<sup>496</sup> Harrison et al., 'Widening Mismatch between UK Seafood Production and Consumer Demand', 1394.

for human consumption. This was matched by decline in the consumption of locally caught fish, in particular herring and mackerel.<sup>497</sup> This decline has been linked with Britain joining the EEC in 1973 and becoming subject to the Common Fisheries Policy. As British fleets had until then favoured distant water fisheries, the quota allocation for British fishermen was low, although some quotas were quite high, such as those for mackerel.<sup>498</sup> Herring, following stock collapse in the 1960s, was subject to severe restrictions.

Figure 49 shows the primary processing methods for herring. It shows a significant decrease in herring processed for human consumption from the late 1970s with a corresponding increase in herring reduced for meal and oil. There was also a significant increase in klondyking. Historically, this referred to a method of preservation where salt and ice were sprinkled on herring to preserve it for export to mainland Europe. However, by the mid-twentieth century, it meant the sale of fish directly from trawlers to foreign ships for immediate export.<sup>499</sup> This fish was sold by Scottish trawlers to ships from Norway, Germany, Denmark, and Iceland,<sup>500</sup> countries whose own fishing grounds were no longer capable of meeting demand.

Figure 49. Scottish herring processing, 1971-1994



Notes: 'Home market' refers to fish processed for human consumption which includes fresh, kippered, redding, marinating, quick freezing, and canning.

Sources: Scottish Sea Fisheries Statistical Tables 1971 to 1994.

Klondyking was appealing to Scottish fishermen. They did not have to land the catch, as it was transferred ship-to-ship, and buyers paid cash at time of transfer. There is no indication this was done to avoid quotas or regulations, rather it was the lack of fuss around landing, transport, and awaiting payment from processors. Klondyking was simply quicker and more convenient. Northern European nations typically bought fish to

<sup>497</sup> Harrison et al., 1395.

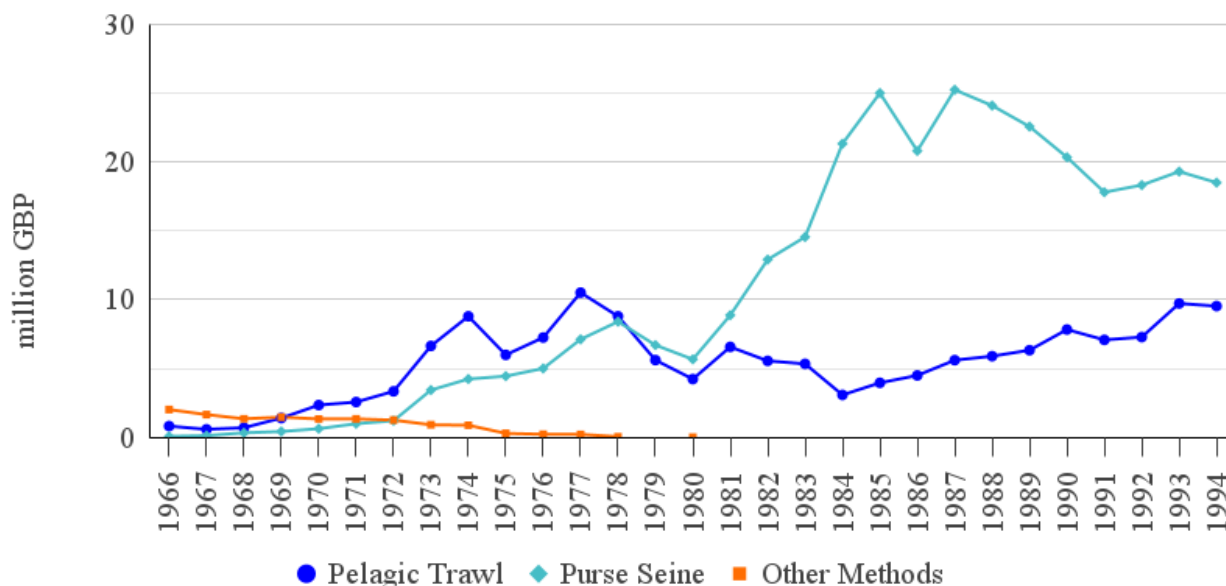
<sup>498</sup> Harrison et al., 1389.

<sup>499</sup> Department of Agriculture and Fisheries for Scotland, Scottish Sea Fisheries Statistical Tables 1989, 6.

<sup>500</sup> Anonymous, 'Bretar', 1 & 14.

transport back to their home nations for rendering. Eastern Europe countries and the Soviet Bloc also practised klondyking in Europe and in North America. Soviet factory trawlers processed klondyked fish entirely onboard, canning for human consumption before rendering the scraps. While Scottish statistics recorded the volume of fish klondyked they did not record how it was caught or what happened to that fish once it was sold. How much was rendered or processed for human consumption is unknown. Some fish was caught with the intention of klondyking and no intention of selling to a home market. In this case there was no concern over its quality, as it was intended for reduction.

Figure 50. Value of Scottish pelagic fisheries by fishing method 1966-1994



Notes: Total pelagic catch comprises of herring, sprat, mackerel, capelin, blue whiting, and redfish. Value of catch is derived from all catches made with those types of fishing gear. Sources: Scottish Sea Fisheries Statistical Tables 1971 to 1994.

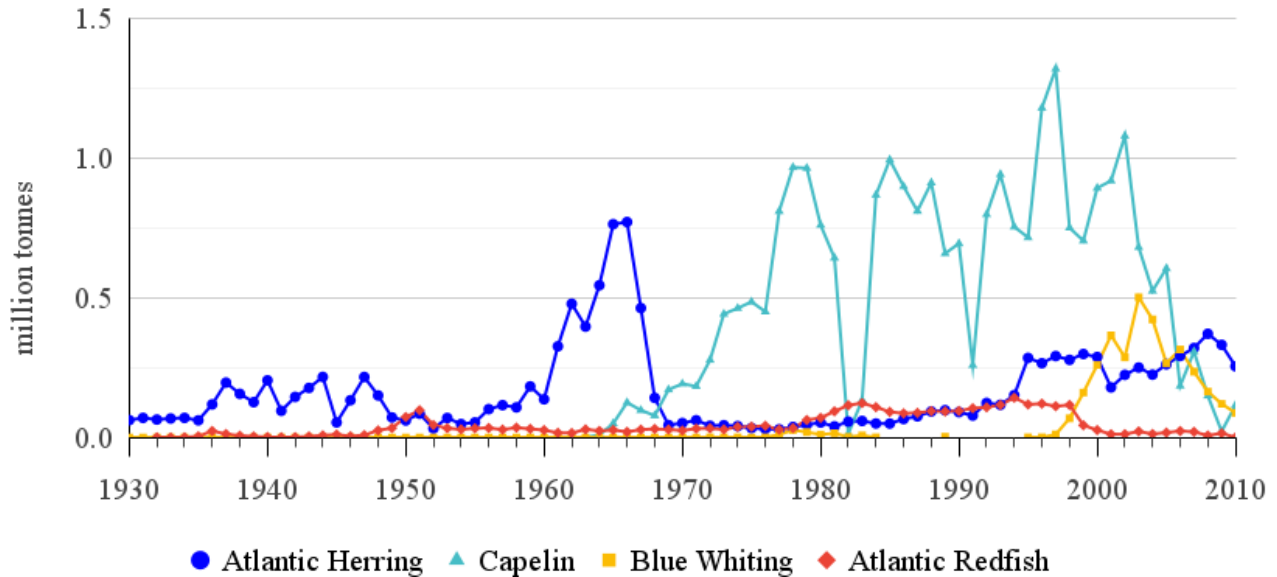
Figure 50 shows the value of pelagic fisheries with the proportion caught by different fishing methods. It shows that in the 1970s the value of the pelagic catch fluctuated between roughly 10 and 18 million GBP, with typically at least half of the value derived from purse seines. By the late 1980s, with the value of the pelagic catch reaching over 30 million GBP, the majority was derived from catches made with purse seines. The proportion of the value of the catch by fishing method also mirrors the proportion of the catch made by each of these fishing methods as previously shown in figure 47.

### 3.2.3 Iceland

Herring was the dominant pelagic catch in Iceland for most of the twentieth century, as shown in figure 51. It shows that herring catches peaked in the mid-1960s, immediately preceding the collapse of the stock at the end of the same decade. Following the collapse of the herring stocks, capelin became the primary pelagic fishery. Capelin regularly outperformed the herring fishery that preceded it by a significant margin, although catches decreased at the turn of the twenty-first century. In the mid-1990s herring fishing

resumed, albeit with much-needed restrictions. Blue whiting and Atlantic redfish were also caught, but on a much smaller scale. Atlantic redfish catches were almost entirely sent for reduction. The capelin fishery has fluctuated significantly since the 1990s with quotas ranging from over a million tonnes to zero,<sup>501</sup> depending on stock estimates.

Figure 51. Icelandic pelagic catches, 1930-2010



Notes: “Atlantic Redfish” are for all redfish as early figures do not differentiate between demersal and pelagic sub-species. These include *Sebastes mentella*, *Sebastes norvegicus*, *Sebastes fasciatus*, and redfishes *nei*.  
Sources: ICES historical landings dataset, 1904-1949; ICES historical landings dataset, 1950-2010.

Iceland had a sizeable reduction industry by the 1940s. The peak of the reduction industry corresponded with the intense herring fishing of the 1960s, as did the salting of herring into barrels for human consumption. Considering that at least 4.5kg of fish is needed to produce 1kg of meal,<sup>502</sup> it is clear that the volume of herring sent for reduction vastly exceeded that processed for human consumption. During this time Icelandic fishermen only used purse seines, the use of which continued to dominate until the 1990s. Pelagic trawling was known from 1949<sup>503</sup> onwards but was not used in any significant way until the mid-1990s.

Figure 52 shows the total pelagic catch as a proportion of the all catches in Iceland, in both volume and value. The total pelagic catch accounted for significant proportion of all fish caught. In Iceland (as in Sweden and Scotland previously) the value is proportionally much lower than the volume. Except for a peak from 2011 to 2013, the value of pelagic catches was typically between 20% and 35% of the total value of all catches. West German trawlers caught redfish in Icelandic waters until 1977, when Iceland extended its territorial waters to 200nm.<sup>504</sup> In 1976 netlofts in Iceland started advertising imported pelagic trawls,

<sup>501</sup> ICES, ‘Capelin (*Mallotus Villosus*) in Subareas 5 and 14 and Division 2.a West of 5’, 3.

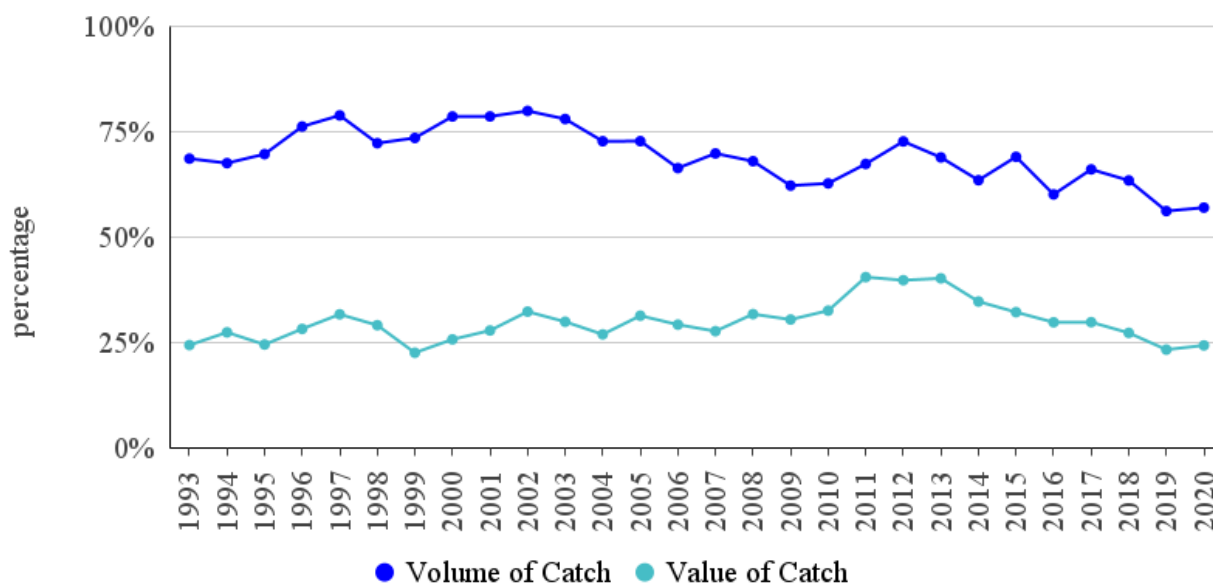
<sup>502</sup> Boyd, ‘Overview of Aquaculture Feeds’, 8.

<sup>503</sup> Anonymous, ‘Danska flottrollið reynt hjer’, 1.

<sup>504</sup> Hjaltason, ‘Iceland and the German Fish Market 1950-1990: Did Germany Get the Fish It Needed after the 200-Mile Extension?’, 278.

with some specifying trawls made by Engel-Netze.<sup>505</sup> Engel trawls were popular until an Icelandic netmaker, Hampiðjan, invented their own pelagic trawl for redfish in the 1980s.<sup>506</sup>

Figure 52. Icelandic pelagic catches: volume and value as a percentage of all catches, 1993-2020



Notes: Pelagic fish are herring, blue whiting, mackerel, capelin, capelin roe, redfish, ocean redfish, and blue whiting. Sources: Hagstofa Íslands.

There is no data, however, on what the proportion of the Atlantic redfish catch was caught with pelagic trawls prior to the 1990s. Since the 1990s it has been almost exclusively fished with pelagic trawls.<sup>507</sup> While this does suggest that a significant proportion of catches in previous decades were caught using pelagic trawls, most redfish catches were made with bottom trawls. Blue whiting was caught almost exclusively with pelagic trawls, starting in the 1970s. Until 1997 these catches never exceeded 25,000 tonnes, after which catches rose to a peak of half a million tonnes in 2003 (figure 51). Blue whiting was largely processed into meal until the early 2000s, at which point it began to be exported frozen. The bulk of the catch was sent for reduction.

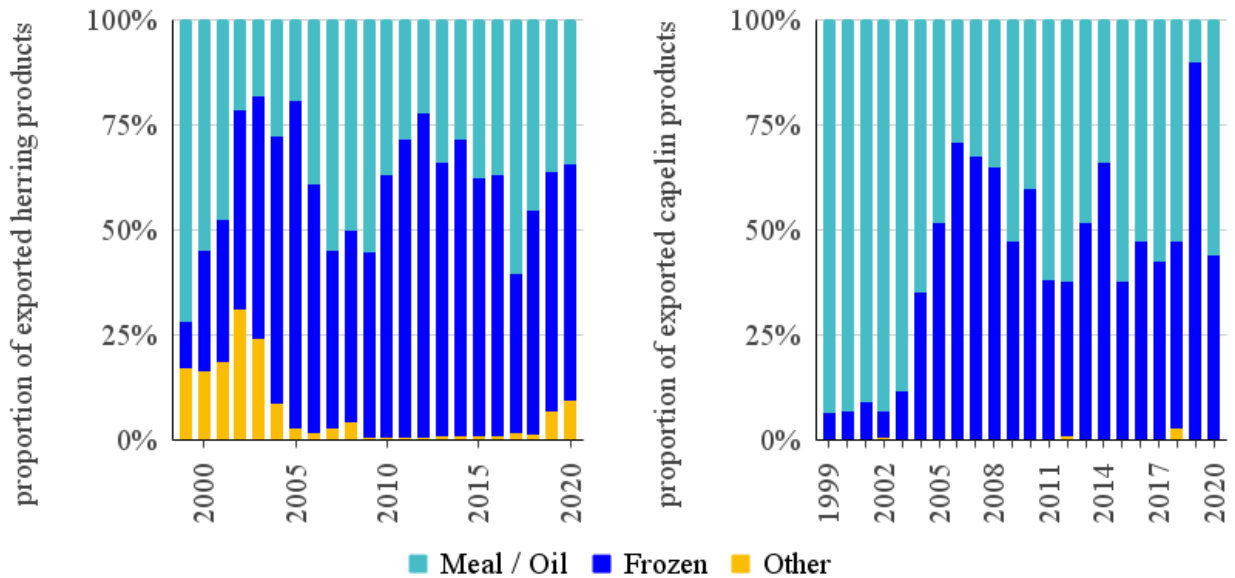
Figure 53 shows export of capelin and herring products. Meal and oil were the main exports until the early 2000s, when exports of frozen fish increased. For herring and capelin, 'other', refers to fish processed for human consumption, either fresh/chilled or salted. This reflects a change in fisheries between the twentieth and twenty-first centuries, with the need to maximise the value of catches. Instead of catching more fish to increase profit, the limited volume of fish must be fully exploited. In order to do so, the catch must be of high quality and processed for human consumption, as this has the highest value. Low quality fish and fish sent for reduction were of low value and thus not the priority.

<sup>505</sup> Anonymous, 'Sandfell ehf: Vestfirðinga eru ótvíræðir brautryðjendur í nútíma flotvörpuveiðum á Íslandi', 25.

<sup>506</sup> Hampiðjan, 'Gloria's 25th Birthday'.

<sup>507</sup> Hagstofa Íslands.

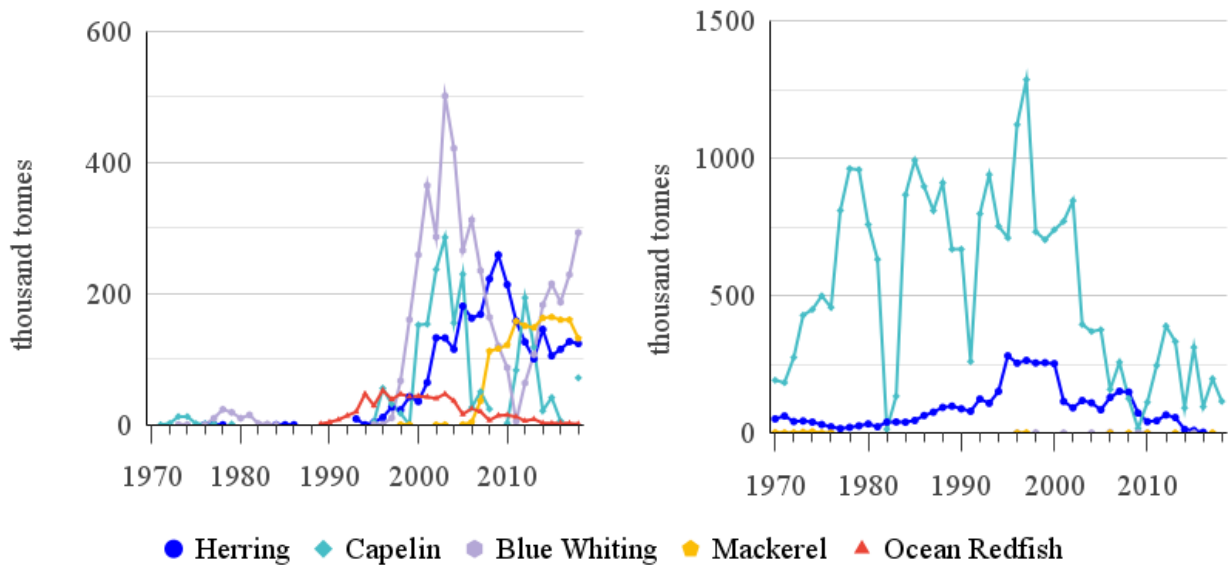
Figure 53. Icelandic exports: herring (left) and capelin (right), 1992-2018



Notes: Figures are for catch volume sent for processing, not the final volume produced.  
Sources: Hagstofa Íslands.

Figure 54 shows the catches made with pelagic trawls and purse seines. The purse seine was used for catching herring and capelin, with the focus on capelin. The pelagic trawl was used to catch a variety of pelagic species, including herring, capelin, blue whiting, mackerel, and redfish. The pelagic trawl was more versatile than the purse seine in this respect. However, the purse seine caught considerably larger volumes of capelin and occasionally herring. It also shows that the pelagic trawl was only used systematically starting in the late 1990s and that it was used for all species within the same decade.

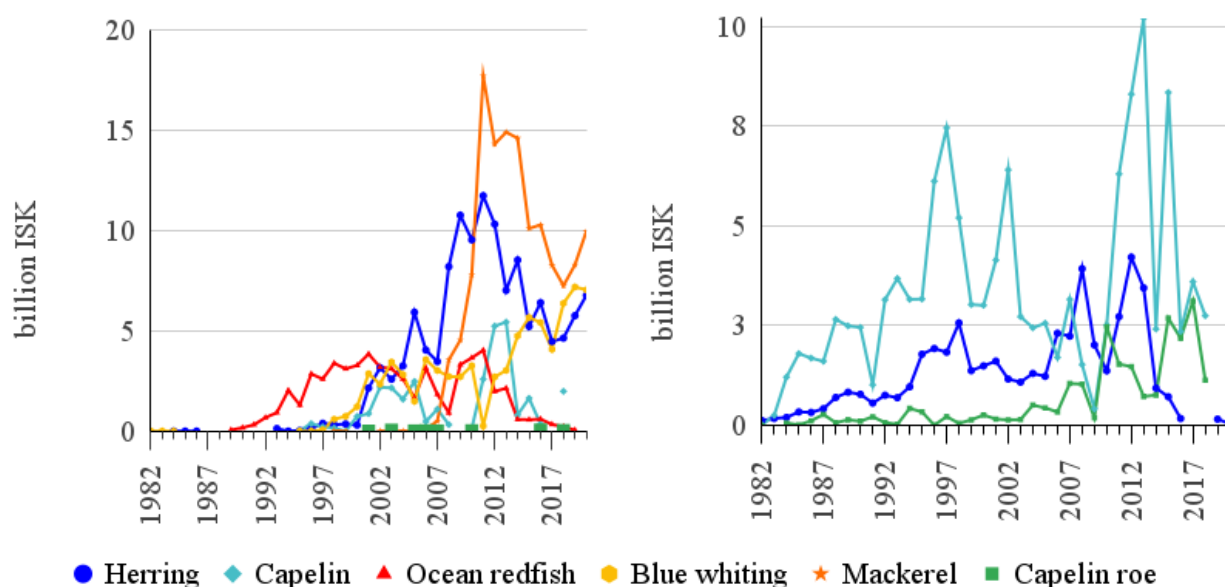
Figure 54. Icelandic catches: pelagic trawls (left) and purse seines (right), 1970-2018



Notes: species with catches of consistently less than 1000 tonnes annually are omitted. Catch by gear for redfish were not available prior to 1982. Figures for capelin include roe.  
Sources: Hagstofa Íslands and Fiskifélag Íslands. Data from Fiskifélag Íslands was kindly supplied by Professor Hörður Sævaldsson at the University of Akureyri.

Figure 55 shows the value of catches made with pelagic trawls and purse seines. Despite the purse seine catching larger volumes, catches made with the pelagic trawl had a greater value. In contrast to figure 54, the value of catches made with pelagic trawls significantly exceeded the value of those made with purse seines. While there was a correlation between the increase in fish processed or preserved for human consumption and the introduction of the pelagic trawl for herring and capelin, there is no realistic relationship between these two. This relationship is not seen in redfish and blue whiting, and unlike the early pelagic trawls in Sweden, there was no link between the fishing gear and quality of the catch or that this had an effect on the value of the catch.

