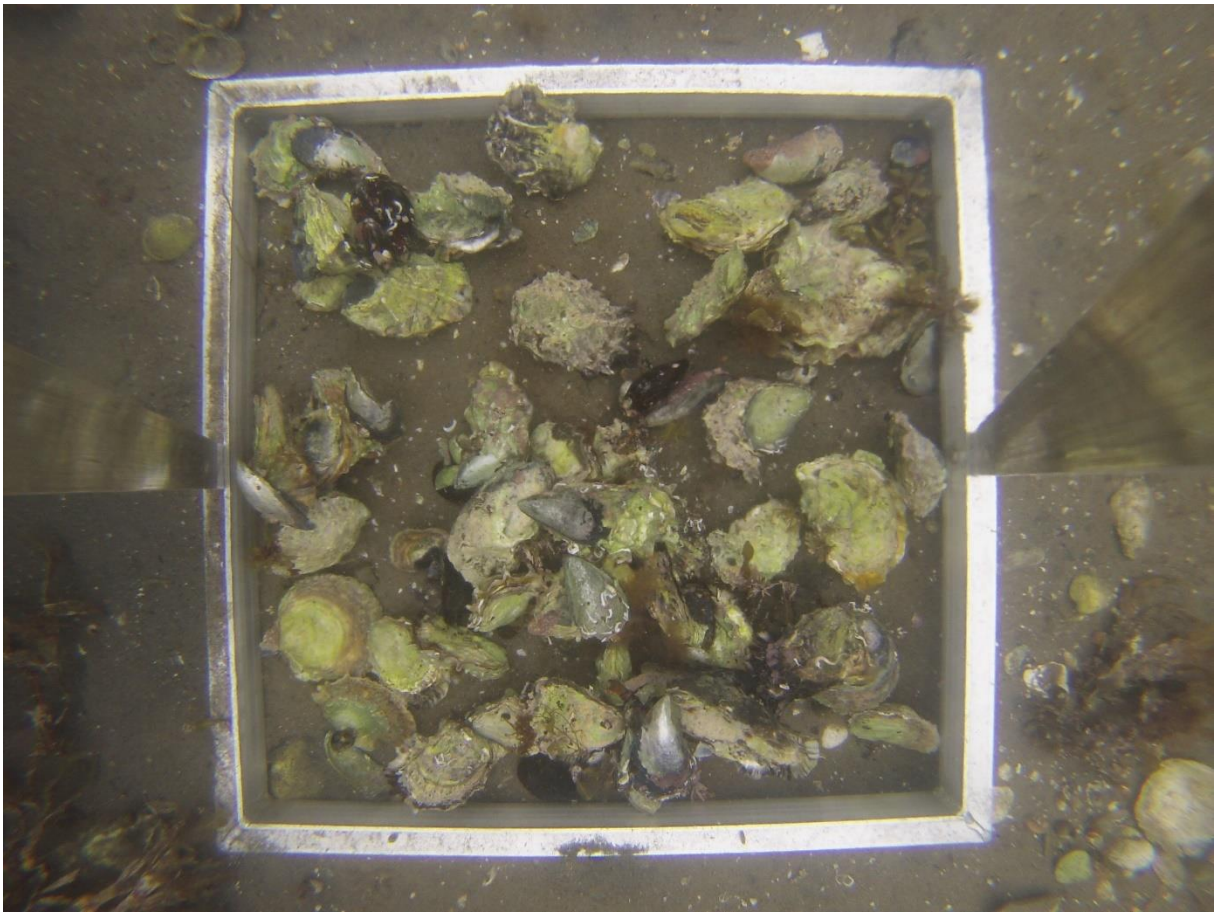
The use of photo and video as surveying tools on sessile organisms in shallow soft-bottom habitats

- Photoframe and videosleigh method



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Abstract

The Institute of Marine Research (IMR) wants to start a systematic survey of shallow, soft-bottom habitats. The IMR wants to implement two new methods using photo and video, the photoframe and the videosleigh method. Where analyzing of an investigation area is done by photo or video instead of in situ. The target groups were Pacific oyster, European flat oyster, Blue mussel and macroalgae. Both methods were tested to see if number of individual Pacific oyster, European flat oyster and Blue mussel could be estimated by use of photo and video. It was also seen if these species could be categorized based on vital status, and if percentage of macroalgae could be estimated. The photoframe method were also tested for measuring of size, both length and width, of Pacific oyster, European flat oyster and Blue mussel. This was tested by comparing data registered by photo or video against in situ registrations done by skin-divers in the field.

The biology of the bivalve species affected the results. This was apparent through underestimation caused by individuals growing onto each other and misclassification of species, especially for Pacific oyster and European flat oyster. Orientation of Blue mussel affected the precision and accuracy of measuring, and in some cases made measuring not possible. Estimating number of individuals was possible when using both methods. Only videosleigh method seemed suitable for categorization of bivalve species based on vital status and estimating percentage coverage of macroalgae. Estimation of size by photo was possible for Pacific oyster and European flat oyster. Determining cohorts by analysis of photo was not possible for either species. Both methods were time-effective regarding analyzing, the analyzation place was moved and both methods were therefore cost-effective. Both methods may be used as a surveying tool in the future, where each method has its strengths and weaknesses. For a systematic survey on soft-bottom habitats, a combination of the methods as they are now may be advantageous.

Contents

Foreword

Writing this master thesis has been a journey. A journey including a new family member. I want to give a special thanks to my partner Håkon Dale for support, help and patience, making it possible for me to write this thesis.

I would like to thank my original supervisor Torjan Bodvin who passed away during the writing of this master thesis. He introduced me to the Pacific oyster and got me interested in this invasive species. I would also give a special thanks to Anders Jelmert at the IMR, for taking the role as my supervisor and help during the fieldwork. Thanks to my supervisor at UiB, Thorolf Magnesen, for following and guiding me this entire process. I would also like to thank my mother, Grete Henriksen, for valuable feedback. Thank you, you all have made this master thesis possible.

1. Introduction

The Institute of Marine Research (IMR) has conducted a systematic survey of pelagic habitats along the southern coast of Norway since 1919. This dataset, obtained during almost a 100 years, is an extremely valuable dataset on changes in the coastal zone (Bodvin, 2016). There is no such systematic survey of immobile species on shallow, soft-bottom habitats today, which means that a huge part of the coastal zone is missing. A similar dataset from these habitats can reveal long term patterns of species distribution and quantity. When surveying both pelagic and benthic habitats at the same time and in the same areas, a long-term dataset may detect how the species and habitats vary together. In the future, surveying of shallow, soft-bottom habitats is going to be a part of the yearly survey which up to now only has been focusing on the pelagic habitat.

An important reason why surveying of shallow, soft-bottom habitats is highly relevant today, is due to alien species, like the Pacific oyster, *Crassostrea gigas* (Thunberg, 1793). The Pacific oyster has newly been renamed to *Magallana gigas* (Thunberg, 1793) in the World Register of Marine Species (WoRMS). This name change is disputed in the scientific community, and an article by 27 scientist argues that the name should be changed back (Bayne et al., 2017). The old name, *Crassostrea gigas*, is therefore accepted as an alternative representation in WoRMS. The Norwegian Artsdatabanken awaits the situation and keeps the official name for the Pacific oyster as *Crassostrea gigas*. The Pacific oyster will be called *Crassostrea gigas* in this master thesis.

Wild living Pacific oysters were first observed in Norway in 2003 and there is now about 200 localities of Pacific oysters in Norwegian waters (Bodvin et al., 2014b). How the Pacific oyster will affect the native fauna is unknown and will be an important aim of future systematic surveys. There have also been several reports regarding the absence of Blue Mussels, *Mytilus edulis* L., along the southern coast, but the reason is unknown (Andersen et al., 2017). A systematic survey could help follow the development of the Blue mussel and may find factors affecting its distribution.

The method used today for surveying of immobile species on shallow, soft-bottom habitats is the standardized quadrant method (Strand et al., 2012), with manual counting and measurements of each individual in the field. This is time consuming and in areas deeper than 1 m, this is also a highly costly method (Strand et al., 2012). The method requires divers, specialized equipment and qualified personnel. IMR wants to implement new methods that can

be more versatile, spending less man-hours in the field, and more cost-effective. For new systematic surveys of shallow, soft-bottom habitats, IMR want to use two new methods; photoframe and videosleigh. To be able to use these methods, IMR need them to be tested with respect to accuracy and precision of counting and measurements of individuals. The aim of this master thesis will be to answer the questions posed by the IMR; how accurate are these methods and may they be used as surveying tools?

1.1 New methods, photoframe and videosleigh

Both methods are a type of remote surveying, where a camera register target species and analyzes are done later, e.g. in a lab. Since they both uses cameras for registration in the field, there is no need for personnel in the water. There is still need for personnel operating the equipment. Both methods can be used anywhere where the water depth is greater than 0.5 m and when there is enough light for the cameras to take pictures or videos of good quality.

1.1.1 Photoframe method

The photoframe method include a frame with a camera attached, which can be lowered into the water from a boat. The camera then takes pictures when the frame hits the seabed, and these pictures can later be analyzed by appropriate software on a computer. The method is assumed to be suitable for detecting immobile individuals, separating them into different species, measuring length and width to estimate size classes, and facilitate age classification.

Remote photo and subsequent analysis have been used in numerous studies in biology. Photos from satellites has been used in studies to classify areas as mussel beds or seagrass meadows with a great accuracy (Müller et al., 2016). Photos taken by AUVs (autonomous underwater vehicle) have been used to categorize habitat type, and biotic and abiotic elements (Bewley et al., 2015; Šaškov et al., 2015; Waddington et al., 2010). In benthic habitats, mobile decapods have been counted by Aguzzi et al. (2011). They focused on how well automatic analysis from photos was compared to manual analysis from photos. They also compared estimations of bacterial mat coverage. As the literature shows and as Aguzzi et al. (2011) also pointed out, remote sensing has been less commonly used for species identification and individual counting. This master thesis will be important to assess how accurate photo analysis is on individual level, especially on benthic immobile species. Measuring of size from images have been done several times, mainly on fish species (Man et al., 2016; Shafry et al., 2011; White et al., 2006). For the study by White et al. (2006), measuring was done for seven different fish species with a great precision and accuracy

The hypotheses in the photoframe experiment are;

H_1: There is a difference between estimating numbers of individuals by photo and in situ. With corresponding H_0: There is no difference between estimating numbers of individuals by photo and in situ.

H_2: There is a difference in estimating individual size (length and width) by photo and in situ. With corresponding H_0: There is no difference in estimating individual size (length and width) by photo and by in situ.

H_3: There is a difference in classification of individuals as dead or alive by photo and in situ. With corresponding H_0: There is no difference in classification of individuals as dead or alive by photo and in situ.

H_4: There is a difference in estimating percentage coverage of macroalgae by photo and in situ. With corresponding H_0: There is no difference in estimating percentage coverage of macroalgae by photo and in situ.

1.1.2 Videosleigh method

The videosleigh is lowered down into the water from a boat to a depth below the lowest anticipated depth for the target species and dragged by a person towards land while filming. The method was assumed to be suitable for detecting immobile individuals. And that by later analysis of the video, the various species and vital status (live/dead) could be determined.

Towed video and subsequent analysis have been used in numerous studies in biology. Remote surveying with use of video has been used to assess coastal changes with respect to morphology (Silva et al., 2014) and mapping of common eelgrass (*Zostera marina*) beds (Lefebvre et al., 2009). Towed video has been validated with respect to Queen conch (*Lobatus gigas*), which is a slow, mobile species. Here they found that both video and in situ counts had similar outcome, and it was concluded that towed video was a reliable sampling tool for that purpose (Boman et al., 2016). Towed video has also been used to estimate density of mobile species such as Thornyheads (*Sebastolobus* ssp.) (Lauth et al., 2004) and the Australasian snapper (*Pagrus auratus*) (Morrison et al., 2006). Towed video has also been tested in Sweden and used for surveillance purposes there, with a focus on the European flat oyster, *Ostrea edulis* L., 1758, and classification of habitat (Lindegarth et al., 2014; Loo et al., 2014; Thorngren et al., 2017). The latest validation of this method regarding the European flat oysters were done in 2017 and found that there was a strong correlation between registration in the field and from video. Based on this, it was assumed that the same results will be achieved here in Norway, and possible also for other bivalve species living in the intertidal and subtidal zone.

The hypotheses in the videosleigh experiment are:

H_5: There is a difference between estimating number of individuals by video and in situ. With corresponding H_0: There is no difference between estimating number of individuals by video and in situ.

H_6: There is a difference in classification of individuals as dead or alive by video and in situ. With corresponding H_0: There is no difference in classification of individuals as dead or alive by video and in situ.

H_7: There is a difference in estimating percentage coverage of macroalgae by video and in situ. With corresponding H_0: There is no difference in estimating percentage coverage of macroalgae by video and in situ.

1.1.3 How to test and validate the two methods

To test these methods, the data from the photoframe and videosleigh were compared to traditional registration/measurements by skin-divers in the field. Testing the hypotheses and assessing differences between the registration methods, may help determine if these methods are suitable for surveillance purposes.

1.2 Target species

Invasion of alien species as Pacific oyster and absence of Blue mussel is a driving force for systematic surveying on soft-bottom habitats. In addition, the European flat oyster is found in similar habitats, and there is a concern about how the Pacific oyster will affect the native European flat oyster (Dolmer et al., 2014). Registration of percentage coverage of macroalgae is of interest as the intertidal zone is often covered with macroalgae. Macroalgae commonly found in the Norwegian coastal zone is Channeled wrack (*Pelvetia canaliculate*), Toothed wrack (*Fucus serratus*), Bladder wrack (*Fucus vesiculous*), Knotted wrack (*Ascophyllum nodosum*) and Spiral wrack (*Fucus spiralis*) (Nervold, 2008). The relative abundance between macroalgae and the Pacific oyster is of interest for long-term surveying. It is not known how the invasive Pacific oyster will affect the native flora and how macroalgae competes with the Pacific oyster for space and affecting its ability to grow.

The target groups were the Pacific oyster, the European Flat oyster, the Blue Mussel and macroalgae in general.

1.2.1 The Pacific oyster, European flat oyster and Blue mussel in Norway

The Pacific oyster is on the Norwegian Black List 2012 (Artsdatabanken, 2017a). The Norwegian Black List is a list of alien species in Norway categorized as having high impact

(HI) or severe impact (SE) on native species. The Pacific oyster is categorized as SE (severe impact) (Gederaas et al., 2012). The European flat oyster is a native species in Norway and is on the Norwegian red list 2015. The Norwegian red list is a list of native species being at risk of extinction within Norway (Henriksen et al., 2015). The European flat oyster is categorized as NT, nearly threatened (Artsdatabanken, 2017c). The Blue mussel is categorized as LC, least concern, and is not a part of the Norwegian red list 2015 (Artsdatabanken, 2017b). The locations where Pacific oyster, European flat oyster, and Blue mussel occurred along the Norwegian coast in 2017 was different (Figure 1.1).

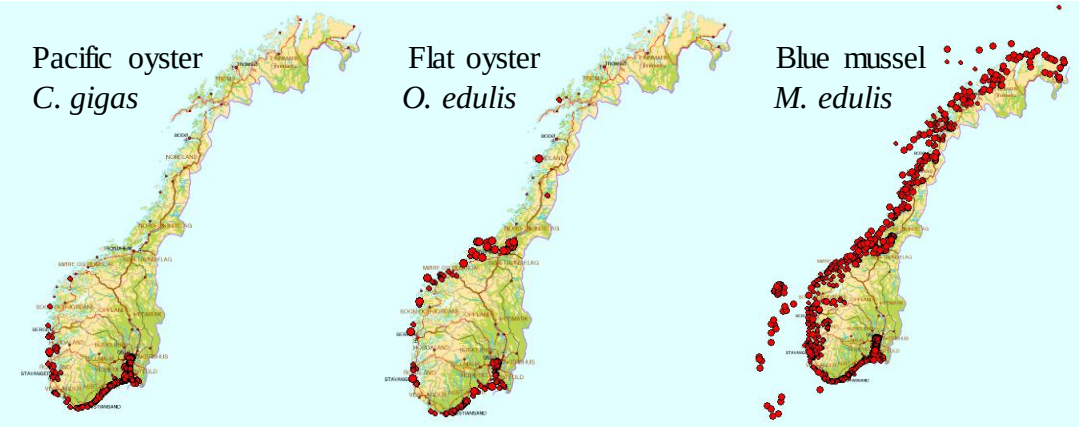

Figure 1.1: Distribution of Pacific oyster (*C. gigas*) (Artsdatabanken, 2017a), European flat oyster (*O. edulis*) (Artsdatabanken, 2017b) and Blue mussel (*M. edulis*) (Artsdatabanken, 2017c).

1.2.2 Pacific oyster

History and spreading of the Pacific oyster

The Pacific oyster is native to Japan and south-east Asia (Nehring, 2011), and its abilities to survive in cold environments (Strand et al., 2011) has made them able to spread and reproduce in non-native areas around the world (Strand et al., 2012). In Europe, the Pacific oysters were first introduced intentionally in Oosterschelde estuary in Netherland by Dutch oyster farmers in 1964 (Dolmer et al., 2014). This was due to a severe decline in the native European flat oyster population (Groslier et al., 2014). Since then, it has been introduced several times within Europe (Bodvin et al., 2014b), both unintentionally and intentionally (Strand et al., 2012). In 1983 were the first wild individuals found in the Dutch Wadden Sea, where these probably originated from a French hatchery (Nehring, 2011). Before 2000 the spreading was slow, but since then there has been an enormous increase, and is now covering large areas in all parts of the Wadden Sea, making dense reef (Bodvin et al., 2014b). Since Denmark and Germany both is a part of the Wadden Sea, the spreading of Pacific oysters introduced them in these countries as well. In Denmark, Pacific oysters is mainly located in the Danish part of the Wadden Sea and in

Limfjorden. Here it has been conducted aquaculture experiments on imported Pacific oysters (Bodvin et al., 2014b). In the Wadden Sea, the biomass has doubled each year for three years. Bodvin et al. (2014b) believed that this development would continue and feared similar development in Norwegian waters. This was not the case. There was a population decline in 2015/2016 due to the oyster herpes virus (OsHv1). It is expected that the population now has stabilized and will fluctuate in size caused by sickness in the future. The population will fluctuate at around 1000 Pacific oysters per m^2 (Reise et al., 2017). Reise et al. (2017) categorizes the first period as "Introduction and establishment", the second period with the enormous increase as the "Expansion phase", after which an "Adjustment phase" will follow. They believed that the Pacific oyster in the Wadden Sea now was in the adjustment phase.

Pacific oysters were first observed in Limfjorden (Denmark) in 2002-2003 (Bodvin et al., 2014b). From Denmark, the species spread to Sweden and the first detection of large numbers of Pacific oysters was in 2007. Since then it has spread along the Swedish west coast. In 1979 and in the 1980s Norway imported Pacific oysters from Scotland for aquaculture purposes several times. There were given 11 permits for Pacific oyster farming in Norway, but these were revoked in 2010. Wild living Pacific oysters were first observed in 2003 in Mefjorden, Vestfold. There are now about 200 localities of feral Pacific oysters in Norwegian waters. The population in one locality in Arendal, Norway (N58.4748, E8.9084) is genetically related to the populations in three localities in Sweden (Bodvin et al., 2014b).

In Europe today, the Pacific oyster can be found along the Atlantic coast, in the Mediterranean, around the British Isles and as far north as Scandinavia (Dolmer et al., 2014).

In Norway the Pacific oysters are mainly found in the upper 50 cm, but also down to 1.5 m water depth (Bodvin et al., 2014a). The northernmost location of Pacific oyster is Eide, Nordmøre (N62.3156, E5.8470) (Artsdatabanken, 2018). Seawater temperatures indicate possible growth as far north as Lofoten Island at approximately 68 N (Bodvin et al., 2014a). The IMR started registration of densities, size and distribution in Norway in 2009 at chosen localities and followed those location for 6 years. One of these localities, Tromlingene (N58.4759, E8.9087), had a relatively large population in 2009, which had decreased dramatically in 2010, caused by the extremely cold winter 2009/2010. In 2011 the population was still small as the winter 2010/2011 was also very cold. Since then the population has shown an increase every year up to 2015 (Bodvin et al., 2014a). Unpublished results of the same study area in 2015 indicated a massive increase in population size, with an estimated population size

of <100 000 individuals (Torjan Bodvin, IMR, personal communication). There are no quantitative studies for this locality after 2015.

Biology of Pacific oyster

Habitat

Pacific oysters can attach themselves to almost any hard surface, but they also exist in soft-bottom habitats, then typically attached to small stones, shells of other molluscs or to conspecifics (Bodvin et al., 2014b). It seems that they prefer oysters and both living and dead Blue mussels as substrate, while shells of other bivalves are of minor importance (Dolmer et al., 2014). At very high densities they also attach to each other, making a reef-like structure (Dolmer et al., 2014). Pacific oysters prefer sheltered waters in coastal marine and estuarine areas with good water circulation, in the intertidal and shallow sub-tidal zone (Dolmer et al., 2014). Along the Norwegian coast, the Pacific oyster has been found from normal water level down to 4-5 meters underneath the lowest water mark (Bodvin et al., 2014b), but they have been observed down to 40 meters (Dolmer et al., 2014).

Reproduction, growth and impacts of abiotic factors

As an intertidal species, the Pacific oyster is very tolerant to varying abiotic conditions, e.g. temperature and salinity, both during growth and reproduction (Strand et al., 2012). The Pacific oyster can grow and reproduce in salinities between 10-42 PSU (Nehring, 2011), and Dolmer et al. (2014) states that gametogenesis begins around 10°C and a salinity of 15-32 PSU. Pacific oysters can tolerate short-term salinity levels as low as 5 PSU (Nehring, 2011). Nehring (2011) report that Pacific oysters need a temperature of 18°C in 4-8 weeks to be able to reproduce, while Dolmer et al. (2014) report spawning down to 16°C. An increase in day length may reduce the temperature requirement which may make spawning possible in northern Norway. In addition, spawning products from one individual induce spawning of other individuals. It has been speculated that coordinated spawning in a densely populated area will be triggered as soon as the temperature requirements have been met for one individual (Bodvin et al., 2014b).

