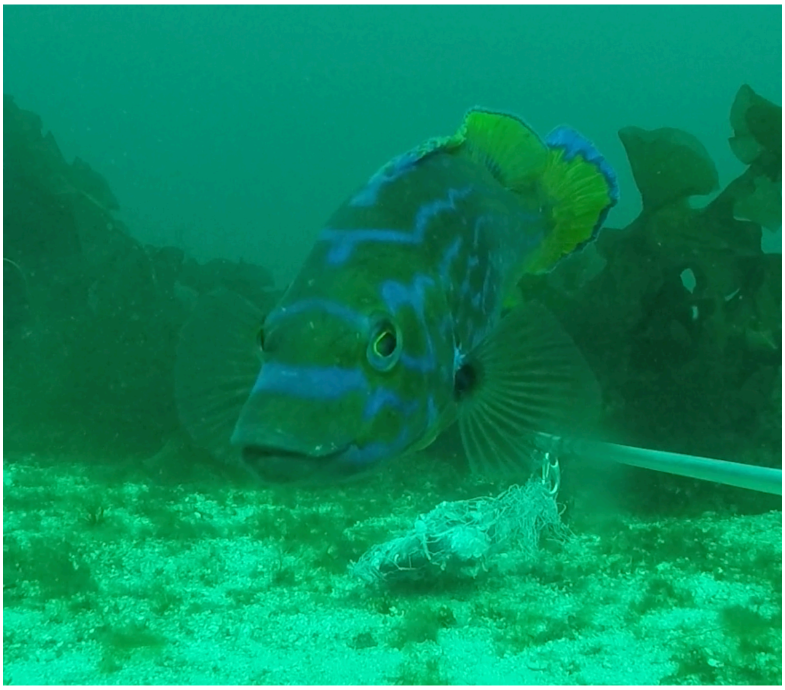
Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Natural Sciences
Department of Biology

Marit Bull

Comparing Baited Remote Underwater Video Systems with Fish Traps Along the Coast of Frøya and Hitra

Master's thesis in Ocean resources
Supervisor: Torkild Bakken (NTNU), Alf Ring Kleiven (IMR) and Antti-Jussi Olavi Evertsen (NTNU)
December 2019



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Preface

This master thesis has been written for the Department of Biology at the Norwegian University of Science and Technology (NTNU) and finalises my studies in Ocean Resources with specialisation in ecosystems. The thesis is the result of a cooperation with the Institute of Marine Research, which started during the spring of 2018.

Marit Bull

Trondheim, December 2, 2019

Acknowledgments

First, I would like to express my sincerest gratitude to my supervisors. Torkild Bakken, thank you for all your advice, support, and good discussions along with quick and helpful responses during the writing process. To my supervisor, Alf Ring Kleiven from the Institute of Marine Research, thank you for the opportunity to participate in this exciting and important project. Thank you for your hospitality and help during the writing process, and for always being enthusiastic about the project. My supervisor from Guri Kunna high school, Antti-Jussi Olavi Evertsen, thank you for great help and assistance at Frøya during visits or fieldwork, and for good talks over coffee.

I would also like to show my gratitude to the kind and welcoming people who participated in the fieldwork in May 2019. Jan Hinriksson, Stian Kleven, and Christine Djønne for their effort with the fish traps during all sorts of weather. The great assistance from the helpful staff at Eir and to my BRUVs-friend, Merete Vik Ottesen, for funny jokes and cheerful mood.

For help in the computer program R, I would like to thank Portia Joy Nillos Kleiven, for her patience with me and good ideas to my dataset. Also a big thanks to Susanna Huneide Thorbjørnsen and Astrid Anette Carlsen for contributing with helpful ideas.

To my fellow students at sealab, thank you for all the good times, support, and laughs during our time together as students.

Last but not least, I would like to thank my family. My parents Brit and Jan Bull, for giving me an early interest in the marine environment and for always supporting my interests. My boyfriend, Andreas Sørbrøden Talberg, for all your love and hours in proofreading my thesis.

Summary

As the oceans of the world undergo anthropogenic impacts from climate change, unsustainable fisheries, and issues related to tourism, oil and gas and the shipping industry, the need for marine conservation efforts such as protected areas has never been more vital. Together with stakeholder's involvement, sampling of biological data is essential when assessing marine areas for protection, both before and after the implementation of a marine protected area.

This study aimed to compare the sampling of fish communities along the coast of Frøya and Hitra, using the two methods: stereo baited remote underwater video systems (stereo-BRUVs) and baited fish traps. Sampling with the stereo-BRUVs recorded a higher number of species (19 species representing 9 families) and a higher species richness per deployment (2.60 ± 0.60 SE), compared to the fish traps (15 species representing 7 families; 1.00 ± 0.18 SE).

Because of the higher species richness and abundance, the stereo-BRUVs would be a better method than traps to monitor temporal changes in fish communities. However, the fish traps showed a greater potential for detecting cryptic species, e.g. the Lemon sole, and would, therefore, have a higher certainty when it comes to species identification than the stereo-BRUVS.

The stereo-BRUVs was able to sample a wider range of lengths of the Atlantic cod but showed few individuals with lengths above 70 cm compared to the traps. Length measurements were performed in the field of view of the camera with the maximum number of individuals of a single species. Results from this study indicate that biases occur due to fish swimming in and out of the field of view, and that some fish could be excluded from being measured. This could affect estimates for species abundance mean length and length-frequencies at the stations.

Results from this study determine that stereo-BRUVs could be a valuable tool in monitoring temporal changes in fish species richness and abundance in the temperate low diversity waters of Frøya and Hitra.

Sammendrag

Verdenshavene blir påvirket av menneskeskapte påvirkninger fra klimaendringer, overfiske, turisme, skipsfartsindustri, olje og gass, og det har derfor aldri før vært viktigere med marin bevaring. Med medvirkning fra interessenter, er innsamling av biologisk materiale essensielt når det foretas vurdering av områder for marint vern, både før og etter et marint verneområde er blitt implementert.

Målet med denne studien var å sammenligne innsamling av materiale fra fiskesamfunn i kystområdene til Frøya og Hitra, mellom agnede stereo video-rigger (stereo baited remote underwater video systems - stereo-BRUVs) og agnede fisketeiner. Innsamlet materiale med stereo-BRUVs registrerte høyere antall arter (19 arter fra 9 familier) og artsrikdom per lokalitet (2.60 ± 0.60 SE), sammenlignet med teinene (15 arter fra 7 familier; 1.00 ± 0.18 SE).

Stereo-BRUVs ville vært en bedre metode enn teiner for overvåkning av fiskesamfunn på grunn av den høyere artsrikdommen og utbredelsen av arter. Fisketeinene viste bedre potensial enn stereo-BRUVs til å fange kryptiske arter, f.eks. lomre, og ville derfor hatt en høyere nøyaktighet når det kommer til identifikasjon av arter sammenlignet med stereo-BRUVs.

Stereo-BRUVs viste en større rekkevidde på lengdemål hos torsk, men hadde få individ over 70 cm sammenlignet med teinene. Lengdemål ble utført i synsfeltet til kameraet med det maksimume antallet individer til en art. Resultater fra denne studien indikerer at biaser oppstår når fisk svømmer in og ut av synsfeltet, og at enkelte fisk vil ikke bli tatt lengdemål av. Dette vil kunne påvirke estimater av artsutbredelse, gjennomsnitt for lengdemål og frekvensen av lengdemål.

Resultater fra denne studien fastslår at stereo-BRUVs kan være et verdifullt verktøy i overvåkning av temporale endringer i artsrikdom og artsutbredelse i tempererte farvann med lav diversitet i kystområdene til Frøya og Hitra.

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Abbreviations

BACI	=	Before-after control impact
EAF	=	Ecosystem Approach to Fisheries
FAO	=	The Food and Agriculture Organization
IMR	=	Institute of Marine Research
IUCN	=	International Union for Conservation of Nature
MaxN	=	Maximum number of individuals for a given species counted within the field of view at the same time
MPA	=	Marine protected area
NGU	=	Geological Survey of Norway
ROMS	=	Regional ocean modelling system
stereo-BRUVs	=	Stereo baited remote underwater video systems

1 Introduction

1.1 Active Management of Marine Resources and Marine Protected Areas

”Active Management of Marine Resources” at Frøya and Hitra, located in the central region of Norway, is a conservation project by the Institute of Marine Research (IMR). The project had its start-up in the fall of 2017, and the aim is to secure marine values and the opportunities to create future values from the ocean. An essential tool in this project will be coastal zone management, and a milestone is to make proposals for marine protected areas (MPA) based on collected data from fieldwork in the coastal regions around Hitra and Frøya (Kleiven et al., 2017, 2019a).

There are different definitions of marine protected areas. The Food and Agriculture Organization (FAO) defines an MPA which favours the conservation of biodiversity and fisheries: ”Any marine geographical area that is afforded greater protection than the surrounding waters for biodiversity conservation or fisheries management purposes will be considered an MPA” (Cochrane et al., 2011, p.9). The International Union for Conservation of Nature (IUCN) has since 2007 used an overall definition for protected areas on land and in the marine environment. The IUCN states that: ”A protected area is a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values” (Stolton et al., 2013, p.8). The IUCN definition of an MPA secures the intention of conservation of nature and do not include purposes where the primary intention is exploitation of resources, e.g. fisheries (Stolton et al., 2013).

The global biodiversity and nature face degradation due to impacts from fisheries, climate change, pollution, tourism, oil and gass, and the shipping industry (WWF, 2018; Soulé et al., 2005; Simard et al., 2016). As a mitigation measure, the world must implement more protected areas to sustain marine biodiversity and the ecosystem services that nature gives the human population (Simard et al., 2016).

The regulations regarding traffic and harvesting inside a specific MPA can vary significantly (FAO, 2018; Stolton et al., 2013):

- MPAs with **multiple use** that allow human traffic, including fishing or other types of harvesting.
- **No impact** MPAs that will enable people to harvest, but with limitations to decrease the impact is has on the area.
- **No-take** MPAs where pepole are allowed to use the area, but any harvesting of a natural or cultural resource is banned.

Guri Kunna high school at Frøya is an important collaborator with the project Active Management of Marine Resources, and assists as a base for the fieldwork and the field equipment (Kleiven et al., 2017, 2019a). The mapping of the areas consists of several surveys and parts of fieldwork. Waterflow and exposure models are conducted with the Regional Ocean Modelling System (ROMS) to illustrate ocean currents around Hitra and Frøya. Surveys and mapping have been conducted to get an overview of the nature type data in the areas, along with user surveys replied to by fisheries to find the spawning grounds for the Atlantic cod. Marine ground maps contrived by the Geological Survey of Norway (NGU) during the fall of 2018 for the project view the different types of bottom sediments in two selected areas, the East coast of Frøya and in Fillfjorden (Kleiven et al., 2019a). The project has chosen four key species/species groups to focus on, and the design of the MPA will aim at protecting these key species. These species/species groups are: Atlantic cod (*Gadus morhua*), scallops (Pectinidae), *Nephrops norvegicus* and different species of wrasse (Kleiven et al., 2017, 2019a).

In addition to the fieldwork, the IMR wishes to suggest areas for protection in Frøya and Hitra, based on user surveys of the different stakeholder groups within these municipalities (Kleiven et al., 2017, 2019a). Involving stakeholders are among the most important steps in implementing an MPA, as they can contribute with important information about the designated area and their interests. Local involvement and influence also give the implemented MPAs legitimacy for the stakeholders. As a result, the MPA have both the environment and the stakeholders interests in consideration (Walton et al., 2013). Fisheries, aquaculture, tourism, residents, and local organisations will together with collected data from fieldwork outline the most suitable areas for protection at Frøya and Hitra (Kleiven et al., 2017, 2019a).

A very similar project has previously been done in Tvedestrand at the Skagerrak coast (Espeland et al., 2016). Together with data collection, user surveys from different stakeholders about the local ocean resources formed the base of a future based management plan of the coastal areas in Tvedestrand (Espeland et al., 2015). The goal here was to create a sustainable management plan for Tvedestrand and develop MPAs with the least possible conflicts of interest from the stakeholders. The MPA in Tvedestrand was implemented in 2012 and collection of data in the years 2013-2016 showed an increase mean size for the Atlantic cod and the European lobster (*Homarus gammarus*), as well as an increase in species abundance for the European lobster and decreased mortality for the Atlantic cod (Espeland et al., 2015, 2016).

Generally, creating MPAs can have several effects (see also illustration in Figure 1.1):

- Abundant adult fish and shellfish reproduce more efficiently, and also, the eggs and larvae can spread to the areas around the MPA (Harrison et al., 2012).
- Younger individuals are allowed to grow up, leading to increased mean size and contributing to higher population densities in the MPA (Moland et al., 2013).
- Adult fish will spill-over to areas surrounding the MPA open for fishing (Brock et al., 2012).

MPAs are increasingly being used to protect commercial species in fisheries (Moland et al., 2013). According to FAO, the goal of fisheries management is to have sustainable fisheries where the resource to harvest is not overexploited but rather left in a condition so that it can be re-harvested (Cochrane et al., 2011). In the later years, fisheries have gotten a broader perspective of management and now considers the entire ecosystem when managing fisheries interest, which has been given the name Ecosystem Approach to

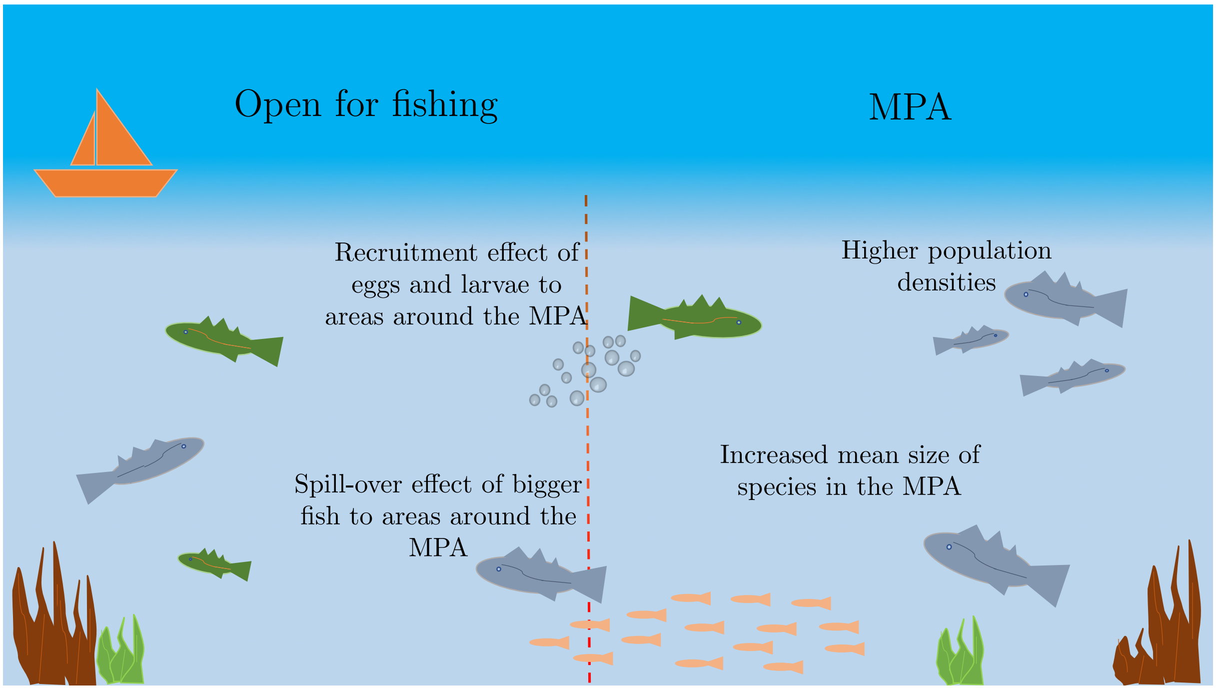

Figure 1.1: Illustration of possible effects from establishing an MPA. Based on illustration from Espeland et al. (2015)

Fisheries (EAF) (Roberts et al., 2005). The EAF protects both species and the species habitats, aiming for healthy marine ecosystems for the fisheries (Gullestad et al., 2017). MPAs can be a method to help develop more sustainable fisheries by protecting and keeping ecosystems healthy (FAO, 2003; Havforskningsinsituttet, 2008).

MPAs in Norway has an area coverage of 243 square kilometres, divided into six areas. By the end of 2020, Norway has committed to protect ten percent of the outer limit of territorial waters, 12 nautical miles from the mainland. Today the MPAs only amount 3.1% of the goal (10%). Land based protected areas have a much higher coverage, with 17 229 square kilometres divided into 195 protected areas. Comparing land based and marine based protected areas, the establishment of MPAs should increase in the marine environment (Miljødirektoratet, 2019).

The Norwegian Ministry of Fisheries and Coastal Affairs implemented four small scale lobster MPAs along the Norwegian part of the Skagerak coast in 2006. Data from 2010 shows that the occurrence of lobster in "catch per unit effort" had increased by 245% inside the MPA and by 85% in the control area for the MPA. The Atlantic cod was also sampled after the implementation of the MPA, and showed an increased mean size of 5 cm inside the MPA compared to the control area (Moland et al., 2013). When assessing an area, the length of the fish caught can tell a lot about age, reproduction and recruitment (Beldade et al., 2012). Organisms from the expected spill-over effect, to areas around the MPAs, have been harder to observe and surveillance during the ”Active Management of Marine Resources” projects’ (Espeland et al., 2015, 2016; Kleiven et al., 2019b).