Figure 55. Value of Icelandic catches: pelagic trawls (left) and purse seines (right), 1982-2018



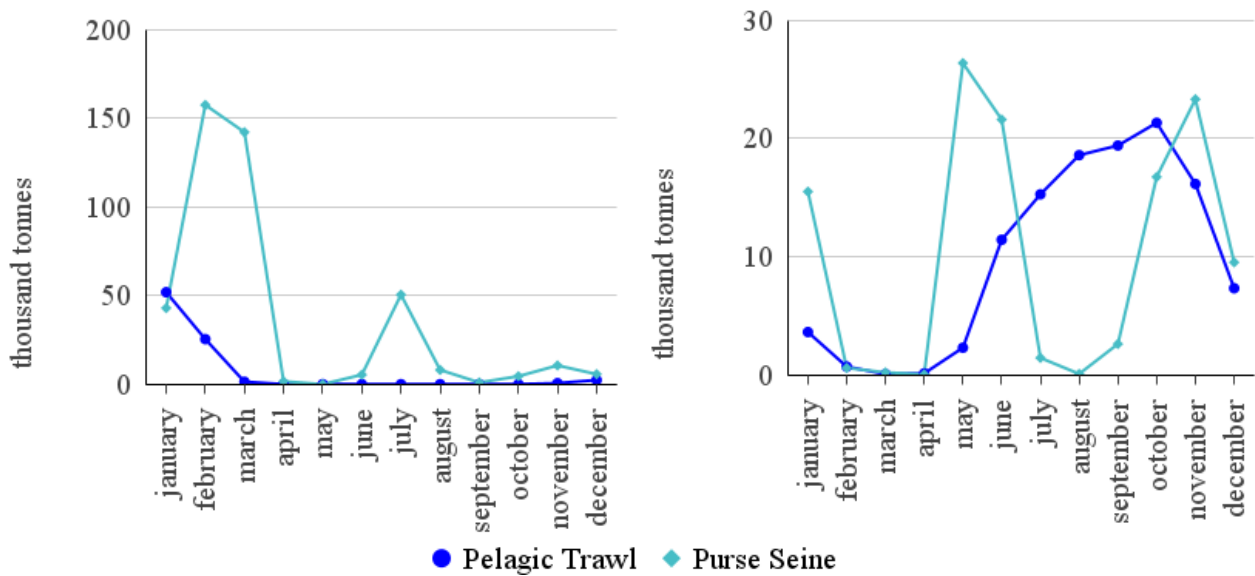
Notes: catches with a value of consistently less than 50 million ISK annually are omitted.  
Herring includes catches of Norwegian spring-spawning herring.  
Sources: Hagstofa Íslands.

Icelandic fisheries statistics show that the value of pelagic catches increased nearly threefold between 2005 and 2013, from less than 10 billion ISK to more than 25 billion ISK.<sup>508</sup> Within this same timeframe the volume of pelagic fish caught decreased, fluctuating between half a million and a million tonnes. Over the first decade of the twenty-first century, pelagic fish caught with pelagic trawls contributed the bulk of the value of pelagic fisheries, while the purse seine becomes in effect supplementary to this. This is largely due to the reduced quota for capelin and capelin roe, which was in effect from the 2005-6 fishing season onwards.<sup>509</sup> Had the capelin quota been higher, the value of catches from the purse seine would have made a greater contribution. Later, in the years 2010 to 2014, the value of purse seine catches increased when the reduced quotas came to an end.

<sup>508</sup> Hagstofa Íslands.

<sup>509</sup> ICES, 'Capelin (*Mallotus Villosus*) in Subareas 5 and 14 and Division 2.a West of 5', 3.

Figure 56. Average monthly catches: capelin (left) and herring (right), 1996-2018



Sources: Hagstofa Íslands.

The average monthly catches for herring and capelin are shown in figure 56. For herring, the pelagic trawl was used mostly from June to December, while the purse seine was used from April to July and then again from October to January. This is less the case for capelin, as both methods were used during the fishing season, and the purse seine was used again in the summer months to catch capelin roe. Each method was used at specific times of year, in response to fish behaviour and migration patterns at those times of year. Either the fish were too dispersed or they were migrating through waters at a depth too deep for purse seines to effectively catch them. The pelagic trawl and the purse seine were therefore tools that were used as and when necessary, with the purse seine being the primary method and the pelagic trawl used to fully exploit pelagic fisheries when the purse seine was not sufficient.

### 3.2.4 Summary

The primary output of pelagic fisheries was not fish for human consumption, but fishmeal and fish oil. This is seen in the three countries examined here and elsewhere. Reduction was an established industry long before the introduction of the pelagic trawl and when the pelagic trawl was used, it was often used to catch fish for this industry. In Sweden during the 1960s large catches were made with pelagic trawls, but these fish were low value, intended for reduction. A decade later in Scotland, during the 1970s, the value of fish caught with pelagic trawl was higher than with other methods. Yet use of the pelagic trawl diminished in favour of the purse seine. In twenty-first century Iceland a similar pattern is seen, with the value of fish caught with pelagic trawls higher than those caught other methods.

In Sweden catches made with pelagic trawls were either of low quality or were perceived to be of low quality. However, the data available is only for a relatively small

sample. It shows that fish caught with the pelagic trawl was worth less than catches caught with other methods, yet significantly larger quantities of fish were caught with pelagic trawls. The volume and value of pelagic fisheries did increase between the late 1940s and mid-1960s, which must be at least in part attributed to the pelagic trawl.

In Scotland the pelagic trawl was first used in the mid to late 1960s, in the same decade as the collapse of the herring stocks. It was used to a great extent until fuel costs rose in the 1970s, at which point the purse seine was preferred instead. The initial popularity of the pelagic trawl perhaps derived from its ease of use. Purse seines were more challenging, but once mastered, yielded much larger catches and required significantly less fuel to operate. However, the dominance of the purse seine did not render the pelagic trawl obsolete. It was still needed in order to fully exploit pelagic fisheries. The pelagic trawl caught fish that were too deep or too dispersed for the purse seine, typically during the winter months. Unlike in the Swedish fisheries, the pelagic trawl did not have such a detrimental effect on the quality of the catch and is seen in the typically higher value of catches made with the pelagic trawl. Ultimately, both methods of fishing resulted in large volumes of fish which were sent for reduction at a time of intense demand by the reduction industry.

The purse seine dominated Icelandic fisheries until the end of the twentieth century, with the pelagic trawl only coming into popular use in the 1990s. By 2010 it was the preferred method for catching herring and redfish, with purse seines preferred for catching capelin. Each method was used for the fisheries they were best suited to. The use of the purse seine fluctuated as the capelin quota fluctuated. The bulk of pelagic catches were processed for reduction, although there was a significant increase in the export of frozen fish for human consumption in the twenty-first century. What is evident is that while the pelagic trawl contributed the majority of the value of pelagic fisheries, this value was not derived from the processing method used.

The connection between the pelagic trawl and the products of pelagic fisheries shifted over the latter half of the twentieth and into the twenty-first century. Limited data for Sweden suggests that pelagic trawl catches were very large but of a lower value than catches for other methods. In mid-century Sweden the pelagic trawl is linked closely to fish caught for reduction, which was still the case in Scotland in the 1970s and 1980s. Both nations focussed their pelagic trawling on herring, with Scotland also using the pelagic trawl to catch mackerel, albeit to a lesser extent than herring. In Scotland the value of pelagic catches was derived mostly from the purse seine, with catches destined for reduction. Twenty-first century Iceland also used pelagic trawling to focus on herring, but shifted the focus to fish for human consumption, as it commanded a higher value than fish for reduction. In Iceland the pelagic trawl was also used for herring, but with a focus on fish for human consumption, which had a higher value. This explains why pelagic trawl catches contributed the majority of the value of pelagic catches.

### 3.3 Productivity

Productivity in this chapter is assessed using catch per unit of effort, or CPUE. This requires data for the total catch volume of fish for each fishing method, as well as the time it takes to catch that fish. The result is either tonnes per hour or tonnes per day. Depending on the available data, it may also be possible to calculate this as either tonnes per unit of total time spent at sea, or as tonnes per unit of time spent actively fishing. Where relevant, both are examined and discussed. Productivity for the countries Sweden, Scotland, and Iceland have been chosen for two reasons. First, each has a relatively reliable data set that can be used to calculate productivity over at least a decade. Second, each covers a different time frame in the history of the pelagic trawl.

Sweden has sample data for the period 1954 to 1963. While it is just for two key harbours and with a limited date range, it represents the earliest use of the pelagic trawl. Unlike the other countries examined here, the competing fishing method was the herring bottom trawl. While it would be possible to find data for purse seines for this time period, they would not be truly comparable unless they were fishing in the same locations with comparable resources (which they were not). Scotland began using pelagic trawls and purse seines in the 1960s, with data available for the whole country. By the late 1960s the pelagic trawl had undergone significant developments in many different ways, from materials and electronic equipment to ships and fishing techniques.

There is also data from Iceland. While Icelanders were well aware of the pelagic trawl as far back as the 1950s, fishermen preferred the purse seine and only began to seriously use the pelagic trawl in the mid-1990s. Catch data by fishing method is available from the mid-1990s. However, concerns over data accuracy and reliability means that productivity is calculated from 2000 onwards. Iceland is an example of the adoption of the pelagic trawl as an already established fishing method and one that continues to be used into the twenty-first century.

Using CPUE in historical studies is not new, and its integration into historical studies is important, if underused.<sup>510</sup> There are several papers and case studies outlining approaches which informed the approach made in this section.<sup>511</sup> There are numerous factors that are relevant and each must be considered. They involve understanding the fishing conditions pertaining to pelagic fisheries, such as fish behaviour, geographical area, and technological change in the fishing fleet.<sup>512</sup> These are all evaluated and discussed to lend much-needed context to the data presented here.

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<sup>510</sup> Poulsen and Holm, 'What Can Fisheries Historians Learn from Marine Science?', 89.

<sup>511</sup> Walden et al., 'Productivity Change in Commercial Fisheries', 289–93.

<sup>512</sup> Engelhard, 'On the Need to Study Fishing Power Change', 89–90.

### 3.3.1 Sweden

Annual fisheries statistical data from Statistiska Centralbyrån contain data from the harbours of Gravarne and Smögen from 1954 to 1963. After this date, the annual reports no longer contain this information. From the mid-1960s Swedish ports ceased to be the primary ports of landing for herring and skrapfisk. Herring was instead landed in Denmark for the reduction industry. By the end of the decade the herring stock had collapsed, effectively ending the North Sea herring fishery for Swedish fishermen.

This dataset is comprehensive for these two ports. Herring bottom trawling and pelagic trawling were only two of the methods detailed, but in this case are the only two that are relevant. The herring bottom trawl is specified as such (sillbottentrål) and is distinct from other types of bottom trawl. There are entries for the purse seine, however, these landings are negligible. There are two sets of entries for each fishing method, one for fishing in the North Sea, and one for fishing in the Kattegat and Skagerrak. The data for each include the number of boats, catch volume, price per kilogram, number of landings, number hours spent at sea per trip, and number hours spent actively fishing while at sea.

Fishermen chose to land their catches in Denmark for the better prices offered by the reduction industry there. Landings at Gravarne and Smögen diminish from the mid-1950s, demonstrating that this preference started prior to being recorded in the statistical reports. Using the data for these ports and the total catch for each species, it is clear that Gravarne and Smögen represent only a small part of the west coast fisheries, even in the mid-1950s. It shows that in 1954 fishermen landed a little more than 11% of Sweden's total herring catch in the harbours of Gravarne and Smögen. This falls to less than 1% by 1963, even when landings from outside of Sweden are excluded. On the one hand, this clearly shows that these ports were not receiving the bulk of the pelagic catch and were thus perhaps not particularly prosperous. On the other hand, these ports must have been chosen for a reason. They most likely represent ports that were known to receive comparatively large landings of fish. Alternatively, they may simply have had the record-keeping to provide a detailed dataset on different fishing methods.

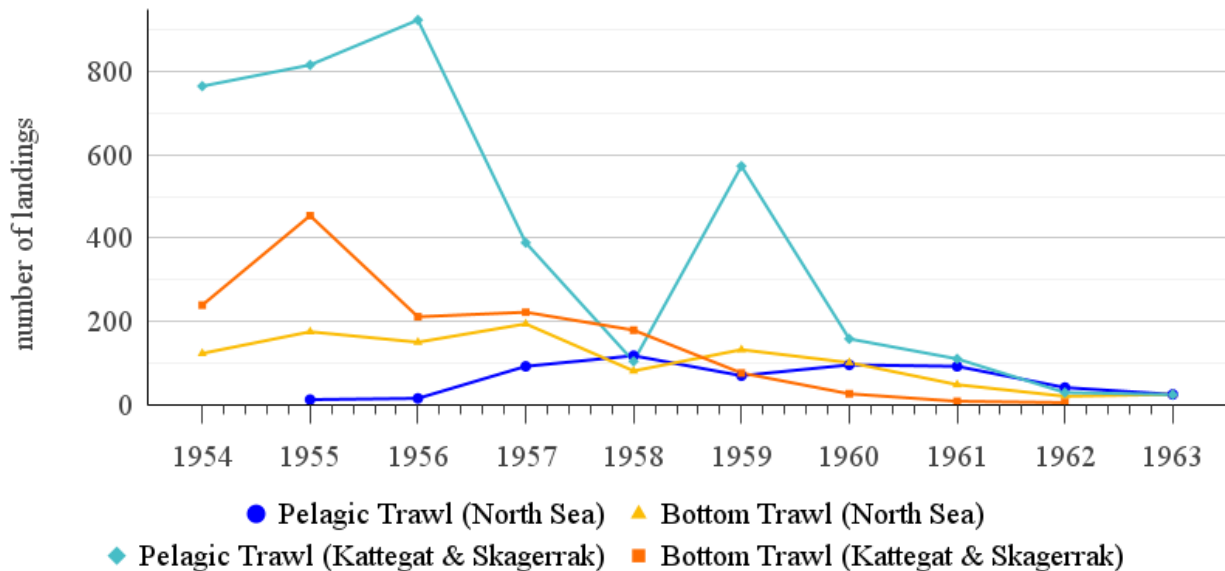
Figure 57 shows the total landings for the herring bottom trawl and the pelagic trawl for two different fishing areas, the North Sea and the Kattegat and Skagerrak. As discussed previously, these diminishing catches reflect Swedish fishermen landing their catches in Denmark and not a decline in these fisheries. Despite this, it does allow us to compare these two fishing methods within two areas. It shows that the volume of fish caught by these methods varied depending on where the fish was caught. The pelagic trawl was by far the most productive, particularly in the Kattegat and Skagerrak in the mid-1950s. In the North Sea, year-round fishing for herring with pelagic trawls only began in 1955,<sup>513</sup> hence the lack of data for 1954. Initially the pelagic trawl in the North Sea was the least

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<sup>513</sup> Byron, *Portraits of the Past*, 165.

productive. However, by the late 1950s pelagic trawling in the North Sea equalled catches made by other methods. There was an overall decline in landings made with herring bottom trawls in the Kattegat and Skagerrak, showing that the pelagic trawl was becoming the preferred gear type. There were no landings at all with herring bottom trawls from the Kattegat and Skagerrak in 1963, the final year recorded.

Figure 57. Swedish landings in the ports of Gravarne and Smögen, 1954-1963



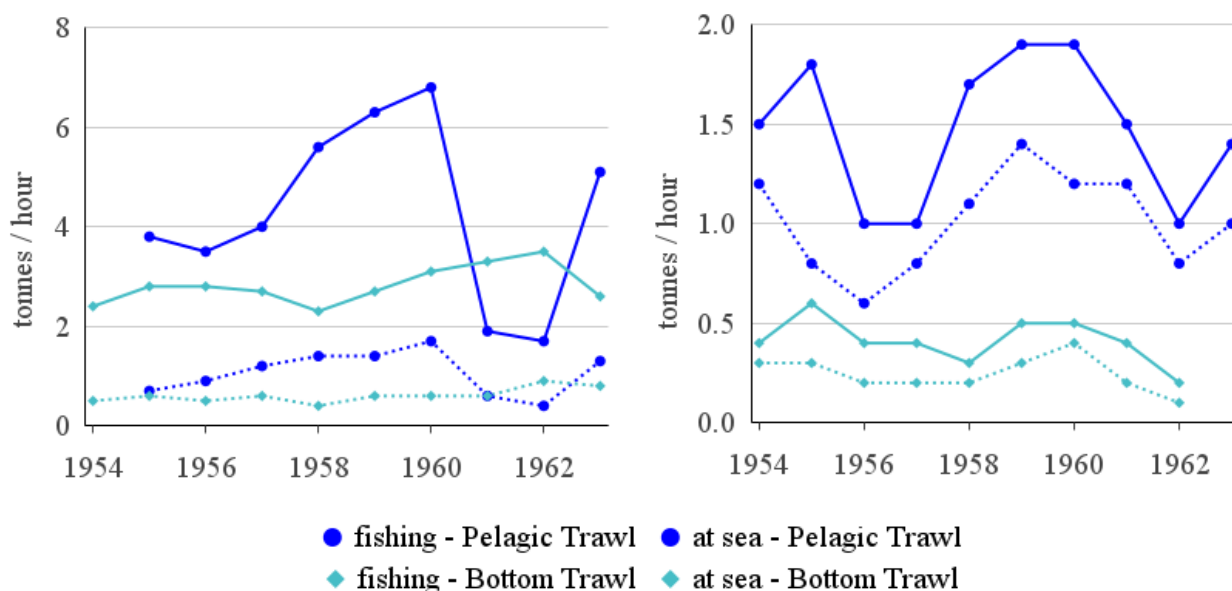
Sources: Fiske 1954 to 1963.

The statistical data collected for the ports of Gravarne and Smögen also recorded what proportion of the catch was herring. For the herring bottom trawl and the pelagic trawl, this was around 90%. Given that herring was the target species, this is hardly surprising, but it also demonstrates that there was some bycatch. For those trawling for reduction, the species or quantity of bycatch would have been irrelevant.

Entries for pelagic trawling count pair trawlers using the pelagic trawl as one landing; it is not possible to differentiate between one-boat trawls and pair trawls. There must have been some one-boat trawls, as the number of boats counted as being part of the pelagic trawl fishery are often uneven. The number of boats participating in the pelagic fishery in the Kattegat and Skagerrak was by far the highest and peaks in 1956 with 292 boats. Even halved to account for pair trawls, this vastly outnumbers the 51 herring bottom trawlers fishing in the same waters in the same year.

Figure 58 shows the catch per hour in tonnes for the pelagic trawl and the herring bottom trawl. On the left is the catch per hour for the North Sea and on the right the Kattegat and Skagerrak. "At sea" refers to the catch per hour at sea. This is the entire fishing trip, from leaving the port to their return. "Fishing refers" to the catch per hour spent fishing. This is only the time spent actively fishing with the gear in the water. This excludes the time it takes to reach the fishing grounds, search for a fishing spot, handle the catch, and then return to port.

Figure 58. Herring catch per hour: North Sea (left), and Kattegat and Skagerrak (right), 1954-1963



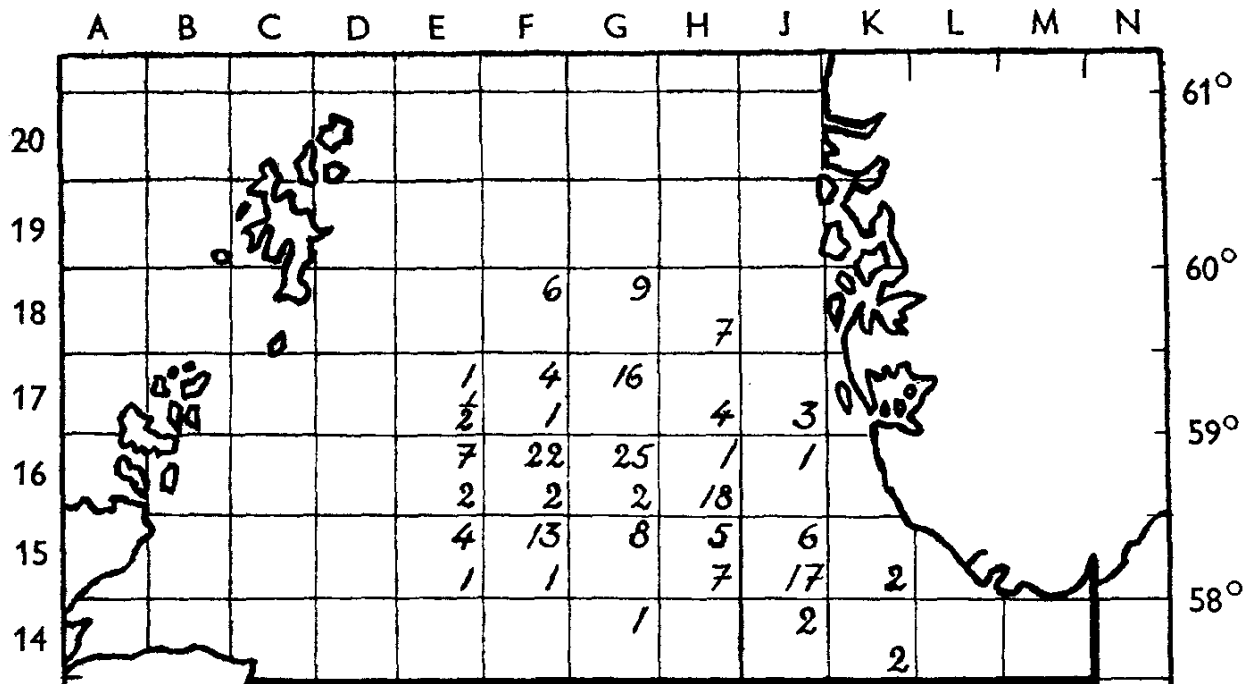
Notes: Data derived from landings recorded at the ports of Gravarne and Smögen. 'Fishing' is for catch per hour spent when only actively fishing. 'At sea' is for catch per hour of the total fishing trip, including when actively fishing. Sources: Fiske 1954 to 1963.

The pelagic trawl was overall more productive than the herring bottom trawl, and in some years, almost twice as much. These early pelagic trawls were almost always pair trawls and were much larger than the one-boat bottom trawls, so they could take a larger catch in one tow.<sup>514</sup> This would allow the pelagic trawlers to make fewer tows. The catch per hour spent fishing is much higher, and shows that the not only was the pelagic trawl catching more per hour fishing, it was also catching more per hour at sea. This is corroborated by the average length of fishing trips, which were usually several hours shorter for pelagic trawling trips than bottom trawling trips.

From 1959 to 1963 Swedish fisheries statistics recorded fishing locations in the North Sea for the boats landing in Gravarne and Smögen (figure 59). It shows that pelagic trawling was typically conducted closer to the Norwegian coast, while fishermen using the bottom trawl ventured further out, into shallower waters. This pattern is more pronounced in later years. Venturing further out meant longer trips, which was necessary as the waters immediately off the Norwegian coast are very deep. While these depths could be bottom trawled, the herring were higher up the water column and not easily caught with bottom trawls. There was no explanation for drop in productivity for pelagic trawls in 1961 and 1962 in the statistical records, so there is no ready explanation. It is most likely linked with fishing conditions and the extremely cold winter of 1961-2, which could have had a detrimental effect on the winter herring fishery.

<sup>514</sup> Byron, 169.

Figure 59. Fishing areas for boats landing in Gravarne and Smögen, 1959



Notes: A section of the diagram detailing landing data for the ports of Gravarne and Smögen.

The number of herring bottom trawl catches is in the top half of the box, with pelagic trawling catches in the lower half.

Sources: Fiske 1959.

In the 1950s it was common practice to use the pelagic trawl at night and the herring bottom trawl during the day,<sup>515</sup> as herring moved higher up in the water column at night. A fishing boat (or two boats) could alternate between gear types on a daily basis. Choice of gear type could also be a seasonal choice, rather than a daily one. In the 1960s the herring bottom trawl was used during between April and October, while the pelagic trawl was used during the main part of the herring season, which typically started in October.<sup>516</sup>

This is also seen in the landing data for Gravarne and Smögen, where pelagic trawl landings were primarily in November, January, February, and March. Herring bottom trawl landings were primarily in July, August, September, and October. There was also a shift in location, with some of these months seeing higher landings in the Kattegat and Skagerrak and other months in the North Sea. There was a clear distinction between the summer bottom trawl herring fishery and the winter pelagic trawl herring fishery.

The proportion of the herring catch caught with the pelagic trawl was thought to be around about half in the 1950s.<sup>517</sup> Data from Statistika Centralbyrån shows that in 1950 over 90% of herring caught by Swedish west coast fishermen was caught with trawls, either bottom trawls or pelagic trawls.<sup>518</sup> Studying the data from Gravarne and Smögen shows that there were significantly more pelagic trawlers than herring bottom trawlers. Even if the number of pelagic trawlers in the Kattegat and Skagerrak were halved, there would still be

<sup>515</sup> Byron, 169.

<sup>516</sup> Johnson, 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966', 36.

<sup>517</sup> Karlsdóttir, Fishing on Common Grounds, 104.