The temperature range for survival however, has not been fully evaluated. The upper thermal limit is considered to be approximately 30°C (Strand et al., 2011), whereas Nehring (2011) report growth up to 35°C. The lower thermal limit is more uncertain. Strand et al. (2012) lists different reported lower thermal limits, which lies between 2°C and -14°C, and Nehring (2011) reports survival when the air temperature is as low as -17°C. Ecological niche modeling based on surface seawater (SST) and atmospheric (AT) temperature has been used to define their thermal limits (Dolmer et al., 2014). Here Dolmer et al. (2014) states that in its native range,

the species maintains self-sustaining populations with SST of 14.0-28.9°C in warmer month and -1.9-19.8°C in colder month, and AT of 15-31°C in warmer month and -23-14°C in colder month. In addition to tolerate extreme temperatures, it has also been found that they tolerate large variations in temperatures. Generally stated, intertidal molluscs often exhibit seasonal variations in their cold tolerance and are more cold tolerant during the winter. The increase in cold resistance is due to a combination of low temperature, low light intensity, and food deprivation (Strand et al., 2011). This means that the Pacific oyster has the possibility to grow and reproduce in Norway under normal temperature circumstances.

The Pacific oysters have high fecundity and produce about 50-100 million eggs (Nehring, 2011), whereas Bodvin et al. (2014b) and Dolmer et al. (2014) reports production of up to 200 million eggs. The eggs are released over several spawning bursts (Nehring, 2011). Fertilization occurs externally, and must happen within 10-15 hours after spawning (Dolmer et al., 2014). This is why spawning induce spawning of other individuals, as they need synchronous spawning for fertilization (Bodvin et al., 2014b). The larvae stage is planktonic and lasts between 2 and 4 weeks. The duration depends on water temperature, salinity and food supply. The larvae have the ability to swim, however it is mainly spread out by currents. This means that long spreading distances is possible, theoretically up to 240 km (Dolmer et al., 2014; Nehring, 2011). This can explain the genetically similarities found between Norwegian and Swedish populations. The larvae then find a suitable habitat and attach themselves permanently by secreting cement. After attachment the larvae metamorphose into juvenile spat. The Pacific oyster has a very high growth rate in good conditions, and can reach a size of 20 cm. In addition, life expectancy can be up to 20 years. Pacific oyster reach maternal age one year after settlement (Nehring, 2011). They are protandrous hermaphrodites, mainly maturing as males first. In areas with good food supply, females are most common. When the food is limited the females can change back into males (Dolmer et al., 2014).

1.2.3 European flat oyster

History and prevalence of European flat oyster

The European flat oyster is found along the Atlantic coast, from Morocco to the coast of Helgeland in Norway. In the last 30 years, the population has been strongly impacted by sickness, especially oyster specific parasites introduced into Europe in 1979. The parasite was spread into Europe by movement of oysters from the United States (Culloty et al., 2007). Scandinavia however, is the only large area without serious illness amongst European flat

oysters (Bodvin, 2011). Newer studies have similar results, this also includes the latest study in 2016 (Mortensen et al., 2016; Mortensen et al., 2017).

In Norway, the European flat oyster is mainly located along the Skagerrak coast (Bodvin, 2011), as can be seen in figure 1.1. Similarly as the Pacific oyster, they decreased dramatically in the harsh winters of 2009/2010 and 2010/2011 (Bodvin, 2011). In 2010 they were classified in the Norwegian red list 2010 as EN, endangered, and has since increased in number enough to be categorized as NT (nearly threatened) in 2015 (Artsdatabanken, 2017c). The increase is not as big as the increase seen in the Pacific oyster.

Biology

The European flat oyster is found down to a depth of 30 m, generally existing in the subtidal zone. The European flat oyster tolerates water temperatures between -1.5 °C and about 35 °C. and can also exist in salinities between 18-40 PSU. The optimal salinity lies between 24 and 34 PSU (Nielsen et al., 2016).

1.2.4 Blue mussel

The Blue mussel is native in Norway and is distributed along the entire Norwegian coast. It is found as south as North Spain, and recently as north as Svalbard (Andersen et al., 2017). In the last years the IMR have gotten several reports regarding absence of Blue mussels. Last year Andersen et al. (2017) compiled the information from all these reports, and found that there were no unambiguously cause for the absence. Hence, what is causing this is not known. There were, however, reported mortalities of Blue mussels in Netherland and France due to sickness (Andersen et al., 2017). The same year as this information was compiled and assessed, Mortensen et al. (2017) found *Marteilia refringens* infected Blue mussels at Bømlo, western Norway. This might have caused several of the disappearances, and the IMR has already a plan for an extended survey and study of affected mussels (Mortensen et al., 2017).

Biology

The Blue mussel live mainly in the intertidal zone, but also down in the subtidal area. They have been observed down to a depth of 40 m. As both the Pacific oyster an European flat oyster, the Blue mussel tolerated varying conditions in salinity levels and temperature. They tolerate a salinity level as low as 4 PSU, but they prefer a salinity above 15 PSU. It seems that Blue mussels are more cold tolerant than Pacific oysters, as they tolerate freezing conditions for several months. The Blue mussels grow and reproduce in temperature between 5 and 20 °C, with a maximum tolerance of 29 °C (Goulletquer, 2004).

Blue mussels have a long-life expectancy, up to 18-24 years, and a high fecundity. The fecundity is affected by food availability and temperature, as with most species. Similar as the Pacific oyster, the larvae stage is planktonic and long spreading distances is possible due to currents here as well. In areas where the Blue mussel thrive and exist at high numbers, they form dense populations called mussel beds (Goulletquer, 2004).

1.2.5 Macroalgae

Brown algae dominates the flora along the Norwegian coast. The species are mainly in order Fucales, with species as Bladder wrack and Knotted wrack. Other apparent species is Channeled wrack, Spiral wrack and Toothed wrack. The intertidal zone in Norway and the northern Europe in general has a zonation pattern. The upper part of the intertidal zone is dominated by Channeled wrack and Spiral wrack. This belt has mainly a water depth less than 0.5 m. The next belt is dominated by Bladder wrack. Followed by a wide belt of Knotted wrack down to the Toothed wrack belt beneath (Nervold, 2008). This zonation pattern is greatly affected by competition. Competition between other macroalgae involve factors as light, space and nutrients. Other biotic factors which impact the distribution is herbivores grazing. The effects of these factors are a complex process (Edwards et al., 2012).

Macroalgae are sessile organisms, which are attached to a hard substratum. This include rocks, gravel and mussels. Algae living in the intertidal zone, for example on mussel beds, are affected by tidal flows. As the tides shift, the abiotic conditions will change and cause salinity and desiccation stress (Karsten, 2012). The salinity can vary between 0 and 33 PSU in the intertidal zone. These factors affect the horizontal distribution of macroalgae. Abiotic factors like this may shift the competitive balance between species (Edwards & Connell, 2012), and affect the zonation pattern. Other factors impacting the local zonation pattern include physical disturbance, herbivory, nutrient availability and pollution (Williams et al., 2013). The factors who determine the lower limit of algae distribution is complex and involve several types of biological competition. It involves both intra- and interspecific competition between algae species and between algae and animals, as Blue mussel (Nervold, 2008). Kelp and other species existing in the sublittoral zone exhibit a more stable environment (Karsten, 2012).

Temperature is also an abiotic factor affecting the distribution of macroalgae, both locally and at a larger geographical scale (Martínez et al., 2012). Both temperature-dependent effects on performance and temperature tolerance (Eggert, 2012). How temperature affects the competition amongst species are less clear (Edwards & Connell, 2012). The physiological responses to temperature changes are not fully understood. Increased temperature has affected

the distribution of Toothed wrack in the Cantabrian Sea (Martínez et al., 2012). Synergistic effects between temperature, climatic and non-climatic physical factors may cause unexpected distributional responses. Martínez et al. (2012) also points out that the interaction between these affecting factors are largely unexplored.

Macroalgae are sessile organisms greatly affected by biotic and abiotic factors around them. Many species may therefore be used as indicator species to indicate changes in the coastal zone. As an example, a species could indicate temperature changes or pollution. As Nervold (2008) states, surveying of both algae and animals along the coast may help the understanding of interaction between different species. It has been found that Bladder wrack and Common limpets (*Patella vulgate*) impact each other. There has also been found that the percentage coverage of macroalgae in general impact distribution and abundance of intertidal gastropods (Marzinelli et al., 2012).

One dominating macroalgae species in the Norwegian shoreline is Knotted wrack. This is a key foundation species, especially at rocky shores where macroalgae completely dominates. The Knotted wrack has a wide temperature tolerance, from beneath freezing and up to 25 ^{o}C, with an optimal temperature of 15 ^{o}C (Marbà et al., 2017).

1.2.6 Pacific oysters impact on coastal ecosystems

Pacific oysters are recognized as ecosystem engineers and the impact they make depend on population size. A high population size creates reefs of a hard structure where there earlier were mobile sediments, hence they raise and stabilize the sediment surface locally. Established Pacific oyster reefs controls local physical variables as flow speed, which influences recruitment, growth and survival of benthic species. Oyster reefs may also protect the intertidal habitat of native bivalves and other invertebrate fauna by preventing erosion. When the Pacific oyster make reefs, they increase the surface area four times compared to a soft bottom habitat. When living in large numbers as reefs, they excrete a vast number of feces, which enriches the sediment organically. This result in sediments with high organic content, ammonia and hydrogen sulphide, and low oxygen levels (Dolmer et al., 2014).

The effects of established non-native species on native populations vary with the ecology of the invader, phase of invasion and nature of the invaded community. The impact is also dependent on trophic level and ecological role of the species affected, and whether similar ecological types are found within the system. The specific impacts of Pacific oysters are not very well studied, especially not in newly invaded areas. And how this will affect the native fauna here in Norway

in the future is not known. The reef structure forms a hard substrate which may aid settlement of other species and refuge from physical stress and predation. There have been demonstrated that the species richness is higher on oyster reefs compared to bare flats (Dolmer et al., 2014).

Biodiversity is found to be higher in Pacific oyster beds than in Blue mussel beds, and also the composition of species was different (Dolmer et al., 2014). Both Pacific oysters and native Blue mussels tend to settle in the same locations, and overgrowth of Blue mussels was and is a concern when the invasive Pacific oyster spreads out. It was assumed that competition with the Pacific oyster for food was limiting the distribution and biomass of Blue mussels (Dolmer et al., 2014). Nielsen et al. (2016) found that they do not compete for food. The two species select different types of microalgae, which is also reflected in their soft tissues. In addition, Blue mussels also can use the Pacific oyster reefs as habitat and increase their survival. Coexistence is therefore possible, and has been observed in Limfjorden, Denmark. But overgrowth may still be possible as the Pacific oysters are competitively superior and the exact factor or factors responsible for coexistence is unknown. Changes in any one factor can induce dominance of Pacific oyster, and the Pacific oyster remains a potential risk for Blue mussels to be locally extinct (Dolmer et al., 2014).

Native European flat oysters and invasive Pacific oyster has different ecological niches. The European flat oysters live more subtidal and has a more limited tolerance range for temperature and salinity compared to Pacific oysters (Dolmer et al., 2014; Nielsen et al., 2016). In areas where both species exist, the Pacific oysters can exist deep enough to interact with the European flat oyster. Pacific oysters have a very rapid growth and Nielsen et al. (2016) found that they have similar food preferences. This means that the Pacific oyster can dominate European flat oysters localities over time (Dolmer et al., 2014).

Dolmer et al. (2014) had conducted a risk assessment on both short term and long-term changes in temperature and pH, whereas two different scenarios of long term changes were included. The impact of Pacific oysters where divided between different habitats, Dolmer et al. (2014) have summarized their results in table 1.1. They have included present knowledge of interactions with Blue mussels, temperature controlled distribution and recruitment, acidification, predation and health status (Dolmer et al., 2014). The soft-bottom habitat type investigated in this Master thesis, represent important habitats for Pacific oysters in Scandinavia.

Table 1.1: Table created by Dolmer et al. (2014) of the results of the risk assessment. See the article for more information regarding categorization of habitat and climate models.

	Short term **Temp.: 1-2°C** **pH: -0.15**	**Long term** **Temp.: 2.5-3.0°C** **pH: -0.25**	**Long term** **Temp.: 3.0-3.5°C** **pH: -0.35**
Low energy Rock	Limited impact	Moderate impact	Moderate impact
Low energy Littoral sand and mud	Limited impact	Moderate impact	Moderate impact
High energy Littoral sand and mud	Moderate impact	Moderate impact	Moderate impact
Low energy Littoral biogenic reefs	Moderate impact	Moderate impact	Moderate impact
High energy Littoral biogenic reefs	High impact	High impact	High impact
Low energy Sublittoral sediment	Limited impact	Limited impact	Limited impact
High energy Sublittoral sediment	Moderate impact	High impact	High impact

Expected impact on soft-bottom habitats, were a moderate impact where the sediments were sand and mud, regardless of the energy present. The energy impacts whether the Pacific oyster was expected to affect sublittoral sediments, both in a short and long term scale.

1.3 How biology of target species affect sampling

When using the photoframe method as a tool for quantity measuring, the photoframe will be placed out randomly within an investigation area a certain number of times. When placing the photoframe out randomly, the densities within the frame will change. Not only caused by random distribution within the experimental area, but also by the biology of the different target species. As both Pacific oyster and Blue mussel prefer the intertidal zone, placement of the photoframe in the intertidal zone will most likely be dominated by these two species. Opposite, the European flat oyster prefers the subtidal zone, and will most likely dominate this area. This depth-dependent species distribution will most likely be apparent in the videosleigh method as well, as the sleigh is dragged from the subtidal to the intertidal zone. Further, within the water depth each species exists, they increase in number as the water depth decreases. Pacific oyster

and Blue mussel will have higher densities close to land, while the European flat oyster will have maximum density below the lowest water mark. Different species of macroalgae are expected to exhibit a zonation pattern. This could be detected by both the photoframe and the videosleigh method if determined to species. Here, macroalgae was treated as a group, and therefore existing and distributed inconsistently within both the intertidal and subtidal zone.

Since sampling will be done at different depth, there will most likely be seen different densities of Pacific oyster, European flat oyster and Blue mussel. Testing both methods for different densities is therefore important. Testing at different depths will then most likely cover different densities and indicate whether this affect the accuracy and precision to the new methods.

2. Materials and Methods

2.1 Location

The experimental area consisted of two localities (figure 2.1), which had multiple sheltered sites with soft bottom. Containing suitable habitats for the four groups of interest: Pacific oyster, European flat oyster, Blue mussel and macroalgae. Both localities were used testing the photoframe method, and only locality 2 was used testing the videosleigh method.

Figure 2.1: Map showing the two localities used during the experiment. Locality 1 N58.2639, E8.5011. Locality 2 N58.4456, E8.8337.

2.2 Photoframe

2.2.1 Construction

The photoframe was an aluminum frame of 0.5 x 0.5 m footprint (Figure 2.2). Attached to the frame was a GoPro Hero 3 camera, approximately 0.5 m above the seabed. This type of camera was used in a previous study where they classified similar areas (Loo & Scherer, 2014). The camera took pictures from above, covering the frame area.

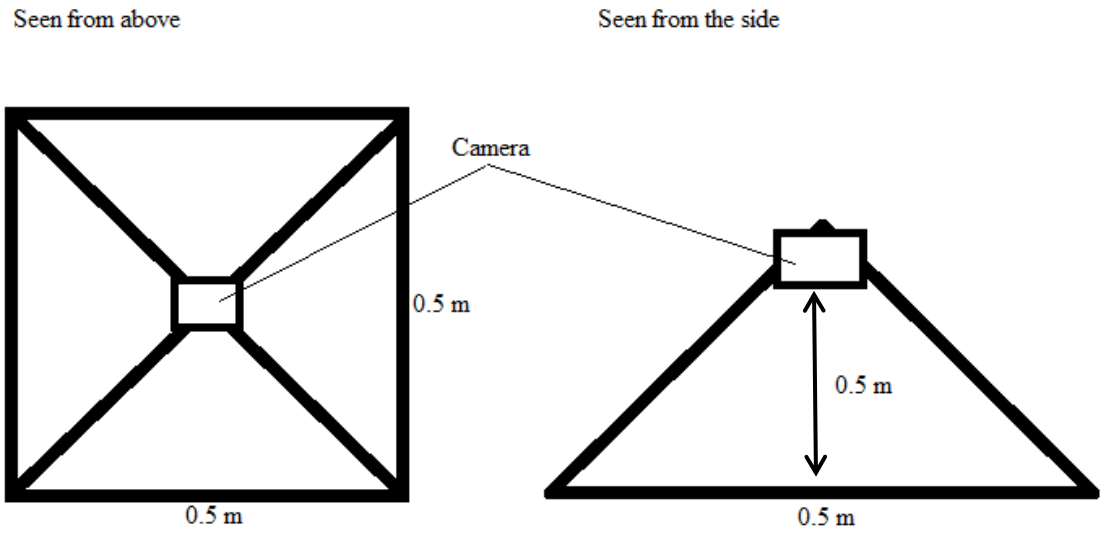

Figure 2.2: Illustration of the photoframe.

2.2.2 Experimental design

The aim of this experiment was to determine if photo could be used to determine number and size of different shells. The presence of target groups was the only criteria for placement of the frame within the experimental area. The frame was placed out 36 times, making 36 photos to be analyzed. When the frame was placed on the bottom, the camera was turned on, and set to take one picture per second. The camera was set to take one picture per second to ensure at least one analyzable picture was taken from each placement. To identify the photos later, a note with sample number (1…n…36) were held beneath the camera. After the frame was photographed, the target content within the frame was counted and measured manually. Every Pacific oyster, European flat oyster and Blue mussel were measured with respect to length and width. If some individuals were grown into and/or over each other and made measurement impossible, NA was noted. Each individual counted was registered as living or dead. The occurrence of macroalgae was noted as percentage coverage, and other species were disregarded.

2.2.3 Statistical methods and analysis

Statistical analysis used the term frame as photos of each frame placement, n = 36. And the term sample for the number of individuals counted or measured within a frame, n varies.

One photo, representing the clearest image of the bottom content, was chosen for each of the 36 frames. When analyzing the photos, it was important that the photos were randomized. This was important to ensure that there would be no conformation bias when analyzing the photos (Thorngren et al., 2017), since the same person both analyzed photos and did the fieldwork. When this method is going to be used in the future, the personnel analyzing the photos would

have no prior knowledge about the content. It was important that this also was the case when testing the method. For this reason, all 36 frames were randomized by creating random names before analyzing.

The program ImageJ was used to measure the shells detected. For each photo, the scale was set by using the frame (0.5 m) as a reference length. Both length and width were noted when possible, when not possible NA was noted.

The statistical program R was used to analyze the data. When analyzing count data, Kruskal-Wallis rank sum test (McDonald, 2009) was used to assess differences. Count data was also assessed for correlation by Spearman correlation test (McDonald, 2009). Length and width measurements had an assumed normal distribution as it was continuous data, and assessment of differences was carried out by ANOVA, and a linear model was used to create regression lines (McDonald, 2009).

2.3 Videosleigh

2.3.1 Construction

A videosleigh with two cameras was used (figure 2.3). One camera facing forward and one camera downward. Both cameras were 0.5 m above the seabed. The size of the videosleigh frame is noted in the illustration (figure 2.3), and in more detail in appendix A. A rope was used to drag the sleigh towards land, and it was attach to the sleigh at point A. On the sled runner, tape stripes of 5 cm length were used to make a reference length, so that measuring of individuals were possible.

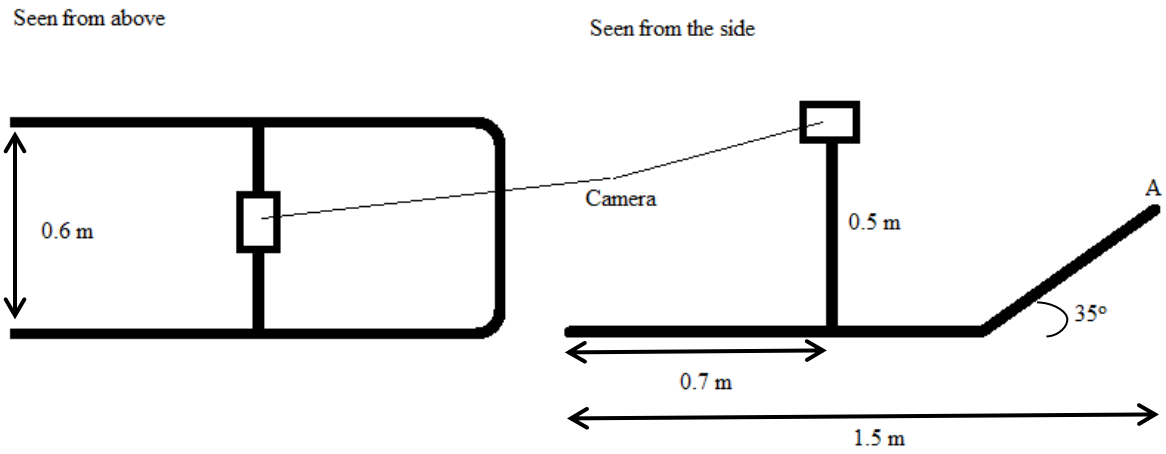

Figure 2.3: Illustration of the videosleigh.