To improve the public’s opinion about the MPAs, there is a great need for more examples of areas before and after implementing the restrictions (Russ, 2002; Willis et al., 2003; Tetreault and Ambrose, 2007; Osenberg et al., 2011). The effects can be shown with sufficient ”before-after control impact” (BACI), an approach that samples inside and outside the desired area before and after implementing the MPA (Kleiven et al., 2019b; Moland et al., 2013). The BACI design is described to be the most powerful method to show the effects from an MPA on the selected protection area and also the areas surrounding it (Russ, 2002; Willis et al., 2003; Tetreault and Ambrose, 2007; Osenberg et al., 2011).

Surveillance of populations of different types of species has usually been done with fishing gear that works both selective on the species and the habitat (Hilborn and Walters, 1992). In marine management today, there is increasing pressure to monitor the effects of fishing on several species than just the target species (Fletcher, 2006). As a result, video monitoring has become more usual. With video, ecosystems are studied and different fish assemblages can be observed, measured, and quantified (Watson et al., 2007, 2009, 2010). Marine conservation includes observing biodiversity, the abundance of species, and population characteristics in the ecosystem over time (Peters, 1986). Use of video enables monitoring of temporal changes in an ecosystem, surveillance of anthropogenic influence, and how conservation techniques work (Mclean et al., 2011). Monitoring with video can also give reasonable estimates on the fish length and species abundance (Harvey and Shortis, 1998).

1.2 Stereo-BRUVs: Stereo Baited Remote Underwater Video Systems

One of the methods used for sampling biological data in the project "Active management of marine resources" is the stereo baited remote underwater video system (stereo-BRUVs or BRUVs). The video-system consists of two low-cost, GoPro cameras with housing placed in stereo onto a rig with bait (Letessier et al., 2015). It is a relatively new method to collect data in the marine environment in temperate waters (Espeland et al., 2015). The BRUVs can collect data from midwater to benthic habitats, and videos are later analysed in which the species and individuals are characterised, counted, and measured (Letessier et al., 2015). Stereo-camera systems solve many problems with manual sampling since the method has low impact on the environment. The BRUVs would never be in direct contact with the specimen and therefore have minimal effect on the target species and environment, which makes this method suitable to monitor species that are vulnerable, e.g. red-listed species (Harvey et al., 2007).

1.2.1 Advantages of Using Stereo-BRUVs

Another advantage of using BRUVs is the small size of the action cameras, which makes it more available under challenging sites. The method is a safer way to collect data as it needs no involvement from humans under water. Several BRUVs can be deployed at the same time and give a larger spatial coverage. Stereo-BRUVs also enables time series and can generate large data sets. The video-rig can be lowered to different depths and have lightning installed if it is placed in depths of the aphotic zone. The fact that the BRUVs use GoPros makes it relatively cheap, and also these types of cameras are excellent for stereo use (Letessier et al., 2015).

The fact that the videos can be analysed after conducting the fieldwork gives an advantage of saving time in the field, and one could use more time afterwards to specify the species observed on film (Harvey et al., 2001).

1.2.2 Challenges With Using Stereo-BRUVs

There are also some negative aspects to consider when using BRUVs to collect data. After the fieldwork, there is a considerable amount of work remaining, because it takes time to analyse each site filmed (Holmes et al., 2013). A challenge with BRUVs is to observe all the smaller individuals and species. Research on the nearshore rocky reef ichthyofauna of Southeast Australia compared BRUVs with underwater visual census (UWC). It revealed that UWC overall observed a higher number of species and individuals while BRUVs seemed to underestimate density of herbivorous and territorial species, which could be because of the bait as the BRUVs showed a higher species richness and abundance than UWC in predators. Because of these findings, it is suggested that one should use different types of methods to study species richness and abundance (Colton and Swearer, 2010).

The BRUVs gives an estimate of species abundance as a result of the MaxN, which is "the maximum number of individuals for a given species counted within the field of view at the same time" (Harvey et al., 2013a, p.12). MaxN is a number for the relative density (not absolute), and will provide an estimate for the species abundance (Harvey et al., 2013a; Watson et al., 2010; Harvey et al., 2013b; Hill et al., 2014; Malcolm et al., 2015).

1.2.3 Use of Bait in Stereo-BRUVs

The most significant uncertainty the BRUVs has is probably related to the use of bait (Priede and Merrett, 1996). It is indefinite in what degree that bait affects the stereo-BRUVs, but the fact is that previous studies show that bait is especially favourable at attracting predators (Colton and Swearer, 2010; Dorman et al., 2012; Hardinge et al., 2013). A study performed by Harvey et al. (2007) used stereo remote underwater video systems both with and without bait. The results showed that the bait attracted more predators and scavenging species than the one without the bait, but the baited video-rig also showed that there was a higher similarity between replicate samples within chosen habitats. The stereo-BRUVs will add greater statistical power to expose spatial and temporal changes in the habitat of fish assemblages and relative abundance among species (Harvey et al., 2007). Other studies suggest a shorter deployment time (shorter than

15 minutes) of the stereo-BRUVs to stop the bait plume from spreading too far and get a more accurate number for relative abundance when observing the immediate area (McLaren et al., 2015; Coghlan et al., 2017).

In complex habitats, the abundance of species can be challenging to reaffirm (Willis et al., 2000; Watson et al., 2005), and therefore, when choosing study design of an experiment, it is favourable to select a method that maximises the mean and minimises the variance in standard errors, which will increase the power of the chosen program for analysis (Winer, 1991; Underwood and Chapman, 2003). A previous study with Langlois et al. (2010) showed lower variation in measurements with stereo-BRUVs compared to diver operated stereo video (Langlois et al., 2010). The BRUVs is a method that is suitable for surveilling of temporal and spatial changes and therefore makes it suitable for the BACI-method to observe an area before and after implementing an MPA (Espeland et al., 2016; Langlois et al., 2010, 2012b).

1.2.4 Comparing Stereo-BRUVs with Traps

Fish traps can have a lower environmental impact compared to other traditional fishing tools that can have higher mortality or habitat destruction. However, the capture efficiency is usually low and usually selective on the bottom-fish. The number of entrances to the trap are among the factors that can influence catch efficiency the most, and one entrance has shown to increase capture compared to traps with two entrances. (Furevik and Skeide, 2003; Jørgensen et al., 2017). In terms of the number of chambers in the trap, the two chamber traps have shown to be an efficient tool for capturing fish. It can capture relative high numbers of fish, and can be especially selective to the Atlantic cod. However, by-catch of crabs in the bottom based two chamber traps can be a problem, and therefore, rising the traps from the bottom with buoys can be a solution (Jørgensen et al., 2017; Løkkeborg et al., 2014).

When comparing the BRUVs with traps, previous studies show different species selectivity among the two methods, and that the stereo-BRUVs will detect more species and individuals than the ones caught by the traps (Harvey et al., 2012; Wakefield et al., 2013). Studies also suggest that stereo-BRUVs capture a higher amount of smaller fish than traps (Langlois et al., 2015, 2012a), which is consistent with that smaller fish could escape the mesh within traps (Newman et al., 2011), get frightened by larger fish (Harvey et al., 2012) or get eaten by larger fish (Uzars, 2000).

1.3 The Aim of the Study

The aim of this study was to compare data from stereo baited remote underwater videosystems with traps from fish communities along the coast of Frøya and Hitra. Subgoals in the study were to:

- Compare the strength and weaknesses of BRUVs and traps as surveying methods.
- Investigate the differences that occur in fish assemblages.
- Examine the variation in the Atlantic cod length, using the two methods.

2
Material and Methods

2.1 Study Sites

Active Management of Marine Resources chose the locations of interest in the coast of Frøya and Hitra for the sampling of data with the BRUVs and traps. As the locations for MPAs are not nominated yet, it was decided to spread out data sampling in larger sites of the study area. For logistical reasons, the sampling was clustered into six different study areas. Figure 2.1 shows a map of the six locations: Kvenvær, East of Frøya, Mausund, Bremneset, Strømfjorden, and Storfjorden.

2.2 Samling Design and Equipment

2.2.1 Sampling Design

Sampling points for the BRUVs and traps were drawn from a systematic randomised selection and made out the collection of 765 possible stations for the fieldwork. Weather conditions like wind and ocean currents were taken into consideration when areas and stations were decided for each day.

The plan for the sampling design was originally to place out the BRUVs and traps at the same stations with deployment of the BRUVs first and then traps the day after, however, the weather conditions were unstable and made the sampling design difficult to follow as planned. The order of BRUVs- and traps-sampling was changed from the original plan for some of the stations (Table 2.1).

Sampling with the BRUVs and traps occurred from May 2nd to 11th of 2019. Six stereo-BRUVs were deployed at 146 stations in the five study sites: Kvenvær, East of

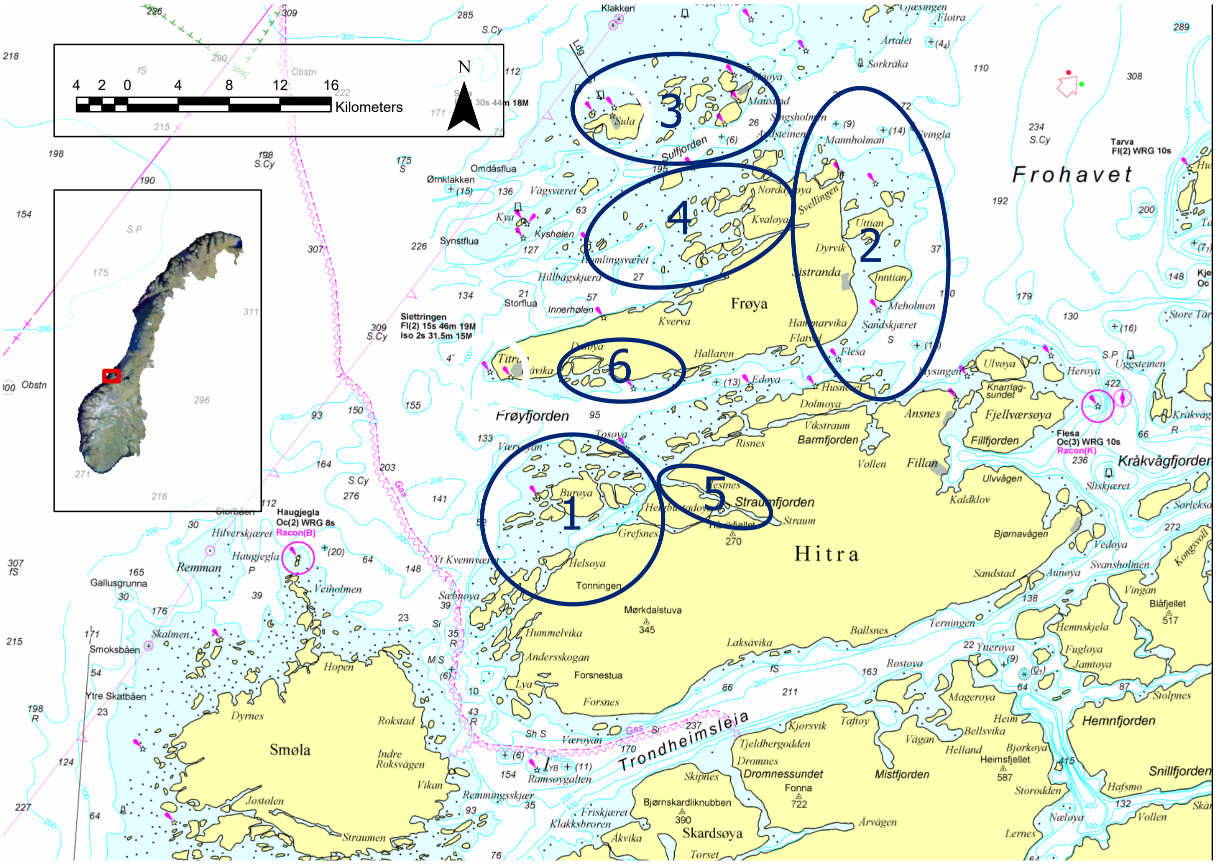

Figure 2.1: Map of study site: coastal areas in Frøya and Hitra. Areas of interest are 1: Kvenvær, 2: East of Frøya, 3: Mausund, 4: Bremneset, 5: Strømfjorden and 6: Storfjorden. Source: the Norwegian Mapping Authority 2019. Datum: ETRS 1989, Projection: UTM Zone 32N.

Frøya, Mausund, Bremneset, and Storfjorden. The BRUVs were deployed at depths between 8 and 30 meters with a mean depth of 20 m ± 0.44 SE. The traps were deployed at 81 stations at depths ranging from 12 to 32 meters with a mean depth of 23.0 m ± 0.55 SE, in the three study sites: Kvenvær, Bremneset, and East of Frøya.

The BRUVs and traps were deployed at 78 common stations in the three study sites: Kvenvær, Bremneset and East of Frøya. The common stations where both the BRUVs and traps were deployed are listed in Table 2.1, and displayed on the map in (Figure 2.2).

For further results in this study, only common stations between the BRUVs and traps were used to compare the two methods. The stations have been used to study the use of BRUVs compared to traps, differences in fish assemblages, and length of the Atlantic cod. Other observations from BRUVs that were from the stations which were not in common with traps, have been used to present specific species observations.

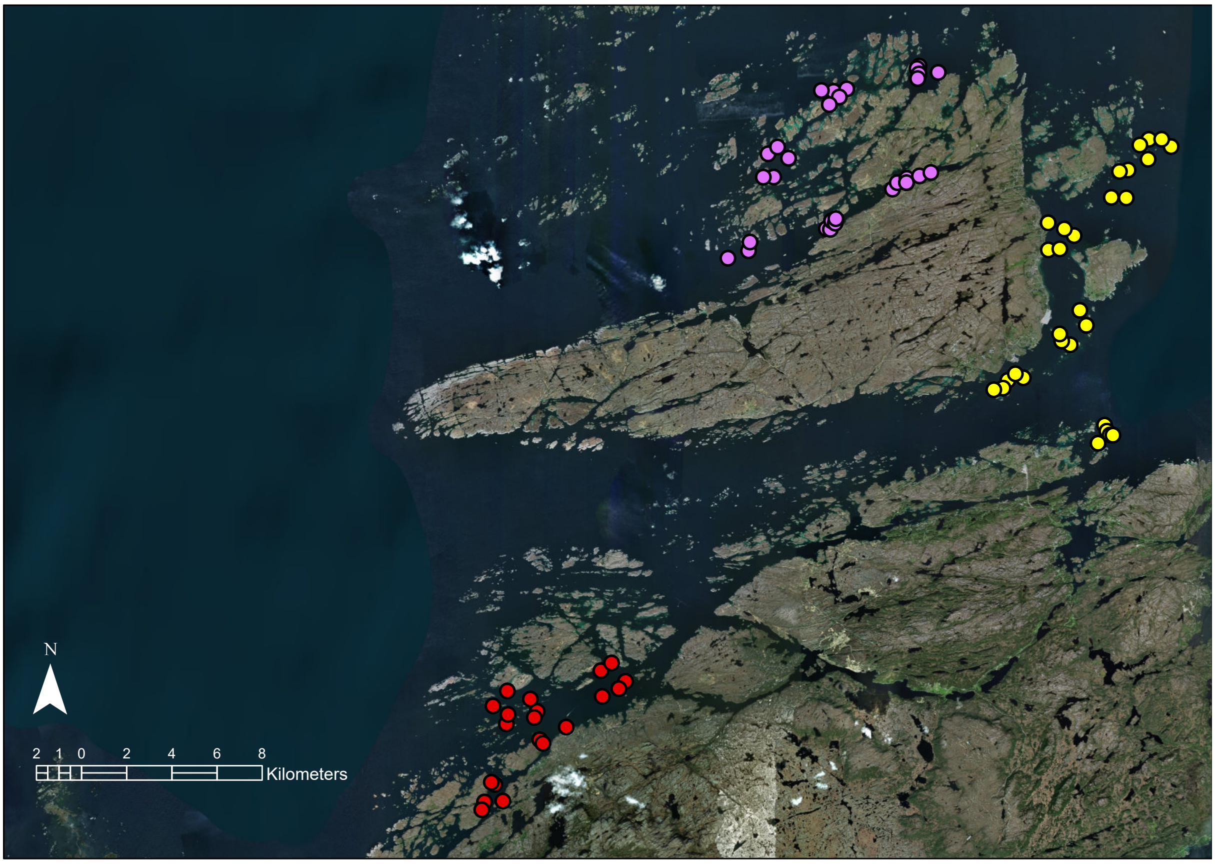

Figure 2.2: The 78 common stations for stereo-BRUVS and traps from the three areas. **Kvenvær** (red), **East of Frøya** (yellow) and **Bremneset** (purple). Source: ESRI Imagery Basemap 2019. Datum: WGS 84, Projection: UTM Zone 32N.