<sup>518</sup> Statistika Centralbyrån (Sveriges Officiella Statistik), Fiske År 1950, 19.

considerably more pair trawlers than herring bottom trawlers. However, with fuel costs and more crew needed for pair trawling, the pelagic trawl may not have been much more profitable than the herring bottom trawl. In the decade prior to the widespread adoption of sonar and net monitoring devices, pair trawling at night may not have been worth the risk for some fishermen.

As the statistics do not continue after 1963, it is not possible to determine if the use of the pelagic trawl increased, or whether it continued to be more productive than other pelagic fishing methods. However, other data are recorded after this date: in 1970 a count of each type of fishing gear, by their use, is included. It shows that there were 735 herring bottom trawls, compared to only 358 herring pelagic trawls.<sup>519</sup> It was standard for fishermen to keep spare trawls on board in the event of damage. Bottom trawls needed to be mended or replaced more frequently than pelagic ones, as contact with the seabed abraded or tore holes in the netting. In the 1970s the collapse of the North Sea herring stocks forced Swedish fishermen to fish in the Baltic, where they continued to use the pelagic trawl, even though the very uneven seabed of the Baltic frequently snagged them<sup>520</sup> causing damage.

The continued reliance on herring bottom trawls despite the comparable productivity could be attributed to a number of factors. This ranges from the practical to the traditional. The pair pelagic trawl had two practical disadvantages; firstly, that it required two boats to tow it, and secondly, it was primarily used at night. Either one of these would have been a challenge, even to experienced fishermen. Together, it was likely too dangerous or complex a method for some fishermen. The herring bottom trawl would have been easier and safer to use, presenting fewer risks even if it was not as profitable.

While sources show that some fishermen were swift to adopt the pair pelagic trawl, they equally demonstrate that there were as many (or more) who preferred to continue with the herring bottom trawl. Of course, there were some who used both. Tradition also dictated fishing grounds; if familiar fishing grounds were not suitable for pair pelagic trawling, then this would restrict its use. This could present an example of path dependency, where custom determines practise, despite the clear advantage of advances in fishing gear.

### 3.3.2 Scotland

Scotland has a statistical dataset in the form of the Scottish Sea Fisheries Statistical Tables. This data has a limited date range, in this case from 1961 to 1994. While this dataset is not particularly detailed, it is for the entire country. Four methods of pelagic fishing are recorded: ring nets, drift nets, purse seines, and pelagic trawls. They include the total

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<sup>519</sup> Fiske Statistik Årsbok 1971, 72–73.

<sup>520</sup> Byron, *Portraits of the Past*, 169.

number of arrivals (landings) and the total number of days absent, catch volume, and the value of catches. Between 1983 and 1994 data on hours spent fishing was also included.

When Scotland adopted pelagic trawls and purse seines, they were used alongside two older methods, ring nets and drift nets. Within ten years they had completely replaced them. The pelagic trawl was initially more popular but by the late 1970s the purse seine was the dominant method for catching pelagic species. Upgrading gear and boats were encouraged by the Herring Industry Board, which actively sought to educate British fishermen about fishing methods from the mid-1960s onwards. Their encouragement extended to sponsored trials with pelagic trawls and purse seines in the 1960s.<sup>521</sup> The Herring Industry Board also assisted with the cost of converting to these new fishing methods, with millions conferred in grants and loans, much of which was spent on new boats, as well as further loans and grants for the modernisation of older boats.<sup>522</sup>

This conversion within a short timeframe allows for a direct comparison between pelagic trawls and purse seines. The conversion appears to have been relatively uncomplicated by attachment to traditional methods or techniques, although there was some resistance<sup>523</sup> to upgrading to newer gear.<sup>524</sup> Both methods were introduced with the same inducements and level of support. Either indecision or diversity can be seen in the swift introduction of multi-purpose boats which operated as pelagic trawlers or purse seiners as required, with some using a new method and an old one, bridging the gap between old and new.

The Scottish Sea Fisheries Statistical Tables also counted boats by “primary fishing method engaged in,” which includes purse seiners and pelagic trawlers. The number of pelagic trawlers was consistently the highest, with purse seiners second. In the mid-1970s there were over a hundred pelagic trawlers – but fewer than twenty-five purse seiners.<sup>525</sup> By 1980 the number of pelagic trawlers had fallen drastically to just forty-two, against forty-six purse seiners.<sup>526</sup> It must be noted that the Scottish Sea Fisheries Statistical Tables did state that data on pelagic trawlers were for both one-boat and pair trawlers, which explains the initially high number of pelagic trawlers.

Figure 60 shows the productivity of Scottish fishing gear. For the first five years the productivity of the pelagic trawl and the purse seine were largely comparable. From 1970 onwards purse seines were demonstrably far more effective, to the extent of being at least two or three times as productive, at a minimum. Yet pelagic trawls continued to be consistently used over the next few decades. Purse seines were initially less effective as they were a difficult and specialised technique, which hampered both their uptake and

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<sup>521</sup> Whitmarsh et al., ‘Natural Resource Exploitation and the Role of New Technology’, 103–4.

<sup>522</sup> Whitmarsh et al., 104.

<sup>523</sup> Wood and Hopper, ‘A Report on the UK Herring Fisheries in the 1980’s’, 20.

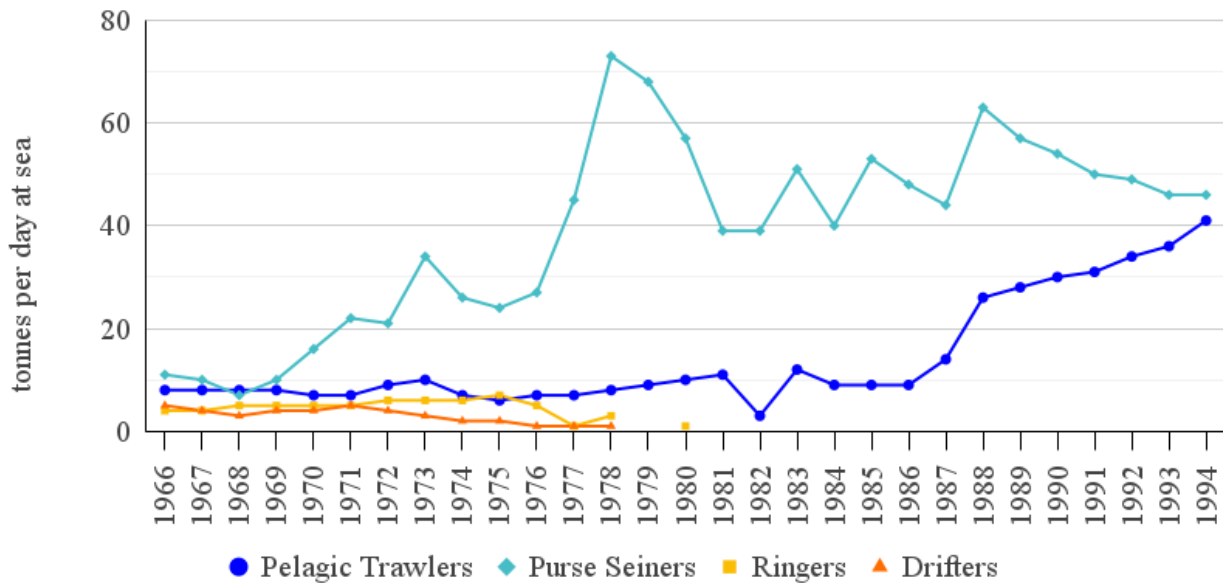
<sup>524</sup> Reid, ‘Underutilization, Undersupply, and Overfishing in the Herring Industry 1930–1980: A Case Study in the Evolution of Britain’s Productivist Fisheries Policy’, 102.

<sup>525</sup> Department of Agriculture and Fisheries for Scotland, Scottish Sea Fisheries Statistical Tables 1976, 50.

<sup>526</sup> Department of Agriculture and Fisheries for Scotland, Scottish Sea Fisheries Statistical Tables 1980, 53.

their use. The later preference for purse seines then derives from the acquisition of knowledge; the realisation that it was far more productive when used properly, and the knowledge to use it properly.

Figure 60. Catch per day at sea for Scottish fishing gear, 1965-1994



Notes: For total catches of all fish for each gear type.

Sources: Scottish Sea Fisheries Statistical Tables 1966 to 1994.

One source from the 1950s stated that purse seining was unsuitable for catching herring in British waters as herring did not shoal densely enough,<sup>527</sup> which may account for the initial popularity of pelagic trawlers over the purse seine. However, another source from earlier in the same decade was more comprehensive in its investigation of herring behaviour. It stated that there was some disagreement regarding herring behaviour, ranging from its responses to different types of gear to whether the herring was even diurnal at all.<sup>528</sup> The North Sea herring was (and still is) comprised of several different stocks with a half-dozen different seasonal spawning grounds (with more in the waters off the west coast of Britain and Ireland).<sup>529</sup> They had similar migration patterns and were often considered to be one stock<sup>530</sup> although they spawned at different times of year. Those disagreements of the 1950s were perhaps then deriving from a lack of comprehensive research at that time into herring in British waters. When it was investigated, it became clear that there was significant variation in herring behaviour. It shows that in Scottish waters herring either formed denser shoals at depth, spreading out when closer to the surface, or kept to a larger single mass.<sup>531</sup> If herring had been observed as spreading out when close to the surface, this could have influenced the initial decision to use pelagic trawls over purse seines.

<sup>527</sup> Hodgson, *The Herring and Its Fishery*, 48.

<sup>528</sup> Balls, 'Environmental Changes in Herring Behaviour', 274–75.

<sup>529</sup> Frost and Diele, 'Essential Spawning Grounds of Scottish Herring', 722–23.

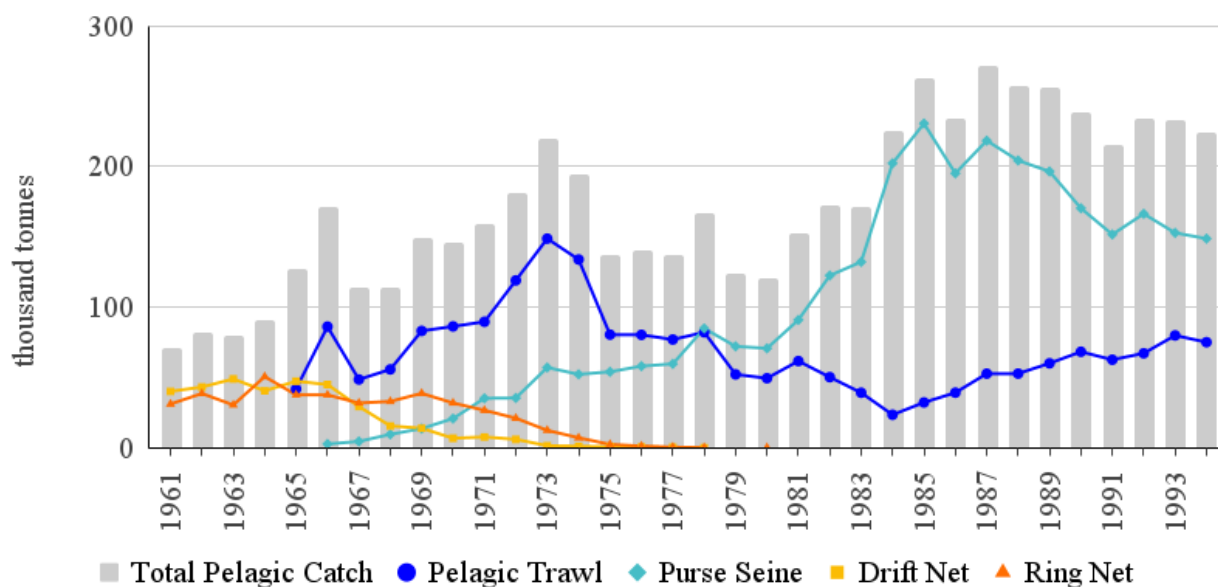
<sup>530</sup> Frost and Diele, 723.

<sup>531</sup> Balls, 'Environmental Changes in Herring Behaviour', 276.

The fishing season changed for herring. In the 1960s it was a summer fishery, but by the 1980s was primarily conducted over the winter months. A Canadian report from the 1960s describes pelagic trawling around the north of Scotland in July, albeit on a German pelagic trawler. This report states that while the individual catches made with the pelagic trawl seemed meagre, they were still better than could be expected with a purse seine, as the herring at this time of year were in thin shoals and stayed closer to the seabed<sup>532</sup> and so were not dense enough or high enough in the water column to be caught effectively with purse seines.

By the mid-1980s the herring season had shifted from summer to winter, to October through March.<sup>533</sup> This change in fishing season can also be seen in the data on pelagic trawler gross earnings by month. This dataset was only recorded between 1975 and 1980, but it clearly shows that the income from pelagic trawlers was mostly in the winter months, mainly between September and February.

Figure 61. Catch volume by fishing method in Scotland, 1965-1994



Notes: Total pelagic catch is for all methods combined. Catch by method is for all fish caught with that gear type.  
Sources: Scottish Sea Fisheries Statistical Tables 1966 to 1994.

Figure 61 shows catch by fishing gear. The volume of fish caught with purse seines begins to exceed that of pelagic trawls starting in 1978. Pelagic trawls were still used to catch herring, even after the collapse of the North Sea herring stocks, albeit in declining numbers. The use of the pair pelagic trawl decreased in favour of the one-boat pelagic trawl in the 1970s.<sup>534</sup> From 1974 the pair pelagic trawl was almost only used for catching sprat,<sup>535</sup> a fishery which declined significantly from 1979 onwards. There were also significant herring catches made off the west coast of Scotland, in the Atlantic Ocean, from

<sup>532</sup> Johnson, 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966', 56.

<sup>533</sup> Greenstreet et al., 'Fishing Effects in Northeast Atlantic Shelf Seas', 121–22.

<sup>534</sup> Greenstreet et al., 112–14.

<sup>535</sup> Greenstreet et al., 109–10.

a different herring stock. This fishery seems to have been the focus of pelagic trawling until 1977, as herring catches made with pelagic trawls were far greater than those for purse seines until that date. 1977 is also the date when the British herring fishery was officially closed.<sup>536</sup> After this date catches of herring with purse seines were typically twice the size of those made with pelagic trawls. While the use of the pelagic trawl was already declining, this must be recognised as a significant factor in the ascendance of the purse seine. Fishermen had to seek alternative fisheries.

From 1975 onwards catches for mackerel with purse seines were consistently higher than those made with pelagic trawls. They increased significantly until the early 1980s, when mackerel accounts for about two thirds of the purse seine catch. By the end of the 1980s purse seines caught over 120,000 tonnes of mackerel annually, while the pelagic trawl typically caught around twenty-five tonnes. Sprat was another alternative fishery, targeted for reduction starting in the early 1970s.<sup>537</sup> It was the first fishery that the pelagic trawl was used in, with 90% of the pelagic trawl catch in 1965 being sprat. However, sprat catches declined almost immediately in favour of herring. The sprat fishery declined significantly from 1979. Sprat was the only fishery not exploited with purse seines.

From the 1960s onwards purse seining increased in Shetland and off the northeast coast of Scotland.<sup>538</sup> Shetland had been exposed to purse seining in the 1960s by visiting Norwegian fishermen.<sup>539</sup> At first, Shetland fishermen rejected purse seining as being just too different from the traditional drift netting; not only was it a different kind of fishing gear, it operated different kinds of boats and at different times of year. Their reluctance was based on a number of factors, which included tradition, fear that overfishing would negatively affect prices, and the prohibitive cost of new gear.<sup>540</sup>

There was also an element of competition between the Shetland drift netters and the Norwegian purse seiners. To some Shetlanders, converting to purse seining might have been economically beneficial but perhaps felt too much like giving up on a well-established tradition. The enormity of the changes required was also a major factor, especially as many were older men who saw little point in change so close to retirement. This included the time and effort to learn what was a highly organised and mechanised technique, which was also time-sensitive.<sup>541</sup>

The knowledge and skill of skippers has been proven to be critical for the productivity of fishing gear.<sup>542</sup> While pelagic trawling was not conducted in Scotland prior to 1965, it was one with a skill set easily transferred from bottom trawling. Pelagic trawling works best

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<sup>536</sup> Department of Agriculture and Fisheries for Scotland, *Scottish Sea Fisheries Statistical Tables 1981*; Wood and Hopper, 'A Report on the UK Herring Fisheries in the 1980's', 1.

<sup>537</sup> ICES, 'ICES FishMap Species Factsheet - Sprat', 3.

<sup>538</sup> Greenstreet et al., 'Fishing Effects in Northeast Atlantic Shelf Seas', 112–13.

<sup>539</sup> Goodlad, 'Old and Trusted, New and Unknown: Technological Confrontation in the Shetland Herring Fishery', 61.

<sup>540</sup> Goodlad, 77.

<sup>541</sup> Goodlad, 75–76.

<sup>542</sup> Pascoe and Coglan, 'The Contribution of Unmeasurable Inputs to Fisheries Production', 595–96.

with equipment such as a netsounder, which were expensive – but even with this additional cost, they were still cheaper to purchase than purse seines. To argue the opposite is to point out that Scottish fishermen had previously practised ring netting, which was similar in concept to purse seining, also a transferable skillset. Either way, their choice would have been partly based on economy and partly on experience.

In the late 1980s and 1990s the productivity of pelagic trawls increased significantly while the productivity of purse seines decreased somewhat. It has already been established that from the 1970s onwards the pelagic trawl was used seasonally and at times when the purse seine was ineffective. This was in part to catch the maximum quantity of fish permissible, as purse seines alone could not fish the entire quota available. This is also a factor in its productivity; it was used to target fish quickly. Instead of waiting for the shoals of fish to rise in the water column to be caught with purse seines, a trawler used the array of electronic equipment available to target and catch the fish with a pelagic trawl. This was “aimed trawling”, as discussed in the previous section on technological development. It allowed for trawlers to minimise the time spent towing and increased productivity significantly. The pelagic trawl was the more versatile choice, as it was used to target a wider array of pelagic fish successfully, even if the volumes caught were smaller.

An increase in productivity can also be linked to the introduction of GPS in the late 1980s. It has been demonstrated that this allowed fishermen greater efficiency in locating known fishing grounds, reducing the time spent searching. It helped fishermen to fully exploit a particularly productive area more effectively, as they could accurately tow over the same area productive areas repeatedly.<sup>543</sup> It also allowed data to be recorded and shared, with productive areas prioritised and unproductive areas marked to be avoided.

Ultimately, tradition was quickly abandoned in favour of productivity. At first, this benefitted pelagic trawling over the older methods, which were quickly phased out. However, pelagic trawling then decreased in favour of purse seining, for two reasons: fuel efficiency and productivity. It was not abandoned completely, as it was needed to exploit fisheries at times when purse seining was not effective. The pelagic trawl was retained in order to catch otherwise unreachable fish. This is partly due to the comparative ease of pelagic trawling compared to purse seining – the gear was easier to use and store, as well as being cheaper. Further, the adoption of multi-purpose vessels made maintaining additional equipment relatively straightforward.

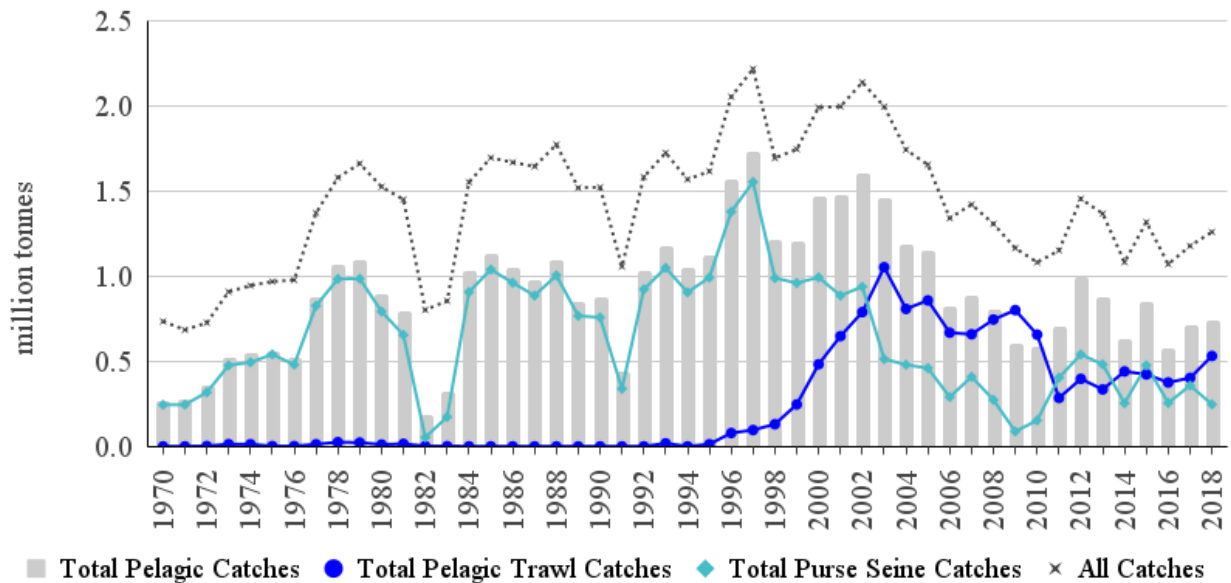
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<sup>543</sup> Robins, Wang, and Die, ‘The Impact of Global Positioning Systems and Plotters on Fishing Power in the Northern Prawn Fishery, Australia’, 1650.

### 3.3.3 Iceland

Pelagic fish (including redfish) comprised between 50% and 75% of total catches in Iceland from the 1970s onwards. Capelin was the main pelagic catch at this time, becoming the main pelagic catch following the collapse of the herring stocks in 1960s. It accounted for at least 75% of the total pelagic catch until 2000. From 2000 onward catches were comprised mainly of herring and blue whiting, which was supplanted by mackerel from 2008 onwards. Until the end of the twentieth century the purse seine was the preferred fishing method, as shown in figure 62. Pelagic trawling was used in the 1980s but not adopted on a large scale until the 1990s. Its use peaked in the mid-2000s before declining again soon after.

Figure 62. Icelandic pelagic catches and methods, 1970-2018



Notes: Other methods with catches of less than 30,000 tonnes annually are omitted.

Catches for redfish are omitted due lack of data on method of capture.

Sources: Hagstofa Íslands and Fiskifélag Íslands.

The pelagic trawl was first used in the 1950s, although the most successful Icelandic design, the Breiðfjörð trawl, was only used for a few years in the 1950s to catch cod.<sup>544</sup> A number of other pelagic trawl designs were tested in the 1950s,<sup>545</sup> but none were used commercially. In the 1970s a handful of boats adopted pelagic trawls for catching blue whiting<sup>546</sup> and redfish. However, there is no data on the fishing gear used in the redfish fishery, plus there was initially no differentiation between pelagic and demersal sub-species of redfish. As a result, it is not possible to determine the extent to which the pelagic trawl was used before the 1990s.

There is detailed logbook data available for Icelandic fishing boats which can be used to calculate productivity. Prior to 1990 this data is somewhat unreliable; in 1997 the

<sup>544</sup> Anonymous, 'Bylting í fiskveiðum', 4.

<sup>545</sup> Guðjónsson, 'Yfirlýsing', 7.

<sup>546</sup> Anonymous, 'Börkur tefst í Noregi', 16.

Directorate of Fisheries started using a boat monitoring system<sup>547</sup> which improved the accuracy of reporting, especially within Icelandic waters.<sup>548</sup> As increased and systematic use of the pelagic trawl only began in the late 1990s, calculating productivity for the pelagic trawl from the year 2000 onwards is an acceptable compromise. Despite this, there are still issues in calculating days at sea and days spent fishing, as a single fishing trip could involve fishing for more than one species, or using more than one kind of gear.

There are significant fluctuations in the productivity of each type of fishing gear, regardless of species caught. One explanation for this is the previously mentioned overlap in data regarding days spent at sea, however, this is unlikely to be the core reason. As days spent at sea refers to the entire fishing trip, any active hindrance to fishing will result in a longer fishing trip, reducing productivity. One factor is poor weather, which can delay fishing, as occurred in early 2015.<sup>549</sup> This can result in fishermen intensifying fishing when the weather permits, as well as turning to other fisheries to compensate. Environmental factors can also affect fish behaviour, where shoals are not dense enough to allow effective fishing with purse seines, or have an effect on migration patterns making them harder to locate. A particularly bad year, in terms of weather or fish behaviour, could result in productivity changes which have little to do with the fishing gear itself.