2.3.2 Experimental design

The aim of this experiment was to determine if video could be used to determine number of individuals of the different species, and to determine if the accuracy and precision are dependent on the density of individuals. The presence of target groups was the only criteria for placement of transects within the experimental area. A transect line was laid out, with a length of 15 meters and markings every 5 meters (figure 2.4). The transect line was laid out perpendicular to the shoreline, such that different depth was represented in each transect. This was because it was assumed different densities at different depth, and it was important to test the method on different densities. It was ensured that the transect line were at a minimum depth of 0.5 m, such that the camera always was under water. The camera needed to be under water to make clear videos. The videosleigh was then placed at the start, the deepest point on the transect line (0 m, figure 2.4), and both cameras were turned on and set to filming. To identify the transect films later, a note with transect and trip number (transect 1…n.…10 and trip 1…n…3/6) were held in front of each camera. One person stood on land and pulled the sleigh towards land with a slow constant speed, approximately 0.2 m/s (min. 0.12 m/s, max. 0.27 m/s), while another person in the water assured that the sleigh followed the transect line. This speed was found appropriate in a study which also used towed video (Lindegarth et al., 2014). When the sleigh reached the upper end of the transect line, the sleigh was then placed at 0 m again, and pulled towards land along the same transect line repeatedly. At the 7 first different transect lines the same transect line was dragged and filmed 3 times, the following 3 transect lines were dragged and filmed 6 times. This research design made it possible to assess both accuracy and precision of the videosleigh method. Since the videosleigh is manually operated, it is affected by weather, wind and the seabed topography. Repeatedly filming of one transect would also ensure at least one film was analyzable (Gitmark et al., 2016). The front camera was not used for further analyzing in this experiment. In the future it was thought to help give an overview of the environment as there would be no personnel in the water observing this.

After each transect replicate, the target species within the transect area made by the sled runners was counted manually by skin-divers. The existence of macroalgae was noted in percentage coverage. Other species were disregarded. The area made by the sled runners were divided into sectors, where individuals was counted within each sector. Each sector existed of 5 meters, making 3 sectors – 1) 0-5 m, 2) 5-10 m and 3) 10-15 m, as illustrated in figure 2.4. There was assumed different densities in the different sectors, as the different sectors were at different depth. Dividing into different sectors when counting gave counting results from different densities, as was a part of the experimental aim.

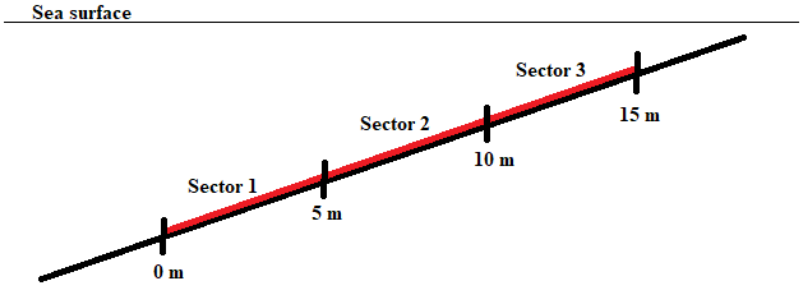

Figure 2.4: Illustration of the transect line and different sectors each transect was divided into.

2.3.3 Statistical methods and analysis

Raw data consisted of video files with multiple replicates of same transect. Windows Movie Maker was used to cut the video files such as each video was of one replicate. Similar as the photoframe method, randomization was important to ensure that no conformation bias occurred when analyzing the videos (Thorngren et al., 2017). Also, in this method, the personnel analyzing the videos when this method is used later would have no prior knowledge about the content. Therefore, all 39 videos were randomized by creating random names before analyzing.

The statistical program R was used to analyze the data. When analyzing count data, Kruskal-Wallis rank sum test was used to assess differences (McDonald, 2009). Count data was also assessed for correlation by Spearman correlation test (McDonald, 2009).

3. Results

3.1 Photoframe method

3.1.1 Counts of individuals

The total number of individuals counted in situ was higher than the number counted by photo (table 3.1). The Pacific oyster was the only species having more individuals counted by photo compared to in situ. There were only 3 more individuals counted by photo. Both European flat oyster and Blue mussel had a larger difference, 30 and 18 individuals respectively. Counts within each of the 36 frames are shown in appendix B, and divided into species in appendix C.

Table 3.1: Summarized counts of individuals in photo and in situ, separated in species and in total. And percentage of individuals detected by photo compared to in situ, separated in species and in total.

Species	**Number of individuals counted in photo**	**Number of individuals counted in situ**	**Percentage of photo estimate**
Pacific oyster	221	218	105.24 %
European flat oyster	25	55	45.45 %
Blue mussel	107	125	85.60 %
Total	353	398	88.69 %

The methods by which the individuals were counted were tested for difference with a Kruskal-Wallis rank sum test. The total number of individuals counted in situ and by photo was significantly different ($P = 0.008$). Frames with two or less number of individuals was removed. The remaining frames were not significant different from each other ($P = 0.090$). When assessing correlation, a spearman correlation test was done. The total number of individuals had a significant correlation coefficient (r_s) of 0.970 ($P = 2.2\times10^{-16}$) (figure 3.1 A). Removing frames with two or less number of individuals when assessing correlation was also done. This reduced the correlation coefficient ($r_s = 0.920$, $P = 8.6\times10^{-11}$).

The total number of individuals was divided into species; Pacific oyster, European flat oyster and Blue mussel (figure 3.1, B-D). All three species had a significant spearman correlation coefficient ($P = 2.7\times10^{-10} – 0.039$). The correlation coefficient (r_s) was 0.874 for Pacific oyster, 0.556 for European flat oyster and 0.893 for Blue mussel. When assessing differences, both counts of Pacific oyster and Blue mussel were significant different between counting methods ($P = 0.012$ and 0.009). The European flat oyster was not significant different between photo and in situ counting ($P = 0.212$).

The total number of individuals detected in photo, compared to detection in situ, was 88.69 %. This was not transferable to species level, which had variable percentage level of detection by photo (table 3.1).

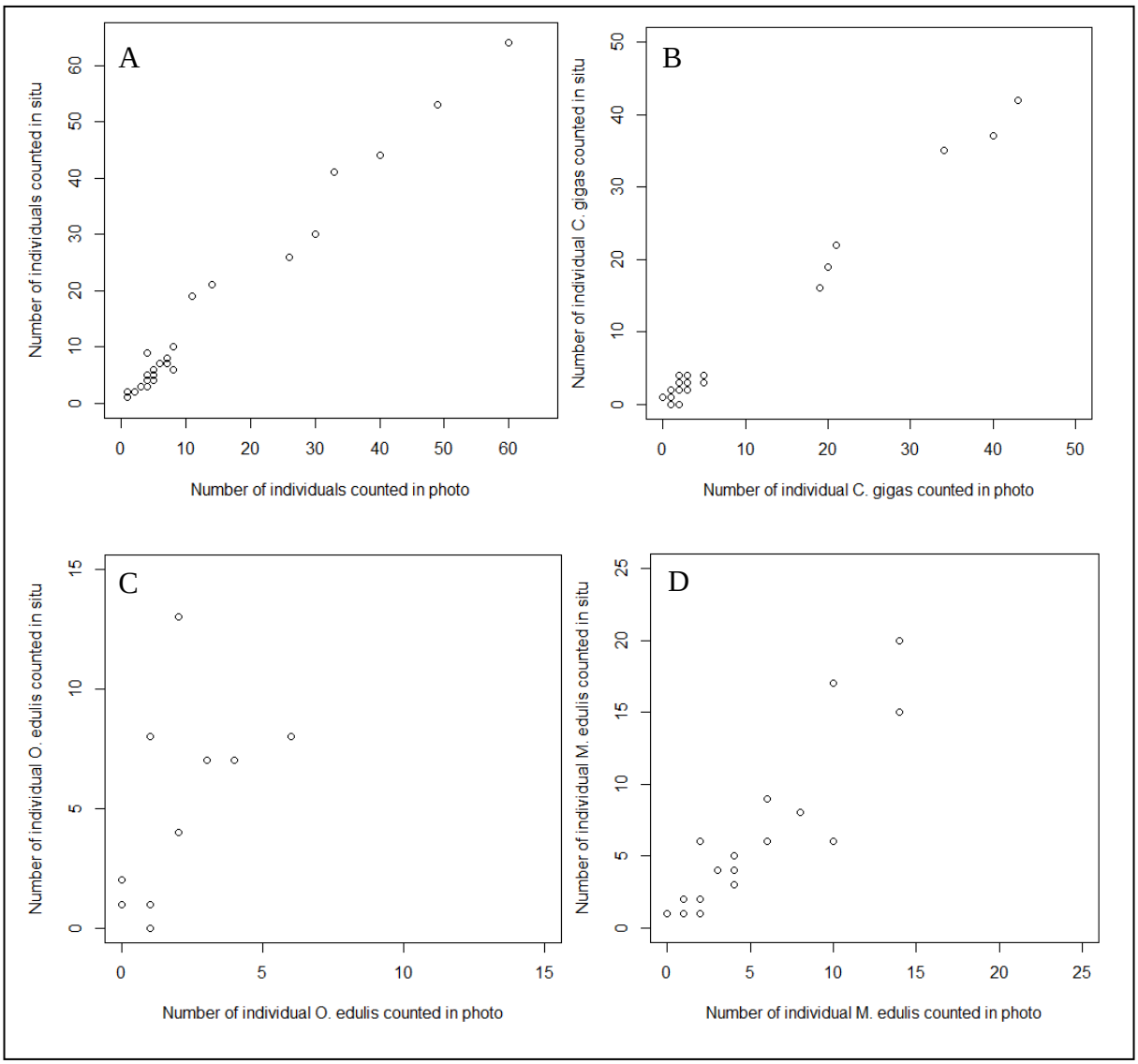

Figure 3.1: Scatterplot of number of individuals counted both in situ and by photo, where a point represents a frame. A: All individuals, $r_s = 0.970$, $P = 2.2\times10^{-16}$ and n=36. B: Pacific oyster, $r_s = 0.874$, $P = 2.7\times10^{-10}$, n = 30. C: European flat oyster, $r_s = 0.556$, P = 0.039, n = 14. D: Blue mussel, $r_s = 0.893$, $P = 9.0\times10^{-10}$, n = 26.

3.1.2 Lengths and widths measurements

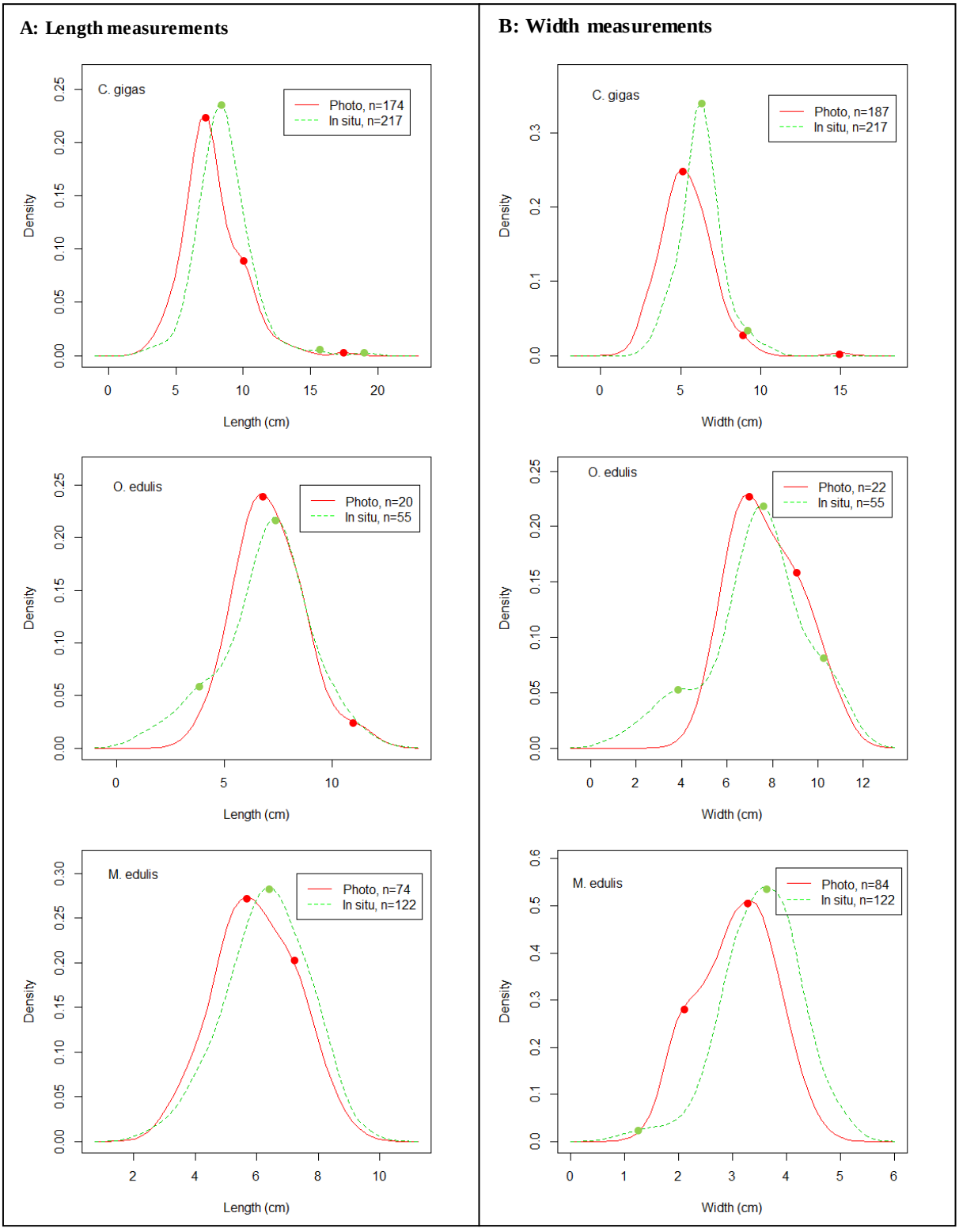

Figure 3.2: Frequency plot showing the frequency of each size measured, both by photo and in situ. The red solid line indicates the measurement frequencies done by photo, and the green dashed line represent in situ measurements. A illustrate length measurements and B illustrate width measurements, both separated into species Pacific oyster, European flat oyster and Blue mussel. The cohorts found by photo was marked by a red point, and in situ cohorts found was marked with a green point.

Frequency diagrams of length and width measurements within each species are illustrated in figure 3.2. Based on Pacific oyster length measurements, there appeared to be three cohorts by photo and in situ analysis. By photo, there were one cohort with a length around 7 cm, superimposed on a cohort with length around 10 cm, and one with length about 17.5 cm (few individuals). In situ, the cohorts appeared with a length around 7, 15 and 19 cm, where the cohorts of 15 and 19 cm had few individuals. The width measurements by photo show a large cohort with a width of 5 cm, followed by two smaller cohorts at 9 and 15 cm. In situ width measurements show a large cohort at around 6 cm superimposed on a smaller cohort with a width of 9 cm.

Two cohorts were apparent from length measurements of European flat oyster both by photo and in situ. The two cohorts found were at different lengths. By photo there was a large cohort at around 7.5 cm length and a smaller cohort at around 11 cm. Whereas in situ found a small cohort with length of 4 cm, and a larger cohort at 8 cm length. Width measurements by photo show two cohorts superimposed on each other, one with a width of 6.5 cm and one of 9 cm. In situ show a cohort with width of 3.5 cm, 8 cm and one at around 10 cm.

From length measurements of Blue mussels there appeared as two superimposed cohorts by photo and only one in situ. The photo cohorts had a length of 5.5 cm and 7 cm, and the in situ cohort at 6.5 cm. The two cohorts visible in photo was clearer in width measurements. One cohort with width of 2 cm and one with width of 3 cm. Width measurements done in situ seemed to show two cohorts. One small cohorts with a width of 1 cm, and a large containing almost every individual with a width of 3.5 cm.

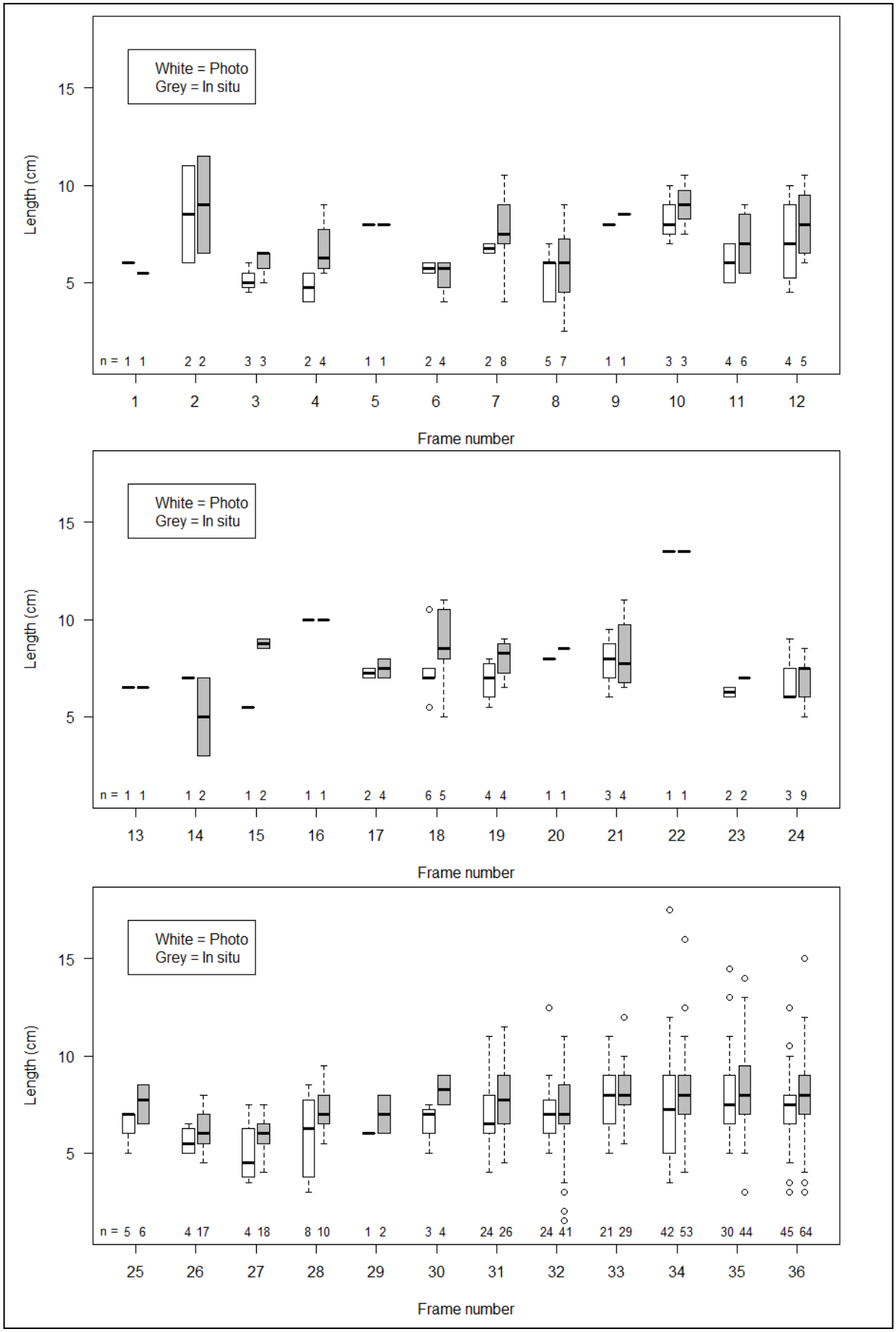

Figure 3.3: Boxplot of lengths measurements, where the box represent data within quartile (Q) 1 and 3 (called IQR), where the hard line is the median. The whiskers include measurements Q3+1.5IQR (upper) and Q1-1.5IQR (lower), more extreme values are plotted as points. n represent sample number of individuals measured within each box.

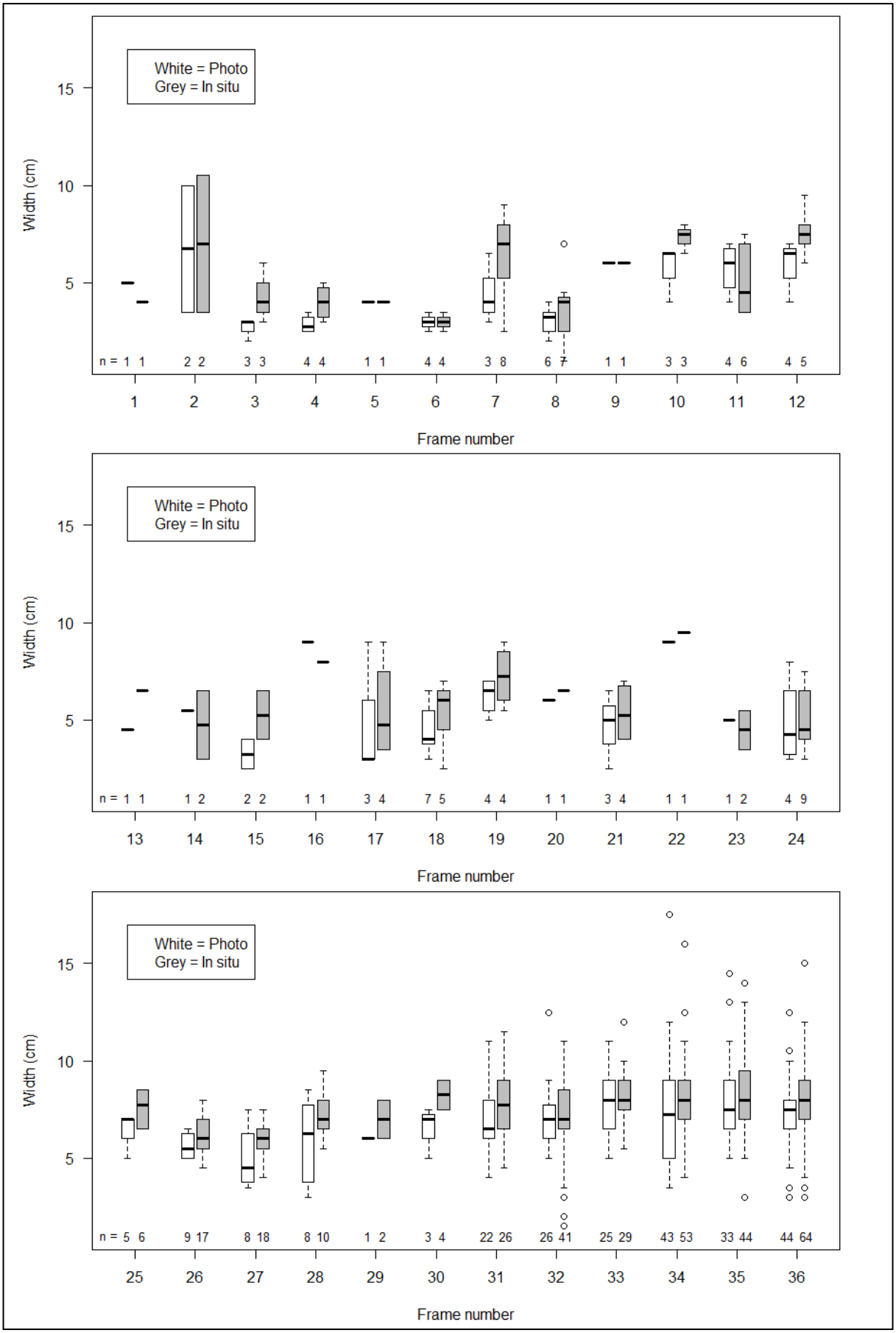

Figure 3.4: Boxplot of widths measurements, where the box represent data within quartile (Q) 1 and 3 (called IQR), where the hard line is the median. The whiskers include measurements Q3+1.3IQR (upper) and Q1-1.5IQR (lower), more extreme values are plotted as points. n represent sample number of individuals measured within each box.