2.2.2 Stereo-BRUVs

The BRUVs (Figure 2.3) consist of a welded metal frame with two GoPro-cameras, spaced 0.7 meters spacing apart and with an inward convergent angle of 8 degrees. Underwater housing for the GoPros enables extra battery time and deeper deployment (Figure 2.4). The angle of the GoPros enables stereo measurements up to 10 meters from the cameras. A bait bag with two-three chopped frozen herring (*Clupea harengus*) was attached in front of the video-rig with 1.5 meters distance from the cameras. The six video-rigs were deployed consecutively and left for at least 60 minutes per station, 3-5 times each day during the field days. It was important that the maximum depth at the stations was limited to 30 meters, due to deployments deeper than this could result in darker images and a difficult time analysing the videos. In addition to the video sampling, each of the BRUVs had a CTD-logger attached to measure depth and temperature of the station. Each day after sampling, recordings were exported to external hard drives.

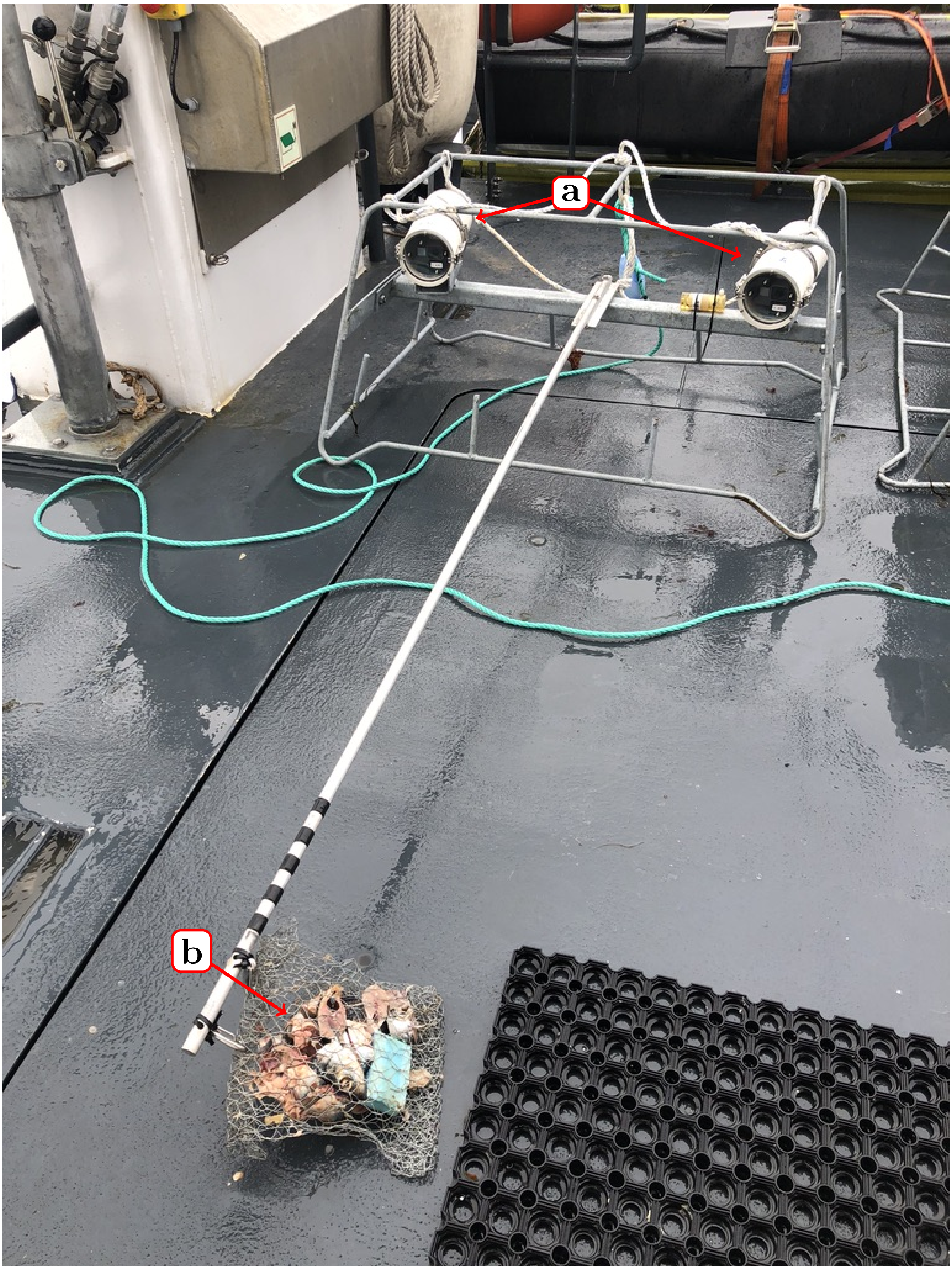

Figure 2.3: Stereo-BRUVS with **a** two Camera houses with 0.7 meters spacing and **b** bait bag with 1.5 meters distance to the cameras.

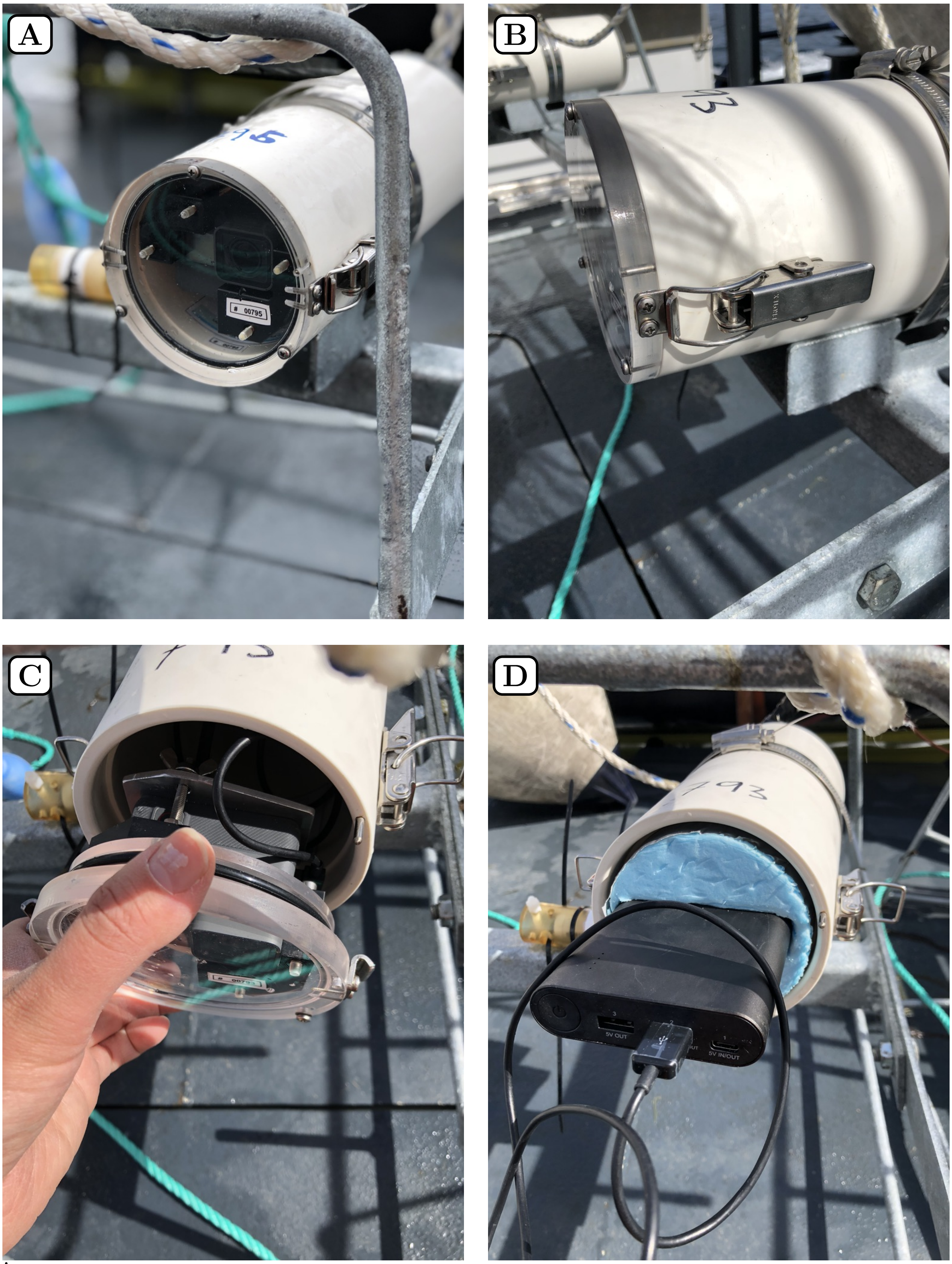

Figure 2.4: Installation of the camera house: **A** Sealed camera house with GoPro behind the plexiglass. **B** Eccentric latch for sealing of the camera house. **C** Installation of the GoPro-camera to the power bank. The camera is attached to the plexiglass. **D** Power bank placed steadily in a customised styrofoam plate

2.2.3 Traps

The method of using traps was chosen because this type of fishing gear can fish at all depths with minimal mortality and achieve realistic estimates for catch per unit effort.

The traps (Figure 2.5) are divided into two chambers consisting of four walls with top and bottom (0.8 x 1 x 1.3 meters). A weight of five kg with 2.5 meters of rope attached to the trap made it possible for the trap to land correctly on the seabed, and buoys on the top of the trap kept it upright (Furevik and Skeide, 2003). Bait was split into two bags and consisted of chopped frozen herring in approximately same amount as in the BRUVs.

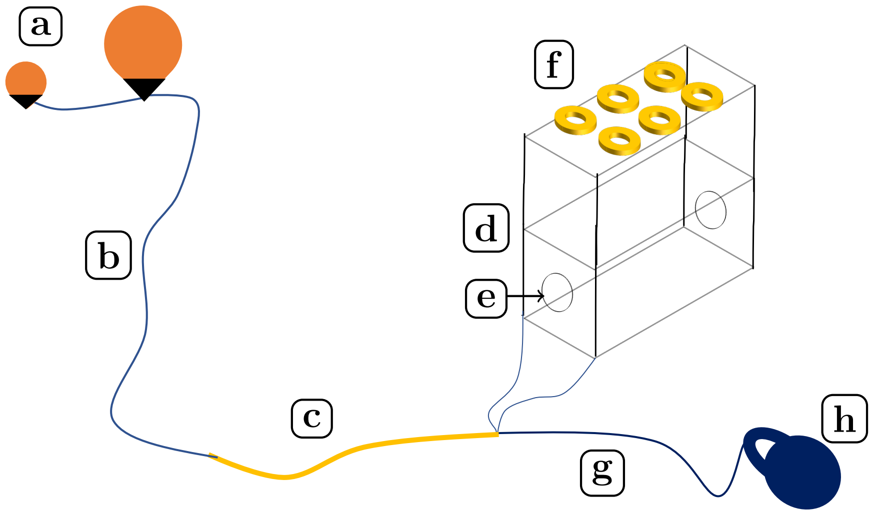

Figure 2.5: Illustration of the trap. It consisted of the components: **a** buoys, **b** Sinking rope, **c** Floating rope, **d** Trap, **e** entrance to trap, **f** six buoys, **g** sinking rope, and **h** weight.

Captured fish was identified and measured (Figure 2.6A) at site and released after sampling. Specimens of the Atlantic cod was measured and tagged with T-bar anchor tag for "capture-mark-recapture" purposes (Kleiven et al., 2016) (Figure 2.6B and 2.6C), and a small piece of the caudal fin was sampled for genetic purposes (Figure 2.6D). For this particular study, the data sampled on the Atlantic cod for capture-mark-recapture- or DNA-purposes will not be used in further results, as these data were sampled for long-term statistics in the project.

Figure 2.6: Fish captured in traps and sampling on the different individuals. **A** Measurement of common dab (*Limanda limanda*). **B** and **C** Tagging of Atlantic cod (*Gadus morhua*) with T-bar anchor tagging gun. **D** Sampling a piece from the caudal fin from Atlantic cod for DNA-purposes

2.2.4 Vessels

Active Management of Marine Resources was able to borrow the inspection vessel Eir from the Directorate of Fisheries for the biological sampling with the BRUVs in the field period of 2019. This type of large vessel enables deployment of the BRUVs at a variety of weather conditions and locations. Equipped with a powerful line hauler, good space on deck, and a very helpful staff made Eir a well suited base for the fieldwork with the BRUVs.

For sampling with the traps, Guri Kunna High School assisted with a workboat equipped with a line hauler, echo-sounder and a GPS. The boat had a capacity of 12 traps and three persons, and worked as a base for the deployment of the traps.

2.3 Video Analysis

2.3.1 Calibration

Calibration of the cameras was performed in March 2018 using the program CAL by SeaGIS. The calibration was done to achieve accurate measurements of the fish length (SeaGIS Pty Ltd, 2015).

2.3.2 EventMeasure

Videos from the 146 stations of deployment of the BRUVs during fieldwork in May 2019 were analysed using the software EventMeasure Stereo developed from SeaGIS (SeaGis, 2016). Each station that was sampled had a separate session in EventMeasure where fish communities were analysed. The analysis in EventMeasure started when the video-rig landed on the seabed and continued for 1 hour.

Fish species are identified (Figure 2.7) (Pethon, 2005) and individuals of each species are counted. Relative abundance was given as MaxN, which is the maximum number of individuals for a given species counted within the field of view at the same time. MaxN increased every time one (or several) individuals of the same species entered the field of view and the number of species exceeded the one that was already counted (Harvey et al., 2003, 2010). Then, when all specimens were counted, the fish length was measured in the MaxN image for each species (Figure 2.8). All individuals that were possible to register were counted and measured, without any restrictions regarding the distance from the camera to the individual.

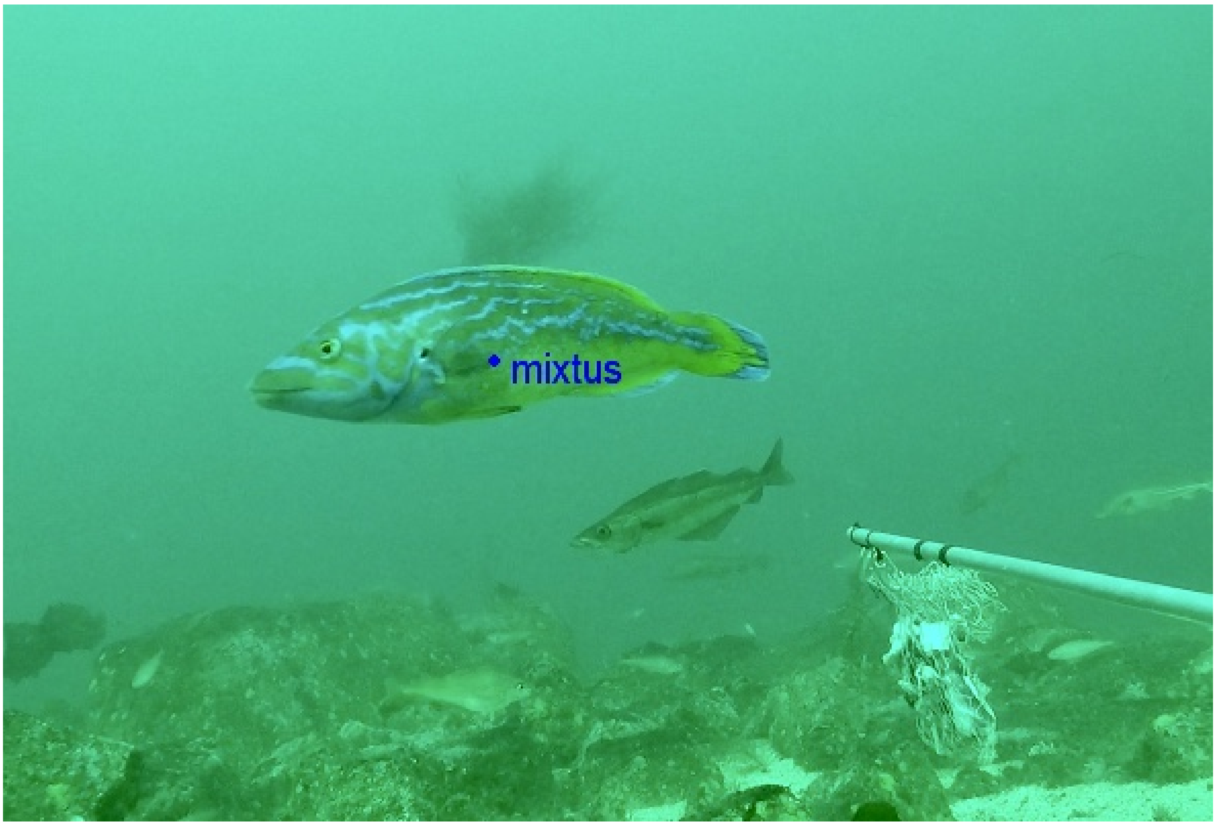

Figure 2.7: Screenshot from EventMeasure. Identifying the species Cuckoo wrasse (*Labrus mixtus*).