Quotas are also a key factor in understanding productivity in pelagic fisheries. Since the introduction of quotas, the capelin quota has varied from zero to over half a million tonnes, depending on stock size. The quota is shared with Greenland, Norway, and the Faroe Islands, with Iceland typically taking the lion's share. Several significant fluctuations in the catch per day can be ascribed to low quotas or cessation in fishing. Concerns over stock sustainability led to the capelin fishery being closed early in the 2008 fishing season<sup>550</sup> and it was closed completely for the 2019-2020 season.<sup>551</sup> Quotas could also be increased partway through the fishing season. Logbook data shows that purse seines were primarily used to catch capelin and herring. Mackerel and blue whiting were rarely caught using purse seines. Pelagic trawls were used to catch herring, capelin, blue whiting, and mackerel.

Figure 63 shows the catch per day at sea for pelagic trawls and purse seines. It shows that the purse seine was consistently more productive than the pelagic trawl. However, while not as consistently productive as the purse seine, the pelagic trawl was occasionally as effective as the purse seine. It is also clear that the pelagic trawl was more versatile in that it is used to target a greater variety of species than the purse seine.

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<sup>547</sup> Suhendar, 'Comparison of Vessel Monitoring System (VMS) between Iceland and Indonesia.', 13.

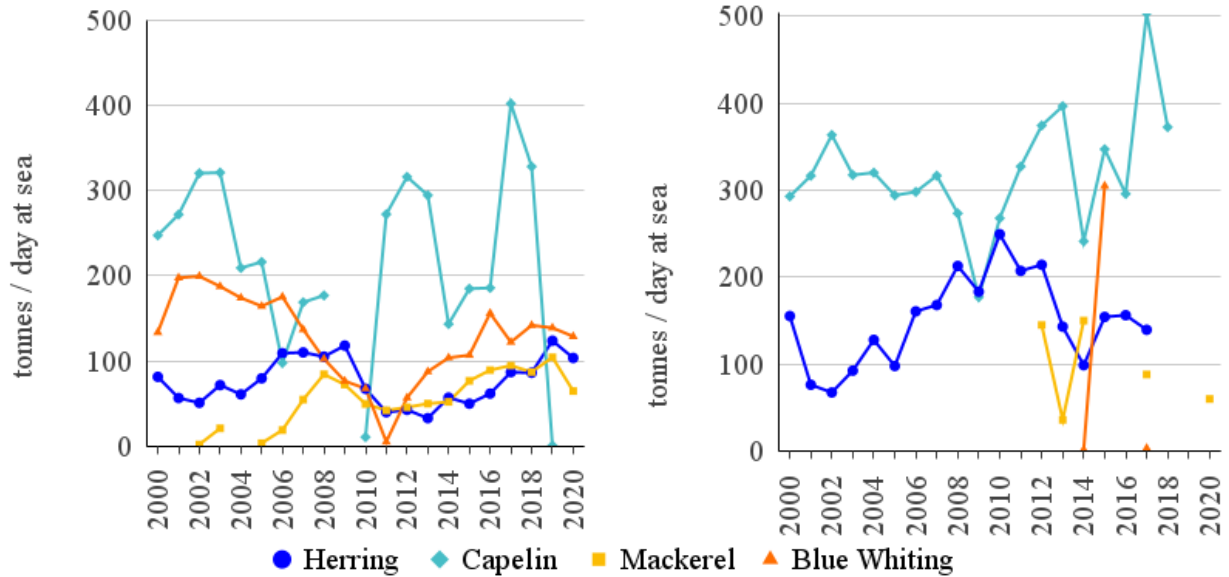
<sup>548</sup> Geirsson, 'Case Study of the Icelandic Integrated System for Monitoring, Control and Surveillance', 38–39.

<sup>549</sup> Hjul, 'Storms Disrupt Iceland Fishing'.

<sup>550</sup> Anonymous, 'Iceland Announces Shock Capelin Fishing Ban', 1.

<sup>551</sup> Marine & Freshwater Research Institute, Iceland, 'Advice for TAC of Capelin in the Iceland-East Greenland-Jan Mayen Area for the 2020/2021 Fishing Season Based on Autumn Survey (7. September – 5. October 2020)', 1–2.

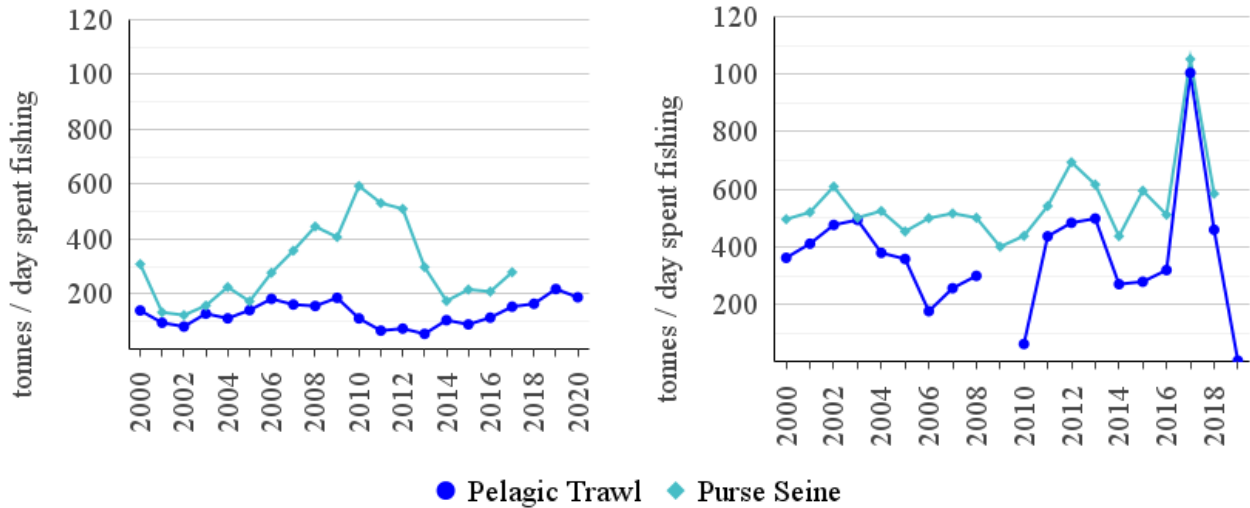
Figure 63. Catch per day at sea: purse seines (left) and pelagic trawls (right), 2000-2020



Source: Fiskistofa [Directorate of Fisheries]. 2022.

A more precise measure of productivity is catch per day spent fishing; this strips out the days spent searching for fish or days wasted due to adverse fishing conditions. There are still fluctuations in productivity, for the same reasons as before, but they are less pronounced. Figure 64 shows catch per day spent fishing, for herring and capelin. It shows that purse seining was significantly more productive than pelagic trawling.

Figure 64. Catch per day spent fishing: herring (left) and capelin (right), 2000-2020



Source: Fiskistofa [Directorate of Fisheries]. 2022.

Between 2010 and 2012 the purse seine caught more than three times as much herring as the pelagic trawl in the same space of time. For capelin, the contrast between purse seines and pelagic trawls is less dramatic, yet still sufficiently pronounced. Purse seines were catching larger quantities of fish than pelagic trawls, which could need several tows over several days to catch the equivalent quantity.

Despite the purse seine being more productive, the pelagic trawl continued to be used. As previously discussed, the pelagic trawl was used when the purse seine could not

be used effectively. The purse seine was more productive when used at the same depth as the pelagic trawl and when the shoals of herring and capelin were not too dispersed for the purse seine to catch effectively. The pelagic trawl was used either when the fish were too deep for the purse seine to reach, or when the fish were not shoaling close enough together. Seasonal migration and shoaling behaviour were seen with both herring and capelin in Iceland, with seasonal use of seines and pelagic trawl already demonstrated in figure 56 (chapter 3.3.2). The use of both types of gear was then necessary in order to fully exploit the quota for these species within the accepted time limits imposed by a seasonal fishery and further potential hindrances such as bad weather.

### 3.3.4 Summary

In Sweden, pelagic trawls were consistently more effective than herring bottom trawls. However, the greater volume caught in a single tow damaged the fish. Much of this fish ended up reduced into meal and oil, so this was of little concern. When the North Sea herring stock collapsed, pelagic trawls were used to catch Baltic herring instead, albeit in far smaller volumes. Swedish fishermen did not use purse seines. Were it possible, it would be illuminating to see how the early pair pelagic trawls compared to the purse seine.

The pelagic trawl came to Scotland a little later, in the 1960s. It was consistently used for several decades until the 1970s, when purse seines became favoured instead. Pelagic trawls were not as productive as purse seines, yet they continued to be used, despite the increased fuel costs. This is because pelagic trawls were particularly efficient in specific circumstances, either at times of year when fish were not in sufficiently dense shoals to be caught with purse seines, or were migrating through waters too deep for purse seines. This specialised use also occurs in Iceland, where pelagic trawls saw more use from the 1990s onwards. Despite fishing in different waters, the same factors applied to these migratory pelagic fish stocks. They moved through waters too deep for purse seines or shoaled too thinly. Ultimately, pelagic trawls were more versatile than purse seines, even though they were less productive.

While CPUE is a useful tool in understanding how effective fishing gear is, it cannot reveal why. The results must be assessed in light of their respective contexts, as CPUE alone does not explain why the pelagic trawl continued to be used despite being less effective than the purse seine. When mitigating factors are accounted for, they demonstrate that the pelagic trawl's usefulness goes beyond its productivity. They show that the pelagic trawl developed into a flexible tool for fishermen to use when needed, and that it was often used alongside, rather than competing with, other fishing methods.

## 3.4 Employment

Employment of fishermen is an important aspect of fisheries. It informs us as to the extent to which the industry is operating and indicates how modernised it became following the introduction of mechanisation. Overall, employment in fisheries has decreased steadily since the mid-twentieth century. This is one of the consequences of technological development in boats and fishing gear, alongside that of catch quotas and fishing restrictions.

Mechanisation reduced the need for manual labour on board ship and different types of fishing gear have different crew requirements. This is seen in both the number of crew needed and in the skills required of the crew. The skill and experience needed to operate one type of fishing gear is not necessarily transferable to another type of gear. Analysing employment in fisheries should reveal whether pelagic trawling can be linked to a decrease in the number of fishermen, if different fishing methods required different crew requirements, or had different pay structures. Pelagic trawling, bottom trawling, and purse seining are all specialised areas within commercial fishing. They have different skillsets and require resources and experience to operate successfully.

### 3.4.1 Fishermen

In Sweden a steady decline in the number of fishermen from the mid-twentieth century onwards is acknowledged in the annual statistical data, but no explanation is offered. A minor factor in the declining number of fishermen was the modernisation of the fishing fleet in the 1950s and 1960s. The major factor was the collapse of the herring stocks in the 1960s. Many fishermen went bankrupt. Many fishermen had acted as guarantors for each other's loans; where one defaulted, others were sure to follow.<sup>552</sup> There was a 72% decrease in the number of professional fishermen between 1945 and 1979, with an 80% decrease in occasional fishermen. Occasional fishermen were those who had other employment, typically farmers in rural areas and fishing communities who undertook seasonal work,<sup>553</sup> and this decrease was largely due to the lack of seasonal or temporary labour post-war.<sup>554</sup>

Professional fishermen took part in three censuses undertaken in the 1970s. These relied on self-reported data collected in 1973, 1976, and 1979. Figure 65 shows the age distribution of fishermen taken from these censuses. It shows that many professional fishermen were over the age of 50. This represents a large body of fishermen with considerable experience and skill in handling fishing gear and they would have contributed to the ongoing use of traditional fishing gear.

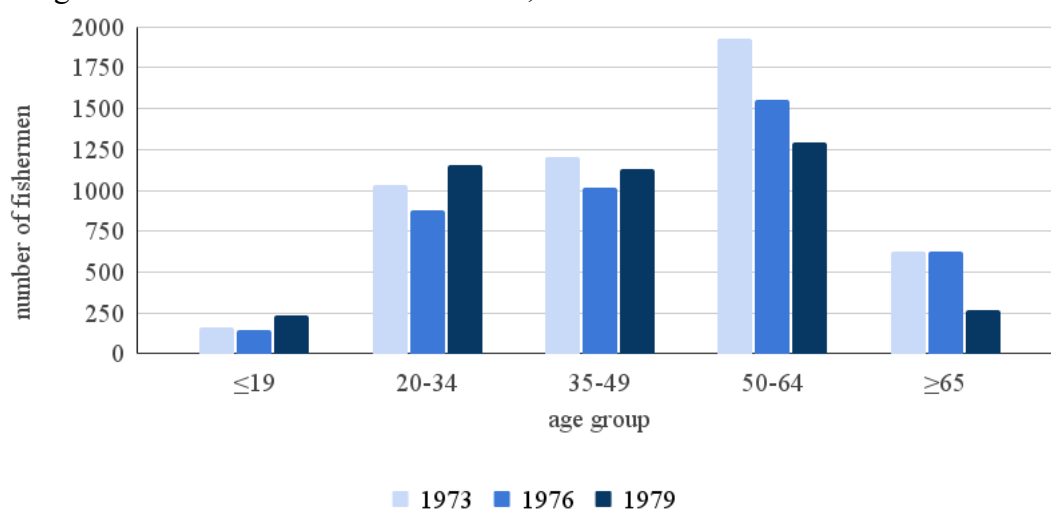
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<sup>552</sup> Byron, *Portraits of the Past*, 165.

<sup>553</sup> Löfgren, 'Resource Management and Family Firms: Swedish West Coast Fishermen', 85.

<sup>554</sup> Löfgren, 85.

Figure 65. Age distribution of Swedish fishermen, 1973-1979



Source: Fiskestatistik Årsbok 1973, 1976, and 1979.

In Scotland, too, there was a steady decrease in the number of fishermen between 1961 and 1980, as seen in the Scottish Sea Fisheries Tables. This records the number of both full-time and occasional fishermen. This decrease was less drastic than in Sweden, with the largest decrease in partially employed fishermen, of around 50%. In contrast, regularly employed fishermen saw a drop of only 12% in the same time frame. This is logical given the increase in longer voyages away from home, making commercial fishing less of an occasional day job and more a professional long-term occupation. The nature of the work also disincentivised newcomers in particular, especially among young men, with many quitting after just one fishing trip.<sup>555</sup> This meant that there was a high turnover of fishermen at the most inexperienced level.

In contrast to Sweden and Scotland, employment in the fisheries sector in Iceland increased steadily until the 1990s. This was alongside a steady increase for employment in trawling from the mid-1970s onwards. This was mirrored by an increase in the size of the bottom trawler fleet from the 1960s, until quotas became fully transferable in the 1990s. After this point employment in fisheries and aquaculture decreased.<sup>556</sup>

It is highly unlikely that the pelagic trawl played a significant role in the steady decrease in employment of fishermen in the twentieth century. The reasons for this are instead connected to the changing world post-war with greater opportunities and better working conditions presented elsewhere, as well as in the mechanisation and modernisation of fishing fleets which significantly reduced labour requirements. This was further accelerated by the collapse of the herring fisheries in the 1960s and subsequent decommissioning of fishing fleets towards the end of the twentieth century.

The core data and contemporary source material for this thesis is largely derived from three nations, Sweden, Scotland, and Iceland. However, the Soviet Union was a significant

<sup>555</sup> Davis, 'Transatlantic Danger', 171.

<sup>556</sup> Hagstofa Íslands.

fishing power and should be discussed. It was estimated that 4400 Soviet fishing boats were in operation in 1974, representing 54% of the global fishing fleet at that time.<sup>557</sup> It was also estimated that half a million people were working in the Soviet fishing industry in 1961, although only a third of those were sea-going.<sup>558</sup> Fishing was driven by a need to maximise efficiency to provide a stable protein source.<sup>559</sup> The approach of the state in the interwar period was that fisheries had been previously underutilised and poorly organised, leading to periods of poor catches.<sup>560</sup> The fishing industry was reorganised, divided into sub-ministries and then into further sections based on geographic areas, with several fleets operating within each area.<sup>561</sup> This re-organisation made each coastal fisherman a member of a collective, of which there were many, depending on the region and fleet. These separate collectives were often in some form of bureaucratic conflict<sup>562</sup> and there was a lack of clear communication between them.<sup>563</sup> Fishermen were trained through one of a number of schools of various levels.<sup>564</sup> A western source posits that this training could also be considered a means of training seamanship into a large number of personnel who could then be transferred into the navy; he further stated that intelligence ships had been noted as operating within fishing fleets on many occasions.<sup>565</sup>

### 3.4.2 Crews

Determining crew size is challenging, as this varies from ship to ship depending on their individual requirements. Side trawlers of the 1950s had a crew complement of 12 to 20 men. Stern trawlers of the 1960s onwards had a similar complement despite typically being larger; this was due to the use of mechanised deck machinery for handling the trawl and catch. The factory freezer trawlers of the 1970s had a much larger crew complement ranging from 30 to 100 people, but not all were fishermen. Those employed to process fish below decks were effectively factory workers, with little or no training in seamanship or in handling fishing gear.

The skipper was the final authority, determining when, where, and how fishing would take place. Even if the skipper was not the owner of the boat, he was still in a position of responsibility and was employed for his knowledge and skill. The ability and experience of the skipper cannot be easily quantified,<sup>566</sup> and yet is known to have a significant impact on productivity.<sup>567</sup> The process of acquiring experience in using new gear, as well as the newer,

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<sup>557</sup> Anonymous, 'The Soviet Fishing Industry: Prospects and Problems', 2.

<sup>558</sup> Armstrong, 'Soviet Sea Fisheries since the Second World War', 162.

<sup>559</sup> Armstrong, 160.

<sup>560</sup> Ferguson-Cradler, 'Managing Economies, Managing Nature', 482.

<sup>561</sup> Ferguson-Cradler, 483.

<sup>562</sup> Ferguson-Cradler, 483.

<sup>563</sup> Armstrong, 'Soviet Sea Fisheries since the Second World War', 160–61.

<sup>564</sup> Armstrong, 162.

<sup>565</sup> Armstrong, 179.

<sup>566</sup> Houghton, 'The Fishing Power of Trawlers in the Western English Channel between 1965 and 1968', 136.

<sup>567</sup> Pascoe and Coglan, 'The Contribution of Unmeasurable Inputs to Fisheries Production', 595–96.

bigger stern trawlers, had an effect on efficiency and productivity. Norway proved the exception to the skipper's ultimate authority in the purse seine fishery. Here the skipper is only in charge of the transportation<sup>568</sup> and it was instead the *nat-bos* (net boss) who took charge of the purse seine and the crew of about 24 men when it was being used.<sup>569</sup> In the USSR the captain of a trawler had the power to choose fishing areas and procedures.<sup>570</sup> The captain was provided with information on fisheries and was expected to share this with his peers, although whether this happened is debatable.<sup>571</sup>

Transferable skills are another factor in choice of fishing gear. Whereas a skipper with experience of bottom trawling can adjust to using pelagic trawls, the knowledge and experience of purse seining cannot be applied to another gear, nor can a lifetime of only purse seining be applied elsewhere. There are also challenges in transferring skills from purse seining for herring to purse seining for other species. In the twenty-first century, purse seining has become a specialised skill that belongs more to an older generation.

In Sweden small motor boats were used for the herring trawling fishery until the 1960s and had small crews<sup>572</sup> of 3 to 7 men.<sup>573</sup> These figures do not specify as whether they were bottom or pelagic trawling for herring. In Scotland, numbers varied greatly for deck crew; in the 1960s there were 4 to 6 men on the small Shetland purse seine boats,<sup>574</sup> which increased to 8 men in the 1970s.<sup>575</sup> A British source of the 1970s stated that a stern trawler of the late 1960s and early 1970s had 25 crew whereas a side trawler needed 20 crew, a 25% increase.<sup>576</sup> However, this source did not specify if this was for ships of relative size or power. Stern trawlers were much bigger than side trawlers, particularly in the 1960s and early 1970s. In the 1980s, this changed once again when smaller trawlers were built, needing only 9 to 14 crew with larger trawlers needing 12 to 14 crew.<sup>577</sup> This was a direct result of increased mechanisation combined with a reduction in trawler sizes.

In Iceland, there was a decrease in average crew size for trawlers in the 1970s which reflects the shift from side trawlers to stern trawlers. The average crew for a trawler declined from 32 in 1960 to 16 in 1990.<sup>578</sup> A stern trawler in the late 1980s could have as few as 15 crewmembers.<sup>579</sup> There is no comparable data for purse seiners. There is some data for pelagic trawlers and purse seiners from 2000 to 2018, as shown in figure 66. It shows that crew sizes reduced in size by about 25% in this time period.

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<sup>568</sup> Hodgson, *The Herring and Its Fishery*, 44–45.

<sup>569</sup> Goodlad, 'Old and Trusted, New and Unknown: Technological Confrontation in the Shetland Herring Fishery', 74.

<sup>570</sup> Armstrong, 'Soviet Sea Fisheries since the Second World War', 167.

<sup>571</sup> Armstrong, 168–70.

<sup>572</sup> Hasslöf, 'Customs, Laws and Organization in Nordic Fishing', 232–33.

<sup>573</sup> Löfgren, 'The Making of a Fisherman: The Social Context of Socialization in a Swedish Fishing Community', 92.

<sup>574</sup> Goodlad, 'Old and Trusted, New and Unknown: Technological Confrontation in the Shetland Herring Fishery', 74–75.

<sup>575</sup> Byron, 'Skippers and Strategies', 228.

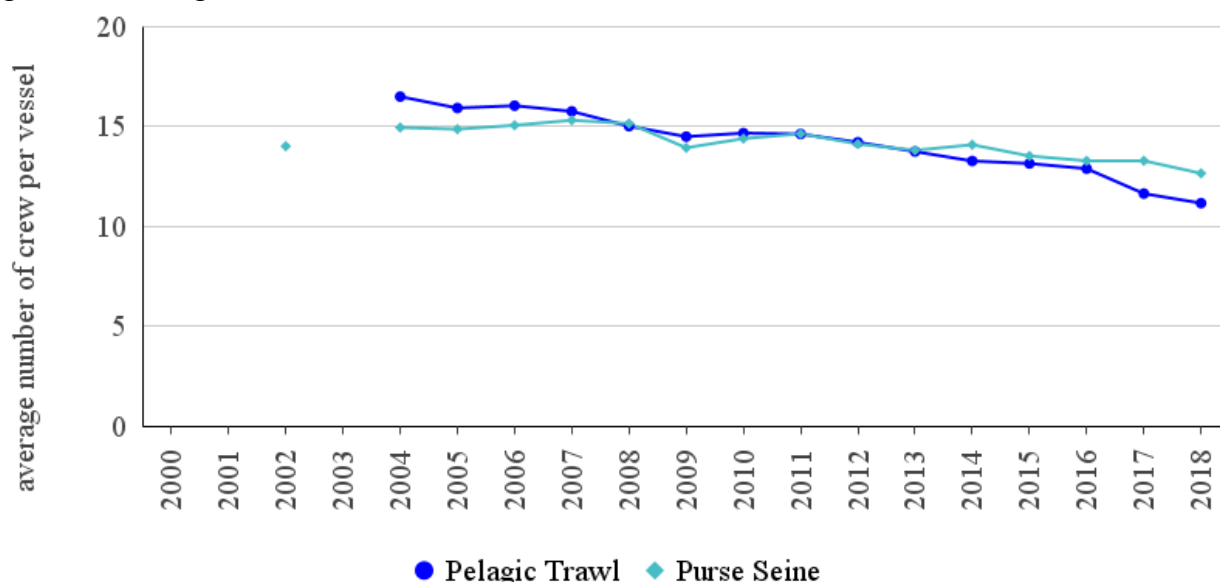
<sup>576</sup> Kerr, 'Mechanisation of Trawl Gear Handling Aboard Shelter-Deck Stern Trawlers in the Atlantic Fisheries', 30.

<sup>577</sup> Godfrey and Godman, 'The Scottish Fishing Industry: Technical Opportunities and Political Constraint', 195.

<sup>578</sup> Jónsson and Magnússon, *Hagskinna: Sögulegar Hagtölur Um Ísland - Iceland Historical Statistics*, 314.

<sup>579</sup> Personal communication with Quentin Bates.

Figure 66. Average Icelandic crew size, 2000-2018



Source: Fiskistofa [Directorate of Fisheries]. 2022.