Figure 3.3 show the lengths measurements and figure 3.4 show the width measurements of every measurable Pacific oyster, European flat oyster and Blue mussel found, grouped in frame and counting method (see appendix D for all measurements). As shown from both figures, the number of individuals (n) varies both between frames and within frames. Of the 36 frames, 7 contained only 1 individual, and an assessment of differences with ANOVA (analysis of variance) was not possible. Within each remaining frame there were no significant differences between in situ and photo measuring of length (P = 0.074 - 0.949). Within two frames (no. 34 and 36), the width measurements were significantly different between photo and in situ measurements (P = 0.009 and 0.027, respectively). The remaining frames were not significantly different (P = 0.072 - 1).

When comparing all measurements, there was a significant difference between both length and width measurements done in situ and photo (P = 0.008 and 1.2×10^{-5}, respectively). Since n varied within frames, an assessment of how this affected the results was done. There were created four groups; 1) 0 %, 2) 1-30 %, 3) 31-50 % and 4) 51-100 %. Where the percentage given in each group represented percentage difference in n between counting method within each frame. See appendix E and F for more details about the placement of each frame within these groups. The group (2) were the difference in n where 1-30 %, both length and width measurements were significant different (P = 0.001 and 0.006, respectively), whereas other percentage differences (group 1, 3 and 4) where not (P = 0.214 - 0.528). When comparing only the mean lengths and widths of every frame, the results was not significant different (P = 0.099 and 0.111, respectively), including all frames and variations in n.

When looking further at the mean length and width of each frame, the linear relationship between in situ and photo measuring is apparent in figure 3.5 and 3.6. The red lines indicate how the relationship would look like if the mean length/width was the same, a perfect (1:1) relationship. The black line represents the actual regression line between the two counting methods.

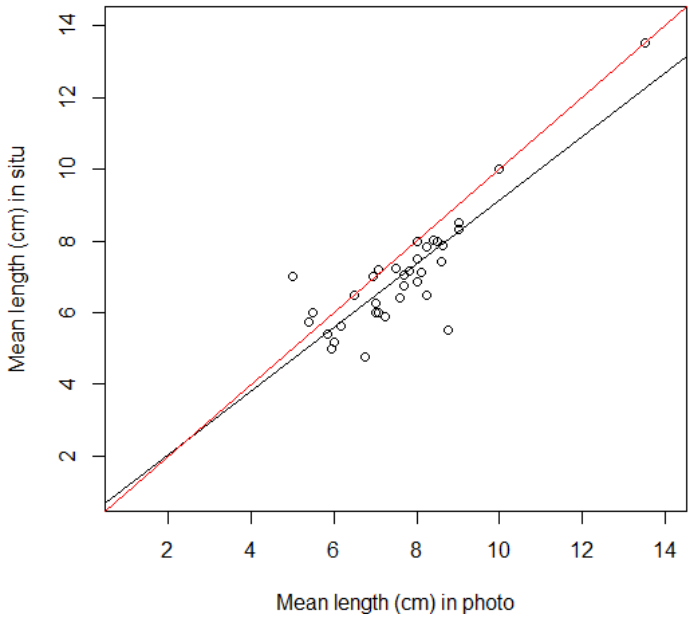

Figure 3.5: Comparison of mean length (cm) measurements done by photo against mean length (cm) measurements done in situ. Each point represents one frame, n=36. The red line shows a perfect 1:1 relationship, and the black line represent the actual regression line, $y_i = 0.249 + 0.887x_i + \varepsilon_i$ ($P = 2.4\times10^{-11}$).

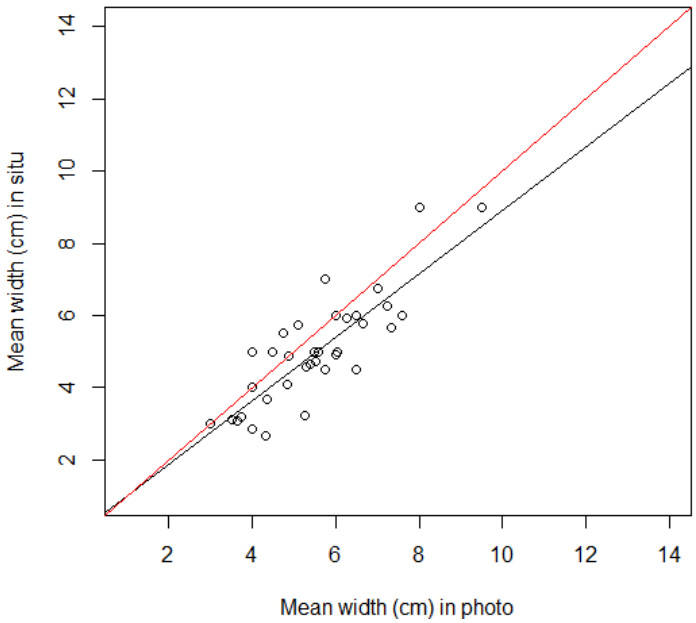

Figure 3.6: Comparison of mean width (cm) measurements done in photo against mean width (cm) measurements done in situ. Each point represents one frame, n=36. The red line shows a perfect 1:1 relationship, and the black line represent the actual regression line, $y_i = 0.113 + 0.880x_i + \varepsilon_i$ ($P = 3.8\times10^{-10}$).

Both the mean length and width measurements done in photo can explain the measurements done in situ ($P = 2.4\times10^{-11}$ and 3.8×10^{-10}, respectively). The linear model of mean lengths explained 73 % of the variability, while the linear model of mean width explained 69 %. The regression lines for the mean measurements was as follows;

$$\text{(1) Length: } y_i = 0.249 + 0.887x_i + \varepsilon_i$$
$$\text{(2) Width: } y_i = 0.113 + 0.880x_i + \varepsilon_i$$

Where y_i was the mean length/width in situ of every shell in frame i, x_i was the mean length/width in photo of every shell in frame i and ε_i was the residual error of frame i.

It was apparent that both mean length and width measurements, are after a certain point, smaller in situ than in photo, i.e. shells appeared bigger in photo.

Mean length and width measurements of each species compared between photo and in situ was illustrated in figure 3.7. Mean length and width measurements in photo of Pacific oysters could explain the measurements in situ ($P = 8.3\times10^{-7}$ and 3.0×10^{-4} respectively). The linear models explained 64 % and 43 %, respectively, of the variability within the data. It was apparent that there were few frames containing European flat oyster, therefore making few point to form the regression line. Length measurements in photo could not explain in situ measurements ($P = 0.091$). The linear model explained 40 % of the variability. Width measurements by photo could explain in situ measurements ($P = 0.013$), and the linear model explained 55 % of the variability. When looking at Blue mussels there were no apparent relationship between photo and in situ measurements. Lengths measurements done in photo could explain in situ measurements ($P = 0.048$), but the linear model explained only 17 % of the variability within the data. The width measurements by photo could not explain the width measurements in situ ($P = 0.724$), and the linear model explained only 0.06 % of the variability within the data.

The regression lines of each species and each measurement was given in table 3.2 beneath, in accordance with significance level.

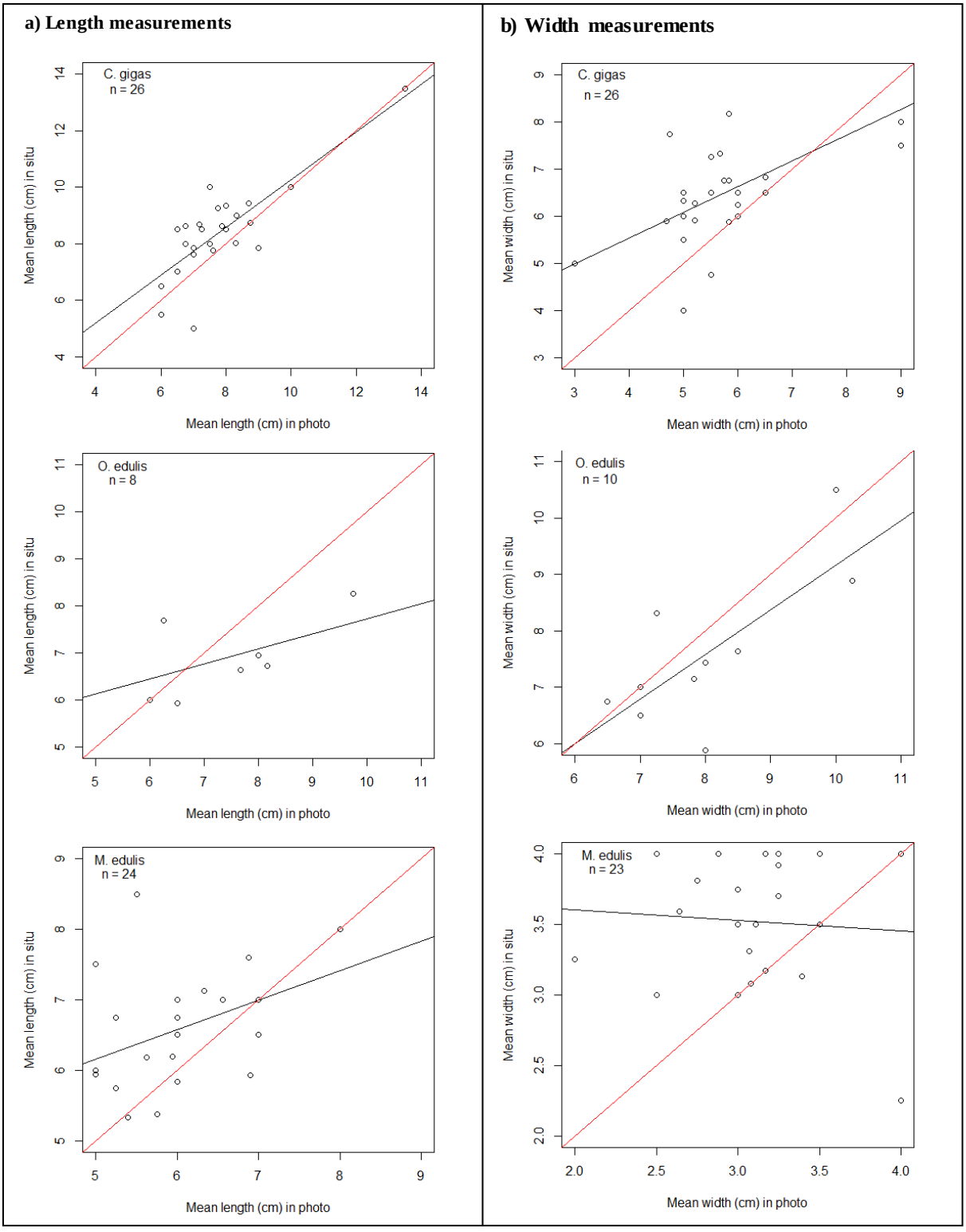

Figure 3.7: Comparison of mean measurements, where a) illustrate length and b) width measurements, each separated in species Pacific oyster, European flat oyster and Blue mussel. Each point represents one frame, number of frames (n) included varied. The red line shows a perfect 1:1 relationship, and the black line was the regression lines found. The different regression lines with corresponding P-values were presented in table 3.2 beneath.

Table 3.2: Regression lines with corresponding significance level of each species, both length and width measurements.

Species	Regression line	Significance level (P-value)
Pacific oyster	(3) Length: $y_i = 1.8092 + 0.844x_i + \varepsilon_i$	8.3×10^{-7}
	(4) Width: $y_i = 3.342 + 0.547x_i + \varepsilon_i$	3.0×10^{-4}
European flat oyster	(5) Length: $y_i = 4.529 + 0.320x_i + \varepsilon_i$	0.091
	(6) Width: $y_i = 1.232 + 0.793x_i + \varepsilon_i$	0.013
Blue mussel	(7) Length: $y_i = 4.068 + 0.419x_i + \varepsilon_i$	0.048
	(8) Width: $y_i = 3.758 - 0.766x_i + \varepsilon_i$	0.724

Where y_i was the mean length/width in situ of every shell in frame i, x_i was the mean length/width in photo of every shell in frame i and ε_i was the residual error of frame i.

3.1.3 Living and dead individuals

The number of living and dead individuals registered in situ and by photo was given in table 3.3. The total number of individuals was higher in situ regardless of registration as living or dead. When assessing this difference with a Kruskal-Wallis rank sum test it was significantly different for both living and dead registrations (P = 0.003 and 0.005). The only count highest by photo was of living Pacific oyster. An assessment with a Kruskal-Wallis rank sum test revealed a significant difference in both registration of living and dead individuals of Pacific oyster (P = 0.000 and 0.004).

European flat oyster and Blue mussel had both higher counts in situ. The only not significant difference between registration method was found between dead Blue mussels (P = 0.056). European flat oyster, both dead and living, and living Blue mussels were significantly different (P = 0.001 – 0.489) between categorization method.

Table 3.3: Number of individuals registered as living or dead, divided into species.

Species	Individuals registered as living		Individuals registered as dead	
	Photo	In situ	Photo	In situ
Pacific oyster	218	206	4	11
European flat oyster	18	42	7	13
Blue mussel	104	115	3	10
Total	340	363	14	34

3.1.4 Percentage coverage of macroalgae

Percentage coverage of macroalgae was determined to the nearest five percent. 11 of the 36 frames contained macroalgae (see appendix C for more details). Within them the largest

difference was 10 % between the two registration methods, with a mean of 4 %. The two registration methods were plotted against each other in figure 3.8. An assessment of difference between the two methods was done with a Kruskal-Wallis rank sum test, and no significant difference was found (P = 0.319). A spearman correlation test was done to assess if the two registration methods varied together. The correlation coefficient (r_s) was 0.452 and was not significant (P = 0.162).

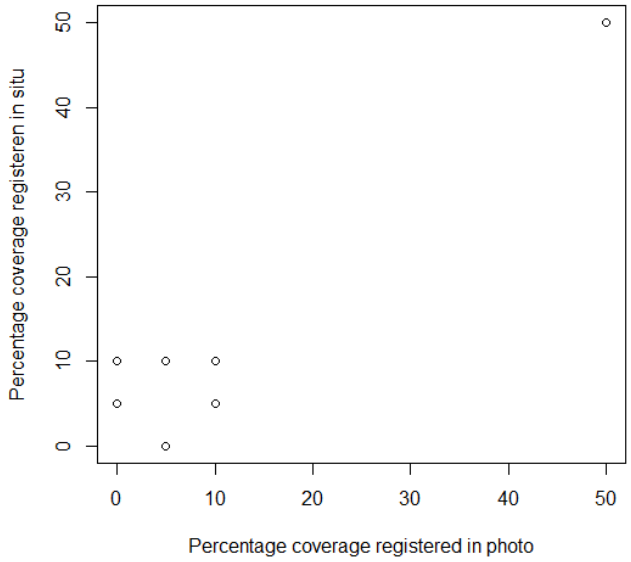

Figure 3.8: Scatterplot of percentage coverage registered by photo against percentage coverage registered in situ. r_s = 0.4524 (P = 0.162). Each point represents a frame, n = 11.

3.2 Videosleigh method

3.2.1 Counts of individuals

Table 3.4: Summarized counts of individuals counted by video and in situ, separated into species and in total. And percentage of individuals detected by video compared to in situ, separated into species and in total.

Species	Number of individuals counted in video	Number of individuals counted in situ	Percentage of video estimate
Pacific oyster	735	1069	68.76 %
European flat oyster	49	279	17.56 %
Blue mussel	946	1339	70.65 %
Total	1730	2687	64.38 %

The total number of individuals detected by video, compared to detection in situ, was 64.38 %. The detection level was similar for Pacific oyster and Blue mussel, while only 17.56 % of European flat oyster were detected by video (table 3.4).

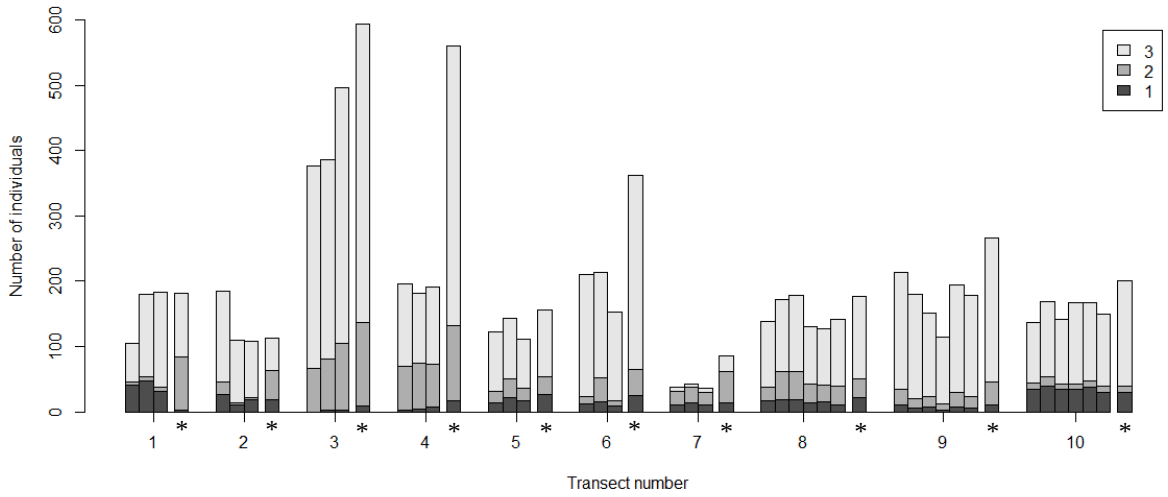

Figure 3.9: Plot of total number of individuals found in each transect. Each sector within the a transect was marked with different shades of gray as legend describes. * was number of individuals counted in situ, whereas other counts were done by use of video.

Figure 3.9 show the variability within video-counting, and between video and in situ counting within the same transect and/or sector (see appendix G for detailed counts). A Kruskal-Wallis rank sum test was performed to assess the difference in mean number of individuals counted by video and in situ, including all transects. There was no significant difference between the two counting methods (P = 0.437).

The counts were separated into different sectors, as these sectors had mainly different densities. None of the sectors had significant differences between the two counting methods (P = 0.457 - 0.581).

The precision of video counting varied between 4 and 67 individuals for all species combined (table 3.5). For Pacific oyster the precision was between 1 and 31 individuals, for European flat oyster between 1 and 6 individuals, and for Blue mussel between 2 and 61 individuals. There were few transect where the in situ count fell within the video ± SD count, none of which were of only European flat oysters.

Table 3.5: Comparing the mean video count ± standard deviation to in situ count within each transect, divided into species. Green markings meant that in situ count fell within video ± SD.

Transect	All individuals		Pacific oyster		European flat oyster		Blue mussel	
	Video±SD	In situ	Video±SD	In situ	Video±SD	In situ	Video±SD	In situ
1	156±44	181	58±20	90	6±3	16	92±23	75
2	134±44	104	68±20	59	4±4	11	62±26	34
3	419±67	594	225±10	264	1±2	30	193±61	300
4	189±8	560	109±5	296	4±5	52	76±11	212
5	126±16	156	35±21	30	9±6	41	82±10	85
6	192±35	362	69±18	125	2±1	26	121±33	211
7	39±4	86	10±1	9	3±1	11	33±2	66
8	148±22	176	50±7	40	10±5	41	90±21	95
9	172±35	266	66±13	114	4±6	26	102±22	126
10	155±14	201	53±9	53	5±1	22	96±8	126

When comparing the mean number of all individuals counted by video against number of all individuals counted in situ they relate as illustrated in figure 3.10 A. They had a spearman correlation coefficient (r_s) of 0.976, which were significant ($P = 2.2\times10^{-16}$). Transect 3, 4 and 6 had more than 300 individuals counted in situ and appeared to have a large difference between video and in situ counting (figure 3.9). Hence, these transect would possibly impact the results in a negative way. When excluding those transects, the spearman correlation coefficient was reduced ($r_s = 0.964$, $P = 0.003$).

When dividing the total count into species (figure 3.10 B-D) there were found no significant difference between registration methods ($P = 0.347 – 0.437$). Pacific oyster and Blue mussel had both significant correlation coefficients (r_s), 0.903 and 0.948 ($P = 0.001$ and 2.9×10^{-5}). European flat oyster, did not have a significant correlation coefficient (r_s) 0.067 ($P = 0.854$).