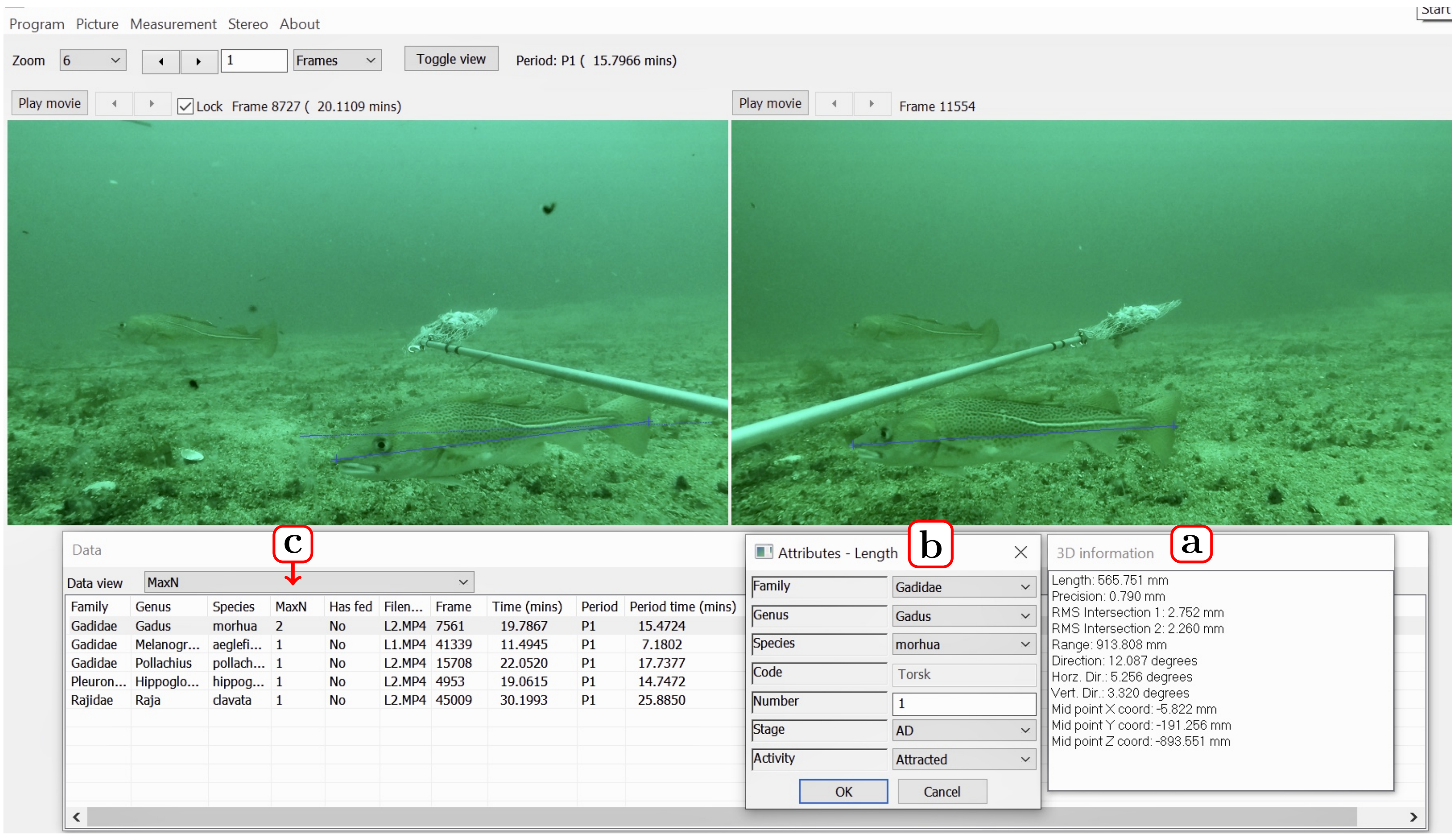

Figure 2.8: Screenshot from EventMeasure of a measurement of the Atlantic cod (*Gadus morhua*). Length measurement of the individual (from nose tip to tail fin) is conducted in both the left and right picture frame. EventMeasure calculates the final measure from the mean of the two measurements in the box **a** "3D-information". Further characteristics on the individual that is measured are chosen in the box **b** "Attributes -Length". Features like family, genus, species, the growth stage of the fish, and if the fish is attracted to the bait or not is selected. The program also displays a table **c** were MaxN is given. MaxN is a number for the frame with the most counted individuals of each species, and here the value of MaxN for cod is 2.

2.4 Data Treatment and Statistical Analysis

After fieldwork and analysis (for BRUVs) in EventMeasure, datasets for MaxN, fish length, and average length were generated to compare the two methods at the common stations.

All data treatment and statistical analysis were either performed with Microsoft Excel, version 15.31 (2017) or R-studios, version 3.6.1 (2019). The main method for plotting data in R-studios was performed with R library ggplot2 (Wickham, 2016).

For the statistical analysis, a significance level of $p<0.05$ was used when detecting statistical difference between the BRUVs and traps. Data for the Atlantic cod length was fitted with a linear regression model to evaluate the residual distribution. ANOVA was used to study the difference between the two methods in cod length (Appendix A).

When assessing the statistical significance in cod length, it was taken into account that this type of study on length measurements should have some reasonable sense when it comes to the p-value. $p=0.05$ is often used as a limit for significance. However, this should more often be reconsidered and adapted for the study it would apply to since a larger p-value would not necessarily mean that the effect is less important (Wasserstein and Lazar, 2016).

Table 2.1: Stations in common for the stereo-BRUVs and traps in the study sites: Kvenvær, Bremneset and East of Frøya.

Station	Area	Date BRUVs	Date Traps	Latitude	Longitude	Depth (m)
1B02	Kvenvær	02.05.19	03.05.19	63.553448	8.386945	12
1B08	Kvenvær	02.05.19	03.05.19	63.551010	8.384415	15
1B11	Kvenvær	02.05.19	03.05.19	63.547335	8.412984	20
1B04	Kvenvær	02.05.19	03.05.19	63.542185	8.389448	25
1B01	Kvenvær	02.05.19	03.05.19	63.540791	8.392267	32
1G02	Kvenvær	02.05.19	03.05.19	63.524241	8.349735	27
1G08	Kvenvær	02.05.19	03.05.19	63.517689	8.357131	26
1G14	Kvenvær	02.05.19	03.05.19	63.525103	8.346659	31
1G03	Kvenvær	02.05.19	03.05.19	63.517240	8.340760	13
1G09	Kvenvær	02.05.19	03.05.19	63.514128	8.338470	15
1K04	Kvenvær	03.05.19	05.05.19	63.548347	8.359593	32
1K12	Kvenvær	03.05.19	05.05.19	63.552122	8.360930	30
1K06	Kvenvær	03.05.19	05.05.19	63.555451	8.347476	23
1K15	Kvenvær	03.05.19	05.05.19	63.561451	8.360141	19
1K14	Kvenvær	03.05.19	05.05.19	63.558336	8.380724	28
1H07	Kvenvær	03.05.19	05.05.19	63.569855	8.443446	23
1H08	Kvenvær	03.05.19	05.05.19	63.565739	8.465518	25
1H04	Kvenvær	03.05.19	05.05.19	63.562783	8.459623	24
1H02	Kvenvær	03.05.19	05.05.19	63.572965	8.452912	28
1H09	Kvenvær	03.05.19	05.05.19	63.559647	8.444891	26
4A11	Bremneset	05.05.19	06.05.19	63.800789	8.648346	23
4J13	Bremneset	05.05.19	06.05.19	63.766593	8.594936	27
4F15	Bremneset	05.05.19	06.05.19	63.808530	8.742411	26
4F05	Bremneset	05.05.19	06.05.19	63.811008	8.725202	20
4J10	Bremneset	05.05.19	06.05.19	63.774120	8.608131	26
4F06	Bremneset	05.05.19	06.05.19	63.810069	8.723364	24
4F03	Bremneset	05.05.19	06.05.19	63.807904	8.725081	17
4F12	Bremneset	05.05.19	06.05.19	63.806046	8.723953	21

4A15	Bremneset	05.05.19	06.05.19	63.801804	8.660153	28
4A12	Bremneset	05.05.19	06.05.19	63.798577	8.653519	21
4A15	Bremneset	05.05.19	06.05.19	63.801130	8.637338	14
4A14	Bremneset	05.05.19	06.05.19	63.795523	8.644542	18
4J01	Bremneset	05.05.19	06.05.19	63.775826	8.589688	26
4J08	Bremneset	05.05.19	06.05.19	63.778555	8.598218	27
4J14	Bremneset	05.05.19	06.05.19	63.766543	8.585602	28
4EE14	Bremneset	05.05.19	07.05.19	63.734211	8.554283	30
4EE11	Bremneset	05.05.19	07.05.19	63.737235	8.572710	22
4EE05	Bremneset	05.05.19	07.05.19	63.740707	8.574004	29
4K06	Bremneset	06.05.19	07.05.19	63.762056	8.701756	29
4K07	Bremneset	06.05.19	07.05.19	63.764634	8.705980	22
4H14	Bremneset	06.05.19	07.05.19	63.746177	8.642509	30
4H15	Bremneset	06.05.19	07.05.19	63.745938	8.646076	24
4H10	Bremneset	06.05.19	07.05.19	63.749328	8.647215	20
4H12	Bremneset	06.05.19	07.05.19	63.748402	8.650410	22
4H02	Bremneset	06.05.19	07.05.19	63.750186	8.650978	24
4K09	Bremneset	06.05.19	07.05.19	63.764674	8.714231	28
4K04	Bremneset	06.05.19	07.05.19	63.766373	8.714538	25
4K03	Bremneset	06.05.19	07.05.19	63.767360	8.725925	28
4K15	Bremneset	06.05.19	07.05.19	63.768734	8.736140	10
2C01	East of Frøya	08.05.19	08.05.19	63.782134	8.932035	18
2C15	East of Frøya	08.05.19	08.05.19	63.779262	8.952074	21
2C10	East of Frøya	08.05.19	08.05.19	63.782186	8.943569	25
2C05	East of Frøya	08.05.19	08.05.19	63.779874	8.923961	22
2C03	East of Frøya	08.05.19	08.05.19	63.774211	8.931376	18
2B05	East of Frøya	09.05.19	11.05.19	63.668506	8.892710	29
2B04	East of Frøya	09.05.19	11.05.19	63.666124	8.894802	17
2B02	East of Frøya	09.05.19	11.05.19	63.664616	8.897634	23
2B06	East of Frøya	09.05.19	11.05.19	63.664513	8.900153	22
2B15	East of Frøya	09.05.19	11.05.19	63.661307	8.886834	22

2M08	East of Frøya	09.05.19	11.05.19	63.687256	8.819791	27
2M01	East of Frøya	09.05.19	11.05.19	63.686210	8.805859	23
2M05	East of Frøya	09.05.19	11.05.19	63.688832	8.812625	18
2M13	East of Frøya	09.05.19	11.05.19	63.683123	8.801622	23
2M14	East of Frøya	09.05.19	11.05.19	63.682470	8.793358	20
2K03	East of Frøya	10.05.19	08.05.19	63.758854	8.911799	28
2K08	East of Frøya	10.05.19	08.05.19	63.769921	8.913420	16
2K07	East of Frøya	10.05.19	08.05.19	63.769351	8.905674	25
2K09	East of Frøya	10.05.19	08.05.19	63.758866	8.911476	20
2K02	East of Frøya	10.05.19	08.05.19	63.759046	8.898379	16
2J13	East of Frøya	10.05.19	09.05.19	63.714130	8.870288	18
2J14	East of Frøya	10.05.19	09.05.19	63.700419	8.861774	17
2J15	East of Frøya	10.05.19	09.05.19	63.701896	8.854096	25
2J09	East of Frøya	10.05.19	09.05.19	63.704712	8.852294	24
2G14	East of Frøya	10.05.19	09.05.19	63.738130	8.841917	23
2G12	East of Frøya	10.05.19	09.05.19	63.738527	8.852197	20
2G15	East of Frøya	10.05.19	09.05.19	63.743829	8.865030	23
2G09	East of Frøya	10.05.19	09.05.19	63.746452	8.856225	28
2G04	East of Frøya	10.05.19	09.05.19	63.748891	8.841692	24

3
Results

This chapter will present the results which were retrieved from the fieldwork data, collected in the study sites along the coast of Frøya and Hitra. Table 3.1 presents the species names for fish observed or captured during fieldwork with the stereo-BRUVs and traps, invertebrates are not included among the results (Appendix B). The table contains catch and observations from all the study sites were BRUVs and traps were deployed, not only the common stations. The table is yet included to illustrate the total species finding and to give the English and Norwegian common names for the species. In total, the stereo-BRUVs and traps sampled 24 species of fish.

The comparisons which follows in the next sections of the results only apply to the 78 stations the stereo-BRUVs and traps had in common.

Table 3.1: Fish species observed or captured during fieldwork with the stereo-BRUVs and traps. All stations findings where the stereo-BRUVs and the traps were deployed are included in the table.

Genus species	**English**	**Norwegian**
Anarhichas lupus (Linnaeus, 1758)	Atlantic wolffish	Gråsteinbit
Callionymus lyra (Linnaeus, 1758)	Dragonet	Vanlig fløyfisk
Ctenolabrus rupestris (Linnaeus, 1758)	Goldsinny wrasse	Bergnebb
Eutrigla gurnardus (Linnaeus, 1758)	Grey gurnard	Knurr
Gadus morhua (Linnaeus, 1758)	Atlantic cod	Torsk
Galeus melastomus (Rafinesque, 1810)	Blackmouth catshark	Hågjel
Gobiusculus flavescens (Fabricius 1779)	Two-spotted goby	Tangkutling
Hippoglossus hippoglossus (Linnaeus, 1758)	Halibut	Kveite
Labrus bergylta (Ascanius, 1767)	Ballan wrasse	Berggylt
Labrus mixtus (Linnaeus, 1758)	Cuckoo wrasse	Blåstål/Rødnebb
Limanda limanda (Linnaeus, 1758)	Common dab	Sandflyndre
Melanogrammus aeglefinus (Linnaeus, 1758)	Haddock	Hyse
Merlangius merlangus (Linnaeus, 1758)	Whiting	Hvitting
Microstomus kitt (Walbaum, 1792)	Lemon sole	Lomre
Molva molva (Linnaeus, 1758)	Common ling	Lange
Platichthys flesus (Linnaeus, 1758)	European flounder	Skrubbe
Pleuronectes platessa (Linnaeus, 1758)	European plaice	Rødspette
Pollachius pollachius (Linnaeus, 1758)	Atlantic pollock	Lyr
Pollachius virens (Linnaeus, 1758)	Saithe	Sei
Raja clavata (Linnaeus, 1758)	Thornback skate	Piggskate
Sebastes viviparus (Krøyer, 1845)	Norway redfish	Lusuer
Squalus acanthias (Krøyer, 1845)	Spiny dogfish	Pigghå
Trisopterus minutus (Linnaeus, 1758)	Poor cod	Sypike
Brosme brosme (Ascanius, 1772)	Cusk	Brosme

3.1 Fish Assemblages in the Stereo-BRUVs and Traps

The results in this section compares the family assemblage and species abundance between the stereo-BRUVs and traps, and also presents some difficulties in species identification in EventMeasure.

In total, the BRUVs and traps sampled 524 fish, where the traps captured 25% of the individuals. Of the 391 fish observed by the BRUVs, 70% was identified to species, while the rest was unidentifiable.

Figure 3.1 views the total fish family assemblage for the traps (A) and stereo-BRUVs (B). Most of the individuals observed on video from stereo-BRUVs were from the Gadidae family, and the next most individuals were from the Pleuronectidae family. The same applies to observations in the traps. The observations from the stereo-BRUVs registered four families (Callionymidae, Labridae, Triglidae, and Gobiidae) that the traps did not catch while the traps caught two families that were not observed by the stereo-BRUVs (Scorpaenidae and Scyliorhinidae).

Some families were rarely found, with only one species observed for each family. The families Anarhichadidae, Rajidae, Callionymidae, and Triglidae occurred as one percent among the total fish family assemblage for stereo-BRUVs. In the traps, the families Rajidae, Scorpaenidae and Scyliorhinidae occurred at one percent or less among the observed families assemblages (Figure 3.1).

Tabel 3.2 presents the different fish assemblages in stereo-BRUVs and traps (species relative abundance and species richness). The stereo-BRUVs and traps showed both differences in species richness and species abundance, were the BRUVs had a mean number of 5.01 individuals per station, while the traps had a mean of 1.72 individuals per station. The Atlantic cod, Whiting (*Merlangius merlangus*) and the Atlantic wolffish (*Anarhichas lupus*) were among the few species the two methods were able to sample similar abundance numbers of.

The Labridae family occurred as five percent of the total fish families assemblage (Figure 3.1) with three different species,*Ctenolabrus rupestris*, *Labrus bergylta* and *Labrus mixtus* (Table 3.2). No labrides was observed in the traps at any of the stations.