There is very little information on crew sizes in the USSR. However, the fishing fleets utilised a large number of support vessels<sup>580</sup> which, while not actively fishing, transported catches and supplies. By the 1960s factory freezer trawlers had large crews of up to a hundred people, some of which included women whose only job was to process the catch.<sup>581</sup> Crews considered their quarters onboard as better than other countries, though this improvement was likely a necessity as they often undertook longer fishing trips than their non-Soviet contemporaries.<sup>582</sup> However, the accuracy of this is debatable. The presence of women and the improved living conditions were far from ubiquitous. In the 1980s American translators worked on board Russian trawlers in the Pacific during joint American-USSR fishing trips. One female translator reported that there were only six women out of a crew of over 85 and described the toilet as little more than a hole in the floor. The showers were decrepit and hot water was only available when the captain chose to turn it on, which was about once every ten days.<sup>583</sup>

### 3.4.3 Shares

Fishermen have, for the most part, been paid in a share of the value of the catch. This could be before or after expenses such as fuel and gear, and typically resulted in a third going to the owner, a third to the skipper, and a third divided among the crew. The exact portion was somewhat negotiable and was not necessarily the same for each individual. This further varied from country to country (and from region to region) depending on the

<sup>580</sup> Anonymous, 'The Soviet Fishing Industry: Prospects and Problems', 4.

<sup>581</sup> Heidbrink, 'A Second Industrial Revolution in the Distant-Water Fisheries?'

<sup>582</sup> Armstrong, 'Soviet Sea Fisheries since the Second World War', 173.

<sup>583</sup> Oakley, Hair of the Dog: Tales from Aboard a Russian Trawler, 39.

size of the boat and the fishery it was occupied in. It could be further complicated by the role of unions, skipper-owners, and the unpredictability of fisheries.

In Sweden in the 1960s most fishermen owned and operated their own boats, or were part-owners of a boat. Crew were typically paid in a share of the net income.<sup>584</sup> Owners, part-owners, and workers receive an equal share of the net income, with boat crews often consisting of family members or extended family; sons were given an ownership share when they began working in the family business, without having to purchase it.<sup>585</sup> As boats and gear were typically inherited, those children who left the family business to buy their own boats were then bought out by their family members.<sup>586</sup> This effectively provided financing for those starting out. For larger boats, there could be several joint owners, each of which received a larger share than the deck crew.<sup>587</sup>

In Scotland, a share system was also traditional, with the value of the catch divided between the owner, skipper, and crew. This was after the cost of fuel and expenses had been deducted, along with a share set aside for the owner.<sup>588</sup> In 1960s Shetland, there were equal shares for all crewmember.<sup>589</sup> However, only half the boat's earnings was divided between the crew, with the other half reserved for the cost of maintaining the boat.<sup>590</sup> There was also a history of deck crew contributing to the cost of the boat and/or the fishing gear, sometimes making them part owners,<sup>591</sup> for which they would also receive a share. From the 1970s onwards, as fishing boats became bigger and more expensive, ownership became centralised. By 1977, 70% of the Scottish deep sea fishing fleet was owned by just 7 companies.<sup>592</sup> In the early 1970s, the crew cost was between 35% and 40% of the total operating costs.<sup>593</sup> This meant that the share traditionally set aside for the owners had increased, reducing that of the deck crew.<sup>594</sup>

Iceland often had a minimum wage for deck crew in the event of a poor trip,<sup>595</sup> made in agreement between owners and one of the numerous worker's unions. However, this was a minimum and the share typically exceeded this. The introduction of quotas in the 1980s and their complete transferability by the early 1990s meant that ownership of fishing rights became concentrated among a small number of businesses, effectively centralising and diminishing the fishing fleet.<sup>596</sup>

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<sup>584</sup> Statistika Centralbyrån (Sveriges Officiella Statistik), Fiske 1964-66, 10.

<sup>585</sup> Löfgren, 'Resource Management and Family Firms: Swedish West Coast Fishermen', 91.

<sup>586</sup> Löfgren, 91-92.

<sup>587</sup> Hasslöf, 'Customs, Laws and Organization in Nordic Fishing', 234.

<sup>588</sup> McCall Howard, 'Sharing or Appropriation?', 321.

<sup>589</sup> Goodlad, 'Old and Trusted, New and Unknown: Technological Confrontation in the Shetland Herring Fishery', 71-72.

<sup>590</sup> Byron, 'Skippers and Strategies', 228-29.

<sup>591</sup> McCall Howard, 'Sharing or Appropriation?', 326.

<sup>592</sup> Godfrey and Godman, 'The Scottish Fishing Industry: Technical Opportunities and Political Constraint', 196.

<sup>593</sup> Kerr, 'Mechanisation of Trawl Gear Handling Aboard Shelter-Deck Stern Trawlers in the Atlantic Fisheries', 30.

<sup>594</sup> McCall Howard, 'Sharing or Appropriation?', 329.

<sup>595</sup> Matthíasson, 'Fixed Wage or Share', 90.

<sup>596</sup> Runolfsson and Arnason, 'Evolution and Performance of the Icelandic ITQ System', 40-41.

Fishermen in Estonia under Soviet rule received a salary.<sup>597</sup> Fishermen in the USSR also received a salary, which was calculated on a number of variables, including overtime and bonuses.<sup>598</sup> They only earned between a fifth and a third of their British contemporaries, but this was still largely an above average wage.<sup>599</sup> The numerous fishing fleets were encouraged to compete with each other and over production was rewarded with bonuses, all of which would have increased wages.<sup>600</sup> This productivity was encouraged at every level, as management also received bonuses for reaching or exceeding targets.<sup>601</sup> Like the share system, productivity was rewarded.

A share system incentivises the crew to perform well in order to maximise the profit of a fishing trip.<sup>602</sup> The same can be said of captains, as they typically receive a larger share. This could have the unintended effect of discouraging the adoption of a new type of fishing gear, as unfamiliarity with it would affect productivity, even if only in the short term. However, if using new gear was unavoidable, it would also have incentivised those crews to ensure its future success. Existing fishing gear would have been more attractive, as a familiar and proven technique for earning money. The risk of failure would inhibit the uptake of new fishing gear, especially among aging fishermen who were close to retirement, and did not wish to invest in new equipment.<sup>603</sup>

The fishing fleets of the USSR quickly adopted new technologies and experimented with new fishing gear.<sup>604</sup> Here there was a drive to further increase efficiency and productivity, which meant investing money in its operation. More importantly, this was of little financial risk to captain or crew as they continued to receive a basic wage, even if the fishing outcome was poor.

### 3.4.4 Summary

It is clear that determining what crew size is required for a certain type of gear is very difficult without accurate data. Most examples are for a specific boat, operating in a specific region, and for a particular fishery. There can be great variation between vessels which appear to be very similar in size or capacity, even when using the same gear in the same fishery. This is further complicated when crews are made up of family members. There are also the personal preferences of the owner or skipper to take into account, as well as the experience of the skipper and crew.

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<sup>597</sup> Vetemaa, Eero, and Hannesson, 'The Estonian Fisheries', 95.

<sup>598</sup> Armstrong, 'Soviet Sea Fisheries since the Second World War', 161–62.

<sup>599</sup> Armstrong, 179.

<sup>600</sup> Armstrong, 161.

<sup>601</sup> Armstrong, 159.

<sup>602</sup> Guillen et al., 'Remuneration Systems Used in the Fishing Sector and Their Consequences on Crew Wages and Labor Rent Creation', 1.

<sup>603</sup> Goodlad, 'Old and Trusted, New and Unknown: Technological Confrontation in the Shetland Herring Fishery', 77.

<sup>604</sup> Armstrong, 'Soviet Sea Fisheries since the Second World War', 173.

What is certain is that stern trawlers required fewer deck crew than side trawlers, and that many pelagic trawlers were stern trawlers. In the twenty-first century pelagic trawlers needed fewer crew than purse seiners. It has been established that the pelagic trawl was rarely the dominant method of catching fish. When this is considered, it is clear that the number of fishermen employed on pelagic trawlers was only a fraction of the total workforce, even without definitive data. Thus, the impact of the pelagic trawl on employment in the twentieth century is small.

The biggest impact on employment was modernisation, which affected all fishing methods. This is seen even in the twenty-first century, where crew sizes become smaller when using the pelagic trawl, due to the nature of packing and handling the gear. This is also due to mechanisation, where the net drum makes hauling and storing the pelagic trawl much easier than the more precise and complex packing away of the purse seine.

The advantages of using the pelagic trawl were a larger catch and thus a larger share. While a smaller crew meant a larger share, this is unlikely to be the determining factor in choosing the pelagic trawl. The employment of deck crew was decided upon by the skipper and the owner, who frequently had a larger share to begin with. When using new gear, it was in the best interests of skipper and crew to make it work, and work well. However, the same can be said of existing fishing gear. Rather, the share system prohibits the adoption of new gear or techniques due to the risk of reduced profit. The opposite of this can be seen in Soviet fisheries, where new gear and techniques are quickly adopted at little to no financial risk to the captain or crew.

### 3.5 Boats and Gear

The pelagic trawl was made possible by a number of technological innovations, each of which played a role. Some aided fishermen in the use of the pelagic trawl, while others helped drive its development. These innovations made for more effective and efficient pelagic trawls, which were used to full effect with the aid of auxiliary equipment. They include advances in propulsion, onboard processing equipment, ship design, synthetic fibres, and fishing aids like sonar.

In the late nineteenth century sailing boats were replaced with steam and motor boats, allowing for consistent speed regardless of the wind and the power to tow larger trawls with large catches. The progression of sail to steam is well documented, alongside the adoption and development of diesel motor engines. Some nations, like Scotland, had steam trawlers before the motor trawler while others, like Sweden, skipped steam and went straight to motor. Over the course of the early and mid-twentieth century older wooden fishing boats were replaced with larger, steel hulled boats. This was followed in the mid-twentieth century by the introduction of the stern trawler, which had a ramp and hydraulic equipment for hauling up the trawl and its catch. The first stern trawlers were also among the first factory trawlers, as multiple decks allowed fish to be processed and frozen onboard. This enabled a greater degree of deep-sea fishing as these trawlers could undertake fishing trips of several weeks or even months. In addition, these ships could also be multi-purpose boats, using multiple types of fishing gear.

The mid-twentieth century saw other advances in shipbuilding, such as engine efficiency and bollard pull capacity, which allowed for hauling larger trawls and larger catches. Polyamide fibres, such as nylon, became popular despite their expense. Synthetic fibres were more durable and lighter than their organic counterparts so trawls could be larger. These trawls were used by newly designed trawlers with the capacity to tow the trawl and its catch, as well as to process the catch and preserve it on board. Sonar and transducer devices played a key role in locating fish, and in handling fishing gear while it was in the water. Sonar had been introduced in the early twentieth century but was developed further in the 1960s with the pelagic trawl in mind.

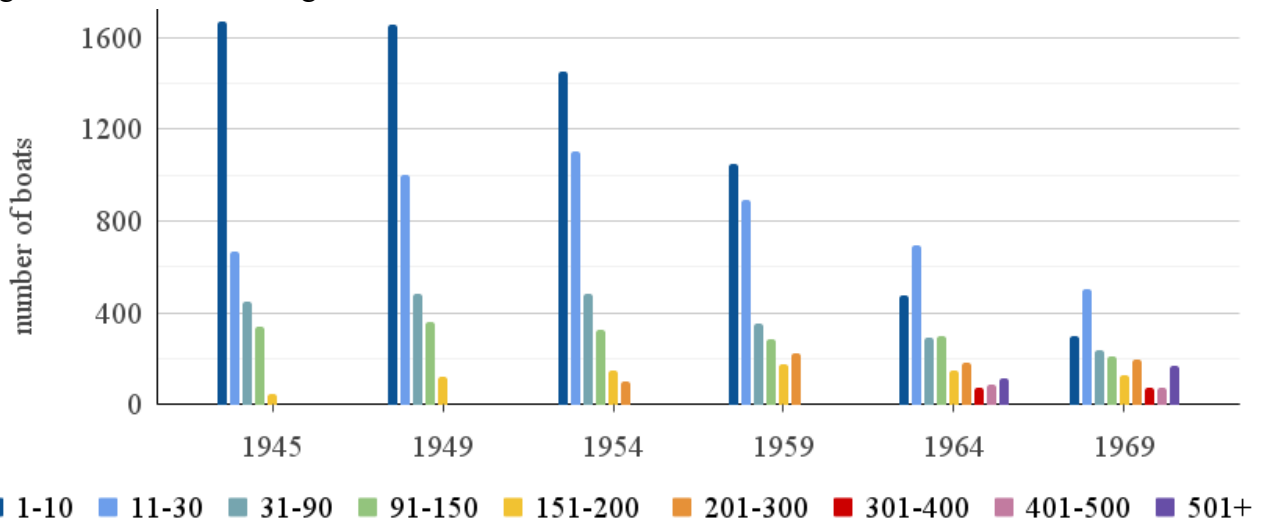
In this chapter technological innovation and development is examined from the vantage of economic importance. Each development and innovation became part of the array of equipment needed to successfully use the pelagic trawl. The decision to use the trawl by fishermen was based on a number of factors, including affordability, availability, effectiveness, and suitability. Examining this demonstrates a number of reasons as to why and how the pelagic trawl was used.

### 3.5.1 Boats

The first pelagic trawls were pair trawls in Sweden in the 1930s, used with small motor boats, in the relatively protected waters of the Skagerrak and Kattegat. These boats used the hot-bulb engine as it was more fuel efficient and easy to maintain, even though it took up more space than other diesel motor engines.<sup>605</sup> The pair pelagic trawl was bigger and lighter, not just through the use of synthetic fibres, but because they were not using trawl doors. This also meant that a greater volume of the fish could be caught in one fishing trip. As two boats were used, there was double the hold space. Perhaps this was why Swedish fishermen preferred to fish with smaller side trawlers in pairs.<sup>606</sup>

While there are no records specifically for pelagic trawlers, in 1945 Statistiska Centralbyrån recorded the total number of fishing boats by horsepower. There were several categories, which were regularly adapted over the next twenty years, reflecting the changes in the Swedish fishing fleet. In 1945 the highest category was  $\geq 151$ hp, with the category  $\geq 201$ hp added in 1952. Almost a decade later, in 1961,  $\geq 501$ hp was added, with  $\geq 701$ hp the following year. Finally, in 1966,  $\geq 1001$ hp was added.

Figure 67. Swedish fishing boats, 1945-1969



Notes: Some categories are amalgamated in order to present consistent categories across the timeframe presented.

Sources: Fiske 1945 to 1968; Fiskestatistik Årsbok 1945 to 1969.

Figure 67 shows that from the mid-1940s onwards the number of small powered fishing boats decreased significantly while the number of powered larger boats increased. In 1945 over 70% of the fishing fleet had 30hp or less. By 1969 this had dropped to little more than 40%. And yet, only 16% of boats had 301hp or more in 1969. Despite upgrades to engines and boats, most were operating with 300hp or less. While this data was for all kinds of fishing boats, it is clear that 300hp or less was sufficient for the Swedish pair pelagic

<sup>605</sup> Bornmalm and Lagerqvist, 'From Rustic Fishing Boats to Steel Trawlers', 75–77.

<sup>606</sup> Bornmalm and Lagerqvist, 81.

trawlers. Robert Larsen's 1965 Atom Trawl specified two 18 metre boats of 150 to 240hp each.<sup>607</sup> This was updated in 1978 to two 22 to 28m boats of 300 to 400hp each.<sup>608</sup>

Swedish fishermen did not process their catches onboard, preferring to deliver it fresh, so there was no need for onboard processing equipment. By the 1960s Swedish fishermen had a reputation for efficient handling of their catches, to the extent that it stayed fresh for up to a week.<sup>609</sup> As most fished close to home, these trips were typically only a few days long, well within the limit for fresh or chilled fish. Given that much of the pelagic fish caught was sent for reduction, there was little demand from fishermen using pelagic trawls to invest in expensive equipment and sacrifice hold space to it. Danish fishermen catching fish for reduction recognised its low quality and value<sup>610</sup> and it is likely that Swedish fishermen felt the same way. It also was noted that the sheer volume of landings for reduction in Esbjerg sometimes meant that catches brought into port fresh began to decay during the long wait for unloading.<sup>611</sup> With a focus on large catches of low value and low quality pelagic fish, there was little incentive for fishermen using the pelagic trawl to invest in upgrading their boats outside of increasing hold space and horsepower. It was not until the 1970s, after the collapse of the herring stocks, that steel hulls became standard and the first stern trawlers were constructed for Swedish fishermen.<sup>612</sup> They also had diesel engines, developed over the previous decades to be smaller and more efficient, taking up far less space on board by the 1960s.<sup>613</sup>

There were early attempts to bring processing equipment in board fishing vessels. Germany had, prior to the Second World War, designed several experimental vessels to operate as factory-freezer trawlers in the fishing grounds near Greenland and Canada. They had factory plants which could deep freeze fish as well as process oil and meal.<sup>614</sup> They never made it to those fishing grounds, due the events of the Second World War.

Post-war, other vessels were built with factory plants on board. *Jörundur* (figure 68), was built in 1949 with the capacity to process fish oil and meal on board, as well as fish for human consumption. Built in Britain for an Icelandic owner, *Jörundur* was a large diesel trawler at 167ft (51m). *Jörundur's* new owner was proud of its efficiency, stating that compared to a steam trawler, which used £50 of oil a day, *Jörundur* used only £33 of fuel. This saved about £5000 a year, based on the ship being at sea for 300 days a year. This was further aided by the use of an aluminium alloy in some of the construction, which reduced the weight of the boat, saving both fuel and freeing up space in the hold. Further, the new oil plant would generate £3000 annually and the meal plant would generate between

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<sup>607</sup> Design no. 128 in FAO, FAO Catalogue of Fishing Gear Designs, 1965.

<sup>608</sup> FAO, FAO Catalogue of Fishing Gear Designs, 1972, 105.

<sup>609</sup> Johnson, 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966', 35.

<sup>610</sup> Byskov, 'Esbjerg's Fishmeal Industry: Competition, Conflict and Cooperation', 145–46.

<sup>611</sup> Byskov, 145–46.

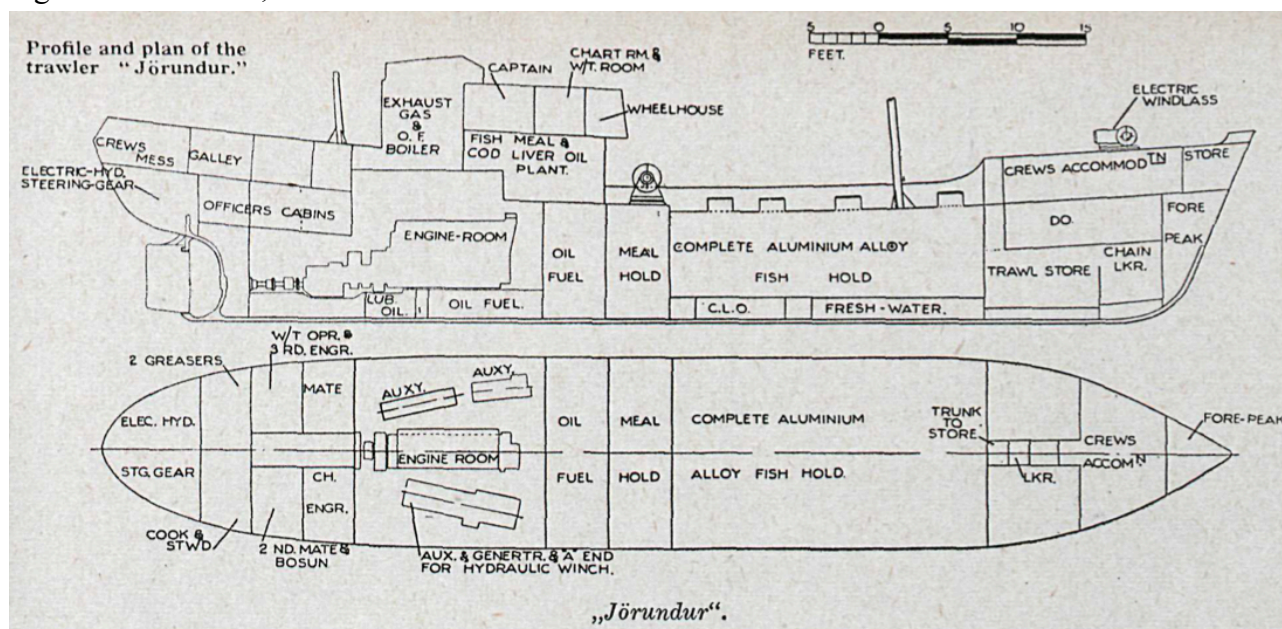
<sup>612</sup> Bornmalm and Lagerqvist, 'From Rustic Fishing Boats to Steel Trawlers', 85–86.

<sup>613</sup> Bornmalm and Lagerqvist, 75–77.

<sup>614</sup> Heidbrink, 'A Second Industrial Revolution in the Distant-Water Fisheries?', 180–81.

£4000 and £5000 annually. This meant that it would generate £15,000 more annually than a new steam trawler. Iceland mainly had steam-powered fishing boats, so *Jörundur* was an outlier at this time, as well as being a trawler rather than a purse seiner. The transition from steam to motor in Iceland occurred in the 1970s with the aid of a government supported programme aimed at modernising and stabilising the fisheries sector.<sup>615</sup>

Figure 68. *Jörundur*, 1949



Sources: Anonymous. 'Skip og vélar'. *Sjómannaþláðið Víkingur*, 1 July 1949.

Pre-war there was little market for frozen fish products in Britain and Europe.<sup>616</sup> In Britain frozen fish was not well-received by the British public.<sup>617</sup> It did not appeal to commercial buyers due to early problems with the unpleasant appearance of frozen fish, as well as the perception that only low quality fish was frozen.<sup>618</sup> Public perception in Britain changed with the introduction of convenience foods, such as fish fingers, which quickly became a popular consumer product<sup>619</sup> from the mid-1950s onwards<sup>620</sup> in America and Europe.<sup>621</sup> This was around the same time that refrigerators become cheaper and more readily available, as well as the development of transportation infrastructure. This allowed frozen fish to be easily transported, stored, and sold with little extra cost to the consumer. This change was necessary as post-war Europe was experiencing an increased and ongoing need for cheap and reliable food sources. This need was met using large, long-distance stern trawlers, the first of which was *Fairtry*.

<sup>615</sup> Sverrisson, 'Small Boats and Large Ships', 244–45.

<sup>616</sup> Heidbrink, 'A Second Industrial Revolution in the Distant-Water Fisheries?', 181.

<sup>617</sup> Robinson, *Trawling*, 214.

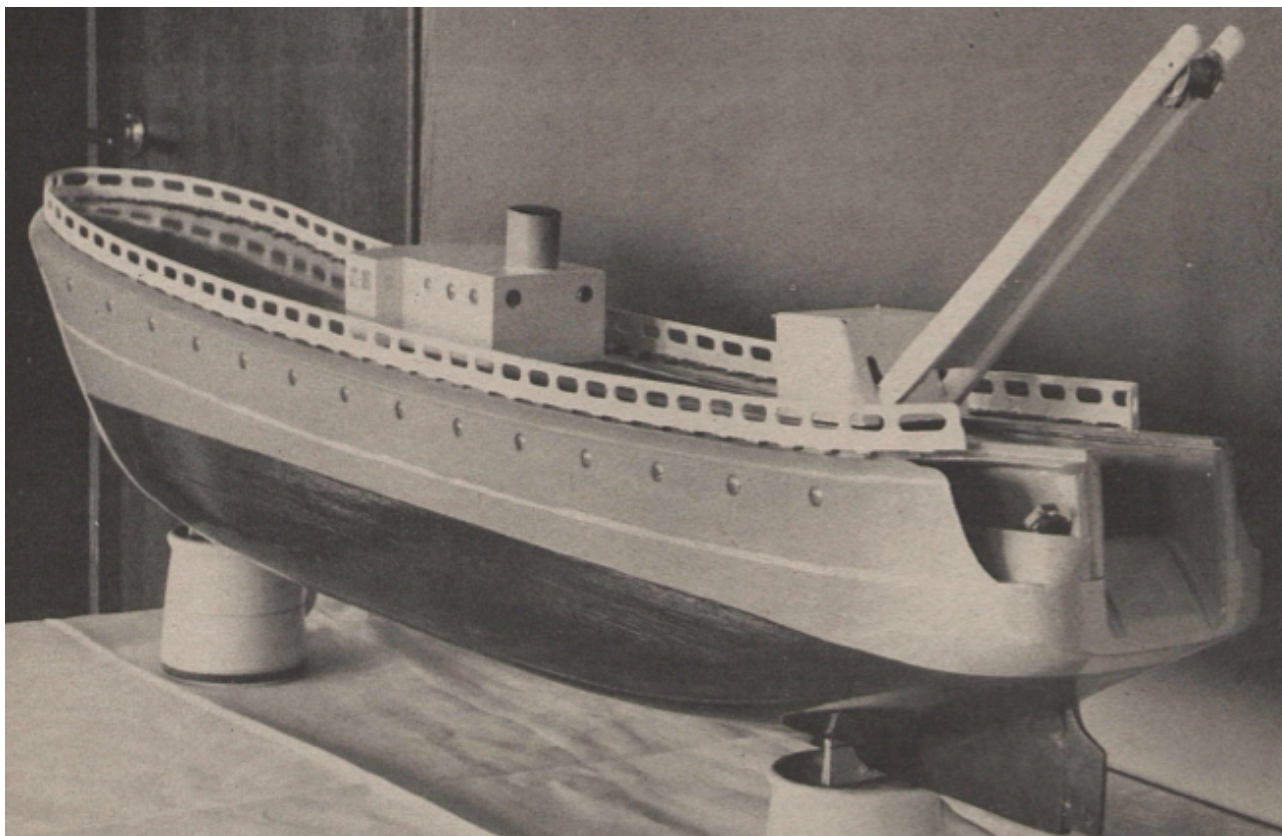
<sup>618</sup> Campbell, *The Fairtry Experiment*, 41–42.