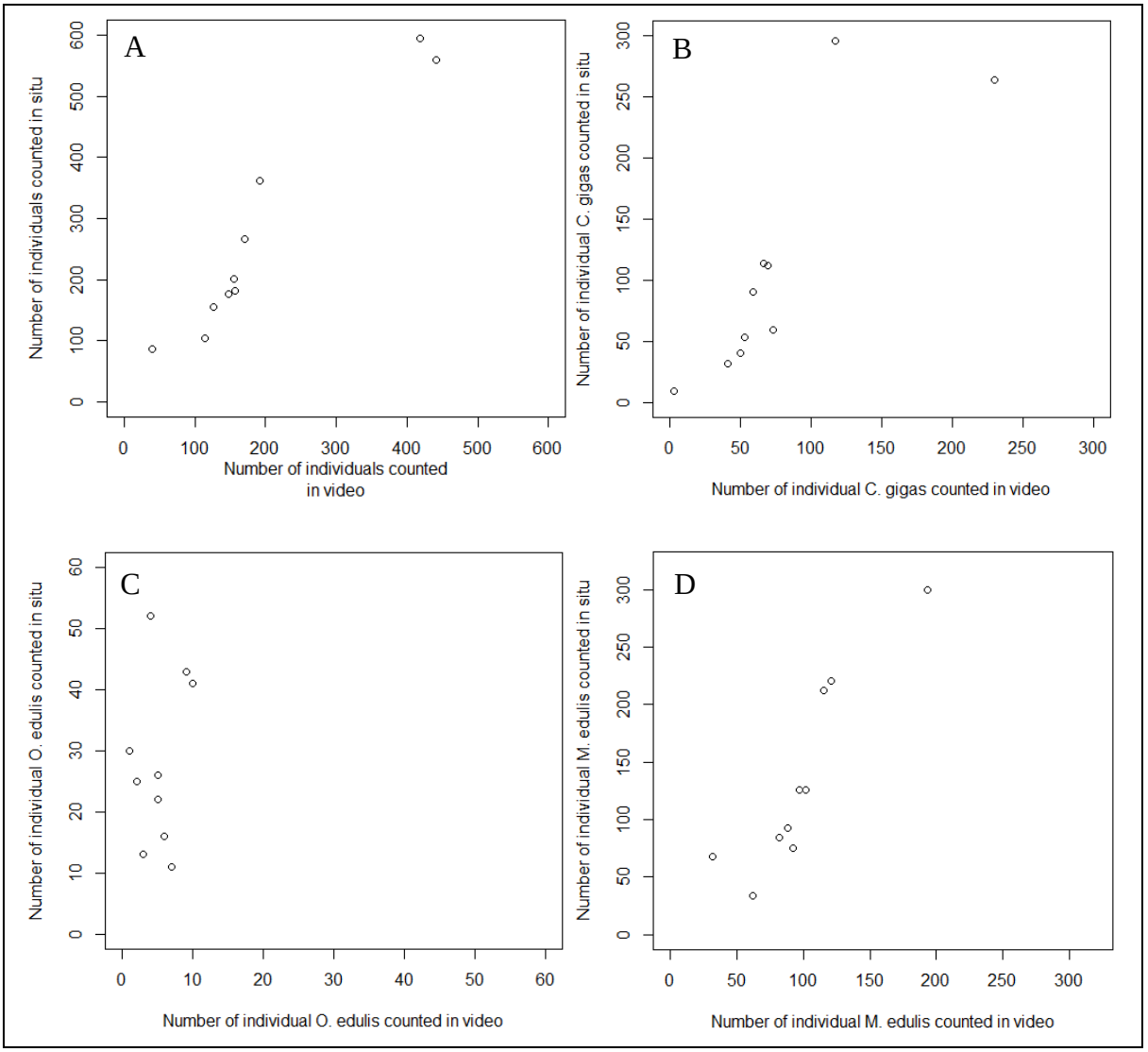

Figure 3.10: Scatterplot of number of individuals counted both in situ and by video, where a point represents a transect, n = 10. A: All individuals, $r_s = 0.976$ and $P = 2.2\times10^{-16}$. B: Pacific oyster, $r_s = 0.903$ and $P = 0.001$. C: European flat oyster, $r_s = 0.067$ and $P = 0.854$. D: Blue mussel, $r_s = 0.948$ and $P = 2.9\times10^{-5}$.

When dividing each transect into the 3 sectors, the pattern in figure 3.11 appears. As also was apparent in figure 3.9, sector 1 had fewer individuals than sector 3, whereas sector 2 was in between. Sector 3 had the highest spearman correlation coefficient ($r_s = 0.830$), which were significant ($P = 0.006$). Sector 1 and 2 had not a significant spearman correlation coefficient ($r_s = 0.333$ and 0.273, $P = 0.349$ and 0.449).

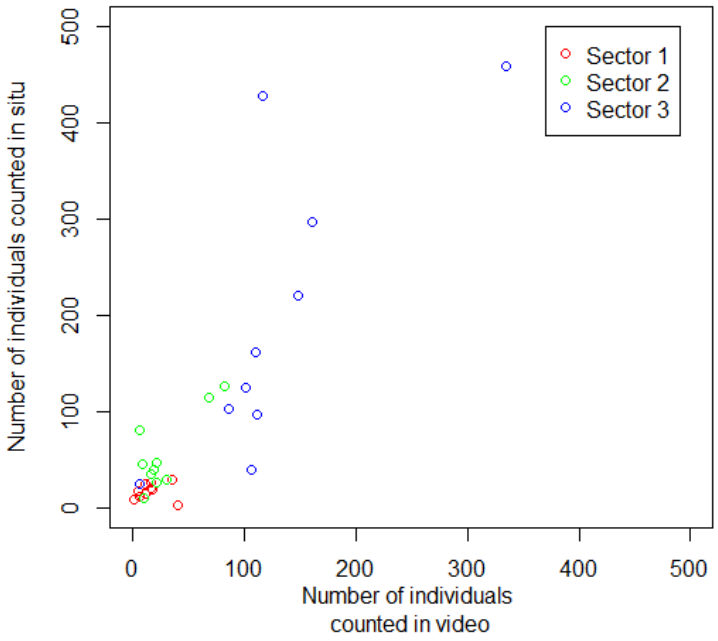

Figure 3.11: Scatterplot of number of individuals counted by video against individuals counted in situ, separated in sectors. Red represent sector 1, green sector 2 and blue sector 3. Sector 1: $r_s = 0.3333$, $P = 0.349$, sector 2: $r_s = 0.2727$, $P = 0.448$ and sector 3: $r_s = 0.8303$, $P = 0.006$.

3.2.2 Living and dead individuals

The total number of individuals was higher in situ regardless of registration as living or dead (table 3.6). When looking further into species count, Pacific oyster registered as dead was the only count higher by video compared to in situ. When assessing differences with a Kruskal-Wallis rank sum test between video and in situ registrations, there were found no significant differences. Both within each species, and in total ($P = 0.353 – 0.850$).

Table 3.6: Number of individuals registered as living or dead, divided into species.

Species	Individuals registered as living		Individuals registered as dead	
	Video	In situ	Video	In situ
Pacific oyster	721	1033	40	36
European flat oyster	30	213	22	66
Blue mussel	471	690	513	649
Total	1295	1937	690	751

3.2.3 Percentage coverage of algae

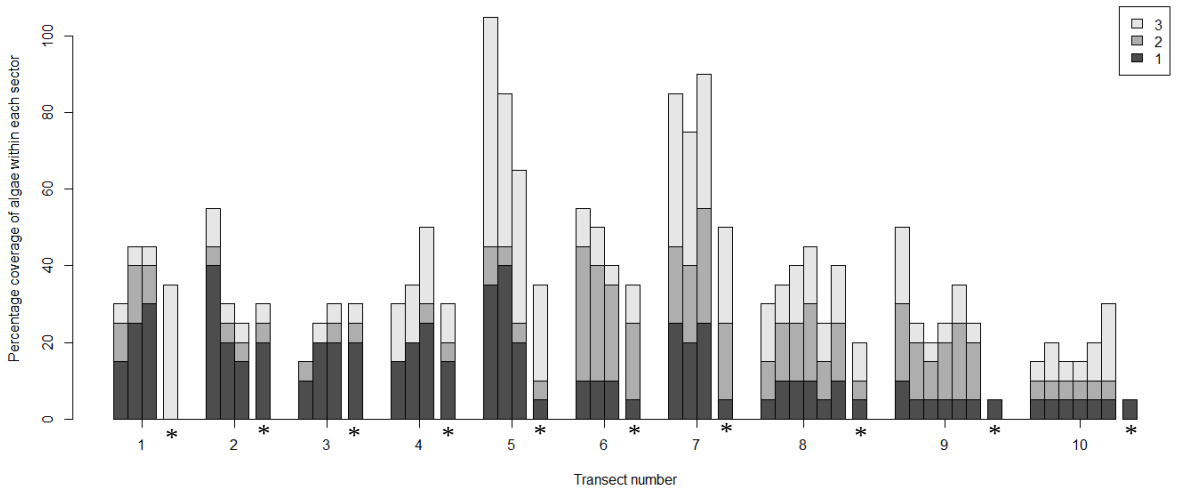

Figure 3.12: Plot of percentage coverage in each transect, divided into three sectors. The sectors were marked with different shades of gray as legend describes. * was percentage coverage registered in situ, whereas other registrations were done from video.

Figure 3.12 show the variability of percentage coverage of algae registered in different transect and within each sector (see appendix G, table A.G2 for more details). There were on average a 5.9 % higher percentage coverage found by video than in situ. A Kruskal-Wallis rank sum test was used to assess differences between the mean percentage coverage found by video and in situ, including all transects. There were found no significant differences (P = 0.120) between the two registration methods. It did not appear from figure 3.12 that the percentage coverage varied consistently between sectors. When comparing registration methods within the three sectors, there were found no significant differences (P = 0.136 - 0.212).

The mean percentage coverage of algae registered by video was plotted against the percentage coverage of algae registered in situ in figure 3.13. The two registration methods had a spearman correlation coefficient (r_s) of 0.8789, which were significant (P = 0.001).

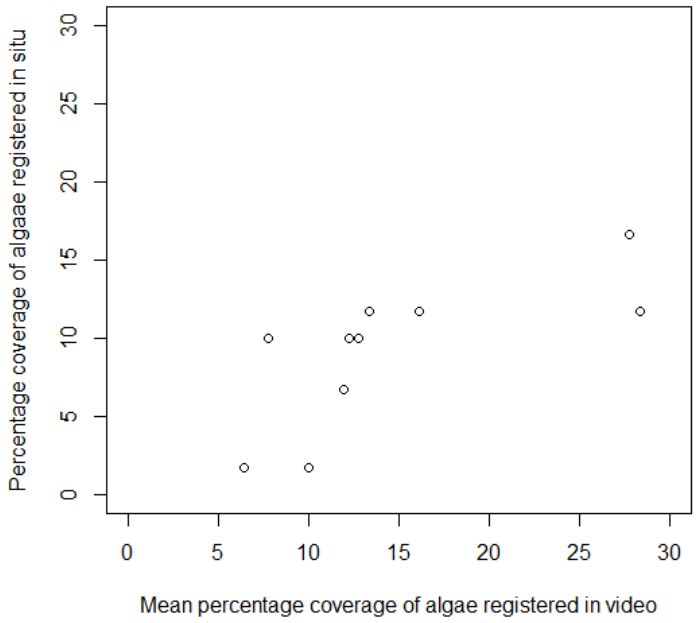

Figure 3.13: Scatterplot of mean percentage coverage registered in video against percentage coverage registered in situ. r_s = 0.8789 (P = 0.001). The points represent transects, n=10.

3.3 Analyzing time

The average time used to analyze one photo/video is summarized in table 3.7. The time used to analyze each frame took on average 1.47 minutes longer in situ than by use of photos. The extra work prior to analyzing in the photoframe method was turning the camera on and take a picture of an identification note. This took about 10 seconds. When taking this into account, photo analyzing was still faster. The in situ analyzing time in the videosleigh method took 28.17 minutes longer than video analyzing. As this method did not have an equivalent method with manual counting, the work prior to analyzing would be the same for the actual use and when testing the method. With a speed of about 0.2 m/s and a transect line of 15 m, a transect took 75 s to film. The time spent of filming was and will be affected by drag speed, transect length and number of replicates wanted.

Table 3.7: An overview of the average time used to analyze one photo and one video (one video equals one trip within one transect).

Analyzing place	**Average time used (minutes) per photo**	**Average time used (minutes) per video**
Photo/Video	6.74	18.33
In situ	8.23	46.50

The differences in analyzing time between photo/video and in situ registrations, was in both methods not significantly different from each other (P = 0.051 and 0.375), see appendix H for detailed time spent of each photo and video.

4. Discussion

4.1 Photoframe method

Comparing counting done by photo against in situ counting within the investigation area was one of the aims of the photoframe method. Since the photoframe method was to be compared to in situ registrations, the in situ registrations were treated as the correct number of individuals. In situ registrations may also contain errors. There were not done an investigation on how well in situ counting was in the photoframe method. In situ counting within frames was the traditional method (Strand et al., 2012) used for surveying species similar the target species in this experiment. This traditional quadrant method has been used for several years and counting of individuals in this method has been treated as the correct number of individuals within an investigation area. When counting within a fixed frame, each individual counted could be physically removed from the investigation area. Ensuring that the risk for overlooking an individual or counting an individual twice was minimized. The in situ count in the photoframe method was therefore treated as the correct number of individuals.

4.1.1 Estimating number of individuals

The photoframe method detected 88.69 % of all individuals registered in situ (table 3.1). As this method had not been tested before, it was difficult to interpret if this was a high or low number of individuals. A study of still photos was done in Australia for analyzing down to benthic group, but they did not classify down to species. They found that out of 9000 photos, only 0.52 % of points analyzed could not be classified (Waddington et al., 2010). Compared to this study, the detection level from the photoframe method was low. This study show how accurate photo estimation can be. Individuals were not classified down to species, making classification easier. This may have affected the difference found in detection level. When comparing the detection level with a study who used towed video and similar target species (Thorngren et al., 2017), the conclusion was that a detection level of about 80 % was satisfying. Compared to this study, the detection level in the photoframe method was adequate.

A study on differences between resolution used when analyzing a photo from a photoquadrat found that the highest resolution (100 points) was necessary to be comparable to divers observations (Rein et al., 2011). In this method all individuals seen was counted, not a certain number of random points. This meant that resolution was as high as possible, and as Rein et al. (2011) found, this was comparable to divers observations, in this case the in situ counts. They found that taxa registered was still higher in diver observations. If number of taxa could be compared to number of individuals, these findings indicate that divers would observer more

individuals compared to photo registrations. In this experiment there were in general and in total found more individuals in situ compared to photo registrations.

When testing the hypothesis H_1 posed in the introduction for all species combined, there were found a significant difference. The H_1 hypothesis could not be rejected. This significance could have been caused by large differences in some frames (see appendix B for more details of counts within individual frames), which had a large impact on the results. When removing frames with two or less individuals there were not found a significant difference. An error in frames with very few individuals would result in a high percentage difference, hence affecting the results greatly. When using this method in the future these results indicated that frames with few individuals were especially important to analyze thoroughly.

Regardless of the significant difference between counting method, there were found a significant spearman correlation coefficient. Which meant that the two counting methods varied in the same matter. This indicated that number of individuals seen in situ reflected the number of individuals seen in photo. From these results remote counting seemed to work. An interesting result was that excluding frames with two or less individuals reduced the spearman correlation coefficient. Of the frames with two or less number of individuals, only one was different in photo and in situ (see appendix B). This gave a higher spearman correlation coefficient.

Blue mussel

If using a detection level of 80 % as adequate, the photoframe method detected the Blue mussel satisfying. Even though the Blue mussel had a high percentage detection level, there were a significant difference between counting method. Meaning that the H_1 could not be rejected. As discussed earlier, frames with high percentage differences affects the results greatly, and when looking at Blue mussels, there were five frames with a difference of 50 percent or higher (see appendix C for more detailed count within each frame). As for all species combined, there were also found a significant spearman correlation coefficient for Blue mussels.

Pacific oyster

The detection level of Pacific oyster was 105.24 % by photo, meaning that the Pacific oyster was overestimated by 5.24 %. When testing the H_1, there were found a significant difference and the H_1 could not be rejected. The Pacific oyster had a significant spearman correlation coefficient, however lower than for all species combined.

European flat oyster

The detection level of European flat oysters was lower than the total percentage of all individuals (45.45 %). Since the detection level was halved, and lower than the satisfying level, the detection level for European flat oysters was defined as low. Despite this low percentage found, there were not a significant difference between counting method. H_1 could be rejected and the corresponding null-hypothesis was accepted. In addition, the spearman correlation coefficient was significant. As was apparent from figure 3.1 D, this was not a perfect 1:1 relationship. Meaning that the two counts vary in the same matter, where the in situ counts always was much higher than photo counts. As discussed earlier, the cause of the differences found in Blue mussel and Pacific oyster was probably caused by frames with large percentage differences. It was reasonably to believe that large percentage differences between counting methods was not present here. Detailed counts within each frame revealed several frames with large percentage differences between counting method (see appendix C for more details). The absence of large percentage errors was not causing the lack of significance in European flat oyster count. Since there were large variations between counting methods and a generally low detection level, there might be issues with the statistical testing. Number of frames contained European flat oyster was only 11. A small sample number may cause that an actual significant difference present was not found. Hence, the rejecting of H_1 may be incorrect. This was reasonably to believe as the detection level was low, and that large errors between counting methods was present. It did not seem that European flat oysters were accurately counted by photo regardless of significance level found.

In this experiment there were found relatively few European flat oysters compared to Pacific oysters. Knowing Pacific oysters preferring European flat oysters as substrate, Pacific oysters were probably growing onto many European flat oysters. Shadowing them and making them more difficult to spot. When counting in situ, it was possible to lift clusters up and examine them closer. Thereby avoiding the effects of shadowing. Another explanation for the high number of Pacific oysters and low number of European flat oysters was misclassification of individuals into different species. Misclassification might explain some of the large underestimate of European flat oyster and the overestimation of Pacific oyster (Bodvin, 2011). The possible errors from misclassification was explored in more details beneath.

Misclassification of species

Summarized counts from the photoframe method were shown in table 3.1, where it became clear that only counts of Pacific oysters were estimated higher by photo than in situ. Of the

three different target species counted, Blue mussels was easily identified. Blue mussels was both different in shape and color compared to Pacific oyster and European flat oyster (Goulletquer, 2004; Nehring, 2011). Pacific oyster and European flat oyster was more alike. These two species are separated morphological by their shape (length/width ratio), thickness and smooth/sharp edges (Bodvin, 2011; Nehring, 2011). From a two-dimensional image from above, its mainly the morphological characteristics of shape who was apparent. The Pacific oyster however, has a very variable shape, and can have a similar length/width ratio as the European flat oyster (Nehring, 2011). This similarity would make misclassification possible. Misclassification can to some degree explain how European flat oysters were greatly underestimated, while the Pacific oyster were overestimated, as some European flat oysters were registered as Pacific oysters. Misclassification cannot be the only explanation, since the over- and underestimate was not equal.

A survey on rocky shores by Pech et al. (2004) who used photos for estimating percentage coverage of Blue mussels and other species, found that 37 % of photos included objects with diffuse boundaries. This lead to misclassification, and to inaccurate estimation of percentage coverage. Since morphological differences was used to classify oysters into European flat oyster and Pacific oyster, diffuse boundaries would make this more difficult. Diffuse boundaries could lead to misclassification and good image quality was very important to minimize this. To know which degree misclassification had occurred, one need to ensure that all individuals were observed and registered to exclude missed individuals.

4.1.2 Estimating individual size

The frequency plots (figure 3.2) show that length and width measurements appeared either slighter smaller or slightly bigger by photo compared to in situ. This difference appeared to be different for each species. Where Pacific oyster and Blue mussels appeared slightly smaller by photo, and the European flat oyster appeared slightly bigger. Since this appears as a continuous issue within a species, there might be a problem with the scale used for measuring in photo. The calibration of length was set by using the frame as the reference length (50 cm). Since bivalve species grow onto each other, a number of individuals may therefore be in a plane closer to the camera than the reference length. This would make some individuals appearing bigger by photo than in situ. Since Pacific oyster and Blue mussels appeared smaller, this indicated that other error sources were present. Bivalve species often exhibit different orientations, which affects whether an individual appeared smaller or bigger by photo. Other error sources which may affect individuals differently was diffuse boundaries and pixel resolution. Diffuse

boundaries may affect both the accuracy and precision of measuring, as size estimation involved measuring between boundaries. If these boundaries were inaccurate, the measurements would also be inaccurate. Meaning that diffuse boundaries may give a lower precision, as there would be a larger spread of length and width measurements done by photo. This was not tested in this experiment, as only one camera type was used and no comparisons between photo analyzation was done. Diffuse boundaries may also affect the accuracy by making photo measurements different from the true values measured in situ. The existence of diffuse boundaries may be caused by pixel resolution used. A low number of pixels would affect the accuracy and precision in a negative manner. However, the lowest pixel number necessary for accurate measuring need to be studied by comparing different pixel resolutions. In this experiment there were used a GoPro Hero 3 camera, with 11 MP (megapixels). These error sources could all cause difference in length and width measurements at individual level. To which extent has not been investigated further here.

The frequency diagrams (figure 3.2) was plotted to asses if cohorts could be detected by photo. Detection of cohorts would give information if a population reproduces. How often it reproduces and size of new cohorts. It did not seem that both length and width measurements done by photo reflected the cohorts found from the measurements done in situ. If errors in measuring was caused by errors in scale or any other consistent error, the cohorts would still be visible from a frequency diagram. This was not the case. Meaning that error sources not affecting all individuals consistently was present and affected the results greatly. Such that length and width measurements by photo could not be used to assess cohorts. Error sources like this was explored in detail above.