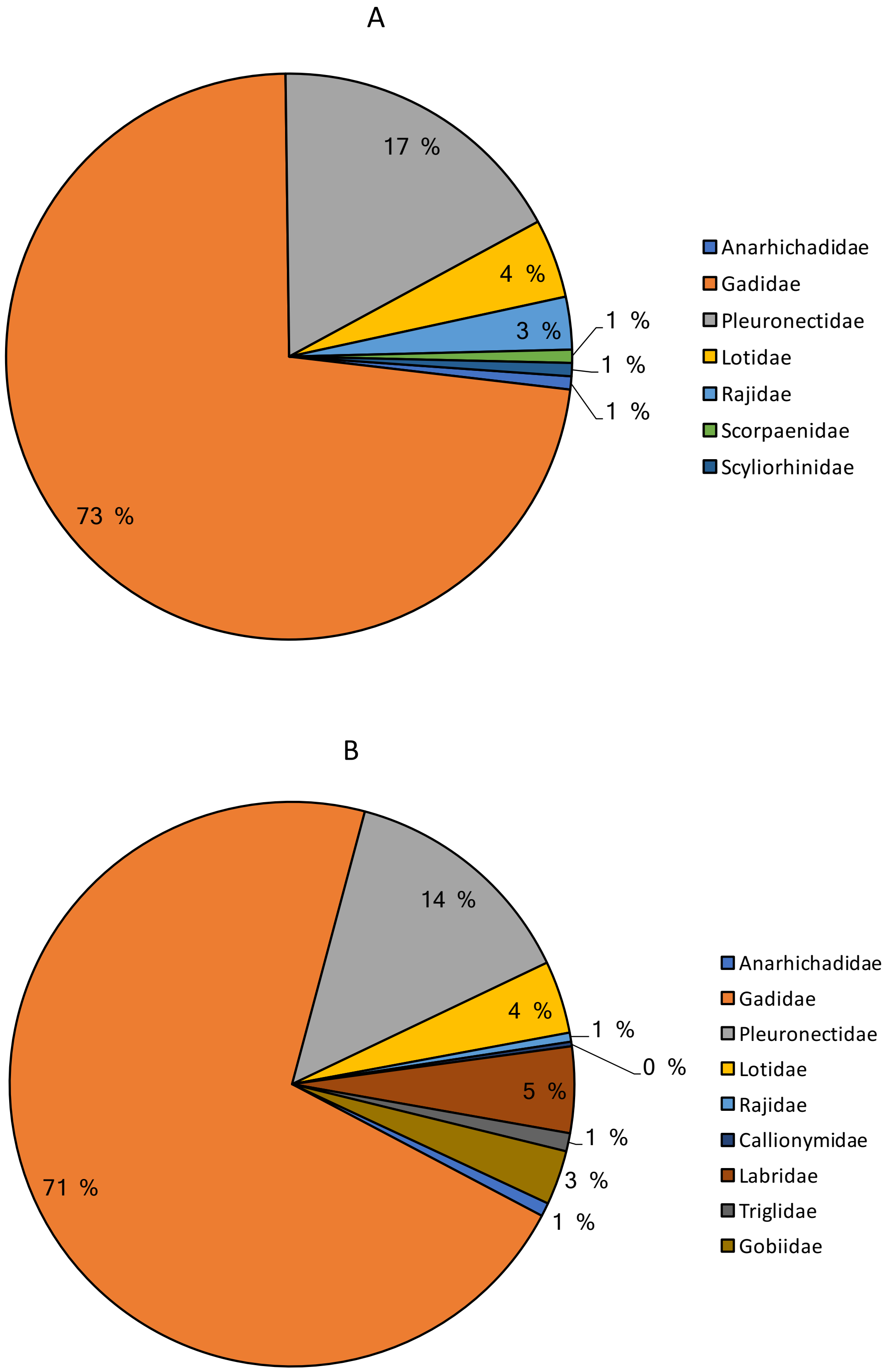

Figure 3.1: Proportions of the total fish family assemblage captured in the traps (A) and stereo-BRUVs (B), based on mean count of species from the 78 common stations.

Table 3.2: Relative abundance (mean ± SE) of fish caught in traps and observed on stereo-BRUVs for the 78 common stations. ”-” indicates that no individuals were observed or caught.

Family	**Genus species**	**Traps**	**Stereo-BRUVs**
Anarhichadidae	*Anarhichas lupus*	0.01 ± 0.01	0.04 ± 0.02
Gadidae	*Gadus morhua*	1.12 ± 0.21	1.32 ± 0.17
Scyliorhinidae	*Galeus melastomus*	0.01 ± 0.01	-
Pleuronectidae	*Hippoglossus hippoglossus*	0.01 ± 0.01	0.09 ± 0.03
Pleuronectidae	*Limanda limanda*	0.17 ± 0.07	0.06 ± 0.03
Gadidae	*Melanogrammus aeglefinus*	0.01 ± 0.01	0.22 ± 0.06
Gadidae	*Merlangius merlangus*	0.01 ± 0.01	0.01 ± 0.01
Pleuronectidae	*Microstomus kitt*	0.04 ± 0.03	-
Lotidae	*Molva molva*	0.08 ± 0.03	0.21 ± 0.06
Pleuronectidae	*Pleuronectes platessa*	0.08 ± 0.02	0.03 ± 0.07
Gadidae	*Pollachius pollachius*	0.06 ± 0.03	0.55 ± 0.09
Gadidae	*Pollachius virens*	0.03 ± 0.02	0.12 ± 0.04
Rajidae	*Raja clavata*	0.05 ± 0.03	0.03 ± 0.02
Scorpaenidae	*Sebastes viviparus*	0.01 ± 0.01	-
Gadidae	*Trisopterus minutus*	0.03 ± 0.02	0.32 ± 0.12
Callionymidae	*Callionymus lyra*	-	0.01 ± 0.01
Labridae	*Ctenolabrus rupestris*	-	0.08 ± 0.04
Triglidae	*Eutrigla gurnardus*	-	0.05 ± 0.03
Gobiidae	*Gobiusculus flavescens*	-	0.16 ± 0.09
Labridae	*Labrus bergylta*	-	0.01 ± 0.01
Labridae	*Labrus mixtus*	-	0.18 ± 0.04
Pleuronectidae	*Platichthys flesus*	-	0.01 ± 0.01
Pleuronectidae	Uknown Flounder	-	0.49 ± 0.11
Gadidae	Uknown Gadidae	-	1.03 ± 0.48
Labridae	Uknown Wrasse	-	0.05 ± 0.03

The Atlantic cod (*Gadus morhua*) (Figure 3.2) was the most abundant species observed or caught in both methods. Figure 3.3 shows the mean abundance of species compared between stereo-BRUVs and traps. Both the methods seem to sample large proportions of Atlantic cod, but the stereo-BRUVs appears to sample more individuals of the species Poor cod (*Trisopterus minutus*) and Atlantic pollock (*Pollachius pollachius*). While traps sample more individuals of the species Common dab (*Limanda limanda*).

Figure 3.2: Screenschot from EventMeasure, identifying a Atlantic cod (*Gadus morhua*)

Even though stereo-BRUVs and traps have sampled an equal amount of species from the Pleuronectidae family, Figure 3.3 displays how stereo-BRUVs observed more individuals in total from this family as the proportion of "Unknown Flounder" is quite high. The amount of "Unknown Flounder" indicates that this family was challenging when it came to identifying to species level. Several flounders analysed in EventMeasure were identified to the family level, Pleuronectidae.

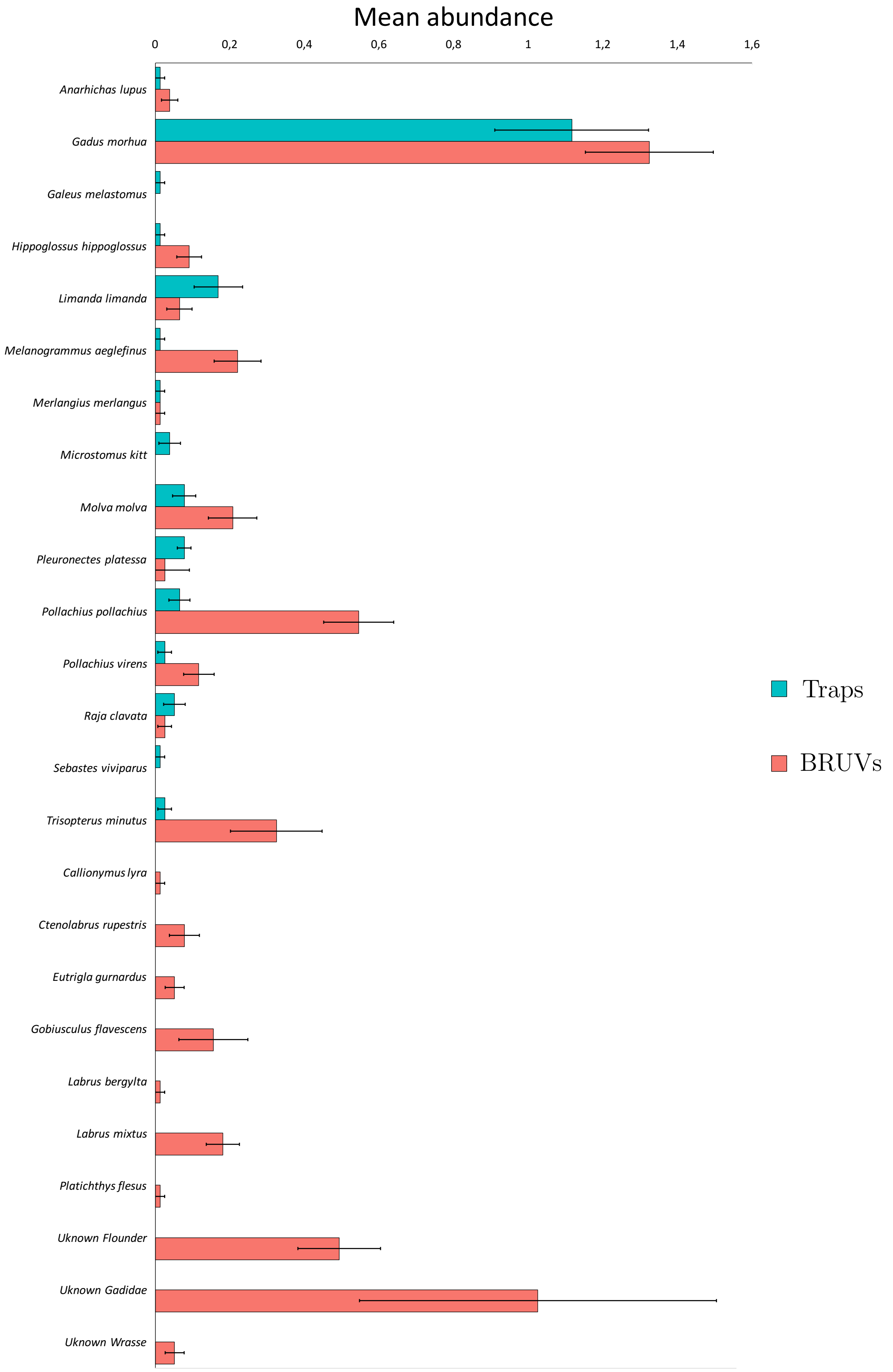

Figure 3.3: Mean abundance by species for the stereo-BRUVs and the traps ± SE.

Figure 3.4 illustrates how flounders could occur in the picture in EventMeasure. These flounders (**a** and **b**) could qualify as more than one species in the Pleuronectidae family because of how they appear in the image.

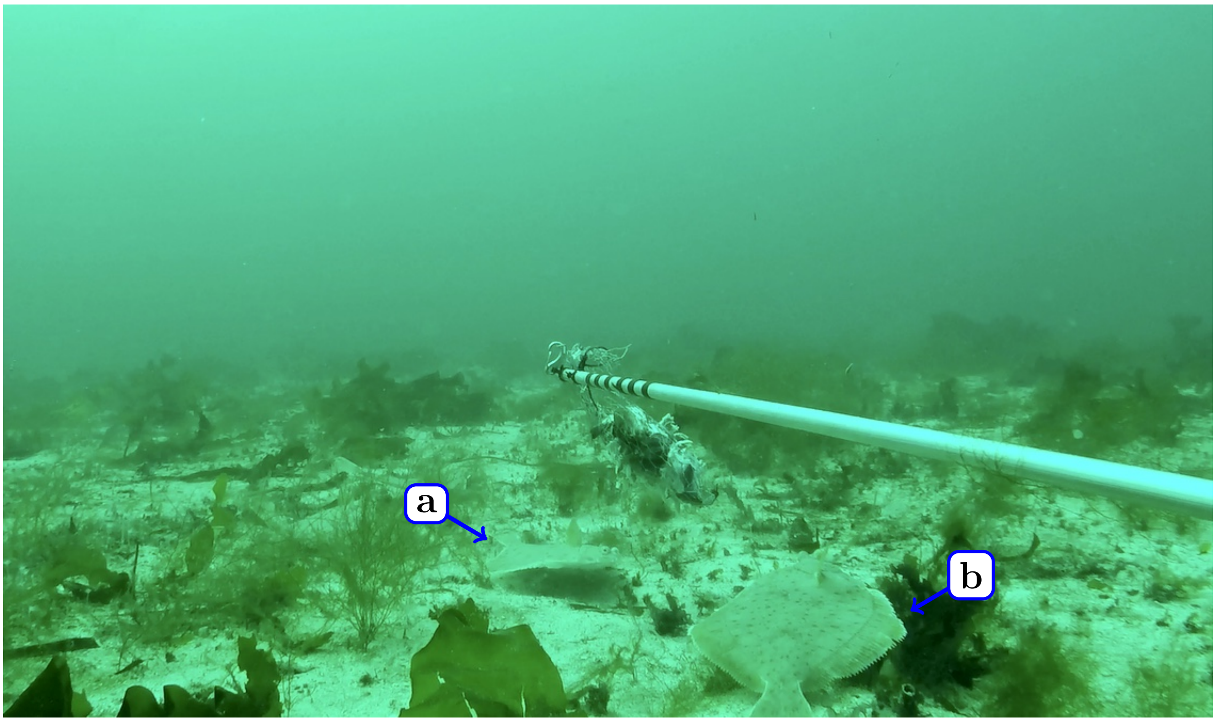

Figure 3.4: Screenshot from EventMeasure with two unidentified flounders (a and b).

The proportion of "Uknown Gadidae" and the associated SE bar for this group was quite high (Figure 3.3). Several shoals of fish appeared in the image on the stereo-BRUVs. These shoals, often appearing in very high numbers, were often challenging to characterise to species and to count the size of the shoal (Figure 3.5), indicating that there would be an increased uncertainty regarding these observations.

Figure 3.6 highlights which species that were unique for the two methods and the species they had in common. Species unique for the stereo-BRUVs were the Dragonet (*Callionymus lyra*), Goldsinny wrasse (*Ctneolabrus rupestris*), Grey gurnard (*Eutrigla gurnardus*), Two-spotted goby (*Gobiusculus flavescens*), Ballan wrasse (*Labrus bergylta*), Cuckoo wrasse (*Labrus mixtus*), and European flounder (*Platichthys flesus*). The traps had three unique species, the Blackmouth catshark (*Galeus melastomus*), Lemon sole (*Microstomus kitt*), and Norwegian redfish (*Sebastes viviparus*).

The Dragonet, Goldsinny wrasse and Two-spotted goby are relatively small in size and are therefore difficult to catch in the fish traps that were used in this study.

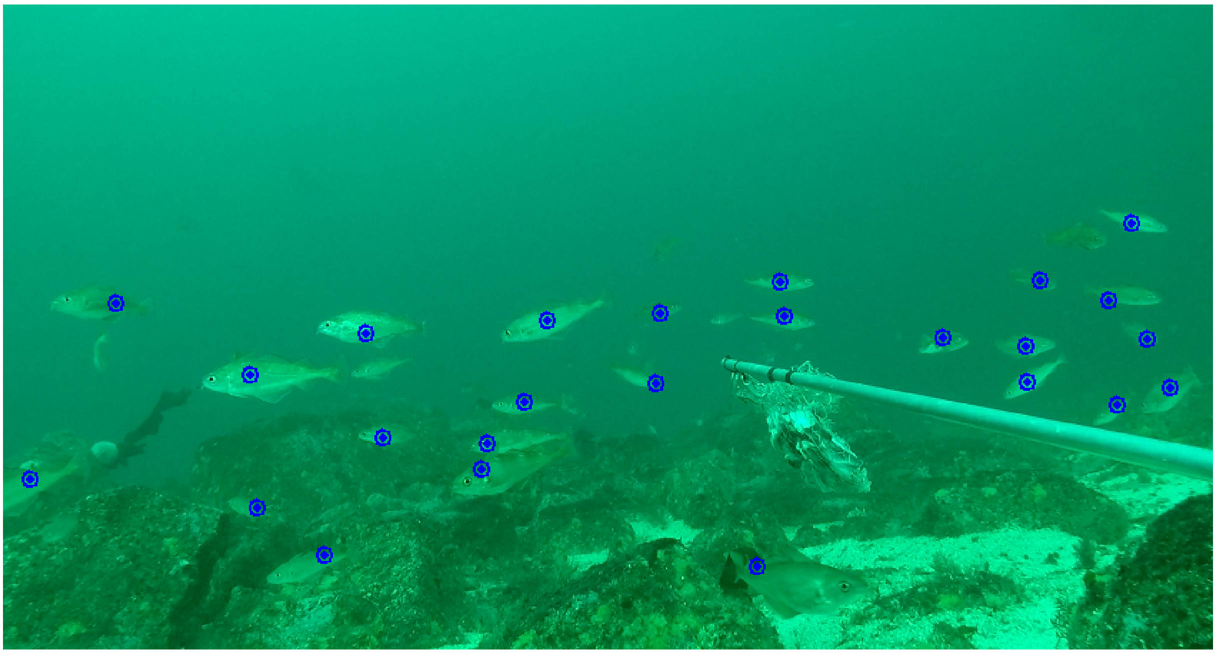

Figure 3.5: Screenschot from EventMeasure, counting a Gadidae shoal in what appears to be the species Poor cod (*Trisopterus minutus*).