<sup>619</sup> Campbell, 54–55.

<sup>620</sup> Heidbrink, 'A Second Industrial Revolution in the Distant-Water Fisheries?', 182–83.

<sup>621</sup> Reid, 'Evolution in the Fish Supply Chain', 37.

Figure 69. Andres Gunnarsson's stern trawler design, 1945



Source: Anonymous. 'Rætt við Andres Gunnarsson, Hugvitsmann og Vélstjóra, sem setti fram hugmyndir um skuttogara árið 1945'. *Tíminn*, 24 March 1974. Page 7

The first purpose-built stern trawler, *Fairtry*, was launched in Scotland in 1953 by Christian Salvesen & Co., a whaling company. They were inspired by *Fairfree*, which was converted in 1947 from a military minesweeper into an experimental stern trawler.<sup>622</sup> *Fairfree* had been initially purchased by Sir Charles Dennistoun Burney to test his parotter, an unsuccessful experimental one-boat pelagic trawl.<sup>623</sup> The idea of trawling from the stern was not a new one. Boats had trawled from the stern in the Mediterranean<sup>624</sup> and stern ramps had been used on whaling ships since the 1920s.<sup>625</sup> The idea was seen elsewhere too; a model stern trawler design was made in Iceland in the 1940s (figure 69).

In 1953 a Russian delegation to Britain showed an interest in *Fairtry's* layout and stern ramp.<sup>626</sup> They met with *Fairtry's* shipbuilders, but placed no orders. Instead, they swiftly ordered twenty-four stern factory freezer trawlers (BRMTs) from a West German shipyard,<sup>627</sup> two of which were fishing off Newfoundland by 1956. There were two classes of Russian BMRTs,<sup>628</sup> the Pushkin-class and the Mayakovsky-class, both of which heavily

<sup>622</sup> Campbell, *The Fairtry Experiment*, 30.

<sup>623</sup> Robinson, *Trawling*, 215.

<sup>624</sup> Osio, 'The Historical Fisheries in the Mediterranean Sea: A Reconstruction of Trawl Gear, Effort and Trends in Demersal Fish Stocks', 17–19.

<sup>625</sup> Heidbrink, 'A Second Industrial Revolution in the Distant-Water Fisheries?', 181.

<sup>626</sup> Campbell, *The Fairtry Experiment*, 59–60.

<sup>627</sup> Robinson, *Trawling*, 218.

<sup>628</sup> БМРТ: большой морозильный рыболовный траулер or BRMT: large fishing freezing trawler.

resembled *Fairtry*. British fishermen nicknamed the Soviet imitations 'Fairski's' due their close resemblance.<sup>629</sup>

There were advantages to using stern trawlers instead of side trawlers for pelagic trawling. The stern ramp hauled the trawl onboard with minimal manpower<sup>630</sup> using net drums. This allowed for different trawls to be stored when not in use.<sup>631</sup> A stern trawler could tow two trawls at the same time. A trawler could also tow a trawl while the previous catch was still being processed, which a purse seine vessel could not. Another advantage lay in its ability to operate in poor weather.<sup>632</sup>

By 1970 the USSR were operating "hundreds of ships"<sup>633</sup> – these were the BRMTs and the SRTM freezer trawlers,<sup>634</sup> as well as several other new designs. In 1970 there were about 900 large factory-freezer trawlers in operation globally, of which there were about 400 in the USSR, 50 in West Germany, and 40 in Britain.<sup>635</sup> Side trawlers continued to be used by some.<sup>636</sup> The factory freezer stern trawlers of the 1960s were large and unsurprisingly expensive. They carried large crews, typically between 75 and 100 people, of which most were employed in processing the catch. In the 1950s and 1960s the purchasing price of a factory-freezer trawler like *Fairtry* was around £750 000. In comparison a smaller trawler, with a crew of 20 to 30, cost around £250 000.<sup>637</sup> However, by the 1970s a variety of designs were available, so the price could vary considerably.

It is important that a trawler has sufficient power to tow a trawl at a consistent speed. The towing capacity of a boat is its bollard pull capacity. From the 1960s it was used to define the towing power of tug boats, often with great inaccuracy.<sup>638</sup> The significance of bollard pull capacity was not fully realised until the 1960s, when smaller stern trawlers with less power were constructed; the earlier generation of stern trawlers were large distant-water ships with greater horsepower than the side trawlers they replaced.<sup>639</sup>

Hans Hermann Engel tells of a trawler captain using a pelagic trawl who was upset that he did not catch any fish; he could see the shoal on the netsounder entering the mouth of the trawl, yet the trawl was empty. It transpired that the towing speed was the same speed as the fish swimming, and they simply escaped by moving in a different direction from the trawl.<sup>640</sup> It was therefore important to tailor the trawl to the trawler.

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<sup>629</sup> Personal communication with Quentin Bates.

<sup>630</sup> Brandt, *Fish Catching Methods of the World*, 257.

<sup>631</sup> Brandt, 258.

<sup>632</sup> Brandt, 257.

<sup>633</sup> Hjul, 'Shelter-Deck Stern Trawlers Built Since 1963', 205.

<sup>634</sup> Hjul, 207.

<sup>635</sup> Eddie and Chaplin, 'The Development of the Modern Stern Trawler', 8.

<sup>636</sup> Robinson, *Trawling*, 217.

<sup>637</sup> Eddie and Chaplin, 'The Development of the Modern Stern Trawler', 8.

<sup>638</sup> Stewart, 'It's All About Bollard Pull', 5.

<sup>639</sup> Eddie and Chaplin, 'The Development of the Modern Stern Trawler', 14.

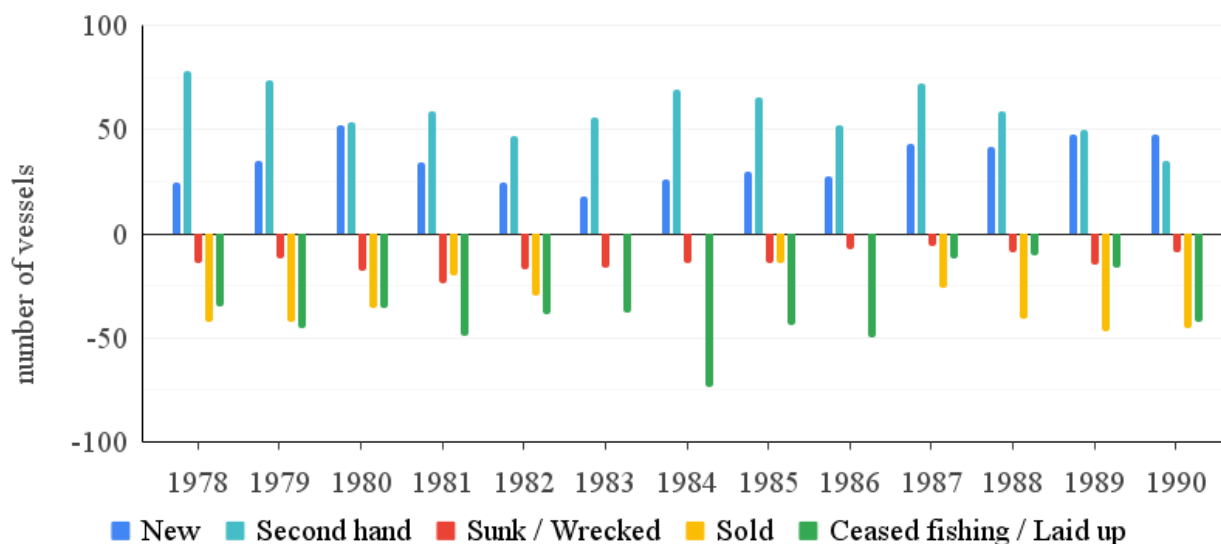
<sup>640</sup> Personal Communication with Hans Herman Engel.

Scotland encouraged modernisation in fisheries in the 1960s, offering financial assistance to fishermen to upgrade their vessels and gear.<sup>641</sup> The Scottish Sea Fisheries Statistical Tables record only one steam trawler in operation by 1966, and none from 1967 onwards. This was only a year after the pelagic trawl was introduced in Scotland and the same year in which the purse seine was first used. They also recorded the number of fishing boats by length; this shows that the number of boats in the 60 to 79ft category (18 to 23m) increased gradually between 1962 and 1977.

The 1972 *FAO Catalogue of Fishing Gear Designs* has a Scottish pair pelagic trawl design which specifies two boats of 150 to 180hp each and 15 to 23m in length.<sup>642</sup> This is after the successful modernisation of the Scottish fishing fleet in the mid-1960s which saw ring nets and drift nets replaced by purse seines and pelagic trawls. The successful adoption of these new methods had almost completely eradicated the old methods by the mid-1970s. The pelagic pair trawl remained in use for some time, although it had diminished significantly; the Scottish Sea Fisheries Statistical Tables for 1994 still recorded catches made with "single boat and pair pelagic trawl."<sup>643</sup>

The Scottish Sea Fisheries Statistical Tables show that the number of boats under 40ft (11m) decreased between 1962 and 1977, although not as drastically as the larger boats over 110ft (33m). The number of boats of 80 to 109ft (24 to 33m) remained largely the same. However, this is for all fishing vessels regardless of fishing method. Nevertheless, this does indicate that there were a large number of smaller boats operating constantly, with only a handful of large fishing boats staying in use over the same time period.

Figure 70. Scottish fishing boats, 1978-1990



Notes: Data is for boats over 30 feet in length (9.1m).

Boats 'sold' refers to those sold to new owners outside of Scotland, excluding those made within Scotland.

Sources: Scottish Sea Fisheries Statistical Tables 1982 to 1990.

<sup>641</sup> Whitmarsh et al., 'Natural Resource Exploitation and the Role of New Technology', 105.

<sup>642</sup> FAO, *FAO Catalogue of Fishing Gear Designs*, 1972, 102.

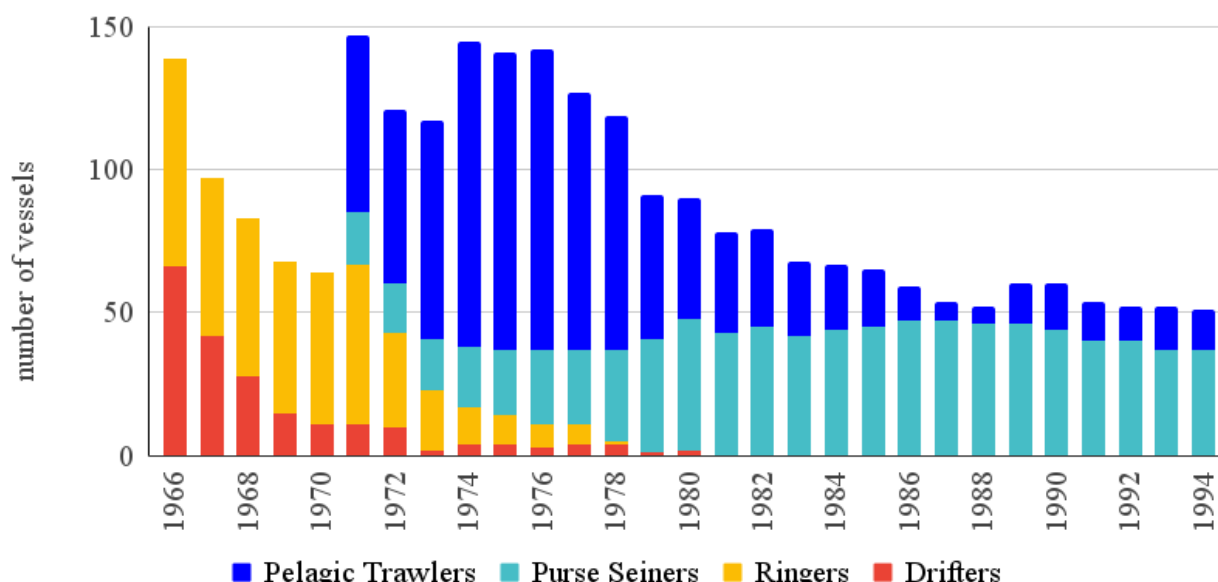
<sup>643</sup> Department of Agriculture and Fisheries for Scotland, *Scottish Sea Fisheries Statistical Tables 1990*, 50.

Figure 70 shows the number of boats added and lost from the register of fishing boats in Scotland. It shows that for much of the 1970s and 1980s most new fishing boats were second-hand, suggesting either thrift or caution in purchasing a custom-built fishing boat. Unfortunately, this data did not discuss how often a boat changed hands between Scottish owners. This would indicate the rate at which owners upgraded from a second-hand boat to a new one, or how often a single vessel changed hands before it left Scotland or was decommissioned. Overall, more boats were removed than added, with a considerable number sold to owners outside of Scotland. Some are a result of the inexorable decline in drifters and ringers but most result from periods of decommissioning in the mid-1980s and again in the 1990s.

Between 1971 and 1994 the Scottish Sea Fisheries Tables recorded the number of fishing boats by primary purpose (figure 71). This statistical data comes with the caveat that the counting of boats is based on the method of fishing “mainly engaged in” or “the normal method” of fishing. This demonstrates that those recording this data were well aware that there was a discrepancy between intended function and actual function.

Multi-purpose, or combination, vessels appeared in Scotland by the 1960s.<sup>644</sup> Stern trawlers were considered best suited to this approach.<sup>645</sup> However, it seems unlikely that this multi-purpose approach applied to this first generation or so of pelagic trawlers, as these were considered specialised boats for a specific fishing method.<sup>646</sup> As with Sweden, the initially high number of pelagic trawlers to other boats were most likely due to the use of the pair trawl.

Figure 71. Scottish fishing boats by primary purpose, 1966-1994



Sources: Scottish Sea Fisheries Statistical Tables 1966 to 1994.

<sup>644</sup> Brandt, *Fish Catching Methods of the World*, 273.

<sup>645</sup> Eddie and Chaplin, 'The Development of the Modern Stern Trawler', 21–22 & 45.

<sup>646</sup> Addison, 'The Last of the Dual-Purpose Herring-Drifters and Seine-Netters in the 1960s'.

The diminishing number of pelagic trawlers indicates that by the 1980s they were either engaging in other fishing methods, or that these boats were sold or even scrapped. The fuel crisis of 1974 affected the number of trawlers in operation with the cost of fuel increasing to the point where pelagic trawling was no longer profitable. Purpose-built combination vessels appeared with the Tynedraft class of fishing boats designed and equipped to purse seine, trawl, and pair trawl as required.<sup>647</sup> One example of this was the 80ft (24.3m) seiner-trawler *Radiant Way*, built by a shipyard in Scotland for combination purse seining and pair pelagic trawling. Her design specifies a "combination seine and trawl winch," alongside an array of electronic equipment, including a "trawl watch net sounder."<sup>648</sup> Another Scottish built trawler of the 1960s, *Morning Star*, was fitted out not only to purse seine and trawl but for fly dragging seining as well (a type of demersal fishing).<sup>649</sup> Clearly, the dual-purpose approach was adopted early.

In Iceland, no stern trawlers were recorded prior to 1970 and no side trawlers were in operation after 1978.<sup>650</sup> The first stern trawler was built in Iceland in 1973,<sup>651</sup> but many more were bought from Norway and Britain. There were simply too few shipyards in Iceland capable of building such large and specialised trawlers. The stern factory freezer trawler was introduced in the 1980s.<sup>652</sup> By 2000 pelagic trawlers in Iceland were no longer factory freezer ships, instead using refrigerated sea water in tanks to chill whole fish to around -1° C. These were high-capacity trawlers which would take the catch to shore-side processing facilities instead of processing on board. This was because processing on board took longer, had fewer options, and took up hold space. Shore-side facilities could process a catch much more quickly and into a far greater range of products. Many of these trawlers were second-hand from Norway and Scotland, and came equipped for both purse seining and pelagic trawling.

A 2010 report shows that the average age of trawlers in Iceland in the early 2000s to be mostly between 20 and 25 years. This indicates that either older vessels from the 1980s were being repurposed or that they were second-hand vessels.<sup>653</sup> The same report also shows the number of trawlers declining by almost half between 1996 and 2009. However, these figures apply to all trawlers, including those bottom trawling.

By the end of the twentieth century there was a thriving second-hand market for fishing boats, as seen in Scotland in the 1970s and 1980s (figure 71). Many Icelandic fishermen bought older Norwegian or Scottish trawlers second-hand, which came already set up for trawling and purse seining, with equipment such as winches and net drums. Many of these boats had been built as multipurpose or dual-purpose fishing vessels,

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<sup>647</sup> Toward, 'Fishing Vessels'.

<sup>648</sup> Anonymous, 'Power-Packed Radiant Way', 13.

<sup>649</sup> Anonymous, 'Skipper Fits out Purser after Yard Goes Bust', 16–18.

<sup>650</sup> Jónsson and Magnússon, Hagskinna: Sögulegar Hagtölur Um Ísland- Iceland Historical Statistics, 314–15.

<sup>651</sup> Anonymous, 'Ný Fiskiskip - Stálvík SI 1', 17–18.

<sup>652</sup> Runolfsson and Arnason, 'Evolution and Performance of the Icelandic ITQ System', 18.

<sup>653</sup> Sjávarútvegs- og landbúnaðarráðuneytið, Sjávarútvegurinn í tölum - Icelandic Fisheries in Figures - 2010, 14.

designed with space and equipment for using both purse seines and pelagic trawls. These multipurpose fishing boats could have entered the second-hand market as early as the 1970s. Being able to choose between several types of fishing gear from one fishing boat gave fishermen more options and greater flexibility, allowing them to fish at all times of year and in more locations.

### 3.5.2 Sonar

Electronic equipment was a significant advance of the 1950s. Electronic instruments are equipment installed onboard ship (or attached to a trawl) and monitored from the bridge of a vessel. This includes sonar (or echo-sounder/fish finder), as well as radio (or radio-telephone), navigation equipment, and radar. Echo-sounding for fish, by fishermen, was developed in the 1930s and the recording echo-sounder was manufactured for sale in the same decade.<sup>654</sup> The adoption of echo-sounders was briefly interrupted by the Second World War, but they were becoming commonplace by the end of the 1940s.<sup>655</sup> By the 1960s, echo-sounders were well-known devices, common on larger fishing boats alongside the radio-telephone.

Electronic instruments such as echo-sounders and sonar were used by scientists studying fisheries and fishing gear from the 1940s onwards<sup>656</sup> and techniques for this were discussed by those in the field of developing fishing gear in the 1950s.<sup>657</sup> From the 1960s sonar played an important role in monitoring the trawl itself while in the water, as seen in experiments conducted by Schärfe and others (discussed previously). The netsounders was credited as critical to the development of the pelagic trawl.<sup>658</sup>

Swedish fisheries statistics recorded "special equipment" in 1964 and 1969. 'Special equipment' is of four types: sonar, radio, navigation equipment, and radar. They were counted up under seven headings. The most basic piece of electronic equipment was just sonar by itself, but the other six categories were a combination of equipment which includes sonar, demonstrating that this was the basic requirement, more so even than radio. These categories were then further sub-divided by horsepower. In 1964, only boats with 31hp or more were included and in 1969 this was raised to boats with 46hp or more. Of all the boats surveyed in 1964, only 3% had no electronic equipment of any kind, rising to 9% in 1969. However, in 1969 only boats of 46hp or more were surveyed. This could indicate that the smaller, uncounted, boats had electronic equipment – which perhaps skewed the count in 1964. Figure 72 shows the total number of (counted) boats with the "special equipment" they had on board.

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<sup>654</sup> Fernandes et al., 'Acoustic Applications in Fisheries Science', 485..

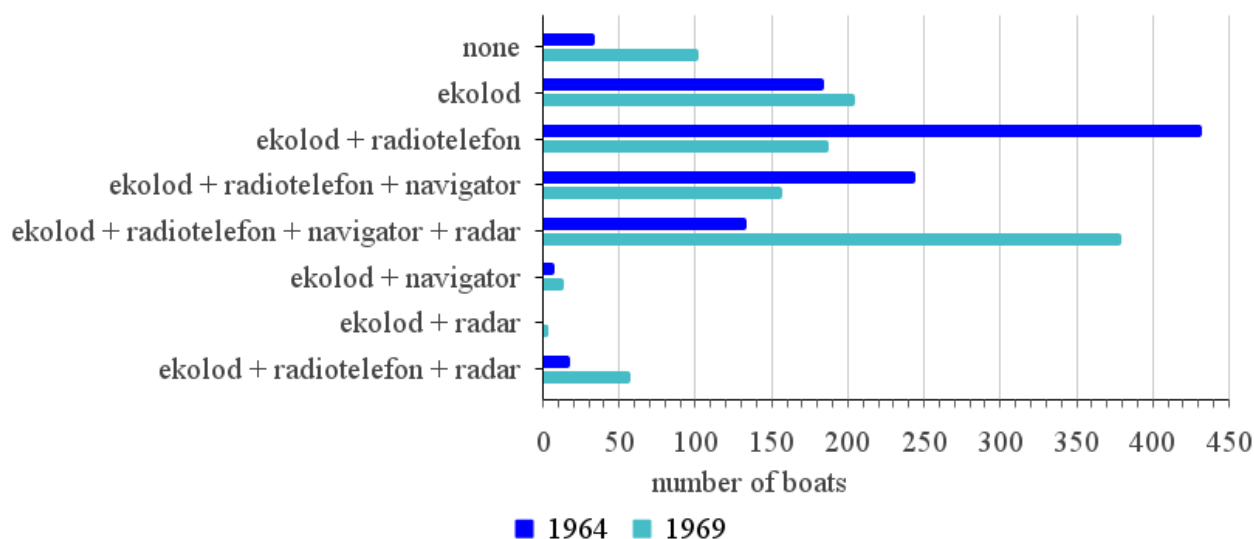
<sup>655</sup> Fernandes et al., 485.

<sup>656</sup> Fernandes et al., 485.

<sup>657</sup> Schärfe, 'Discussion on Fish Detection', 532–37.

<sup>658</sup> Pike, *Fishing Boats and Their Equipment*, 152.

Figure 72. Swedish boats with 'special equipment', 1964 & 1969



Notes: in 1964 only for boats with 31hp and higher and in 1969 only for boats with 46hp and higher.  
Sources: Fiske 1964 and 1969.

Horsepower was divided into four categories; 31-200hp, 201-500hp, 501-800hp, and 801hp+. In 1969 the 31-200hp category was changed, to 46-200hp. In 1964 boats of 31hp or more represented 50% of the fishing fleet, and in 1969 boats of 46hp or more represented 58% of the fishing fleet. Between 1964 and 1969 the number of boats in Sweden decreased by 20%, even as larger boats with more than 601hp are introduced. When looking at these figures by horsepower, it is clear that the larger the boat, the more likely it was to have two or more pieces of electronic equipment. All but one of the boats of 801+hp had all four types electronic equipment, in both 1964 and 1969 (the single exception did not have navigation equipment). In 1964, 70% of these boats in the 501-800hp range had all four types of electronic equipment, 29% had all except radar, and the one lone boat had only sonar and radio. By 1969, 96% of these boats had all four types of electronic equipment, and the rest were only missing radar.