The two frames who had a significant difference (no. 34 and 36), and where H_2 could not be rejected, were the two frames with the highest count of individuals. They were only different regarding width measurements, but the high densities were most likely the cause. Especially Pacific oysters tend to grow onto and into each other at high densities (Dolmer et al., 2014). This would make some individuals partly covered and measuring not possible from a fixed angel. In addition, measuring from a fixed angle may cause errors when measuring bivalve species in different orientations. Because the apparent length and width was depended on angle. Measuring of marine species from photos has earlier mainly been done on different fish species, often with automated programs.

A study who tested how well fish length could be automatic measured, measured the length of a fish manually and then 100 times by an automatic program while altering the fish's position

relative to the camera. They found that a fish of 413 mm length had a high precision, a standard deviation of 1.2 mm (White et al., 2006). From the regression line (1) found in this experiment, an individual with a length of 413 mm would be measured as 463 mm. A difference of 50 mm was considerable higher compared to the standard deviation found when measuring this fish. Meaning that measuring of bivalve species was not as precise as measuring of fish. White et al. (2006) measured one fish against a monochrome background to highlight its shape. Measuring in this experiment included high densities, individuals at different orientations and variable background. Not surprisingly was the precision higher in this experiment.

A study done on assessing differences between camera type, illumination and position was done regarding measuring of fish. In this testing the errors that occurred lied between 0.74 % and 3.68 % (Shafry et al., 2011). A similar test was also done by Man et al. (2016), here the errors lied between 0.74 % and 6.03 %. In the experiment here, it was not possible to compare measurements done by photo and in situ at individual level. This would have involved marking of individuals in the field and make unbiased counting impossible. A group of measurements (a frame) were therefore compared, and individual error percentage was not found. When using the regression lines to assess differences in length and width measured by photo and in situ there were found a higher percentage difference as the length and width increased. The largest length measured was 14.5 cm. Using the regression line (1), this resulted in an error of about 10 %. This was higher than both Shafry et al. (2011) and Man et al. (2016). The largest width measured was 15 cm, resulting in an error of 11 % when using the width regression line (2). As was the case for the study done by White et al. (2006) , these studies was also done in an artificial environment where factors as background and overlapping individuals was not present.

To find these regression lines, a linear model on length and width measurements was done. So that length and width measured in photo could be converted into the corresponding length and width measured in situ. When these methods are used in the future, in situ length and width would not be known. Possibilities for converting photo measurements to in situ may be advantageous when comparing results to earlier studies. The model found that individuals appeared bigger in photo than in situ. Regression lines, (1) and (2), was found for all species to see if length and width measuring was possible. Both regression lines were significant, and in general it seemed like individuals could be measured by photo. It is necessary to divide into individual species. Regression lines for individual species were found, (3) - (8), not all were significant. Regression lines found to be not significant, did not satisfyingly correct for the

variability within the data. This include length measurements of European flat oysters and width measurements of Blue mussels. The regression line for length measurements of European flat oyster explained 40 % of the variability. Lindegarth et al. (2014) argues that 40 % explanation of the variability was a satisfying level in a management context. Meaning that this model may be used in a management context regardless of the lack of significance. The regression line for width measurements of Blue mussels, explained only 0.06 % of the variability and could not be argued for use in a management context. The regression line for length measurements of Blue mussels were found to be significant. Only 17 % of the variability could be described. This model did not seem appropriate even in a management context regardless of the significance of the model. These models correct for errors occurred during measuring by photo. If variables as camera, computer program, distance to the seabed, etc. changes, a calibration routine should be included.

An assessment of how number of individuals measured (n) affected the results were done. There were found that differences between 1-30% in n resulted in a significant difference in both length and width measurements. In the width measurements this category contained frame no. 34 and 36, which had a significant width measurement. These frames were also the two frames with the highest counts of individuals.

From these results it seems that high densities make measuring difficult. And that measuring of individuals was not significantly impacted by differences in individuals (n) measured by photo and in situ. At lower densities both Pacific oyster and European flat oyster was measured accurately, while Blue mussels were not. These species tend to form clusters in soft-bottom habitats, as they need a hard substratum to attach themselves to. Density (shells/m^2) is not the whole picture, as a frame with few individuals could gave all individuals in a cluster.

4.1.3 Classification of individuals as dead or alive

When assessing differences between registration methods regarding vital status, there were found a significant difference in all categories except dead Blue mussels. This meant that for all but dead Blue mussels the H_3 could not be rejected. A survey of European flat oyster in Kosterhavet also categorized individuals as living or dead, and found the results easier to fit to a model for abundance estimation when including both living and dead individuals found (Lindegarth et al., 2014). This meant that they also found this categorization into living or dead as difficult, even though they did not comment this further in their report. It was clear that classification of individuals has been proven difficult. This was not a surprise, as it often requires inspection from several angles. This was not possible when analyzing by photo, where

individuals was only visible from one fixed angle. The photoframe method seemed to be unsuitable for classification Pacific oyster, European flat oyster and Blue mussel as living or dead.

4.1.4 Estimating percentage coverage of macroalgae

Coverage of macroalgae was determined to the nearest five percent and was rounded up. When assessing differences in registration methods, there were found no significant differences. The mean difference was only 4 %, however looking at figure 3.8 it was apparent that this difference varied between 0 and 10 % without consistency. The majority of photos containing macroalgae had only small amounts, between 5 and 10 %. As the coverage was determined to the nearest five percent, a little difference in judgement when analyzing photos could make this little difference big, since the only available category was 5 or 10 %. It was possible that the results would correlate better with use of a finer scale, especially when the coverage was low.

There have been developed automated systems detecting coverage of coral reefs with use of still photos from video. Recognitions rates was ranging between 60 and 77 % (Marcos et al., 2008). On average 60 % of macroalgae was detected in the photoframe method. This was a similar detection level as Marcos et al. (2008) found. They concluded that a detection level of 90 % was sufficiently. Meaning that both studies did not registered percentage coverage sufficiently. A study comparing manual against automatic detection of bacterial mat coverage was done by Aguzzi et al. (2011). When they compared the two detection methods there were found a pearson correlation coefficient of 0.67, which they concluded to be high. When comparing the registration methods in this experiment, there were found a spearman correlation coefficient of 0.452. Compared to the study done by Aguzzi et al. (2011), the photoframe method had a low correlation coefficient. Another study, done by Šaškov et al. (2015), also tested automatic detection of benthic coverage. They found a standard deviation of 1.5 % and 5.3 % for the two species studied. There were also found a tendency of a higher standard deviation as the benthic coverage increased. They concluded that this level was at an acceptable level. Mean difference on percentage coverage was in this experiment found to be 4 %. This value was between the standard deviations found acceptable by Šaškov et al. (2015).

The results regarding percentage coverage of macroalgae were inconclusive. The H_4 hypothesis could be rejected. There were not found a significant spearman correlation coefficient, and the results did not seem to be related.

4.2 Videosleigh method

Comparing counting done in video against the correct number of individuals within the investigation area was one of the investigation aims. Since the videosleigh method was to be compared to in situ registrations, the in situ registrations were treated as the correct number of individuals present within the investigation area. Errors could of course occur here as well. When testing the videosleigh method there were in one case over 600 individuals over an area of 7.5 square meters (80 individuals/m^2). It was possible that an individual was easily missed, and that different observers would miss different individuals. To investigate the precision of in situ counting in the videosleigh method, transect 5, 6 and 7 was counted manually in situ by two different skin divers. There were differences in number of individuals counted. These were not significant different from each other (for more details around individual counts between observers see appendix G). Meaning that precision within in situ counting sufficient. A Swedish research team tested the videosleigh method last year, where they also tested how different observers affected the number of individuals counted in situ. They also found that there were no significant differences between different observers (Thorngren et al., 2017). Even though there were only three transect compared to each other in this experiment, and the lack of significance could be caused by a small sample number. The Swedish results support the use of the in situ counting as the correct number of individuals.

4.2.1 Estimating number of individuals

The videosleigh method had a detection level of 64.38 %, including all species. A study on use of the videosleigh method regarding European flat oysters found a detection level of about 80 % (Thorngren et al., 2017). Using this as a standard, the videosleigh method had a low detection level. In the study by Thorngren et al. (2017) there were a maximum density of only 12.5 individuals/m^2, compared to the maximum of 80 individuals/m^2 in this experiment. When the density increases, especially Pacific oyster grow onto each other, making both accurate and precise counting more difficult.

The precision of video counting was found in table 3.5. Here the three or six videos from each transect were used to find the mean and standard deviation. The standard deviation was ranging between 1 and 67 number of individuals. Only a few times did the in situ count fell within the video ± SD count. From these results it did not seem like video-counting was accurate.

Since that same transect were filmed and counted three or six times, while only once in situ, the mean of video counts was compared to the single in situ count to test the H_5 hypothesis. There were not found a significant difference. The H_5 hypothesis could be rejected and the

corresponding null-hypothesis accepted. When looking at detection level, high densities was possibly causing the difference in detection level between this and the study by Thorngren et al. (2017). Testing the difference between counting methods at different densities, there were not found any significant differences at either low or high densities. As density was not an apparent cause for errors in counting, high density could not explain the difference in detection level. This means that the videosleigh method had a low detection level and could still estimate number of individuals by video.

When assessing correlation, there were found a significant spearman correlation coefficient. Which meant that the two counting methods varied in the same matter. This indicated that number of individuals seen in situ reflected the number of individuals seen in video. From these results, remote counting seemed to work. A significant correlation coefficient was also found in a similar study on towed video for registration of Queen Conch (*Lobatus gigas*) (Boman et al., 2016). Supporting that counting in video reflect the actual number of individuals present within an investigation area.

From statistical testing the videosleigh method did seem to accurately estimate number of individuals by video. From description statistics, detection level, mean and standard deviation it did not. This could mean that the difference between counting was in some way consistently, as also was apparent from figure 3.10. And this consistent error was large enough for the in situ count to fell outside the range of counts done by video.

Blue mussel

If using a detection level of about 80 % as a satisfying level, the detection of Blue mussel was slightly lower, about 70 %. Even though this was lower than what was found satisfying in the Swedish study (Thorngren et al., 2017), it was higher than the total detection level for all species in the videosleigh method. Indicating that within the videosleigh method, Blue mussels had a high detection level. When assessing differences between photo and in situ registrations, there was not found a significant difference and the H_5 for Blue mussel could be rejected. In addition, the spearman correlation coefficient was significant, further supporting that Blue mussels could be accurately counted in video. From table 3.5, 3 out of 10 counts in situ fell within the video ± SD estimation.

Pacific oyster

The Pacific oyster was underestimated by 31.24 %, having a detection level slightly higher than the total detection level for all species. As was the case for Blue mussels, it seemed that within the videosleigh method the detection of Pacific oyster sufficient. The H_5 hypothesis could also

be rejected regarding Pacific oysters, in addition to a significant spearman correlation coefficient. These results support that Pacific oysters could accurately be counted in video. In situ counts of four transect fell within the estimated number of individuals by photo. Meaning that an consistent error in Pacific oyster was not as great as it probably are in total.

European flat oyster

When focusing on European flat oysters, the detection level was only at 17.65 %, an underestimate of 82.35 %. The H_5 hypothesis could still be rejected. The underestimation percentage was at about the same level as the detection percentage found in the Swedish survey (Thorngren et al., 2017). Meaning that the results in this experiment was very low. Thorngren et al. (2017) conducted the study well below the lowest water mark. There was none or few other bivalve species within the investigation area. In this experiment the investigation area was both beneath and above the lowest water mark, and a great number of Pacific oysters and Blue mussels was present. Knowing Pacific oysters prefer European flat oysters as substrate, Pacific oysters were probably growing on and covering many European flat oysters. Another explanation for the difference in detection level between Pacific oysters and European flat oyster was misclassification down to species. The possibility of and possible errors from misclassification was explored in more detail beneath.

Misclassification of species

All counts were higher in situ (table 3.4). There was an underestimation of individuals, but not all species were equal underestimated. As explained above for the low detection level of European flat oysters, some may have been difficult to detect since Pacific oysters were growing over them (shadowing). This was most likely not the case in 80 % of the occasions. As mentioned, another source of error was misclassification. Misclassification has been discussed in greater detail earlier regarding the photoframe method. The causes for misclassification was similar in the videosleigh method. To determine to which extent misclassification occurred, it was necessary to ensure that every individual had been counted.

4.2.2 Classification of individuals as dead or alive

The difficulty in categorization of vital status in the photoframe method did not seem to be followed in the videosleigh method. Here there were found no significant differences between registration methods. H_6 could therefore be rejected, and the corresponding null-hypothesis accepted. The Swedish study included categorizes as "probably living" in addition to living and dead. In the category probably living, there was found a large proportion of the individuals who were categorized as living in situ. They concluded to merge the two categorizes as seeing

differences between "living" and "probably living" was difficult to spot in video (Thorngren et al., 2017). When merging the living categories, they found that towed video could accurate categorize individuals as living or dead. Another Swedish survey mentioned in the photoframe method, found categorization based on vital status difficult (Lindegarth et al., 2014). A survey using dragged video on another target species, Queen Conch, found a significant difference between registration methods (Boman et al., 2016). Regardless of difficulties found in other surveys, the videosleigh method seemed to accurately categorize individuals as living or dead.

4.1.3 Estimating percentage coverage of macroalgae

Coverage of macroalgae was determined to the nearest five percent and was rounded up. From figure 3.12, it was apparent that all registrations done by video, estimated the percentage coverage higher than in situ registrations. There were found no significant differences between registrations methods, and H_7 hypothesis could be rejected. In addition, there was found a significant spearman correlation in the videosleigh method. This meant that the two registrations methods varied in the same matter, which also was apparent from figure 3.13.

When transects were assessed for coverage of macroalgae, this was done within the different sectors also used when counting individuals. This meant that each transect was compiled of three coverage values added together. A little difference in judgement would result in five percent difference, as the coverage was determined to nearest five percent. Since three coverage values were added together, errors could equalize each other. In addition, the coverage of macroalgae was generally higher in the videosleigh method, so that a difference of five percent had less impact on the detection level.

There have been developed system automatically detecting coverage of coral reefs with use of still photos from video. Recognitions rates was ranging between 60 and 77 % (Marcos et al., 2008). As mentioned, there were registered a higher percentage coverage by video, and the detection level of macroalgae was therefore 215 %. Meaning the registration by video found twice the coverage found in situ. Marcos et al. (2008) found a detection level between 60 and 77 %. They concluded that a detection level of 90 % was the sufficient level. A detection level of 90 % means a difference of 10 % from 100 %. In this experiment the detection level was higher. The difference from 100 % exceeded 10 %. Percentage macroalgae was therefore too greatly overestimated by video. A study comparing manual against automatic detection of bacterial mat coverage was done by Aguzzi et al. (2011). When they compared the two detection methods there were found a pearson correlation coefficient of 0.67, which they concluded as being high. The spearman correlation coefficient (0.879) in this experiment can therefore be

concluded to be high. Another study also testing automatic detection of benthic coverage, found a standard deviation of 1.5 % and 5.3 % for the two species studied. They found a tendency of a higher standard deviation as the benthic coverage increased. The conclusion was that this level was at an acceptable level (Šaškov et al., 2015). In this experiment the mean percentage difference was 5.9 %, slightly higher than what Šaškov et al. (2015) found to be acceptable.

4.3 Analyzing time

Both remote analyzing in the photoframe and the videosleigh method was faster than in situ analysis, but not significantly different. Even though the analyzing still took some time, the analyzing site was moved away from in situ, into a lab/office etc. This movement would save cost regarding personnel and equipment out in the field.

A transect of 15 meters covered an area of 7.5 m^2, this was the same area covered by 30 frames (0.25 m^2 x 30 = 7.5 m^2). Average analyzing time per photo was 6.74 minutes, 30 photos would therefore take 202.2 minutes to analyze. The videosleigh method analyzed the same area in 18.33 minutes (on average), a clearly time effective method when looking at square meters covered. Keeping in mind that the videosleigh method did not estimate size of individuals seen. In the photoframe method, the covered area could be spread out over a larger area.

A study done by Pech et al. (2004) compared manual against photo percentage coverage of different species, including Blue mussel. They commented that in situ registration was time consuming, and registration in photo was time saving out in the field. Another study who compared in situ against photo registrations found that analyzing by photo was twice as efficiently as in situ analyzing (Preskitt et al., 2004). Supporting the results as both photo and video analysis as time and cost-effective analyzation methods.

5. Conclusion

The biology of the three target-species who were counted affected the results. Both counting and measuring in the photoframe method and counting in the videosleigh method. This was apparent through underestimation caused by individuals growing onto each other, misclassification of species and orientation making measuring either inaccurate or not possible.

Statistical testing supports the use of both methods for estimating number of individuals by photo/video. The photoframe method had a higher detection level than the videosleigh method. Estimating size in the photoframe method was possible for all three target-species combined, and for Pacific oyster and European flat oyster separate. Detecting cohorts by photo was not possible for either species. The orientation relative to the camera was probably causing the difference found for measuring of Blue mussels. Only the videosleigh method could categorize individuals based on vital status accurately. The percentage coverage of macroalgae were low in the photoframe method, and a coarse scale was affecting the results here. Making the photoframe method not able to estimate the coverage accurately. The videosleigh method was not affected by this and could estimate the percentage coverage. The less time spent analyzing by photo/video than in situ was not significantly different, but it was time-effective in the field as the analyzation was moved and done later. This time saving in the field would also make the methods cost-effective. The videosleigh method could cover an investigation area faster than the photoframe method, keeping in mind that video was not used for size estimation.

The photoframe method may be used as a surveying tool for estimating number of individuals and estimating size of Pacific oyster and European flat oyster. The videosleigh method may be used as a surveying tool for estimating number of Pacific oyster and Blue mussel, categorize species as living or dead and estimate percentage coverage of macroalgae. Depending on the research question and aim, both methods may be used in the future where both has its advantages and disadvantages. For a systematic survey on soft-bottom habitats, a combination of the methods as they are now may be advantageous.

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APPENDIX A: CONSTRUCTION OF VIDEOSLEIGH

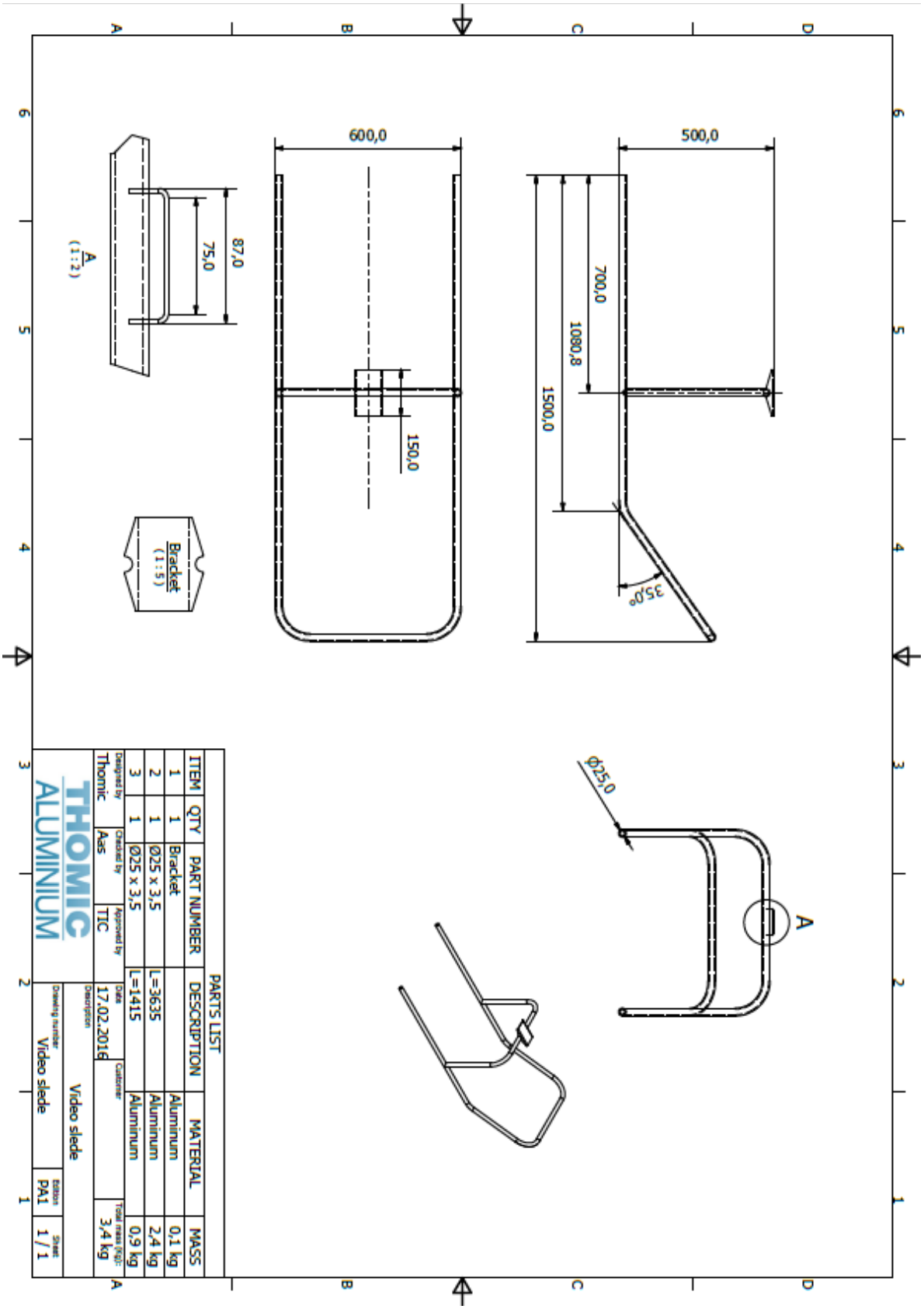

Figure A.A: Detailed drawing of the videosleigh construction. Used for making the videosleigh.