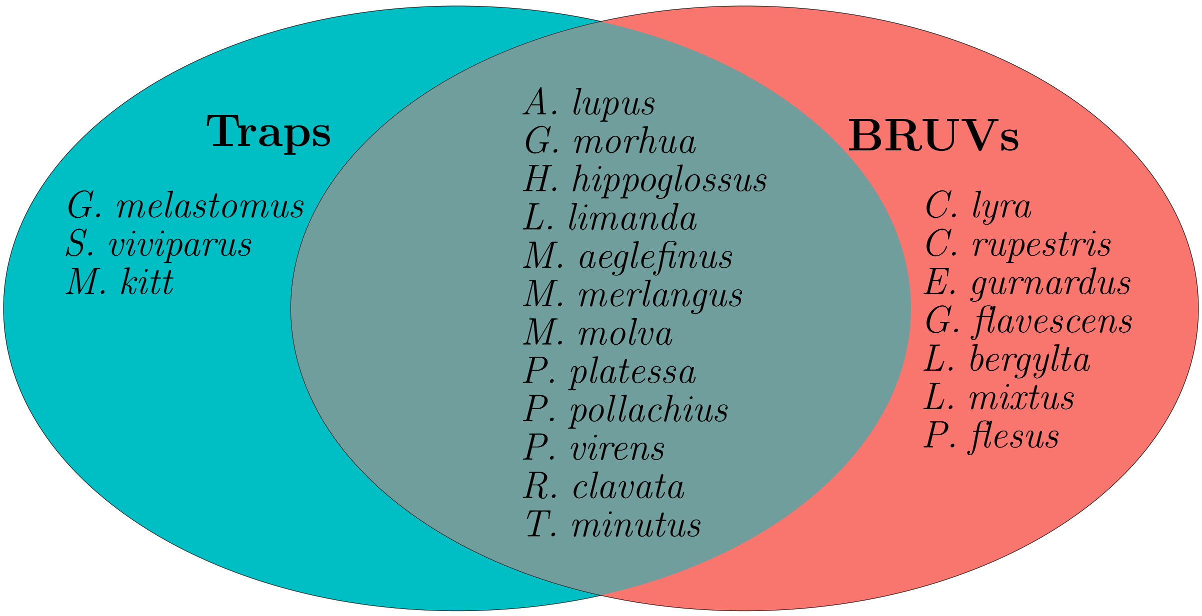

Figure 3.6: Diagram visualizing the differences and similarities in species occurrence between stereo-BRUVs and traps.

3.2 The Use of Stereo-BRUVs and Traps

In this section, results illustrates the use of stereo-BRUVs compared to traps. The stereo-BRUVs had a mean number of species per station of 2.60 ± 0.60 SE, compared to the traps that caught 1.00 ± 0.18 SE.

Figure 3.7 compares the number of occurred species in the two methods, where stereo-BRUVs observed a maximum of six different fish species at the same station, and with traps, it was possible to catch a maximum of three different species from one station. The most common case, observed at 12 different stations (n=12) was for the stereo-BRUVs to observe two species, while the traps caught one species. Next most common case (n=11) was for stereo-BRUVs to observe three species and traps to capture one species. In general, the stereo-BRUVs found a higher number of species. If the two methods had been able to discover the same amount of species, the points in Figure 3.7 would follow the grey line.

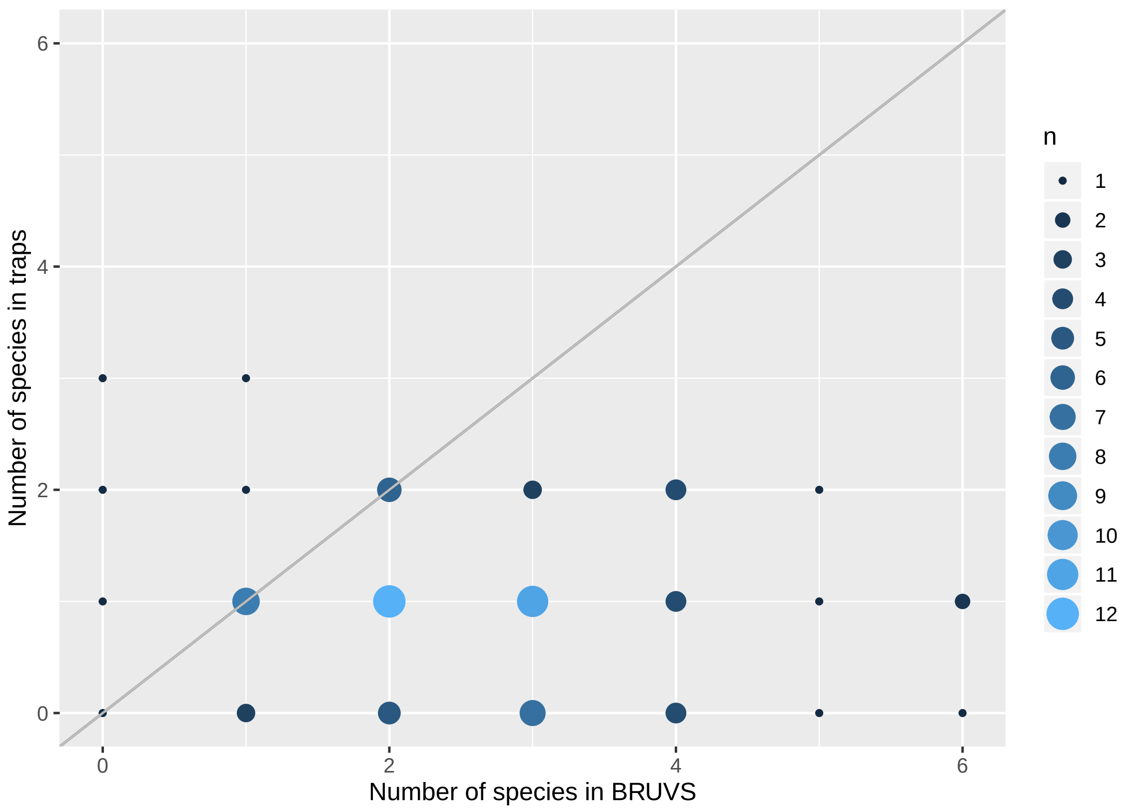

Figure 3.7: Number of observed species in stereo-BRUVs and traps for the common stations. The number of stations which the different numbers of species occurred in is explained by **n**.

Figure 3.8 compares the distribution of species occurrence between stereo-BRUVs and traps for the study sites. The traps had zero catch more often than the BRUVs for all the sites, and a mean catch of approximately one species for all areas. For the areas East of Frøya and Kvenvær, the traps was able to sample up to three species.

For the BRUVs, the mean number of species was close to two for East of Frøya (2.4 specimens) and Kvenvær (2.2 specimens). For Bremneset, the BRUVs had a mean of three species per station. In Bremneset and Kvenvær, the BRUVs sampled up to six species. In East of Frøya, the BRUVs sampled up to five species (Figure 3.8).

There were no similar trends in mean number of species for the two methods in the study sites.

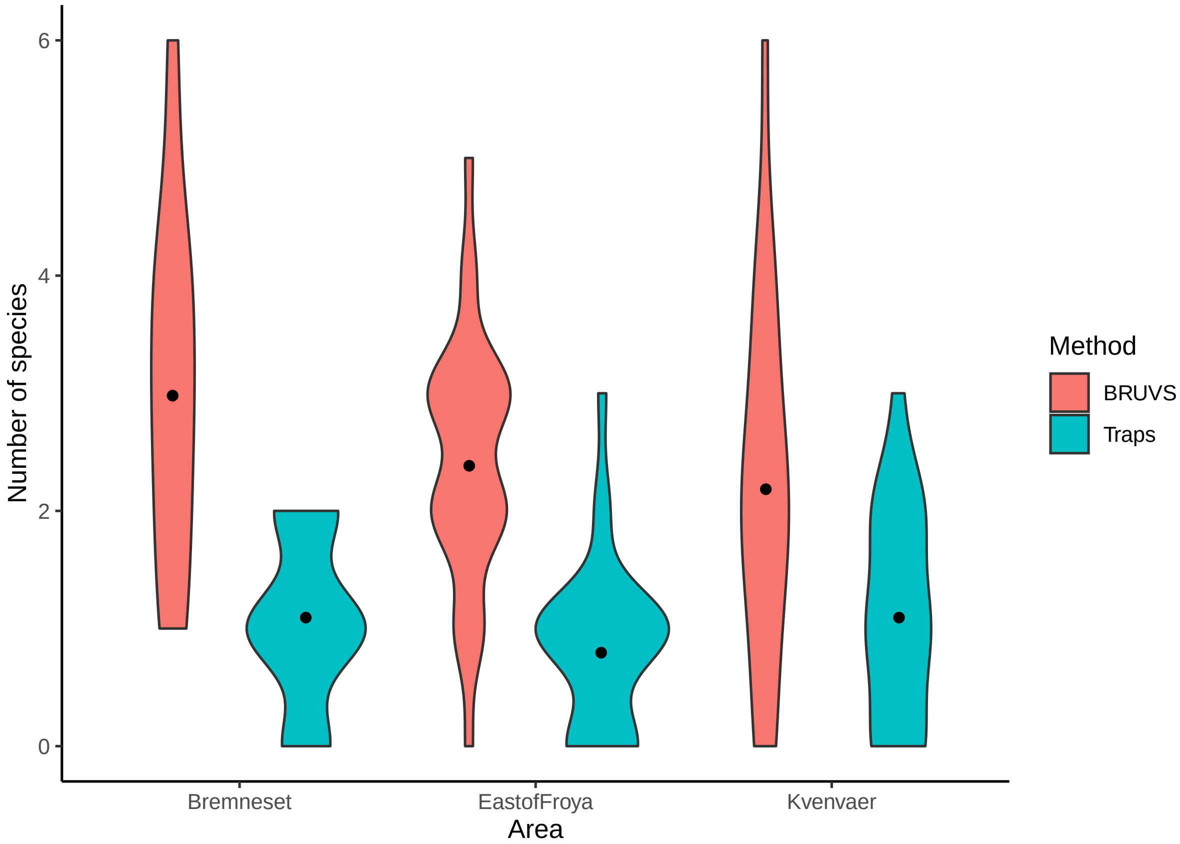

Figure 3.8: Distribution of the species occurrence compared between the stereo-BRUVs and traps for the common stations: Bremneset, East of Frøya and Kvenvær. Mean is illustrated with black points.

3.3 Atlantic Cod Length in Stereo-BRUVs and Traps

In this section, length measurements on the Atlantic cod from stereo-BRUVs and traps were used to compare the methods in regards to differences in length measured and length-frequencies.

As Atlantic cod was the most abundant fish species in both traps and stereo-BRUVs, and one of the focus species in the project, it was natural to focus on this species considering the amount of collected data.

Figure 3.9 shows the frequency distribution of Atlantic cod length in traps (A) and stereo-BRUVs (B). The frequency distribution in traps was close to a fitted normal distribution, while there seemed to be a ”gap” in the 70-90 cm range for BRUVs. If all the stations for BRUVs and traps were included in the distribution, not only the stations in common, then the two methods would be closer to a fitted normal distribution (Appendix C).

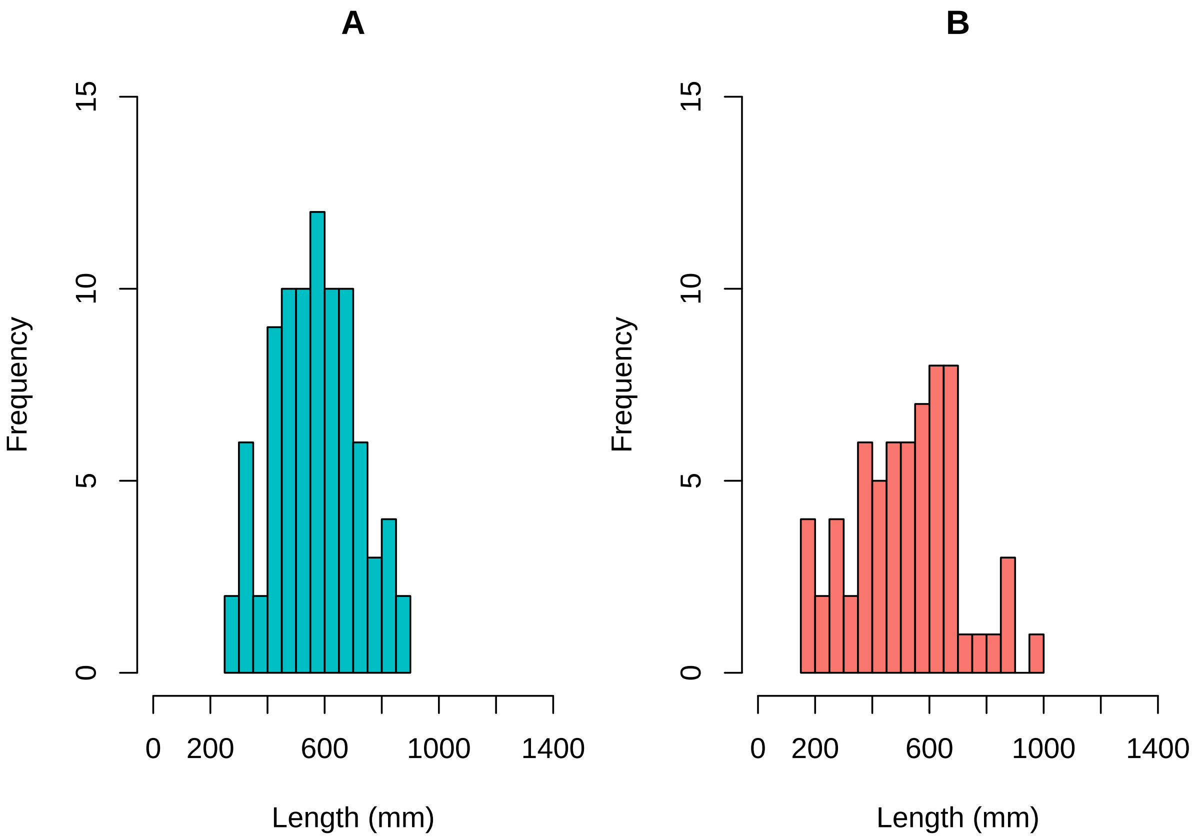

Figure 3.9: Frequency distribution of Atlantic cod total length in common stations between traps (A) and stereo-BRUVs (B).

Length measurements were also compared in the study sites between the two methods. Figure 3.10 present length measurements of Atlantic cod in Bremneset, East of Frøya, and Kvenvær. When looking at the data from each area, the length of the cod in the two methods might seem similar, while a statistical analysis with ANOVA shows a significant difference between the mean length of the two methods, when all the length data for the areas are combined ($p<0.05$, see Table 3.3). Table 3.3 shows a 5 cm higher mean length for cod in the traps, compared to the stereo-BRUVs for the three areas together.

Table 3.3: Estimated mean length for Atlantic cod ± SE, in the stereo-BRUVs and traps. Significance expressed as bold.