For boats of 201-500hp, about 50% in 1964 had sonar and radio, about a 35% had sonar, radio and navigation equipment, 10% had all four, and a handful had either just sonar or another combination of electronic instruments (all of which include sonar). In 1969 this changed; over 50% had all four types of electronic instruments, 25% had all except radar, and the rest had some other combination of equipment. Fewer than 2% of vessels had only sonar.

Of the smaller boats with 31-200hp, 8% of boats had no electronic instruments at all in 1964. A surprising 17% of boats 46-200hp in 1969 had no electronic instruments. The other 83% had at least sonar, and about half had sonar and radio (for both years). Radio was important for the smaller herring boats from the 1940s onwards to communicate between pair trawlers. Some fishermen invested in expensive radio-telephones with private channels. Boats without any electronic instruments may then have been inshore or coastal fishing boats, used seasonally or for setting drift nets. Perhaps they felt they could forgo

expensive electrical instruments, especially if they were operated by occasional or part-time fishermen. Smaller boats would also have struggled to find space for bulky equipment, as well as securing a power source to operate it.

The number of boats with electronic instruments increased over a relatively short period of time even as the number of boats decreased. This was, however, in the years prior or the collapse of the herring stocks. By the mid-1970s it was more common for ships, especially new builds, to have a full array of electronic instruments on board in order to fully maximise their fishing potential. Modern electronic instruments were expensive; one estimate of around 1979 puts this one-sixth of the cost of a new fishing boat.<sup>659</sup> A report of the 1960s found that the cost of some electronic equipment was several thousand Canadian dollars. This was at least twice and sometimes even three times the cost of a new pelagic trawl; the prices can be seen in figure 73. This report also noted that very few Danish or Swedish herring boats had net-sounders in this decade.<sup>660</sup>

Figure 73: Equipment prices as noted by W. W. Johnson, 1966

	<b>Company</b>	<b>Product</b>	<b>Price[CAD]</b>
	Elac	Sonar model ILGY	6800
		Net sonde (1800m cable)	6800
		Net sonde (2600m cable)	7600
		Arcturur recorder	3140
		Atair special recorder	1550
		Atair special recorder with fish-lupe	2875
	Atlas Werke	Net sonde (2000m cable)	7680
		Net sonde (1200m cable)	6460
		Sonar unit	7750
		Fish finder recorder & fish-lupe unit	3875
	Mews & Eitzen	1400 mesh pelagic trawl	3260 - 3800
	Engel-Netze	1200 mesh pelagic trawl	3270
		Spare panels (2 x bottom & 1 x side)	1015
		Süberkrüb trawl doors (3.5m <sup>2</sup> )	1360
	Hirschals Vod & Trawl Bideri	1600 mesh trawl	2725
		1200 mesh trawl	1420
		540 mesh bottom trawl	705
		730 mesh bottom trawl	960

Source: Johnson, Wesley W. 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966'. Project Report. Ottawa: Industrial Development Services: Department of Fisheries of Canada, 1967.

<sup>659</sup> Pike, 141.

<sup>660</sup> Johnson, 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966', 42–43.

### 3.5.3 Gear

In 1949 the price of a pelagic trawl was about \$800, compared to \$9902 for a purse seine.<sup>661</sup> Made of organic fibres, they could be preserved with copper or tar, but this was only effective for a relatively short time. Without any kind of preservation, a trawl made from organic fibres would decay after regular use in as little as 7 days.<sup>662</sup> It had to be spread out after every use to dry, even inside the knots. Therefore, fishermen needed several trawls at any one time, to use while others were drying or undergoing repair.

In the mid-1960s Swedish fishermen carried five trawls when bottom trawling and two trawls in each boat when pair pelagic trawling.<sup>663</sup> A well-cared for trawl, used in colder waters, might last two years.<sup>664</sup> Realistically, a fishing boat expected to use three trawls a month over the course of a single season. With the herring season lasting from October to March, a boat could expect to get through a dozen trawls or more, assuming that there was no damage, no rot from poor storage, and that the trawl was not lost at sea during fishing. Nylon was quickly recognised as stronger and more resistant to abrasion, despite being "terrifically expensive."<sup>665</sup> As a result, only two trawls were needed instead of four.<sup>666</sup> The high price meant only being able to afford two trawls, but the clear advantage was that only two trawls were needed for an entire fishing season, or longer. Johnson, visiting Europe on a fact-finding trip in 1966, noted prices for pelagic trawls in Germany and Denmark (figure 73).

Purchasing multiple trawls was a considerable expense. A count of total fishing gear was included in the Swedish fisheries statistics and shows decreasing quantities of all fishing gear from the 1960s onwards. This was only partly due to the introduction of synthetic materials; the decline in fishing in the decade following the collapse of the herring stocks is also a factor. The pelagic trawl is the exception – there was a brief increase in the number of pelagic trawls in the mid-1960s.

Nylon, a polyamide (PA), was invented in the 1920s and was first tested on fishing nets in 1939.<sup>667</sup> The Second World War delayed its introduction to fisheries until the beginning of 1948.<sup>668</sup> By the end of the 1950s a large number of synthetic materials were available. This included polyesters (PES), polyvinyl alcohols (PVA), and polyvinylchlorides (PVC).<sup>669</sup> Figure 74 shows a range of synthetic materials available in 1972. While seemingly comprehensive, it does not include the trade names of combination fibres or of those manufactured in the USSR.

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<sup>661</sup> Krason, 'Floating Trawls', 3.

<sup>662</sup> Klust, 'The Efficiency of Synthetic Fibres in Fishing Especially in Germany', 140.

<sup>663</sup> Johnson, 'Report on the Herring Midwater and Bottom Trawling in Europe and the United Kingdom, 1966', 36.

<sup>664</sup> Søndergaard, 'The Introduction of Synthetic Fibres in Denmark's Fisheries, c. 1945-1970', 18.

<sup>665</sup> Byron, *Portraits of the Past*, 169.

<sup>666</sup> Byron, 169.

<sup>667</sup> E. I. Du Pont de Nemours and Co., 'Synthetic Fibres in the Fishing Industry', 147.

<sup>668</sup> E. I. Du Pont de Nemours and Co., 147.

<sup>669</sup> Brandt, *Fish Catching Methods of the World*, 206.

Figure 74. Synthetic fibres and their trade names, 1972

POLYAMIDE	POLYESTER	POLYETHYLENE	POLYPROPYLENE	POLYVINYL CHLORIDE	POLYVINYL ALCOHOL	COPOLYMER FIBRES
(PA)	(PES)	(PE)	(PP)	(PVC)	(PVA)	
Amilan	Dacron	Akvaflex	Akvaflex PP	Envilon	Cremona	Clorène
Anid	Diolen	Cerfil	Courlene PY	Fibravyl	Kanebian	Dynel
Anzalon	Griolen	Corfiplaste	Danaflex	Rhovyl	Kuralon	Kurehalon
Caprolan	Grisuten	Courlene	Drylene 6		Kuremona	Saran
Dederon	Tergal	Drylene 3	Hostalen PP (HD)		Manryo	Teviron
Enkalon	Terital	Etylon	Meraklon		Mewlon	Velon
Forlion	Terlenka	Hiralon	Multiflex		Trawlon	Vinitron
Kapron	Tetoron	Hi-Zex	Nufil		Vinalon	Wynene
Kenlon	Terylene	Hostalen G	Prolene		Vinylon	
Knoxlock	Trevira	Laveten	Propylon			
Lilion		Levilene	Ribofil			
Nailon		Marlin PE	Trofil P			
Nailonsix		Norfil	Ulstron			
Nylon		Northylen	Velon P			
Perlon		Nymplex	Vestolen P			
Platil		Rigidex				
Relon		Trofil				
Roblon		Velon PS (LP)				
Silon		Vestolen A				
Stilon						

Sources: FAO. FAO Catalogue of Fishing Gear Designs. 2nd ed. Rome: FAO, 1972.

The advantage of synthetic materials over manila, cotton, or hemp netting was obvious: they did not rot, they were capable of taking great strain, and they did not abrade as quickly. Sweden first tested nylon nets in 1947<sup>670</sup> with great success. Norway starting testing in 1951 and found the catchability of nylon was at least double that of organic fibre netting.<sup>671</sup> This made it extremely desirable but it was far more expensive than cotton or hemp, at around double the price.<sup>672</sup> Despite this, and early teething problems with knotting and stretching, it was became popular very quickly.<sup>673</sup> In some instances, such as in Norway,<sup>674</sup> subsidies were offered to help fishermen purchase nylon nets. Some netlofts bought netting machines to make their own synthetic netting. The fuel crisis of 1974<sup>675</sup> raised prices as synthetic products such as netting were petroleum based. The high cost of nylon netting proved to be insufficiently prohibitive to fishermen. Almost all netting was made from synthetic fibres by the end of the 1960s.

Figure 75 shows the average value of selected gear types in Sweden. In 1971 and 1979 Swedish fishery statistics recorded the number and value of gear by type and purpose. In 1971 there were 258 herring pelagic trawls, 735 herring bottom trawls, and just 49 purse seines. This decreased by 1979 to 214 herring pelagic trawls, 292 herring bottom trawls, and just 46 purse seines. Of these, only the quantity of herring bottom trawls decreases in any meaningful way. This can be linked to the switch to fishing for Baltic herring instead,

<sup>670</sup> Molin, 'Tests with Nylon Fishing Tackle in Swedish Inland Fisheries', 156.

<sup>671</sup> Mugaas, 'Experience with Synthetic Materials in the Norwegian Fisheries', 159.

<sup>672</sup> Martinussen, 'Nylon Fever: Technological Innovation, Diffusion and Control in Norwegian Fisheries during the 1950's', 33.

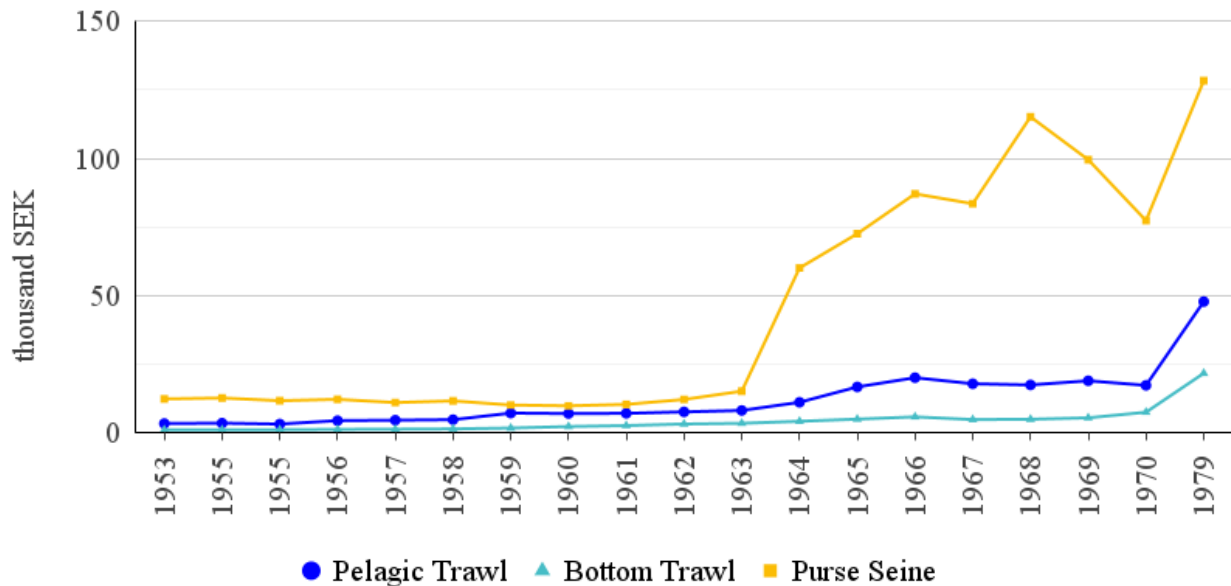
<sup>673</sup> Søndergaard, 'The Introduction of Synthetic Fibres in Denmark's Fisheries, c. 1945-1970', 18-19.

<sup>674</sup> Martinussen, 'Nylon Fever: Technological Innovation, Diffusion and Control in Norwegian Fisheries during the 1950's', 39.

<sup>675</sup> Robinson, Trawling, 244-45.

for which the bottom trawl was wholly unsuited. Even fishermen with experience of using the pelagic trawl found fishing for herring in the Baltic difficult due to variations in the depth of the seabed.<sup>676</sup> The greatest increase in cost was for the purse seine, which required vast quantities of small-mesh netting. The pelagic trawl also increased in cost, eventually becoming at least twice as expensive as a bottom trawl, suggesting that its size was much greater than that of the bottom trawl.

Figure 75. Average value of pelagic trawls and bottom trawls, 1953-1969



Notes: Data is for the west coast fisheries only. Data for is for all small-mesh bottom trawls ([smamaskiga] bottentrålar), all pelagic trawls (flyttråler), and all purse seines (snorpvader).

Sources: Fiske 1953 to 1969; Fiskestatistik Årsbok 1971 and 1979.

Despite the expense, there was a clear advantage with the durability of synthetic fibres and their greater efficiency at catching fish. A single nylon trawl could last decades if properly maintained and repaired, requiring only a backup for emergencies. These trawls could also be recycled, where large sections of netting were removed and then re-used in other fishing gear. Pelagic trawls were cheaper to make than a purse seine. However, pelagic trawls were frequently replaced with newer models, which rarely happens with purse seines. Unlike the purse seine, the pelagic trawl was constantly being redeveloped and adjusted. The purse seine's only significant design development has been an increase in size since the introduction of nylon.

The price difference results partly from the amount of material needed and partly from the personnel needed to manufacture the purse seine. A purse seine requires a huge amount of netting of relatively small mesh. Much less material is needed for a pelagic trawl, which uses larger mesh sizes. The manufacture of purse seines in the twenty-first century is expensive enough that all European netmakers almost always make and/or assemble a significant part of it in cheaper labour markets outside of Europe. A purse

<sup>676</sup> Byron, *Portraits of the Past*, 169.

seine had to be made from nylon, not an alternative synthetic material. Only nylon, a polyamide, had the capacity to return to its original form properly after being stretched. It had the correct density and sank quickly when deployed.<sup>677</sup> Other synthetic fibres did not sink, or sink as quickly, instead needing weights.

The volume of netting in a purse seine made it heavier than other types of gear, took up a more space onboard a fishing vessel, and had to be packed in a specific way (which also required extra deck crew). The size of a purse seine also makes repairs tricky and time-consuming to carry out. A pelagic trawl, on the other hand, is relatively cheap and a trawler can carry at least two without any storage issues.

### 3.5.4 Summary

The pelagic trawl was initially used as a pair trawl, with two small boats towing it. This was the case in Sweden pre- and post-war. Even as the trawl was developed in the 1950s to be used with one boat, the pair trawl dominated. We also see pair pelagic trawling in Scotland from 1966 onwards, although this declined with advances in shipbuilding and netmaking, as well as the fuel crises and decommissioning of vessels in the subsequent decades. We also see a decline in the number of large boats for the same reasons.

In Scotland, statistical data demonstrate that the majority of newly registered boats were second-hand, showing caution and thrift on the part of fishermen during this time. Most of these trawlers would have been stern trawlers. The stern trawler had several advantages over the side trawler, in particular the stern ramp, which made hauling the catch on board much easier and safer. The stern trawlers of the 1960s were typically large vessels, often with factory plants or freezing equipment. These factory-freezer trawlers were capable of catching, processing, and freezing large catches quickly.

The stern trawler was a late-comer to Iceland, but when it did arrive it was already a proven technology, which was then developed further. This was also the case for the pelagic trawl when it began to be used on a large scale. By this time the pelagic trawl was in popular use, the stern trawler had become smaller and used seawater to chill the catch, rather than processing and freezing it at sea. Icelanders also bought second-hand trawlers, from a thriving second-hand market for European fishing vessels and gear.

The further we progress into the latter half of the twentieth century, the higher the chances that the fishing boat will come equipped with sonar and fish-finding equipment, as well as devices to monitor the trawl in real time. Sonar not only made finding and targeting fish easier, it allowed fishermen to monitor the trawl while it was in the water. This allowed fishermen make adjustments while the trawl was in the water, as well as actively targeting shoals. In Sweden, this change is recorded, where the adoption of a greater number of types of equipment, in particular on larger vessels, is clearly seen. The new

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<sup>677</sup> Japan Chemical Fibres Association, 'Synthetic Fibres Used in Japan for Purse Seines and Trawls', 260.

stern and factory-freezer trawlers of the 1960s onwards came with this kind of equipment as standard, as it was necessary for ensuring that fishing gear was used effectively. A second-hand trawler would also come readily equipped, reducing the cost.

The greatest advance for the pelagic trawl were nylon and other synthetic fibres. Synthetic fibres allowed the trawl to be larger, lighter and thus capable of catching bigger volumes of fish. When first introduced the initial cost of synthetic netting was high but the durability made a synthetic trawl worth the investment. Netmakers realised the lightness and durability of synthetic fibres meant that the trawl could be bigger and hold more fish. This occurred over the same time frame as the development of the stern trawler and the factory freezer trawler. These newer, larger, trawlers were capable of towing large trawls and processing the catch. However, when trawlers became smaller in the 1960s and 1970s, trawls had to be tailored to the trawler so that they could be towed effectively.

Of these advances, only the netsounder can be tied definitively to the pelagic trawl, although it could be argued that the development of the stern trawler had roots in the desire to test an experimental type of pelagic trawl. While they benefitted the pelagic trawl immensely, none of them, bar the netsounder, were the cause of these advances. However, they did make using the pelagic trawl efficient and effective and thus more appealing to fishermen as a fishing method, especially when used in conjunction with other fishing methods and/or with multi-purpose vessels.

## 3.6 Discussion

The economic significance of the pelagic trawl can be measured in any number of ways. This section shows the challenges of trying to assess the exact value of the pelagic trawl given the array of available data from the mid-twentieth century and beyond. The pelagic trawl was not the most popular pelagic fishing method, or the most productive. And yet, it continued to be used. As has been demonstrated, the pelagic trawl was needed in order to catch fish that other methods could not reach. Following the introduction of quotas, it became necessary to fully exploit fisheries to maximise their value.

In the first chapter, intensification in of pelagic fisheries, the significance of pelagic fisheries as a whole is discussed in order to give the reader an overview of pelagic fisheries in northern Europe. Here, a significant increase in pelagic catches is shown, growing threefold in just fifty years. In the next chapter, output, it is explained how these large pelagic catches were feeding the reduction industry to produce fish oil and fish meal. In the third chapter, productivity, the pelagic trawl is examined more directly and compared to rival techniques. In the fourth chapter, employment, the overall decline in the workforce is linked to modernisation as mechanisation made handling gear and catches easier and safer. This is also an aspect referred to in the fifth and final chapter, boats and technology. Here the role of synthetic fibres, factory trawlers, stern trawlers, netsounders, and sonar is to make the pelagic, cheaper, easier, and far more effective over time.

In one instance we see that the pelagic trawl was responsible for a 'new' fishery, that of pelagic redfish. The pelagic redfish was identified in the 1950s, with sources indicating that it was systematically fished using pelagic trawls. Here, the pelagic trawl was needed because there was no other fishing method capable of catching pelagic redfish. It is unfortunate that there were no catch data to show us what proportion of the redfish catch was pelagic, or the volume of redfish caught with pelagic trawls. Apart from this example, the pelagic trawl was used in already established pelagic fisheries. The value of these fisheries varies, as much of the pelagic catch was sent for reduction into oil and meal, low value products for most of the twentieth century. In the twenty-first century this changed, with more pelagic fish processed for human consumption instead.

The pelagic trawl aided the exploitation of several pelagic fisheries but was not responsible for the majority of the catches. Nor was it as productive as the purse seine. If productivity was the only metric to measure the significance of the pelagic trawl, then the data demonstrates that it became less effective as it developed technologically from the early Swedish pair trawls of the 1940s to the Iceland pelagic trawls of the twenty-first century. The early Swedish pair pelagic trawls, made of cotton and using glass floats, operating in the North Sea and Baltic Sea, were typically more effective than herring bottom trawls.

There is no relevant data for the purse seine for this time period, but that it was not used in these waters by Swedish fishermen is evidence enough that it was not an effective fishing method in these fishing grounds. It is clear how much more effective the pair pelagic trawl was at this time. Yet, from the surviving records, it seems to have been considered a somewhat crude method. Its catches were worth less than those made with the herring bottom trawl and, as shown in the chapter on output, largely sent for reduction. It was not a method used to catch high-quality or high-value fish. The volume of catches made at this time were huge, made without quotas or fishing restrictions.

By the 1960s the pelagic trawl had been developed further into a variety of one-boat models. They were larger and stronger, courtesy of synthetic fibres and was made more effective through the use of netsounders and sonar. Despite this, it was outmatched by the purse seine in productivity. From the moment the pelagic trawl became 'modern,' it started to become a more specialised tool. This is seen in Scotland, which adopted the pelagic trawl whole-heartedly in the mid-1960s. For the first decade or so of its use, it easily accounts for over half of all pelagic catches, before declining significantly over the early 1980s. This decline is due to a combination of productivity and fuel costs. It was superseded by the purse seine, which was more effective at catching large volumes quickly, as well being far more fuel-efficient. These catches are often of higher value. Here, fish caught with the pelagic trawl is seen to be of higher quality, even if this is more a matter of perception than of reality. And yet, the pelagic trawl continued to be used. Further analysis shows that income from Scottish pelagic trawlers were seasonal, showing that it was used at specific times of year. This was in order to fully maximise the quota in instances where the purse seine was relatively ineffective.

This is a pattern seen in Iceland, too, where the pelagic was first used on a large scale in the 1990s. However, it did not displace the preferred method – the purse seine – rather, it was used in order to maximise pelagic fisheries in two ways. Firstly, to catch fish seasonally when the purse seine was not as effective as usual, and secondly, to maximise the value of that catch. Restricting the catch volume meant that fishermen had to maximise the value of the catch to its full extent. This is then the significance of the pelagic trawl: to maximise pelagic fisheries by exploiting it fully in terms of volume all year round and by ensuring the most value can be obtained from that catch.

## 4 Conclusion

In the beginning, there was a vision from God: the idea for the pair pelagic trawl came to Yngve Bernhardsson as he lay on what he thought was his deathbed. How, exactly, this genesis should be categorised – inspiration, driver of change, or just a dream – does perhaps lie beyond the scope of a PhD thesis. Regardless, this is the beginning of the story for the pelagic trawl. The first half of this thesis investigated the development of the pelagic trawl and the people behind it. The second half takes a different approach by analysing the statistical data about the pelagic trawl. These two halves have different approaches. The first half is qualitative, using narrative to tell a story. SCOT was a strong influence in understanding the social groups, their drivers, examining closure, and in realising the role of failure. But SCOT has its failings, as all theoretical frameworks do. One of these is the failure to consider the consequences of an invention. This is explored in the second part by taking a quantitative approach to available data on pelagic fisheries and the use of the pelagic trawl.

The pelagic trawl had a progenitor, in Yngve Bernhardsson, who held the earliest patent. This is itself unusual and almost unique. Until now, only one other commercial fishing method has a known inventor, - Jens Væver, inventor of the Danish seine. And yet, the origin of the pelagic trawl is a touch clouded, with competition appearing in the form of a rival, Robert Larsen. Despite this, there is a clear sequence of both trawl designs and inventors, from the 1940s through to the 1980s. Each phase of the pelagic trawl's development is defined and understood in several ways; the principal design features, the advances made during each phase, and by their inventors. The inventors associated with each phase are described and understood in regard to the motivations and resources. This thesis shows how their backgrounds and resources play a vital role in how they approach not only trawl design and experimentation, but also how both trawl designs and inventors interact with each other. Individuals designs and the drivers of change for inventors and groups are presented and examined.