APPENDIX B: COUNTS WITHIN EACH FRAME

Table A.B: Number of individuals counted within each frame, both counted in photo and in situ.

Frame number	Number of individuals counted in photo	Number of individuals counted in situ
1	1	1
2	4	3
3	3	3
4	5	5
5	1	1
6	4	4
7	7	8
8	7	7
9	1	1
10	3	3
11	6	7
12	4	5
13	1	1
14	2	2
15	2	2
16	1	1
17	4	5
18	8	6
19	4	4
20	1	1
21	5	4
22	2	2
23	2	2
24	4	9
25	5	6
26	14	21
27	11	19
28	8	10
29	1	2
30	4	5
31	26	26
32	33	42
33	30	30
34	49	53
35	40	44
36	60	64

APPENDIX C: COUNTS AND COVERAGE WITHIN EACH FRAME, DEVIDED INTO SPECIES

Table A.C: Number of individuals counted/percentage coverage within each frame. Divided into counting method, photo and in situ, and into species, Pacific oyster, European flat oyster, Blue mussel and macroalgae.

Frame number	Pacific oyster		European flat oyster		Blue mussel		Macroalgae (%)	
	Photo	In situ	Photo	In situ	Photo	In situ	Photo	In situ
1	1	1	0	0	0	0	0	0
2	1	0	1	1	1	1	5	10
3	1	2	0	0	2	1	0	0
4	0	0	0	0	4	4	10	10
5	0	0	0	0	1	1	0	0
6	0	0	0	0	4	4	0	0
7	5	4	0	2	1	2	0	0
8	0	0	0	1	6	6	0	0
9	1	1	0	0	0	0	0	0
10	3	3	0	0	0	0	0	0
11	3	4	1	0	1	2	10	10
12	3	3	1	2	0	0	0	0
13	1	1	0	0	0	0	0	0
14	1	2	0	0	0	0	5	0
15	0	1	0	0	2	1	0	0
16	1	1	0	0	0	0	0	0
17	2	2	0	0	2	2	0	10
18	5	3	0	0	2	2	5	10
19	2	4	2	0	0	0	0	0
20	1	1	0	0	0	0	0	0
21	3	2	0	0	2	2	0	0
22	1	1	0	0	0	0	5	10
23	1	1	0	0	1	1	0	0
24	2	3	0	0	2	6	0	0
25	2	2	0	0	3	4	0	0
26	0	0	0	0	14	20	0	5
27	0	0	1	0	10	17	0	5
28	2	2	0	0	6	8	0	0
29	0	0	1	1	0	1	0	0
30	2	3	0	0	1	1	50	50
31	20	19	2	4	4	3	0	0
32	21	22	2	13	10	6	0	0
33	19	16	6	8	4	5	10	5
34	40	37	1	8	8	8	0	0
35	34	35	4	7	2	2	0	0
36	43	43	3	7	14	15	0	0

APPENDIX D: ALL LENGTH AND WIDTH MEASUREMENTS

Table A.D: Length and width measurements in cm of every individuals seen by photo and in situ.

Frame	Counting place (photo/in situ)	Species	Length (cm)	Width (cm)
1	Photo	C. gigas	6	5
1	In situ	C. gigas	5.5	4
2	Photo	M.edulis	6	3.5
2	Photo	O.edulis	NA	10
2	Photo	C. gigas	11	NA
2	In situ	O.edulis	11.5	10.5
2	In situ	M.edulis	6.5	3.5
3	Photo	M.edulis	5	3
3	Photo	C. gigas	6	3
3	Photo	M.edulis	4.5	2
3	In situ	C. gigas	6.5	6
3	In situ	C. gigas	6.5	4
3	In situ	M.edulis	5	3
4	Photo	M.edulis	5.5	3
4	Photo	M.edulis	NA	3.5
4	Photo	M.edulis	4	2.5
4	Photo	M.edulis	NA	2.5
4	In situ	M.edulis	5.5	3
4	In situ	M.edulis	6.5	5
4	In situ	M.edulis	6	3.5
4	In situ	M.edulis	9	4.5
5	Photo	M.edulis	8	4
5	In situ	M.edulis	8	4
6	Photo	M.edulis	NA	3.5
6	Photo	M.edulis	NA	2.5
6	Photo	M.edulis	6	3
6	Photo	M.edulis	5.5	3
6	In situ	M.edulis	6	3
6	In situ	M.edulis	4	2.5
6	In situ	M.edulis	5.5	3
6	In situ	M.edulis	6	3.5
7	Photo	M.edulis	NA	4
7	Photo	NA	NA	NA
7	Photo	C. gigas	7	6.5
7	Photo	C. gigas	6.5	3
7	Photo	C. gigas	NA	NA
7	Photo	C. gigas	NA	NA
7	Photo	C. gigas	NA	NA
7	In situ	O.edulis	7.5	7.5
7	In situ	O.edulis	7.5	7
7	In situ	M.edulis	8	4
7	In situ	C. gigas	10.5	7
7	In situ	C. gigas	7	9
7	In situ	C. gigas	7	6.5
7	In situ	M.edulis	4	2.5
7	In situ	C. gigas	10	8.5
8	Photo	M.edulis	7	3.5
8	Photo	M.edulis	6	3
8	Photo	M.edulis	NA	4
8	Photo	M.edulis	4	2.5
8	Photo	M.edulis	4	2
8	Photo	M.edulis	6	3.5
8	Photo	NA	NA	NA
8	In situ	O.edulis	9	7
8	In situ	M.edulis	6	4
8	In situ	M.edulis	7	4
8	In situ	M.edulis	4	2
8	In situ	M.edulis	5	3
8	In situ	M.edulis	2.5	1
8	In situ	M.edulis	7.5	4.5
9	Photo	C. gigas	8	6
9	In situ	C. gigas	8.5	6
10	Photo	C. gigas	10	6.5
10	Photo	C. gigas	7	6.5
10	Photo	C. gigas	8	4
10	In situ	C. gigas	9	7.5
10	In situ	C. gigas	7.5	8
10	In situ	C. gigas	10.5	6.5
11	Photo	C. gigas	NA	6.5
11	Photo	O.edulis	5	5.5
11	Photo	C. gigas	7	4
11	Photo	C. gigas	7	7
11	Photo	M.edulis	5	NA
11	In situ	C. gigas	7.5	5.5
11	In situ	C. gigas	9	7.5
11	In situ	M.edulis	6.5	3.5
11	In situ	C. gigas	8.5	7
11	In situ	M.edulis	5.5	3.5
11	In situ	C. gigas	5.5	3.5
12	Photo	C. gigas	10	7
12	Photo	C. gigas	6	4
12	Photo	C. gigas	8	6.5
12	Photo	O.edulis	4.5	6.5
12	In situ	C. gigas	8	7
12	In situ	C. gigas	9.5	8
12	In situ	O.edulis	6.5	7.5
12	In situ	C. gigas	10.5	9.5
12	In situ	O.edulis	6	6
13	Photo	C. gigas	6.5	4.5
13	In situ	C. gigas	6.5	6.5
14	Photo	C. gigas	6.5	4.5
14	In situ	C. gigas	7	6.5
14	In situ	C. gigas	3	3
15	Photo	M.edulis	NA	4
15	Photo	M.edulis	5.5	2.5
15	In situ	C. gigas	9	6.5
15	In situ	M.edulis	8.5	4
16	Photo	C. gigas	10	9
16	In situ	C. gigas	10	8
17	Photo	M.edulis	7	3
17	Photo	C. gigas	NA	NA
17	Photo	M.edulis	NA	3
17	Photo	C. gigas	7.5	9
17	In situ	C. gigas	8	9

17	In situ	C. gigas	8	6
17	In situ	M.edulis	7	3.5
17	In situ	M.edulis	7	3.5
18	Photo	C. gigas	7.5	6
18	Photo	C. gigas	10.5	6.5
18	Photo	M.edulis	7	4
18	Photo	M.edulis	NA	3
18	Photo	C. gigas	7	4
18	Photo	C. gigas	7	5
18	Photo	C. gigas	5.5	3.5
18	In situ	C. gigas	10.5	6
18	In situ	C. gigas	8.5	6.5
18	In situ	C. gigas	11	7
18	In situ	M.edulis	8	4.5
18	In situ	M.edulis	5	2.5
19	Photo	C. gigas	5.5	5
19	Photo	C. gigas	8	6
19	Photo	O.edulis	7.5	7
19	Photo	O.edulis	6.5	7
19	In situ	C. gigas	9	8
19	In situ	C. gigas	8	9
19	In situ	C. gigas	6.5	5.5
19	In situ	C. gigas	8.5	6.5
20	Photo	C. gigas	8	6
20	In situ	C. gigas	8.5	6.5
21	Photo	M.edulis	6	2.5
21	Photo	C. gigas	8	6.5
21	Photo	C. gigas	9.5	5
21	Photo	C. gigas	NA	NA
21	Photo	M.edulis	NA	NA
21	In situ	C. gigas	11	7
21	In situ	M.edulis	7	4
21	In situ	C. gigas	8.5	6.5
21	In situ	M.edulis	6.5	4
22	Photo	C. gigas	13.5	9
22	In situ	C. gigas	13.5	9.5
23	Photo	C. gigas	6.5	5
23	Photo	M.edulis	6	NA
23	In situ	C. gigas	7	5.5
23	In situ	M.edulis	7	3.5
24	Photo	M.edulis	6	3
24	Photo	M.edulis	6	3.5
24	Photo	C. gigas	NA	8
24	Photo	C. gigas	9	5
24	In situ	C. gigas	7.5	6.5
24	In situ	M.edulis	8	4.5
24	In situ	M.edulis	6	4
24	In situ	M.edulis	6.5	3.5
24	In situ	M.edulis	6	4
24	In situ	M.edulis	7.5	4.5
24	In situ	M.edulis	5	3
24	In situ	C. gigas	7.5	6.5
24	In situ	C. gigas	8.5	7.5
25	Photo	C. gigas	6	5.5
25	Photo	M.edulis	7	3
25	Photo	M.edulis	7	3
25	Photo	C. gigas	7	5.5
25	Photo	M.edulis	5	3.5

25	In situ	C. gigas	8.5	7
25	In situ	C. gigas	8.5	6
25	In situ	M.edulis	7	4
25	In situ	M.edulis	8.5	4.5
25	In situ	M.edulis	6.5	3.5
25	In situ	M.edulis	6.5	4
26	Photo	M.edulis	NA	2.5
26	Photo	M.edulis	NA	2.5
26	Photo	M.edulis	6	NA
26	Photo	M.edulis	NA	3
26	Photo	M.edulis	NA	4
26	Photo	M.edulis	6.5	4.5
26	Photo	M.edulis	NA	3.5
26	Photo	M.edulis	NA	NA
26	Photo	M.edulis	NA	NA
26	Photo	M.edulis	NA	NA
26	Photo	M.edulis	NA	NA
26	Photo	M.edulis	NA	3.5
26	Photo	M.edulis	5	2
26	Photo	M.edulis	5	2.5
26	In situ	M.edulis	7.5	3
26	In situ	M.edulis	4.5	3
26	In situ	M.edulis	8	4
26	In situ	M.edulis	NA	NA
26	In situ	M.edulis	5.5	3.5
26	In situ	M.edulis	6	3.5
26	In situ	M.edulis	6	3.5
26	In situ	M.edulis	5	3
26	In situ	M.edulis	NA	NA
26	In situ	M.edulis	NA	NA
26	In situ	M.edulis	5	3.5
26	In situ	M.edulis	7	4
26	In situ	M.edulis	7.5	4
26	In situ	M.edulis	6.5	4
26	In situ	M.edulis	6	3.5
26	In situ	M.edulis	7	4
26	In situ	M.edulis	6.5	3.5
26	In situ	M.edulis	6	3.5
26	In situ	M.edulis	6	3.5
26	In situ	M.edulis	6.5	3
26	In situ	M.edulis	4.5	3
27	Photo	M.edulis	7.5	NA
27	Photo	M.edulis	NA	3.5
27	Photo	M.edulis	NA	NA
27	Photo	M.edulis	NA	NA
27	Photo	M.edulis	3.5	4.5
27	Photo	M.edulis	NA	2.5
27	Photo	M.edulis	NA	2
27	Photo	M.edulis	4	2
27	Photo	M.edulis	5	2
27	Photo	M.edulis	NA	2
27	Photo	M.edulis	NA	7
27	In situ	O.edulis	6	6.5
27	In situ	M.edulis	6	4
27	In situ	M.edulis	6.5	3.5
27	In situ	M.edulis	6	3.5
27	In situ	M.edulis	4.5	3
27	In situ	M.edulis	7	3.5

27	In situ	M.edulis	5.5	3.5
27	In situ	M.edulis	4	3
27	In situ	M.edulis	7.5	5
27	In situ	M.edulis	4.5	3
27	In situ	M.edulis	6	3
27	In situ	M.edulis	6	3.5
27	In situ	M.edulis	7.5	5
27	In situ	M.edulis	6.5	3.5
27	In situ	M.edulis	7	4
27	In situ	M.edulis	4.5	3
27	In situ	M.edulis	6.5	4
27	In situ	M.edulis	5.5	3
28	Photo	C. gigas	8.5	8
28	Photo	M.edulis	5.5	3
28	Photo	M.edulis	4	1.5
28	Photo	M.edulis	3.5	2.5
28	Photo	M.edulis	7.5	4
28	Photo	C. gigas	7	5
28	Photo	M.edulis	8	3.5
28	Photo	M.edulis	3	2
28	In situ	M.edulis	7	4
28	In situ	M.edulis	8	4.5
28	In situ	C. gigas	9	6
28	In situ	M.edulis	8	4
28	In situ	M.edulis	5.5	3.5
28	In situ	M.edulis	6.5	3.5
28	In situ	M.edulis	5.5	3.5
28	In situ	M.edulis	7	4
28	In situ	C. gigas	9.5	7
28	In situ	M.edulis	6.5	3.5
29	Photo	O.edulis	7	4.5
29	In situ	O.edulis	6	7
29	In situ	M.edulis	8	4.5
30	Photo	C. gigas	9	5.5
30	Photo	C. gigas	7.5	5.5
30	Photo	M.edulis	5	3.5
30	In situ	C. gigas	0	5.5
30	In situ	C. gigas	9	8
30	In situ	M.edulis	7.5	4
30	In situ	C. gigas	7.5	5.5
31	Photo	M.edulis	5.5	3
31	Photo	C. gigas	5	3.5
31	Photo	C. gigas	4	4.5
31	Photo	C. gigas	5.5	4
31	Photo	C. gigas	6	5
31	Photo	C. gigas	7	5
31	Photo	C. gigas	NA	6
31	Photo	C. gigas	9.5	NA
31	Photo	M.edulis	7.5	3.5
31	Photo	C. gigas	6	4
31	Photo	C. gigas	10.5	6
31	Photo	C. gigas	6	4
31	Photo	C. gigas	7.5	4.5
31	Photo	C. gigas	NA	NA
31	Photo	C. gigas	6.5	3.5
31	Photo	M.edulis	6	3
31	Photo	C. gigas	7	4.5
31	Photo	O.edulis	11	10.5
31	Photo	O.edulis	8.5	10
31	Photo	M.edulis	5	NA
31	Photo	C. gigas	6	5
31	Photo	C. gigas	6.5	3.5
31	Photo	C. gigas	6	NA
31	Photo	C. gigas	9	5.5
31	Photo	C. gigas	7.5	5
31	Photo	C. gigas	10.5	6
31	In situ	C. gigas	7	4
31	In situ	M.edulis	5	3
31	In situ	C. gigas	8	7
31	In situ	C. gigas	5.5	4.5
31	In situ	C. gigas	6.5	4.5
31	In situ	C. gigas	6.5	4.5
31	In situ	O.edulis	9.5	10.5
31	In situ	O.edulis	4.5	4
31	In situ	O.edulis	8.5	10.5
31	In situ	C. gigas	11.5	10.5
31	In situ	C. gigas	4.5	5
31	In situ	M.edulis	5.5	2.5
31	In situ	C. gigas	11	9.5
31	In situ	C. gigas	7.5	6
31	In situ	C. gigas	8.5	6.5
31	In situ	C. gigas	9	6.5
31	In situ	O.edulis	10.5	10.5
31	In situ	C. gigas	7	4.5
31	In situ	C. gigas	5.5	4.5
31	In situ	M.edulis	7	4
31	In situ	C. gigas	9	6
31	In situ	C. gigas	8	5.5
31	In situ	C. gigas	7	4
31	In situ	C. gigas	8.5	6
31	In situ	C. gigas	8	7
31	In situ	C. gigas	10.5	6
32	Photo	C. gigas	6	45
32	Photo	C. gigas	8.5	5
32	Photo	C. gigas	5	6
32	Photo	O.edulis	6.5	7
32	Photo	C. gigas	7,5	7
32	Photo	M.edulis	6.5	3.5
32	Photo	M.edulis	6	2.5
32	Photo	O.edulis	6.5	9
32	Photo	M.edulis	6	3.5
32	Photo	M.edulis	7	3.5
32	Photo	C. gigas	NA	NA
32	Photo	C. gigas	7.5	3.5
32	Photo	M.edulis	NA	NA
32	Photo	C. gigas	9	4.5
32	Photo	C. gigas	8	5
32	Photo	C. gigas	6	4.5
32	Photo	M.edulis	NA	NA
32	Photo	C. gigas	NA	6
32	Photo	C. gigas	NA	6
32	Photo	C. gigas	7.5	5
32	Photo	C. gigas	6.5	4.5
32	Photo	M.edulis	6	NA
32	Photo	C. gigas	NA	NA
32	Photo	C. gigas	12.5	7.5

32	Photo	M.edulis	5.5	2
32	Photo	C. gigas	8	4.5
32	Photo	C. gigas	7.5	5.5
32	Photo	C. gigas	7	6
32	Photo	M.edulis	9	NA
32	Photo	C. gigas	NA	5
32	Photo	C. gigas	7.5	4.5
32	Photo	C. gigas	NA	4.5
32	Photo	M.edulis	NA	NA
32	In situ	O.edulis	2	3
32	In situ	C. gigas	7	4.5
32	In situ	C. gigas	7	6.5
32	In situ	C. gigas	11	6
32	In situ	C. gigas	3	4
32	In situ	C. gigas	8.5	6
32	In situ	C. gigas	7	6.5
32	In situ	M.edulis	9.5	4
32	In situ	O.edulis	6.5	6
32	In situ	O.edulis	7.5	8
32	In situ	O.edulis	6.5	7
32	In situ	O.edulis	10	10
32	In situ	M.edulis	5.5	3
32	In situ	C. gigas	7	6
32	In situ	C. gigas	7.5	5.5
32	In situ	C. gigas	7.5	6.5
32	In situ	M.edulis	6.5	3.5
32	In situ	O.edulis	4	4
32	In situ	M.edulis	6.5	4.5
32	In situ	C. gigas	6	4
32	In situ	C. gigas	6.5	5.5
32	In situ	C. gigas	11	6
32	In situ	C. gigas	9.5	8
32	In situ	O.edulis	4	4
32	In situ	C. gigas	9	6
32	In situ	C. gigas	9	6.5
32	In situ	O.edulis	10.5	10.5
32	In situ	O.edulis	8	9.5
32	In situ	O.edulis	1.5	1.5
32	In situ	C. gigas	7	6
32	In situ	C. gigas	7.5	6
32	In situ	M.edulis	6.5	3.5
32	In situ	O.edulis	4	2.5
32	In situ	C. gigas	8	6.5
32	In situ	C. gigas	7.5	6
32	In situ	C. gigas	7.5	6
32	In situ	C. gigas	10.5	6
32	In situ	C. gigas	6.5	6
32	In situ	O.edulis	3.5	4
32	In situ	O.edulis	9.5	6.5
32	In situ	M.edulis	7.5	4
33	Photo	O.edulis	6.5	6.5
33	Photo	O.edulis	NA	9
33	Photo	M.edulis	8.5	3.5
33	Photo	C. gigas	NA	NA
33	Photo	C. gigas	NA	NA
33	Photo	C. gigas	11	5
33	Photo	M.edulis	NA	6.5
33	Photo	C. gigas	10.5	5

33	Photo	C. gigas	10	6
33	Photo	C. gigas	7.5	7
33	Photo	C. gigas	8	6.5
33	Photo	C. gigas	NA	NA
33	Photo	C. gigas	9	6
33	Photo	C. gigas	7.5	3.5
33	Photo	O.edulis	6.5	8.5
33	Photo	M.edulis	7	3
33	Photo	O.edulis	6	7
33	Photo	C. gigas	10	10
33	Photo	C. gigas	NA	8.5
33	Photo	C. gigas	NA	6
33	Photo	C. gigas	8	3.5
33	Photo	C. gigas	9.5	5.5
33	Photo	C. gigas	5	NA
33	Photo	O.edulis	6	6
33	Photo	C. gigas	8.5	4
33	Photo	C. gigas	8.5	5.5
33	Photo	M.edulis	7	3.5
33	Photo	C. gigas	NA	5.5
33	Photo	M.edulis	5	3
33	In situ	O.edulis	7.5	8.5
33	In situ	M.edulis	6	2.5
33	In situ	C. gigas	8	5.5
33	In situ	C. gigas	19	9
33	In situ	O.edulis	9	11
33	In situ	M.edulis	8	4.5
33	In situ	C. gigas	9.5	7
33	In situ	O.edulis	7.5	8
33	In situ	C. gigas	9.5	7
33	In situ	C. gigas	9.5	6.5
33	In situ	C. gigas	8.5	6.5
33	In situ	C. gigas	10	6.5
33	In situ	O.edulis	7.5	7
33	In situ	C. gigas	9	7
33	In situ	O.edulis	7.5	7
33	In situ	M.edulis	7.5	3
33	In situ	C. gigas	8.5	6.5
33	In situ	C. gigas	5.5	3
33	In situ	C. gigas	7	6
33	In situ	C. gigas	8.5	7
33	In situ	O.edulis	7	8.5
33	In situ	M.edulis	8.5	5
33	In situ	C. gigas	12	9
33	In situ	C. gigas	10	8.5
33	In situ	O.edulis	7.5	8
33	In situ	O.edulis	8	8.5
33	In situ	C. gigas	8.5	7.5
33	In situ	C. gigas	8	5.5
33	In situ	M.edulis	8	3.5
34	Photo	C. gigas	11	15
34	Photo	C. gigas	12	5.5
34	Photo	C. gigas	17.5	7.5
34	Photo	O.edulis	8	8
34	Photo	C. gigas	5	3
34	Photo	C. gigas	5	3.5
34	Photo	C. gigas	4	1.5
34	Photo	C. gigas	8	4