Method	Mean length (mm)
BRUVs	515.60 ± 20.22
Traps	**569.10 ± 27.00**

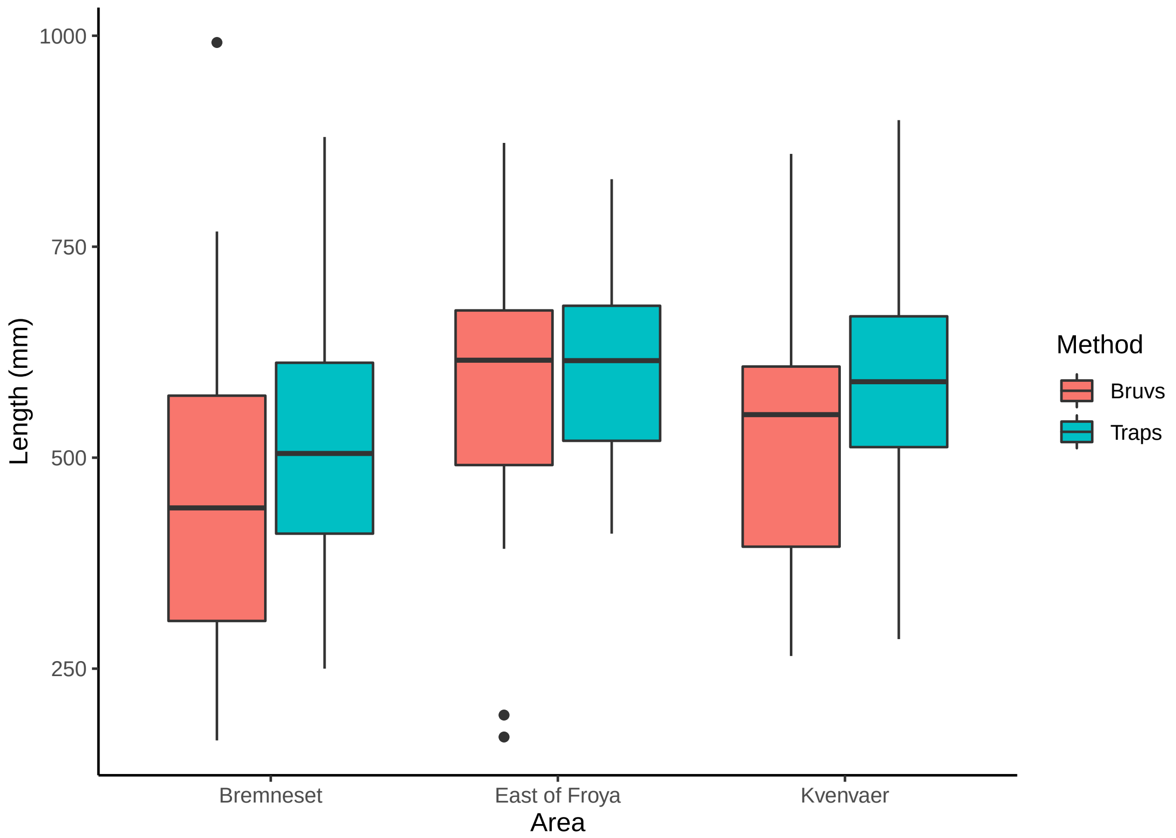

Figure 3.10: Length distribution of the Atlantic cod for the stereo-BRUVs and traps in the common study sites: Bremneset, East of Frøya, and Kvenvær. Each box has a interquartile range with a median of the sampling method as a black line inside the box. Outliers are symbolised as black points.

3.4 Observing Species Traits with Stereo-BRUVs

Results in this section are not exclusively based on stations the stereo-BRUVs and the traps had in common, but also a few selected observations from the stereo-BRUVs that were of interest.

The Spiny dogfish (*Squalus acanthias*) was observed by the stereo-BRUVs (Figure 3.11) at two stations in the area of Mausund. This result is included because the Spiny dogfish is a species on the Norwegian Red List for species and therefore may be of interest for the project "Active Management of Marine Resources".

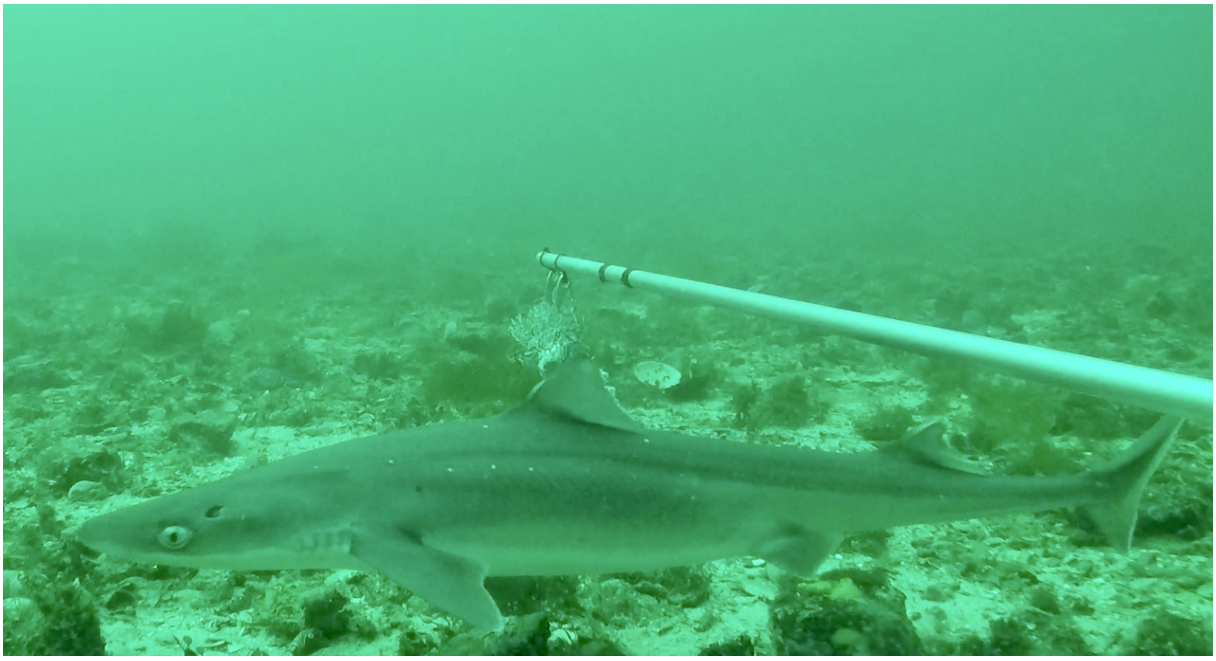

Figure 3.11: Spiny dogfish (*Squalus acanthias*), registered on the Norwegian Red List for Species.

When analysing videos from stereo-BRUVs, it was possible to study the different species traits. Swimming behavior varied between the different species and also how they went for the bait if they were interested in the herring. The cod, if interested in the bait, tended to be more aggressive in snatching the herring compared to other species. The Atlantic pollock (*Pollachius pollachius*) would lurk more around the bait. In the natural habitat around the stereo-BRUVs it was also observed species such as the Atlantic wolffish feeding on a marine gastropod (Figure 3.12).

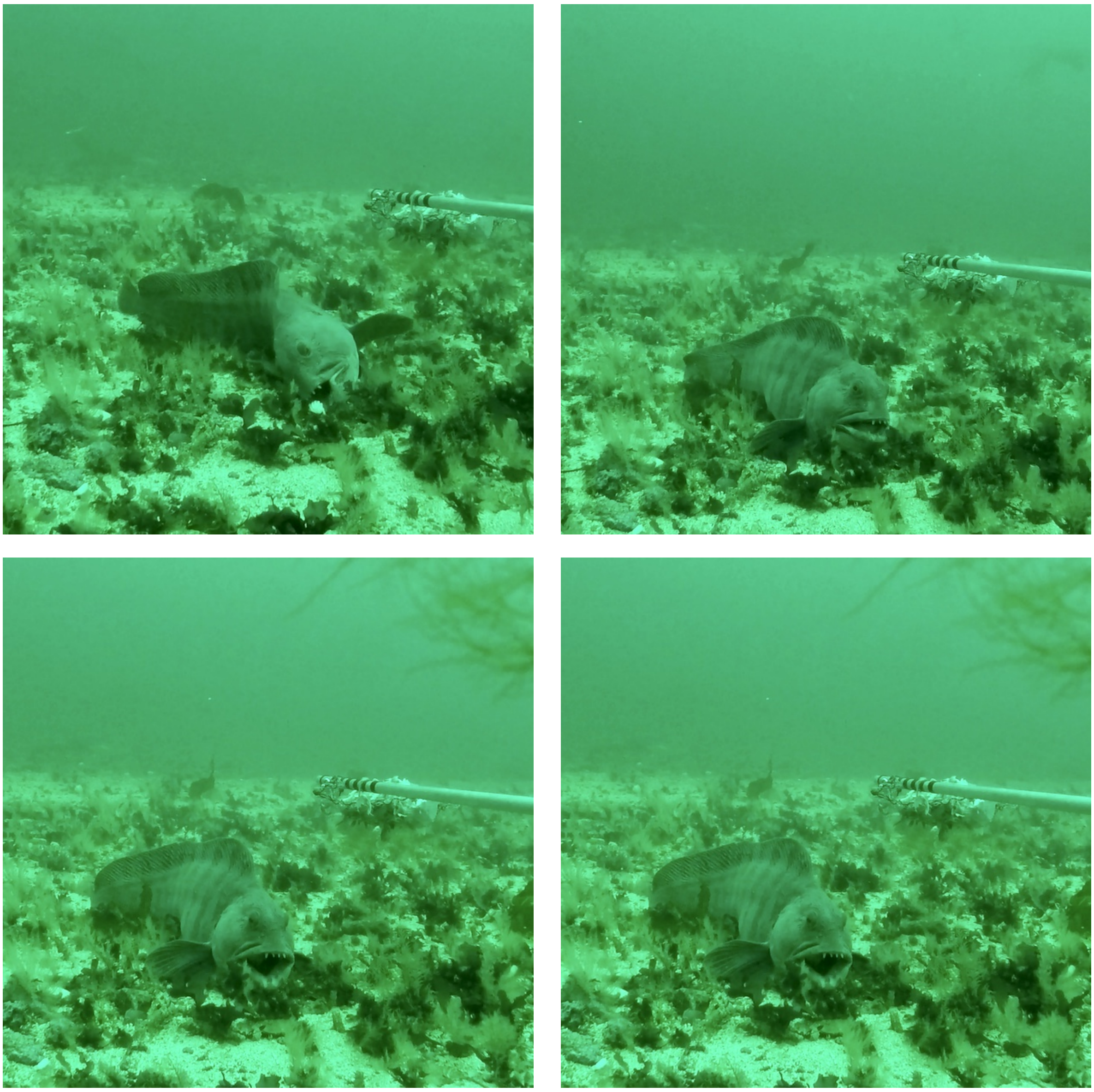

Figure 3.12: Picture series of feeding Atlantic wolffish (*Anarhicas lupus*) picking up a marine gastropod, crunches it, and spits out the shell afterwards.

4
Discussion

When comparing species abundance in the stereo-BRUVs with traps, similarities occurred in the common study sites. The stereo-BRUVs observed in total 19 species with an average of 5.00 individuals for each station, while the traps in total captured 15 species with 1.72 individuals per station. The fish traps identified all individuals to species, unlike the analysis from stereo-BRUVs that showed some limitations related to species identification.

In general, the stereo-BRUVs observe more species and species individuals than the fish traps captured, e.g. at 11 stations, the stereo-BRUVs observed three species, while the fish traps captured one species (Figure 3.7).

The fish traps had a higher frequency in length measurements because not all cod from the BRUVs were measured in EventMeasure. The stereo-BRUVs measured both smaller and larger individuals than the fish traps, but results show few cod above 70 cm in the BRUVs (Figure 3.9). The reason for this might be that numerous smaller cod often occurs together in the field of view as MaxN, while the larger fish more often occurs as fewer individuals or alone, resulting in measurements of the smaller fishes.

The stereo-BRUVs gave opportunities for observation of the stations, and during analysis, a red-listed species, the Spiny dogfish, and several behaviour traits for species were observed (Figure 3.11).

4.1 Fish Assemblage in Stereo-BRUVs and Traps

Both methods sampled the Atlantic cod as the most abundant species, indicating that the stereo-BRUVs and traps do have similarities as sampling tools. Other than the Atlantic cod, the stereo-BRUVs and the traps showed different compositions in the remaining species, indicating that the two methods had different species selectivity, which has been previously described by Harvey et al. (2012). Out of the 19 species observed in the stereo-BRUVs and 15 species captured in the traps, 12 species were in common (Figure 3.6).

Another interesting finding in the species compositions was that no species of wrasse were captured in the traps. Three species of wrasse were observed on the stereo-BRUVs, in addition to a group of unknown wrasse, not identified to species (Figure 3.3). One of the reasons for the non-appearance of wrasse in the traps is probably due to the mesh width on the traps.

Estimated mean abundance of the *Atlantic pollock* in traps was 0.06 ± 0.03 compared with 0.55 ± 0.09 in the stereo-BRUVs. Species from the *Pollachius* genus have previously shown to have a pelagic swimming behavior, swimming above the bottom (Videler and Hess, 1984), making the species less catchable for the traps.

The cryptic presence of the Lemon Sole may explain the lack of observations of this species by the stereo-BRUVs, while it was captured by the fish traps at several stations. The Lemon sole is known as "The Chameleon of the Sea" because it can be very hard to notice on the seabed as it can adapt its morphology to the surroundings (Moen and Svensen, 2014). Previous studies show that cryptic species occur less on the stereo-BRUVs, compared to other sampling methods such as underwater visual sensus (Holmes et al., 2013) and diver operated transects (Watson et al., 2005), and as in this case, with the traps.

When analysing videos from the stereo-BRUVs, 70 % of the observed fish was identified to species. Under several circumstances, it was not possible to identify individuals to more than family. The individuals placed in the groups of unknown Gadidae, unknown flounder, and unknown wrasse were not identified further to species. The group with unknown flounder had a quite high mean abundance of 0.49, as the identification of flounders requires either a trained eye or the opportunity to look more closely at the individual. For instance, can the European flounder occur very similar to the Common dab or the European plaice, with only the shape of the sideline or bone knots along the sideline separating these species (Pethon, 2005).

The two methods sampled in total 524 fish for the common study sites, and the traps captured 25 % of the sampled fish. When assessing the fish species abundance, the stereo-BRUVs mostly observed more individuals of each species compared to the traps, but for three of the species in common, the Thornback skate (*Raja clavata*), European plaice (*Pleuronectes platessa*), and the Common dab, the traps proved to be the best method.

Considering that the stereo-BRUVs was deployed for one hour, and the traps deployed close to 24 hours, deployment time shows that stereo-BRUVs has potential to gather more individuals, despite the shorter deployment time than for the traps (Harvey et al., 2012). Stereo-BRUVs might be a well functioning tool to monitor fish species abundance without intervention from fisheries and methods that could work destructive to the fish habitat or increase the risk for mortality (Letessier et al., 2015; Langlois et al., 2010, 2012a; Watson et al., 2010).

4.2 The Use of Stereo-BRUVs and Traps

4.2.1 Efficiency of the Stereo-BRUVs and the Traps

When comparing the use of the stereo-BRUVs with traps, it is important to look at the efficiency and precision of the methods during sampling. During the fieldwork at Frøya and Hitra, the traps sampled 81 stations while the stereo-BRUVs sampled 146 stations at the same number of days. The stereo-BRUVs can be used more opportunistic and it is more predictable that the sampling will be successful, compared to the traps, since the crew does only have to consider the weather for the next hour instead of 24 hours for the traps.

4.2.2 Number of Species Observed in the Two Methods

The stereo-BRUVs observed a higher mean amount of species than the fish traps, which is consistent with previous studies (Harvey et al., 2012; Newman et al., 2011). Results indicate that the BRUVs sample species more efficiently because it has the capability to detect a higher number of species than the traps. At 11 stations the stereo-BRUVS observed three species, while the traps at the same stations captured one species (Figure 3.7). For assessment of fish communities, the stereo-BRUVs would therefore be the better method to use. As long as the trap survey is focusing on one or two species, this method could work fine, especially if the gear is selective of the species of interest.

When looking specifically at the three study sites, the stereo-BRUVs observes more species than the traps at all the sites (Figure 3.8). Few studies like this presented herein is conducted in temperate waters, however, studies with stereo-BRUVs in tropical waters also showed higher number of species on the stereo-BRUVs compared to the traps (Newman et al., 2011; Harvey et al., 2012).

4.3 Length of the Atlantic Cod in the Stereo-BRUVs and Traps

Stereo-BRUVs showed a lower frequency in total length of the Atlantic cod. Of the 102 counted cod on the stereo-BRUVs, only 66 individuals were measured. However, the fish traps caught 87 Atlantic cod and were able to take length measurements of all individuals (Figure 3.9). The reasons for the lower numbers in length frequencies than counting of cod in EventMeasure is probably due to several reasons. One reason could be because of the station, if the stereo-BRUVs lands on the seabed surrounded by kelp, length measurements could be difficult to perform as the kelp can block parts of the fish or camera.

Another reason for limited length measurements, when analysing in EventMeasure, could be that the measurement takes place within the field of view of the camera with the most counted individuals for a species (MaxN). This was to prevent duplicate length measurements of the individuals. A good length measurement was made when the fish was as straight as possible so that the measurement could be taken from the nose tip to tail fin with the least possible curving on the fish (Harvey et al., 2010). In a field of view with a MaxN of six Atlantic cod, the chance of taking taking measurements of all the individuals, was small.

Also, when length measurements were limited to field of view with MaxN, biases could occur for fish swimming in and out of the field of view, hence not not all individuals were measured. Previous studies show that length measurements taken early in the analysis often consists of numerous smaller fish than the individuals measured later in the analysis (Cappo et al., 2009). These studies could be consistent with the findings in this study, where few individuals of the Atlantic cod had lengths above 70 cm. This might indicate that the larger fish that more often occurred as fewer individuals in the image were potentially excluded from being measured due to the observation procedures in EventMeasure (Figure 3.9).

Length measurements of the Atlantic cod in the stereo-BRUVs showed a wider range than the traps (Figure 3.9), where the BRUVs presents both cod under 25 cm and above 100 cm. The traps may be selective on the size due to the mesh size or the size of the trap itself. Previous studies that compared fish lengths shows both smaller, larger and equal sized fish on the stereo-BRUVs compared to the traditional fishing gear (Langlois et al., 2012a; Harvey et al., 2012). Smaller fish can be absent in the traps because these individuals can be eaten by larger fish in the traps or escape through the mesh. The Atlantic cod has, under previous studies, shown traits to cannibalism when density increases (Uzars, 2000), such as can happen in traps. Smaller individuals can also notice larger fish in the trap and avoid to swim into the trap (Newman et al., 2011). Considering that the traps had a soaking time for about 24 hours, the smaller fish could both have escaped or been eaten in that time, excluding the smallest individuals to be observed when the traps are hauled.