The first phase is the pair trawl, where fishermen were trying to catch unreachable fish in the Kattegat and Skagerrak, herring which rose up higher in the water column at night. These early inventors – Yngve Bernhardsson, Robert Larsen, and Ponte Sterner Persson – were fishermen who became netmakers. They either came from fishing communities or had decades of experience in fishing. They were limited by their environments: their resources, knowledge, and traditions. This meant working with fishermen who used the herring bottom trawl, made from organic fibres, and fishing from small boats without the aid of electronic equipment. Over the years they adapted their designs in response to new advances, upgrading to synthetic fibres and larger boats. This made the pelagic trawls larger, catching larger volumes of fish.

Swedish fishermen were trying to maximise their catches of herring in response to a demand for pelagic fish from the reduction industry. The demand was high but prices are low – large catches were required to make a good profit. Luckily large catches were in demand. In understanding the events of these men's lives we also see that at least two of them were connected. Bernhardsson and Larsen spent years in legal conflict over patent rights in Sweden and Denmark. They were competitors, rivals in a well-populated industry of netmakers. Their ideas were patented and the rights fought over. They were initially a source of income and later a source of pride.

The nature of the inventors, and the pelagic trawl itself, changed in the 1950s. This is the second phase, the one-boat trawl. Synthetic fibres were introduced, as were the first stern trawlers, and the use of electronic equipment like sonar became more widespread. The next generation of inventors were industry professionals: fishing gear technologists. Joachim Schärfe in West Germany was a trained scientist, as was his mentor, Andres von Brandt. In Canada, W. W. Johnson was an ex-fisherman recruited to develop fishing gear by the government. Several scientists in the USA worked on developing a pelagic trawl, Richard McNeely among them. All of these men worked on making a one-boat trawl, something made successful by the invention of a trawl door by a West German naval architect, Franz Süberkrüb. Each of them developed a functioning one-boat pelagic trawl that utilised synthetic fibres, trawl doors (of various types), sonar, and some form of trawl monitoring device. In the USA and Canada this was a depth telemeter. Schärfe, along with the Engel-Netze netloft, created a practical net sounder in West Germany.

But it is the connections between these individuals that demonstrates a greater change. Instead of acting as competitors, they were collaborators, interacting in the professional forums populated by scientists whose work demanded detailed published reports whose data was available on demand. Regular conferences organised by the FAO and working groups formed under ICES provided regular events and forums for consultation and feedback. The problem they were trying to solve is ultimately the same – to catch otherwise unreachable fish – with the added goal of finding the best possible way to catch those fish.

The one-boat trawl had other inventors too, those who bridged the space between fisheries gear technologists and netmakers. One of these was Karl-Hugo Larsson, a Swedish engineer. He tried his hand at designing a one-boat trawl as well as a trawl door design, although his role is, sadly, that of an interesting failure. His interactions with the scientific community is but one demonstration of the wealth of experience that was present at conferences and meetings. Participants ranged from scientists, skippers and fishermen, netmakers, engineers, shipbuilders, to manufacturers of electronic equipment. His work also shows the importance of adopting new materials, which he resisted, as well as the rigorous extent trawl designs were tested by contemporaries.

The last phase of pelagic trawl are its variations. Some were created when the problem was redefined, others speak to new problems. Bernhardsson and Persson used their pair pelagic trawl as the basis for an interchangeable trawl which could also be used as a herring bottom trawl. An Icelandic businessman, A. G. Breiðfjörð, was addressing a slightly different problem. He created a semi-pelagic trawl to avoid the abrasive seabed in order to catch cod, a demersal species. This concept was short lived in Iceland but was reinterpreted only a decade later, when fisheries scientist Claude Nédeléc (and his colleagues) designed similar trawls in France, crediting Breiðfjörð as inspiration. Schärfe tried to create a combination pelagic trawl that could be a pelagic or bottom trawl. The ultimate development was from a fishing gear designer, Stanislaw Okonski, who designed a universal trawl. Of all these variations, only those in France were successful. Most were trying to create a pelagic trawl that was more than just a pelagic trawl, a trawl that was multi-purpose. The problem was redefined; the pelagic trawl needed to be more versatile, to perform in multiple fisheries.

These variations were, bar the semi-pelagic trawl, failures. Their original forms were successful but in trying to improve them they were rendered impractical and inefficient. The semi-pelagic trawl succeeded because here it was made more specialised, to operate at a very particular depth. This was the opposite of what the fisheries gear technologists were trying to achieve with the combination or interchangeable trawls.

The initial driver of change was the desire to catch unreachable fish. This evolved into a personal and professional desire to improve upon existing gear, as demonstrated by the variations on the pelagic trawl. The unreachable fish were, however, the biggest motivator. At first the quantity of fish caught was the focus, needed to supply the reduction industry. This changed with the introduction of fishing restrictions into the need to maximise the value of a limited quantity of fish. This is explored further in the second half of this thesis, where the significance of the trawl is more fully revealed.

The significance of the pelagic trawl is examined using statistical data, supplemented by other source material. This demonstrate how and why the pelagic trawl was used. This is limited by the available data, which are sparse and occasionally relevant. Nevertheless, it is possible (to an extent) for three countries: Sweden in the 1950s and 1960s, Scotland from the 1960s to the mid-1990s, and Iceland from the late 1990s onwards. Luckily, the data for these countries demonstrates how the trawl changes over time, providing a changing view of the significance of the pelagic trawl over more than half a century. In Sweden it was a new method using old materials, in Scotland it was a relatively new method using new materials, and in Iceland it was an established modern fishing method.

The pelagic trawl was consistently used to catch herring, of which several established fisheries existed. Most of this herring (and most pelagic fish) was sent for reduction into oil and meal, a low value commodity. The pelagic trawl caught a low-quality catch, resulting in low value products. To make a profit fishermen needed to catch increasing volumes of fish

which was made possible by a lack of fishing restrictions. This is reflected in the data for Sweden and early Scotland. The pelagic trawl did allow for the discovery and exploitation of a new fishery in Iceland and the northwest Atlantic for pelagic redfish. Following the collapse of the herring stocks in the 1960s the pelagic trawl was also used to catch capelin and mackerel, although this was on a much smaller scale. In Iceland the pelagic trawl was used to catch fish the purse seine could not, which was often sold for human consumption, a high quality and high value product. This is in contrast to the early pelagic trawls in Sweden and Scotland which shows that the pelagic trawl was needed to extract maximum value from a limited volume of fish.








The major, initial, driver of change, the need to catch unreachable fish, is seen in productivity, as demonstrated by CPUE. CPUE shows that from the 1960s onwards the pelagic trawl was nowhere near as efficient as the purse seine. Nevertheless, the pelagic trawl was consistently used. This was typically at times when other methods were not effective, due to either fish behaviour or fishing conditions.

There were limitations to what this thesis could accomplish. Firstly, a cut-off date in the 1980s was needed when following the technological development of the pelagic trawl. This was largely due to the majority of the key developments occurring before this time, and partly due to the thesis having a strict word count. There were also some challenges with source material. For the technological development, early designs lacked detail or were deliberately vague, while the later designs were overwhelming in their design detail. There are numerous inventors and designs not presented in this thesis, again due to word count. It must also be acknowledged that there were numerous netlofts in operation which likely made their own pelagic trawls whose designs have been lost. There is all too likely a missing link or lost innovator. When looking at the significance of the trawl, too often there was no statistical data for the pelagic trawl specifically, or that data was not available. There was certainly no lack of fisheries data, it simply too rarely of relevance. Often the date ranges were too short, or a little too imprecise. Despite this, it was possible to use some statistical data in way that was useful and it was frequently supplemented with a variety of other source material.





This research could easily be continued. The development and significance of the pelagic trawl could be examined up to the present day, analysing the drivers behind its uptake and the ways in which it is used in twenty-first century pelagic fisheries outside of Iceland. This could be pursued by looking at the technological development or by examining the statistical data more intensely, or both. Another possibility would be to apply the approach taken in this thesis to another kind of fishing gear. The Scottish otter (bottom) trawl of the 1880s and Danish seine of the 1840s century are worthy of detailed study, and have known origins. The purse seine, while without known inventor, is also a significant fishing method deserving of further study.

## 5 Appendices

### 5.1 List of Inventors

	<b>Inventor</b>	<b>Invention (earliest known date)</b>
	Yngve Bernhardsson - netmaker, fisherman	Pair trawl – 1944 Interchangeable trawl – 1962
	Robert Larsen - netmaker, fisherman	Pair trawl – 1948 “Atom Trawl”
	Karl-Hugo Larsson - naval architect / civil engineer	One-boat trawl & trawl doors – 1949 “Phantom Trawl”
	Ponte Sterner Persson - fisherman	One-boat trawl – 1949 “stjärntrål” Interchangeable trawl – 1953
	Alf & George Leggatt - fishermen	Pair trawl – 1950s
	Franz Süberkrüb - naval architect	Trawl doors – 1939 & 1959
	Dr. Joachim Schärfe Institut für Netz- und Materialforschung; FAO - scientist, fishing gear designer	One-boat trawl – 1940s Combination trawl – 1960s
	Hermann Engel & Hans-Hermann Engel - netmakers [Engel-Netze]	One-boat trawl – 1960s
	Wesley W. Johnson Department of Fisheries, Canada - fishing gear designer, fisherman	One-boat trawl -1950s “Atlantic Western Trawl” “Diamond Trawl” Combination trawl – 1960s
	Richard McNeely U.S. Fish & Wildlife - scientist, fishing gear designer	One-boat trawl – 1950s “Cobb Trawl”
	A. G. Breiðfjörð - factory owner, businessman, inventor	Semi-pelagic trawl – 1952
	Claude Nédeléc Institut des Pêches Maritimes; FAO - scientist, fishing gear designer	Semi-pelagic trawl – 1958
	Yves Grouselle - inventor, fishing gear designer	One-boat trawl – 1959 Trawl kite – 1959
	Stanislaw L. Okonski Fisheries Central Board, Poland; FAO - scientist, fishing gear designer	Universal trawl – 1964

## 5.2 Timeline of Inventions

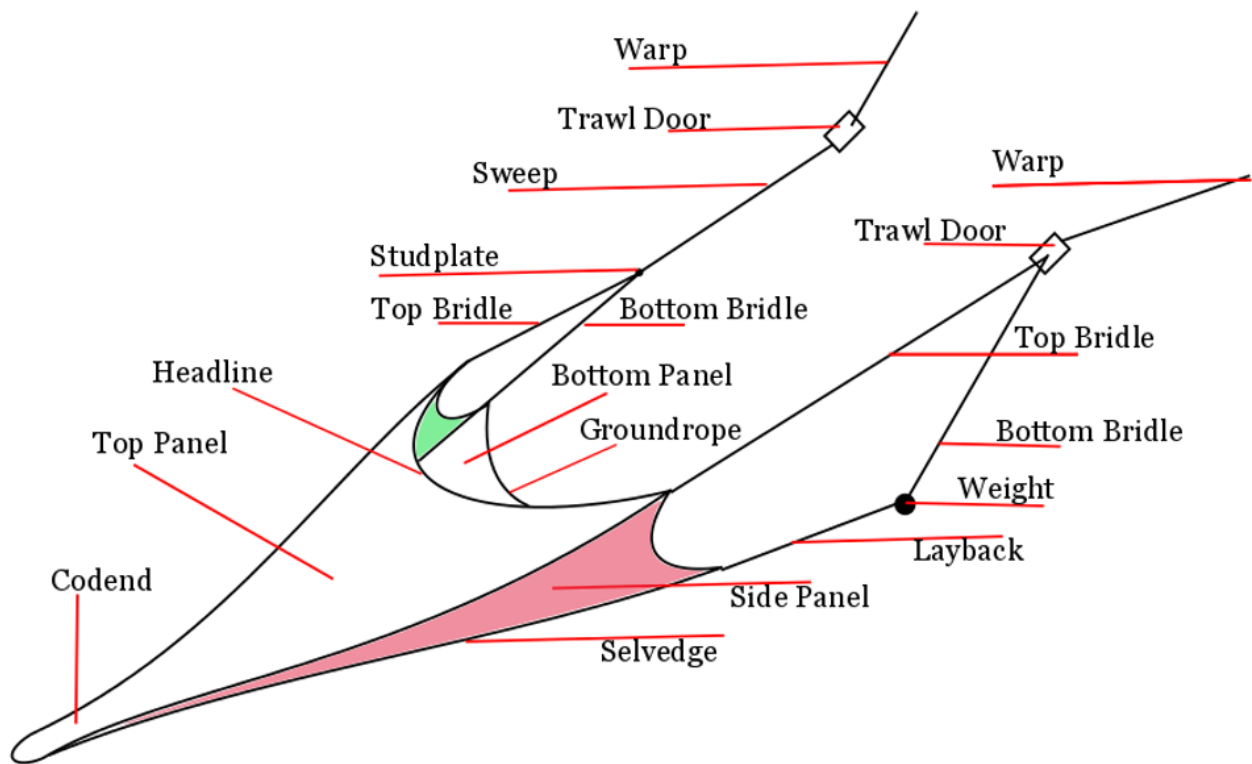
<b>Date</b>	<b>Development</b>	<b>Type</b>	<b>Material</b>	<b>Relevance</b>
1939	 Süberkrüb's pelagic trawl doors	pelagic trawl doors	wood & iron	Polyvalent / high aspect trawl doors for one-boat pelagic trawls
1944	 Berhardsson's trawl	pair trawl	cotton	For catching herring in the North Sea, Kattegat and Skaggerak, and the Baltic Sea
1948	 Larsen's Atom Trawl	pair trawl	cotton	For catching herring in the North Sea, Kattegat and Skaggerak, and the Baltic Sea
1949	 Persson's six-wing Stjärntrål	one-boat trawl	cotton	For catching herring in the North Sea, Kattegat and Skaggerak, and the Baltic Sea
1949	 Larsson's Phantom Trawl (with trawl doors)	one-boat trawl	cotton / plywood	For catching pelagic fishes in the North Sea, Kattegat and Skaggerak, and the Baltic Sea
1948	 Sonar / fishfinder [Furuno Electric Co., Ltd]	electronic equipment	-	Fish detection equipment for commercial fishermen
1948	 Synthetic fibres [DuPont de Nemours, Inc.]	netting	polyamide	Lightweight, durable, abrasion resistant fibres
1950	 Leggatt brothers' trawl	pair trawl	cotton	For catching sprat in the Thames Estuary
1960	 Netsounder [Atlas Werke]	electronic equipment	-	Monitors the trawl while in it is in use
1952	 Breiðförð's trawl	semi-pelagic trawl	polyamide	For catching cod in Icelandic waters
1953	 Persson's trawl	interchangable trawl	cotton	For catching herring in the North Sea, Kattegat and Skaggerak, and the Baltic Sea
1953	 Power block [Puratić]	hydraulic equipment	-	hydraulic gear for hauling purse seines
1953	 Stern trawler	vessels	-	ramp & hydraulic gear for trawls
1953	 Factory trawler	vessels	-	Onboard processing & preservation
1950s	 Schärfe 's trawl	one-boat trawl	polyamide	For catching herring in the North Sea, Kattegat and Skaggerak, and the Baltic Sea

1955		Plastic floats [Polyform AS]	plastic	-	Lightweight, durable, abrasion resistant buoys
1955		Johnson's Atlantic Western Trawl	one-boat trawl	polyamide	For catching pelagic fishes in Canadian and North American waters
1955		McNeely's Cobb Trawl	one-boat trawl	polyamide	For catching pelagic fishes in Canadian and North American waters
1958		Nédélec's trawl	semi-pelagic trawl	polyamide	For catching cod and other semi-pelagic fishes in French waters
1959		Grouselle's trawl	universal trawl	polyamide	For catching pelagic fishes
1953		McNeely's trawl doors	pelagic trawl doors	plywood	For use with the Cobb trawl - strong resemblance to Süberkrüb trawl doors
1955		Johnson & Barraclough's trawl doors	combination trawl doors	aluminium	For both demersal and pelagic trawls
1959		Süberkrüb's pelagic trawl doors	pelagic trawl doors	steel	Polyvalent / high aspect trawl doors for one-boat pelagic trawls
1962		Bernhardsson's trawl	interchangable trawl	polyamide	For catching herring in the North Sea, Kattegat and Skaggerak, and the Baltic
1964		Engel-Netze's trawl	one-boat trawl	polyamide	For catching pelagic fishes
1964		Okonski's trawl	universal trawl	polyamide	For catching pelagic fishes
1960s		Johnson's Diamond Trawl	one-boat trawl	polyamide	For catching pelagic fishes in Canadian and North American waters
1960s		Schärfe's trawl	combination trawl	polyamide	Intended use was as both demersal and pelagic trawl, depth/rigging as required
1970s		Machine netting (1m mesh size)	netting	-	Large mesh netting made from synthetic fibres
1971		Rope mesh trawl [Jager / spaghetti trawl]	one-boat trawl	polyamide	Big long meshes of ~5m (hand made, not machine made)
1972		Big diamond mesh trawl	one-boat trawl	polyamide	Big meshes of ~16m (hand made, not machine made)

### 5.3 Terminology

A number of different terms are used throughout this thesis and efforts have been made to ensure consistency. A glossary is therefore provided, with a diagram to clarify what part of the trawl is being discussed. There are a number of ways in which a trawl can be rigged. In this diagram each side (red or green) represents a different way, both for a one-boat trawl. For a pair trawl, either set up can be used, but without the trawl door.

This diagram is over-simplified; there are multiple components that have not been referenced in this thesis for the sake of clarity. In reality, the exact use and arrangement of components varies greatly depending on time, place, and the skipper in charge.



## 5.4 Glossary

Aimed Trawling	A technique where the locations of a shoal of fish is determined (typically with sonar) and the trawl towed directly at it.
Atlantic herring	<i>Clupea harengus harengus</i> Síld [ÍS] – Sild [DK] – Sill [SE] – Hering [DE] Herring can be found in a number of different stocks. The Atlanto-Scandic stock, which migrates between Iceland and Norway; the North Sea stock, which migrates from Scotland to the British Channel; and Baltic herring. Can be eaten or processed into oil and meal.
Atlantic mackerel	<i>Scomber scombrus</i> Makrill [ÍS] – Makrel [DK] – Makrill [SE] – Makrele [DE] Several mackerel stocks are located throughout the Atlantic Ocean. Is typically eaten and not processed into oil and meal.
Atlantic redfish	<i>Sebastes mentella; Sebastes marinus; Sebastes viviparus</i> Karfi, Djúpkarfi [ÍS] – Rødfisk [DK] – Røtfisk, Kungsfisk [SE] – Rotbarsch, Goldbarsch (DE). Also called beaked redfish, golden redfish. Of the redfish populations only <i>Sebastes mentella</i> (beaked redfish) is pelagic. Found in waters around Greenland, Iceland, the Faroe Islands and the Norwegian Sea. Can be eaten or processed into meal and oil.
Beaked redfish	see REDFISH
Bobbin	A roller which is threaded onto the groundrope. A key feature of bottom trawls, as the bobbins allow the trawl to travel along the seabed. Spherical, semi-spherical, or elliptical in shape. Can be made from rubber, wood, or steel.
Blue whiting	<i>Gadus poutassou</i> Kolmunni [ÍS] – Sortmunde, Blåhvilling [DK] – Kolmule, blåvitling [SE] – Blauer Wittling [DE] Blue whiting can be found throughout the Atlantic. Is typically eaten and not processed into oil and meal.
Brailer	A bucket-style scoop made of a large hoop and netting, used to bring the catch onto the trawler while the trawl is still in the water. Also used with purse seines.
Bridle	A rope or cable which attaches the trawl door to the wings of the trawl. Typically there is pair for each side of the trawl; an upper and a lower bridle.
Bottom trawl	A trawl than can be towed with one or two vessels. Bottom trawls (and its trawl doors) are dragged on the seabed. Bottom trawls for herring were called sillbottentrål in Sweden.

Capelin	<i>Mallotus villosus</i> Loðna [ÍS] – Lodde [DK] – Lodda [SE] – Lodde [DE] Capelin is a migratory fish and can be found in waters around Greenland, Iceland, and Jan Mayen. Can be eaten or processed into meal and oil.
Codend	The terminal end of the trawl into which fish collects and cannot escape.
Combination trawl	A trawl which can be used as either a one-boat pelagic trawl or one-boat bottom trawl. This may involve re-rigging the trawl.
Danleno	see STUDPLATE
Depressor	A shearing device intended to create downforce, designed to be attached to the groundrope.
Elevator	A shearing device intended to create lift, designed to be attached to the headline.
Epipelagic trawl	see SEMI-PELAGIC TRAWL
European Sprat	<i>Sprattus sprattus sprattus</i> Brislingur [ÍS] – Brisling [DK] – Skarpsill [SE] – Sprott [DE] Sprat is found throughout the Atlantic Ocean and Baltic Sea. Can be eaten or processed in oil and meal.
Float	A bouyancy aid which is attached to or threaded onto the headline. Can be made of cork, glass, wood, plastic, or aluminium.
Floating trawl	see PELAGIC TRAWL
Flottroll	see PELAGIC TRAWL
Flotvarpa	see PELAGIC TRAWL
Flyttrål	see PELAGIC TRAWL
Golden redfish	see REDFISH
Groundrope	A section of rope or cable which shields or reinforces the foremost edge of the lower panel. It is to this that bobbins and/or weights are attached.
Headline	A rope or cable which reinforces the foremost edge of the upper panel. It is to this that floats or a kite are attached.
Interchangeable trawl	A trawl that can be used as either a pair pelagic trawl or one-boat bottom trawl. It has to be re-rigged for change of use.
Kite	A shearing device attached to a headline. Attached with ropes (called a false headline). Is used to acheive life to the headline, although is sometimes used to scare fish into the mouth of the trawl. Can be made from canvas and floats or a single specially-designed shearing device.

Layback	A rope or cable connecting the lower bridle to the wing. A weight can be attached at this point.
Lazy deckie	A rope or cable which is used to haul the codend to the ship's side. It is typically secured at one end to the codend and at the other to the headline.
Midwater trawl	see PELAGIC TRAWL
Multi sonde	see NET SOUNDER
Net sounder	A sonar device which is mounted on the headline of a trawl in order to monitor it directly, typically the mouth.
Net sonde	see NET SOUNDER
Otter door	see TRAWL DOOR
Otter board	see TRAWL DOOR
Panel	A peice of netting comprised of sections joined together, usually of graduated mesh sizes. A single panel typically forms one "side" of a trawl, from headline to codend. Two or more panels are required to make a trawl.
Pelagic trawl	Flyttrål [SE] – Flottroll / Florvarpa [IS] Also called a midwater trawl, floating trawl, surface trawl, fly-trawl. A trawl designed to be towed in midwater; it should not touch the seabed. Can be towed by one or two vessels.
Pennant	A section of rope or cable. Typically, this attaches the bridle to the warp, bypassing the trawl door. In some Canadian designs, the warp and bridles are attached to each other directly at a link point. The pennant - a cable or rope - is also attached to this link point at one end. The trawl door is then attached to the pennant at the other end.
Purse seine	An enclosing net which resembles a bag. When deployed, the bottom edge is gathered up, like a drawstring. Typically required multiple vessels to operate. The main vessel was stationary while one or more much smaller vessels deployed the net.
Section	A piece of netting of uniform mesh size. Several pieces are required to form a panel.
Selvedge	A seam created when panels of netting are joined together. Several meshes are needed from each panel, which are then sewn together from headline to codend. A rope or cable is sewn to it for reinforcement.
Semi-pelagic trawl	A trawl which is very close to, but not touching, the seabed. The trawl doors may, however, be touching the seabed.

Shearing board	see TRAWL DOOR
Shoe	A piece of metal which reinforces the edge of trawl door, found on bottom trawl doors where they are in contact with the seabed. Can also function as a weight to maintain the correct orientation of the door. Not typically required of pelagic trawl doors.
Studplate	A device between a bridle and the cable, in order to keep them separate and prevent tangling.
Sweep	A rope or cable which is attaches the studplate to the trawl door.
Trawl door	A shearing device. A pair is required, one for each side of the trawl, to keep it open horizontally when towed through the water.
Warp	A rope of cable which attached a trawl door to the vessel towing it. There is one for each trawl door.
Wing	An extension of a panel. When assembled a trawl has four wings, each one coming to a point, one for each corner of the mouth of the trawl. It is to this which the bridles are attached.
Zipper	A section of selvedge, typically on the codend, which can be opened and closed on demand, in order to remove all or part of the catch more easily.

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