34	Photo	C. gigas	7.5	3
34	Photo	C. gigas	NA	NA
34	Photo	C. gigas	9.5	6.5
34	Photo	C. gigas	7	5.5
34	Photo	C. gigas	NA	NA
34	Photo	C. gigas	9.5	4.5
34	Photo	C. gigas	6.5	6
34	Photo	C. gigas	10.5	7
34	Photo	C. gigas	9	5
34	Photo	C. gigas	6	6.5
34	Photo	C. gigas	NA	NA
34	Photo	M.edulis	7	3.5
34	Photo	M.edulis	8	3.5
34	Photo	C. gigas	6.5	3
34	Photo	C. gigas	NA	NA
34	Photo	C. gigas	NA	NA
34	Photo	M.edulis	5	3
34	Photo	C. gigas	11.5	7.5
34	Photo	C. gigas	10	7
34	Photo	C. gigas	10.5	5.5
34	Photo	C. gigas	7	6
34	Photo	C. gigas	NA	4
34	Photo	C. gigas	3.5	2.5
34	Photo	C. gigas	NA	3
34	Photo	C. gigas	4.5	4
34	Photo	C. gigas	5	2.5
34	Photo	C. gigas	7.5	3.5
34	Photo	C. gigas	9	7
34	Photo	C. gigas	7.5	4
34	Photo	M.edulis	5	4
34	Photo	M.edulis	6	2.5
34	Photo	M.edulis	5	3
34	Photo	M.edulis	4.5	2
34	Photo	C. gigas	4.5	3
34	Photo	C. gigas	7.5	5.5
34	Photo	C. gigas	7.5	6
34	Photo	M.edulis	7	NA
34	Photo	C. gigas	10	6.5
34	Photo	C. gigas	7.5	6.5
34	Photo	C. gigas	6.5	5.5
34	Photo	C. gigas	6	7
34	In situ	C. gigas	16	10.5
34	In situ	C. gigas	11	7
34	In situ	C. gigas	7.5	7
34	In situ	O.edulis	8	8
34	In situ	C. gigas	10	7
34	In situ	C. gigas	9	6
34	In situ	C. gigas	12.5	6.5
34	In situ	C. gigas	8	5.5
34	In situ	C. gigas	8	6
34	In situ	O.edulis	7	7.5
34	In situ	O.edulis	7.5	7
34	In situ	C. gigas	6	5.5
34	In situ	C. gigas	10.5	6.5
34	In situ	C. gigas	8.5	8
34	In situ	C. gigas	8	7
34	In situ	C. gigas	8	6
34	In situ	C. gigas	9	6.5
34	In situ	C. gigas	6	4.5
34	In situ	C. gigas	7	5
34	In situ	C. gigas	9	7
34	In situ	O.edulis	6	7.5
34	In situ	M.edulis	8	4
34	In situ	O.edulis	8	7.5
34	In situ	C. gigas	8	6
34	In situ	C. gigas	7	6
34	In situ	O.edulis	6.5	7.5
34	In situ	C. gigas	8	7
34	In situ	C. gigas	8	6.5
34	In situ	C. gigas	8.5	6.5
34	In situ	C. gigas	9	6
34	In situ	M.edulis	8	4
34	In situ	M.edulis	7.5	4
34	In situ	C. gigas	7.5	4
34	In situ	C. gigas	6	4
34	In situ	C. gigas	4	4
34	In situ	M.edulis	5.5	3
34	In situ	M.edulis	5	3
34	In situ	M.edulis	4	2.5
34	In situ	O.edulis	5.5	7.5
34	In situ	C. gigas	8	6
34	In situ	C. gigas	11	9
34	In situ	M.edulis	5.5	3
34	In situ	M.edulis	6	3
34	In situ	C. gigas	9	6.5
34	In situ	C. gigas	7	6
34	In situ	C. gigas	9	6
34	In situ	C. gigas	10	6.5
34	In situ	C. gigas	7.5	6.5
34	In situ	C. gigas	8.5	5.5
34	In situ	O.edulis	9	7
34	In situ	C. gigas	10	6
34	In situ	C. gigas	10	7
34	In situ	C. gigas	9	6
35	Photo	C. gigas	9	NA
35	Photo	C. gigas	8.5	6.5
35	Photo	C. gigas	7	6.5
35	Photo	C. gigas	6.5	5.5
35	Photo	C. gigas	14,5	7
35	Photo	C. gigas	10	4.5
35	Photo	C. gigas	6.5	5.5
35	Photo	C. gigas	8.5	6
35	Photo	M.edulis	5.5	2
35	Photo	O.edulis	NA	9
35	Photo	C. gigas	NA	7.5
35	Photo	C. gigas	7	4.5
35	Photo	C. gigas	9	7
35	Photo	C. gigas	5.5	8
35	Photo	C. gigas	9	5
35	Photo	C. gigas	NA	NA
35	Photo	C. gigas	7	6.5
35	Photo	C. gigas	6	4
35	Photo	O.edulis	6.5	NA
35	Photo	C. gigas	9.5	6.5
35	Photo	C. gigas	9.5	5.5
35	Photo	C. gigas	NA	9

35	Photo	C. gigas	7.5	6
35	Photo	C. gigas	NA	8.5
35	Photo	C. gigas	NA	NA
35	Photo	O.edulis	8	8.5
35	Photo	C. gigas	NA	NA
35	Photo	M.edulis	5	2
35	Photo	C. gigas	7	5
35	Photo	C. gigas	7	5.5
35	Photo	C. gigas	13	8
35	Photo	C. gigas	8.5	5.5
35	Photo	C. gigas	7.5	5.5
35	Photo	C. gigas	NA	5
35	Photo	C. gigas	6.5	4
35	Photo	C. gigas	11	6
35	Photo	C. gigas	6.5	4
35	Photo	C. gigas	NA	NA
35	Photo	O.edulis	8.5	6
35	Photo	C. gigas	NA	NA
35	In situ	C. gigas	9	7
35	In situ	C. gigas	8	7.5
35	In situ	C. gigas	9	6
35	In situ	C. gigas	11	7.5
35	In situ	C. gigas	14	8
35	In situ	M.edulis	6	3
35	In situ	M.edulis	5.5	3.5
35	In situ	C. gigas	11	5.5
35	In situ	C. gigas	10	6.5
35	In situ	O.edulis	8	10
35	In situ	O.edulis	85	9
35	In situ	O.edulis	7.5	6
35	In situ	C. gigas	7	5.5
35	In situ	C. gigas	10	7
35	In situ	C. gigas	9	5
35	In situ	C. gigas	9.5	4
35	In situ	C. gigas	13	8
35	In situ	C. gigas	10	8
35	In situ	C. gigas	9	7.5
35	In situ	C. gigas	8	5.5
35	In situ	C. gigas	9	5
35	In situ	C. gigas	8	7
35	In situ	C. gigas	7	5.5
35	In situ	O.edulis	7	7.5
35	In situ	C. gigas	9.5	6.5
35	In situ	C. gigas	12.5	7
35	In situ	C. gigas	8	7
35	In situ	C. gigas	8	6
35	In situ	C. gigas	9	7
35	In situ	C. gigas	9	7
35	In situ	O.edulis	3	3.5
35	In situ	C. gigas	8.5	6
35	In situ	C. gigas	6.5	5
35	In situ	C. gigas	6	4.5
35	In situ	C. gigas	11	7
35	In situ	O.edulis	5	6
35	In situ	O.edulis	7.5	8
35	In situ	C. gigas	7.5	5
35	In situ	C. gigas	6	4.5
35	In situ	C. gigas	7	6
35	In situ	C. gigas	8	5.5
35	In situ	C. gigas	8	6
35	In situ	C. gigas	10	7.5
35	In situ	C. gigas	6	5
36	Photo	C. gigas	8.5	7.5
36	Photo	M.edulis	8	3.5
36	Photo	C. gigas	7.5	4.5
36	Photo	C. gigas	7.5	4
36	Photo	C. gigas	7	4.5
36	Photo	C. gigas	7	4.5
36	Photo	C. gigas	4.5	2.5
36	Photo	M.edulis	NA	NA
36	Photo	M.edulis	NA	4
36	Photo	M.edulis	NA	NA
36	Photo	C. gigas	7	5.5
36	Photo	C. gigas	10	6.5
36	Photo	C. gigas	10	5
36	Photo	C. gigas	6.5	NA
36	Photo	M.edulis	7.5	3.5
36	Photo	M.edulis	6.5	3.5
36	Photo	C. gigas	NA	4.5
36	Photo	C. gigas	12.5	8
36	Photo	C. gigas	6	5.5
36	Photo	C. gigas	NA	NA
36	Photo	C. gigas	7.5	5.5
36	Photo	C. gigas	10.5	7
36	Photo	C. gigas	8	NA
36	Photo	C. gigas	7	5
36	Photo	M.edulis	7	3
36	Photo	C. gigas	7.5	4.5
36	Photo	C. gigas	6	3.5
36	Photo	C. gigas	10.5	5
36	Photo	C. gigas	6	6.5
36	Photo	C. gigas	4.5	4.5
36	Photo	M.edulis	NA	NA
36	Photo	M.edulis	7	4
36	Photo	M.edulis	6	NA
36	Photo	C. gigas	7	NA
36	Photo	C. gigas	NA	4.5
36	Photo	C. gigas	NA	7
36	Photo	M.edulis	5	2
36	Photo	C. gigas	8	3
36	Photo	C. gigas	5	6.5
36	Photo	C. gigas	8	5.5
36	Photo	O.edulis	7.5	NA
36	Photo	C. gigas	6.5	2.5
36	Photo	M.edulis	7.5	4
36	Photo	C. gigas	5	2.5
36	Photo	C. gigas	7.5	5
36	Photo	C. gigas	3.5	4.5
36	Photo	C. gigas	6.5	7.5
36	Photo	C. gigas	7.5	3
36	Photo	C. gigas	7.5	4
36	Photo	O.edulis	9	8.5
36	Photo	O.edulis	8	NA
36	Photo	C. gigas	NA	7
36	Photo	M.edulis	8	NA
36	Photo	M.edulis	6.5	3

36	Photo	C. gigas	NA	3
36	Photo	C. gigas	NA	NA
36	Photo	C. gigas	NA	NA
36	Photo	C. gigas	3	4.5
36	Photo	C. gigas	NA	NA
36	Photo	C. gigas	NA	NA
36	Photo	C. gigas	NA	NA
36	In situ	M.edulis	6.5	4
36	In situ	C. gigas	8	7
36	In situ	M.edulis	3.5	2
36	In situ	M.edulis	3	1.5
36	In situ	M.edulis	7	4
36	In situ	C. gigas	9	6
36	In situ	C. gigas	8	5.5
36	In situ	C. gigas	9	6.5
36	In situ	C. gigas	9	7
36	In situ	C. gigas	10	7
36	In situ	C. gigas	8	5.5
36	In situ	O.edulis	8	8.5
36	In situ	O.edulis	6	8
36	In situ	C. gigas	8	5.5
36	In situ	C. gigas	9	6.5
36	In situ	C. gigas	9.5	6
36	In situ	M.edulis	5.5	3
36	In situ	C. gigas	8.5	6
36	In situ	C. gigas	8	6
36	In situ	O.edulis	4	5
36	In situ	C. gigas	9.5	6.5
36	In situ	C. gigas	11	7.5
36	In situ	O.edulis	7.5	8
36	In situ	C. gigas	8	6.5
36	In situ	C. gigas	4	4
36	In situ	C. gigas	9	5.5
36	In situ	O.edulis	7	9
36	In situ	C. gigas	7	5
36	In situ	C. gigas	8	5.5

36	In situ	C. gigas	10.5	6.5
36	In situ	C. gigas	15	10.5
36	In situ	C. gigas	7	4
36	In situ	C. gigas	8	4.5
36	In situ	M.edulis	5	2.5
36	In situ	M.edulis	3.5	1.5
36	In situ	C. gigas	7.5	5
36	In situ	M.edulis	6.5	3.5
36	In situ	C. gigas	8	5.5
36	In situ	M.edulis	6	3.5
36	In situ	M.edulis	4.5	2.5
36	In situ	C. gigas	6.5	5
36	In situ	C. gigas	9	6.5
36	In situ	C. gigas	10	6
36	In situ	C. gigas	9	6
36	In situ	C. gigas	10.5	6.5
36	In situ	C. gigas	8	6
36	In situ	C. gigas	8.5	7
36	In situ	C. gigas	12	8
36	In situ	C. gigas	8	6.5
36	In situ	M.edulis	8.5	4
36	In situ	M.edulis	8	4.5
36	In situ	C. gigas	9	5.5
36	In situ	C. gigas	7	3
36	In situ	M.edulis	7	3.5
36	In situ	C. gigas	7.5	6
36	In situ	C. gigas	10.5	5
36	In situ	C. gigas	6	5
36	In situ	M.edulis	7	3
36	In situ	M.edulis	7.5	4
36	In situ	C. gigas	9.5	6
36	In situ	C. gigas	8	6
36	In situ	O.edulis	7.5	8
36	In situ	O.edulis	7	7
36	In situ	C. gigas	9	7

APPENDIX E: LENGTH – VARIATION IN N MEASURED

Table A.E: Based on number of individuals (n) who were length measured. The table shows placement of each frame within groups based on percentage variation in n (differences in individuals measured in photo and in situ).

Group 1: 0 %	Group 2: 1-30 %	Group 3: 31-50 %	Group 4: 51-100 %
1	8	4	7
2	12	6	24
3	18	11	26
5	21	14	27
9	25	15	
10	28	17	
13	30	29	
16	31	32	
19	33	35	
20	34		
22	36		
23			

APPENDIX F: WIDTH – VARIATION IN N MEASURED

Table A.F: Based on number of individuals (n) who were width measured. The table shows placement of each frame within groups based on percentage variation in n (differences in individuals measured in photo and in situ).

Group 1: 0 %	Group 2: 1-30 %	Group 3: 31-50 %	Group 4: 51-100 %
1	8	11	7
2	12	14	24
3	17	18	27
4	21	23	
5	25	26	
6	28	29	
9	30	32	
10	31	36	
13	33		
15	34		
16	35		
19			
20			
22			

APPENDIX G: COUNTS AND COVERAGE WITHIN EACH TRANSECT, DIVIDED INTO SPECIES

Table A.G1: Counts of individual Pacific oyster and European flat oyster between video and in situ analyzing. The counts were divided into transects and sectors.

Transect	Sector	Pacific oyster								European flat oyster							
		Video						In situ		Video						In situ	
1	1	0	0	1	-	-	-	1	-	2	1	0	-	-	-	1	-
1	2	0	2	0	-	-	-	48	-	1	1	1	-	-	-	12	-
1	3	36	62	73	-	-	-	41	-	1	7	4	-	-	-	3	-
2	1	3	1	2	-	-	-	1	-	1	1	1	-	-	-	2	-
2	2	1	1	0	-	-	-	29	-	0	0	0	-	-	-	8	-
2	3	87	58	51	-	-	-	29	-	1	8	0	-	-	-	1	-
3	1	0	1	0	-	-	-	4	-	0	0	1	-	-	-	3	-
3	2	41	48	55	-	-	-	55	-	0	1	0	-	-	-	8	-
3	3	173	181	177	-	-	-	205	-	0	2	0	-	-	-	19	-
4	1	0	0	0	-	-	-	4	-	0	0	1	-	-	-	2	-
4	2	44	45	47	-	-	-	58	-	0	1	2	-	-	-	7	-
4	3	64	60	67	-	-	-	234	-	0	1	7	-	-	-	43	-
5	1	0	3	2	-	-	-	2	0	7	7	4	-	-	-	18	19
5	2	0	2	2	-	-	-	1	2	2	0	0	-	-	-	6	3
5	3	14	50	31	-	-	-	27	32	7	0	0	-	-	-	17	22
6	1	0	6	0	-	-	-	1	1	0	1	0	-	-	-	10	8
6	2	2	13	2	-	-	-	14	11	2	0	1	-	-	-	7	6
6	3	53	70	60	-	-	-	110	87	0	2	1	-	-	-	9	10
7	1	0	2	0	-	-	-	0	1	2	1	1	-	-	-	4	6
7	2	2	1	2	-	-	-	4	3	0	2	0	-	-	-	5	8
7	3	1	1	1	-	-	-	5	4	1	1	1	-	-	-	2	1
8	1	0	0	3	1	1	0	0	-	2	2	0	2	2	1	8	-
8	2	1	4	10	5	7	7	3	-	4	7	3	8	3	5	14	-
8	3	41	40	50	45	41	41	37	-	3	4	2	8	2	4	19	-
9	1	3	3	2	2	0	2	1	-	1	0	1	0	4	1	6	-
9	2	8	8	6	6	5	7	12	-	4	0	0	0	5	0	12	-
9	3	79	53	53	42	55	59	101	-	4	0	0	0	6	0	8	-
10	1	0	3	1	1	4	1	1	-	3	2	2	0	3	1	8	-
10	2	2	2	2	2	1	1	1	-	1	1	1	1	2	2	4	-
10	3	34	55	46	56	52	54	51	-	1	2	1	1	2	4	10	-

Table A.G2: Counts of individual Blue mussel and percentage coverage of macroalgae between video and in situ analyzing. The counts were divided into transects and sectors.

Tran-sect	Sector	Blue mussel								Macroalgae (%)							
		Video						In situ		Video						In situ	
1	1	39	46	30	-	-	-	1	-	15	25	30	-	-	-	0	-
1	2	4	3	5	-	-	-	21	-	10	15	10	-	-	-	0	-
1	3	22	58	69	-	-	-	53	-	5	5	5	-	-	-	35	-
2	1	22	8	15	-	-	-	16	-	40	20	15	-	-	-	20	-
2	2	18	3	4	-	-	-	8	-	5	5	5	-	-	-	5	-
2	3	51	29	36	-	-	-	10	-	10	5	5	-	-	-	5	-
3	1	0	1	1	-	-	-	2	-	10	20	20	-	-	-	20	-
3	2	25	31	48	-	-	-	64	-	5	0	5	-	-	-	5	-
3	3	137	122	214	-	-	-	234	-	0	5	5	-	-	-	5	-
4	1	3	4	6	-	-	-	11	-	15	20	25	-	-	-	15	-
4	2	23	25	17	-	-	-	50	-	0	0	5	-	-	-	5	-
4	3	62	45	44	-	-	-	151	-	15	15	20	-	-	-	10	-
5	1	7	11	11	-	-	-	6	20	35	40	20	-	-	-	5	10
5	2	16	27	17	-	-	-	20	18	10	5	5	-	-	-	5	5
5	3	69	43	45	-	-	-	59	44	60	40	40	-	-	-	25	20
6	1	12	9	9	-	-	-	14	21	10	10	10	-	-	-	5	5
6	2	8	23	5	-	-	-	19	12	35	30	25	-	-	-	20	10
6	3	134	89	74	-	-	-	178	197	10	10	5	-	-	-	10	5
7	1	9	10	9	-	-	-	10	22	25	20	25	-	-	-	5	5
7	2	19	21	17	-	-	-	38	37	20	20	30	-	-	-	20	20
7	3	4	4	5	-	-	-	18	9	40	35	35	-	-	-	25	25
8	1	15	16	16	11	13	10	13	-	5	10	10	10	5	10	5	-
8	2	15	32	30	15	15	17	13	-	10	15	15	20	10	15	5	-
8	3	57	67	65	35	44	66	69	-	15	10	15	15	10	15	10	-
9	1	6	2	4	1	4	2	4	-	10	5	5	5	5	5	5	-
9	2	12	7	10	2	12	12	11	-	20	15	10	15	20	15	0	-
9	3	97	107	75	60	103	96	111	-	20	5	5	5	10	5	0	-
10	1	32	34	31	33	31	28	20	-	5	5	5	5	5	5	5	-
10	2	6	11	6	5	7	6	5	-	5	5	5	5	5	5	0	-
10	3	58	58	51	68	59	53	101	-	5	10	5	5	10	20	0	-

APPENDIX H: TIME SPENT ANALYZING OF EACH PHOTO/VIDEO

Table A.H: Time spent analyzing content in minutes. Separated into method, photoframe and videosleigh, and analyzing place, photo/video and in situ.

Frame/Transect number	Photoframe method		Videosleigh method	
	Time by photo (min)	Time in situ (min)	Time by video (min)	Time in situ (min)
1	1	5	NA	16
2	3	7	27	16
3	2	6	53	21
4	3	9	NA	21
5	NA	13	57	NA
6	2	NA	41	21
7	NA	9	NA	16
8	3	7	60	17
9	NA	5	41	17
10	3	4	NA	20
11	4	9	-	-
12	NA	N	-	-
13	1	7	-	-
14	2	5	-	-
15	2	4	-	-
16	1	2	-	-
17	3	11	-	-
18	4	7	-	-
19	3	8	-	-
20	1	4	-	-
21	3	NA	-	-
22	2	5	-	-
23	2	4	-	-
24	3	7	-	-
25	3	6	-	-
26	6	14	-	-
27	6	14	-	-
28	NA	10	-	-
29	2	5	-	-
30	3	NA	-	-
31	14	12	-	-
32	22	19	-	-
33	17	NA	-	-
34	30	14	-	-
35	20	15	-	-
36	38	NA	-	-
Mean	6.74	8.23	18.33	46.50