The mean length of the Atlantic cod was similar for the two methods in the three study sites (Figure 3.10). The similar mean length measurements for the BRUVs and traps, indicates that both methods works well to estimate average length of the species. Statistical analysis with ANOVA shows a significant difference between the stereo-BRUVs and traps when assessing all the study sites together. However the ANOVA would expectantly be more precise if both methods had been closer to a fitted normal distribution.

4.4 Observing Species and Species Behavior with the Stereo-BRUVs

4.4.1 Monitoring the Nature Types

The stereo-BRUVs has minimal impact on the environment and the habitat, and surveillance with video is therefore a suitable method when gathering data in areas before and after implementing MPAs. One aim of the project "Active Management of Marine Resources" is to get an overview of the different nature types at Frøya and Hitra. User surveys and mapping by NGU have been gathered information to locate these areas that contained either coral reefs, larger amounts of kelp or eelgrass meadows (Kleiven et al., 2019a). Using stereo-BRUVs as a sampling method, these different nature type data could be monitored during the years of the project.

4.4.2 Red Listed Species

Even though no fish individuals were harmed during sampling with the traps, using stereo-BRUVs would ensure that no fish is negatively affected by the method. When analysing videos from stereo-BRUVs from the study site Mausund (not in common with the traps), Spiny dogfish was observed at two stations. The Spiny dogfish is in the Norwegian Red List for Species with a status described as "severely threatened" (Artsdatabanken, 2015). It is a great advantage of using stereo-BRUVs when observing red-listed species, being able to take length measurements without handling the specimen and risk exposing the fish to stress or unnecessary harm (Letessier et al., 2015).

4.4.3 Observing Species Behavior with the Stereo-BRUVs

The stereo-BRUVs also has an opportunity to monitor species behaviour in situ and to learn new things related to feeding traits and preferences in diet. During analyses in EventMeasure, the Atlantic wolffish was observed feeding on a marine gastropod. Figure 3.12 shows a picture series of the Atlantic wolffish that first pics up the gastropod before the next two pictures show how the the fish crushes and eats the snail until it spits out the shell pieces in the last picture.

The behaviour that the Atlantic cod has towards the bait was also observed in EventMeasure. During several analyses, the Atlantic cod first shows attraction towards the bait by swimming close to the bait bag, maybe inspecting the bait by smelling it. After approaching the bait, the Atlantic cod was several times observed to snatch for the bait, trying to get the herring in the bait bag. This observation was interesting because other species like the Atlantic pollock or the Saithe (*Pollachius virens*), did not take the same drastic approach to the bait. The individuals who appeared in front of the bait, but did not try to take the herring, can belong in the station and make a natural occurrence. These individuals who appeared can also be attracted but lost interest to the bait since they have another diet preference. When the stereo-BRUVs observe these individuals who do not seem that attracted to the bait, it can indicate that the method enables to capture the biological diversity.

4.5 Potential Sources of Error in EventMeasure

4.5.1 Distance Limit for Observations

Some previous studies who have used EventMeasure when analysing stereo-BRUVs have had an upper distance limit from the cameras to the observed individual (Coghlan et al., 2017; Langlois et al., 2010). The limit standardises the sampling area and makes the different analyses more comparable (Coghlan et al., 2017). During this study, no distance limit was set, and all the observations that was possible to identify were registered. Coghlan et al. (2017) suggest an upper limit of 8 meters to have more comparable sampling stations and to have more accurate length measurements. Given that the distance limit could give a more standardised sampling, the accuracy of analysis in EventMeasure would be higher. Based on the study presented herein, it is reason to suggest a distance limit of 10 meters.

4.5.2 Length Measurements Under Challenging Sites

Conducting length measurements were not always possible in EventMeasure. Counting individuals was done using only the left picture frame, while length measurements are dependent on a clear sight in both the left and right picture frames (Harvey et al., 2010). When the stereo-BRUVs land in the kelp forest, as it did several times in this study, the chance to observe both head and tail in both cameras was significantly reduced, as the chance for kelp between the fish and the camera was relatively high.

Another challenging aspect when it came to conducting length measurements in Event-Measure was to take measurements of the smaller species. Several individuals of the species Two-spotted goby was counted, but newer measured. The two-spotted goby is a small species, usually not more than 6 cm long (Pethon, 2005). This type of small species was mostly observed in just one of the cameras, preventing the possibility for length measurements.

Another challenging aspect in taking length measurements was, as already mentioned, a high MaxN (Harvey et al., 2012). In the occurrence of shoals of greater than ten individuals, length measurements can be very challenging. Under analysis of shoals, the best solution would be to take length measurements of a selection of individuals from the shoal.

4.5.3 MaxN as Mean Abundance

MaxN has been described as the maximum number of individuals for a given species counted within the field of view at the same time. Only the maximum number of individuals of a species was counted to avoid duplicate countings on the same individual (Harvey et al., 2012, 2013a). The fact is that fish will swim in and out of the field of view, one small fish that swims out of the field of view, can be replaced with one bigger fish, and the MaxN will not change even though these are two different individuals (Harvey et al., 2012; Cappo et al., 2009).

4.6 Study Design and Challenges

4.6.1 Species Identification

Identification of species based exclusively on morphological pictures from video can be challenging when it comes to certain species groups. The high proportion of unknown Gadidae and unknown flounder clearly shows the limitations in morphological identification. During analysis in EventMeasure, identification of flounders turned out to be the most challenging group when it came to fish. Flounders can have very similar morphology and still be of different species as they adapt their appearance to different looking environments, e.g. the Lemon sole who can occur as a cryptic fish when fully adapted to its habitat (Moen and Svensen, 2014; Pethon, 2005). During the weeks of analysis in EventMeasure, there was a learning process in identifying fish to species. With gradually more taxonomic experience, the numbers of unknown Gadidae, unknown flounder and unknown wrasse would expectantly decrease. If the videos with unknown individuals were analysed one more time after the analysis of the total 146 stations, some could maybe be identified to species.

The challenges regarding species identification on fish also apply to invertebrates, only that this group of species is usually even smaller than fish and therefore even more challenging to notice on video. Invertebrates often have small movements on the seabed, making them difficult to detect. Different species can also be similar if they are not very close to the camera, and in some cases a loupe would be necessary to identify the species. These various issues, when it comes to species identification of invertebrates, was the main reason for not including them in this study. During the fieldwork and sampling with the traps, counting of small invertebrates was not a priority, making the findings of these species groups challenging to compare with the stereo-BRUVs. However, the traps and BRUVs registered catch and observations of species of crab and lobster. The registered number of these individuals were similar, and could have been included in this study. However the amount of time that was left in the study, made it more suitable to focus on the fish assemblages.

4.6.2 The Use of Bait

As briefly mentioned earlier in the discussion, the effect of using bait in this study is important to address. It is difficult to determine the exact disturbance the bait plume has on the natural species abundance for the station. Still, it is fair to expect an increase in the appearance of carnivores (Harvey et al., 2007). Previous studies have found that maximum deployment time should be limited to about 15 minutes to avoid attraction of fish from areas further away from the study site (Coghlan et al., 2017). As this study is conducted in more shallow and temperate waters, it may be optimistic with only 15 minutes of deployment time, and the current sampling time of one hour seems to be more suitable. If this study did not use bait at all, the video stations could be insufficient as well, when fish behind the stereo-BRUVs or just few meters away, would not be attracted to the front of the camera.

If the study was more natural (without bait), one opportunity after the development of equipment and software could be to utilize the possibilities introduced by the field of machine learning. With machine learning, thousands of hours of video in EventMeasure, or even directly from the BRUVs, could be analysed at a rapid speed. If the battery time and equipment could develop in a way that allowed much longer deployment times than one hour and analysis was extended to have automatic detection of fish in the picture, unbaited video-rigs could be a relevant alternative to the BRUVs.

4.6.3 Species Abundance Differences in Stereo-BRUVs and Traps

If the two methods had been able to sample a more similar abundance of each species with higher selections, several statistical analysis would have been possible for more species than just the Atlantic cod. However, the fact that the stereo-BRUVs and traps sampled a similar abundance of the Atlantic cod was suitable for the "Active Management of Marine Resources" project, as the Atlantic cod was one of the key species.

4.7 Impact of the Findings

Considering both the need and expectations to implement MPAs in Norway, all gathering of data and information about the marine environment is important. The need for more knowledge about marine ecosystems has never been greater as the oceans of the world face plastic pollution, climate change, unsustainable fishing and issues related to tourism, oil and gas, and the shipping industry (Soulé et al., 2005; WWF, 2018).

The coastal areas of Frøya and Hitra may have more stakeholders than the usual coastal municipalities in Norway. Aquaculture, fisheries, tourism, education, and the local public, all have interests that they hope is taken into consideration when implementing an MPA. "Active Management of Marine Resources" intention of implementing MPAs in the coastal zones of Frøya and Hitra, is for the stakeholders to identify the most suitable area with the least number of conflicts at the same time as protection of key species in the project is achieved (Kleiven et al., 2019a). With stereo-BRUVs, the essential values along the coast of Frøya and Hitra can be displayed to the stakeholders and the importance of MPAs can be better understood.

Findings from this study are essential as before-data. They will help to improve and standardise the data collection to evaluate the effects of future MPAs at Hitra and Frøya and other temperate regions.

5 Conclusions and Future Work

5.1 Conclusions

The importance of establishing MPAs have never been higher as the oceans of the world face severe anthropogenic impacts and require mitigation measures. Findings from this study with stereo-BRUVs and traps will contribute with essential data for the implementation of MPAs along the coast of Frøya and Hitra.

Sampling with the stereo-BRUVs showed a higher mean number of species per deployment of 2.60 ± 0.60, compared to the traps that had 1.00 ± 0.18 number of species per deployment. There were several differences between the two methods in fish assemblages, and the higher species richness in the BRUVs, indicates that the stereo-BRUVs would be a better tool suited for surveillance of fish communities over time. The fish traps seemed to sample cryptic species better than BRUVs, especially the Lemon sole. Fish species identification of observations by the stereo-BRUVs had some limitations, which resulted in groups of "unknown" for flatfish, Gadidae and wrasse.

The stereo-BRUVs was able to sample a greater range of lengths of the Atlantic cod but showed few individuals with lengths above 70 cm compared to the traps. The fact that length measurements were performed in the image with MaxN is suggested to influence the correct mean length and length-frequency at the stations, as biases stemming from fish swimming in and out of the image could be excluded from being measured. It can be argued for that larger cod could more often occur as fewer individuals or alone compared to the smaller fish.

5.2 Recommendations for Future Work

In regards to the setup for the stereo-BRUVs, looking into the possibilities of using artificial intelligence, such as machine learning, for automatic video analysis, should be considered. This could increase the possibilities for analysing a larger amount of data, faster and estimate the total amount of individuals for a given species.

To standardise the sampling station and the data collection, a simple adjustment to the current study design would be to implement an upper distance limit between the camera and the specimen. An appropriate choice of distance limit could be 10 meters, based on the fact that EventMeasure enables reliable length measurements up to 10 meters away from the camera.

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A Appendix

```
anova(lm(Number~Method, data = LengthsBT))
Analysis of Variance Table

Response: Number
           Df  Sum Sq Mean Sq F value  Pr(>F)
Method      1  105901  105901  3.9846 0.04774 *
Residuals 149 3960083   26578
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> summary(lm(Number~Method, data = LengthsBT))

Call:
lm(formula = Number ~ Method, data = LengthsBT)

Residuals:
    Min      1Q  Median      3Q     Max
-350.58 -109.58    1.42  110.93  476.42

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   515.58      20.22  25.497   <2e-16 ***
MethodTraps    53.49      26.79   1.996   0.0477 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 163 on 149 degrees of freedom
Multiple R-squared:  0.02605,	Adjusted R-squared:  0.01951
F-statistic: 3.985 on 1 and 149 DF,  p-value: 0.04774
```

B
Appendix

Table B.1: All observed/captured species by stereo-BRUVs and traps at Frøya and Hitra 2019.

	Relative Abundance	
Genus species	Traps	BRUVs
Anarhichas lupus	0.01	0.04
Cancer pagurus	1.29	0.05
Carcinus maenas	0.05	-
Gadus morhua	1.10	1.31
Galeus melastomus	0.01	-
Hippoglossus hippoglossus	0.01	0.09
Homarus gammarus	0.05	0.01
Hyas coarctatus	0.03	-
Limanda limanda	0.17	0.06
Lithodes maja	0.08	0.01
Melanogrammus aeglefinus	0.01	0.22
Merlangius merlangus	0.01	0.01
Microstomus kitt	0.04	-
Molva molva	0.08	0.21
Pleuronectes platessa	0.08	0.03
Pollachius pollachius	0.06	0.54
Pollachius virens	0.03	0.12
Raja clavata	0.05	0.03
Sebastes viviparus	0.01	-

Trisopterus minutus	0.03	0.32
Asterias rubens	-	0.04
Callionymus lyra	-	0.01
Ctenolabrus rupestris	-	0.08
Echinus esculentus	-	0.08
Eutrigla gurnardus	-	0.05
Gobiusculus flavescens	-	0.15
Labrus bergylta	-	0.01
Labrus mixtus	-	0.18
Marthasterias glacialis	-	0.01
Nephrops norvegicus	-	0.01
Pagurus bernhardus	-	0.35
Pagurus prideaux	-	0.03
Platichthys flesus	-	0.01
Uknown Flounder	-	0.49
Uknown Gadidae	-	1.01
Uknown Wrasse	-	0.05

C
Appendix

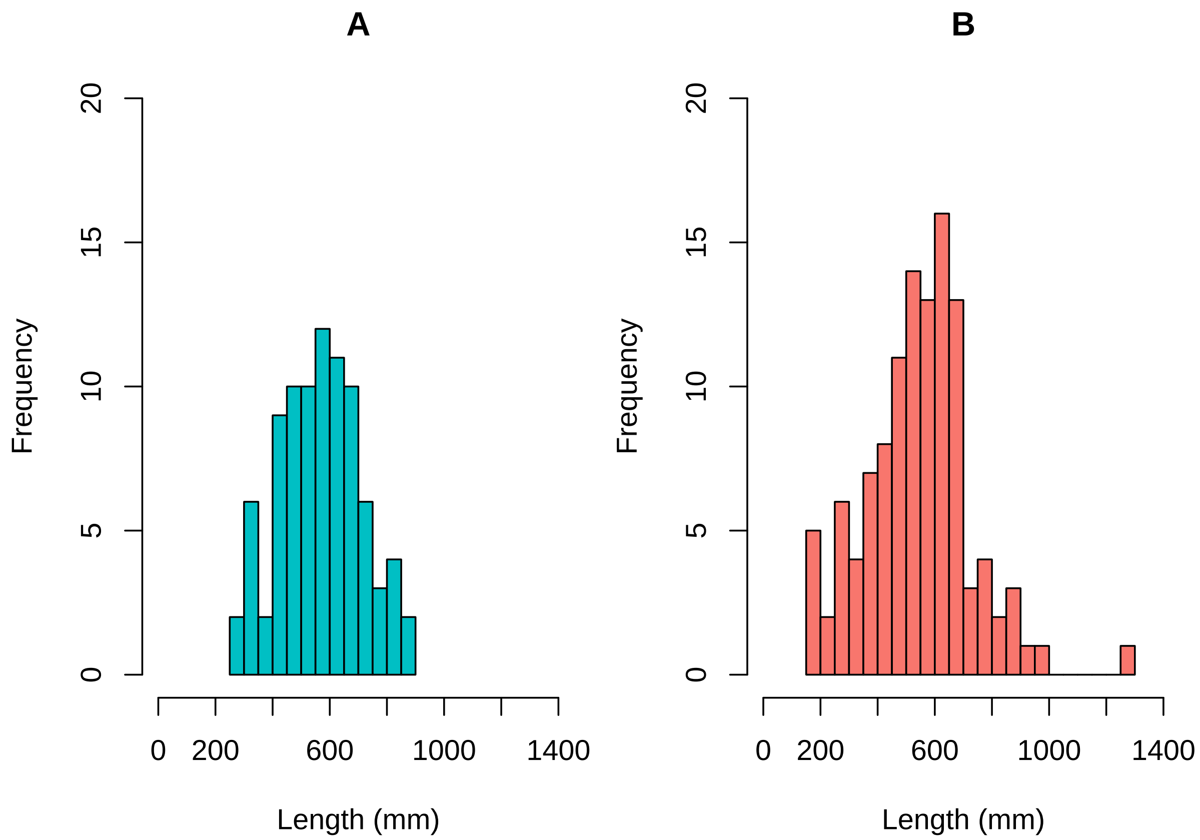

Figure C.1: Frequency distribution of Atlantic cod length in **A** traps and **B** stereo-BRUVS. All stations from the traps and the stereo-BRUVS are included.

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