Harvesting wild Pacific oysters, *Crassostrea gigas* – developing methods for locating and live-storing marketable individuals.

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Abstract

Invasive species has transformed marine habitats all around the world, and will likely continue to do so due to both natural and anthropogenic factors. Invasive species are usually seen as a threat and considered harmful, there are however also species that could be considered to have a positive impact. One of these species is the Pacific oyster (*Crassostrea gigas*), an oyster species native to the Pacific coast of Asia that recently arrived in the Swedish west coast. Local bodies have expressed an interest in creating a market of these Pacific oysters growing in the wild. In order to evaluate if such a market is possible a field survey was conducted to determine in which population densities most marketable oysters could be found. Further, a live-storage method was tested, lowering the oysters into different depths to ensure a fresh supply of oysters throughout the summer. The result shows an abundance of marketable individuals, with a slight decrease in number in higher population densities. The live-storage trial showed a positive outcome at the deepest depth (14m), where the oysters increased in both size and weight and the mortality level was low. The result indicates that a market of the wild Pacific oyster is possible, and that a live storage method would be a suitable option on the west coast of Sweden.

Language: English | Key words: oyster, Crassostrea Gigas, live-storage

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1 Introduction

Marine ecosystems have always been subjected to natural changes, but ecological changes due to anthropogenic factors are increasing. An example of this is the increased distribution of alien species to new regions (Diederich, et al. 2005). The spreading of invasive species can be traced back to the beginning of agriculture and is continuously increasing through human action either intentionally or unintentionally. Today invasive species are considered one of the greatest threats to the ecological and economical well being of the planet. Marine invasive species are commonly carried through maritime transport or brought to new regions for economical benefits.

The Pacific oyster, *Crassostrea gigas,* is an invasive species that has been deliberately and unintentionally dispersed all over the world. Originating from Japan and Northeast Asia, the Pacific oyster can today be found all around the world as an important aquaculture species. The Pacific oyster can survive in a wide variety of different environments and has a very high growth rate, which also contributes to the fact that the species is considered an invasive species in many parts of the world. To Europe, the Pacific oyster was introduced in 1964 by Dutch oyster farmers as a substitute for the heavily exploited stocks of the native European oyster, *Ostrea eduli*s (Nehring, 2011).

In 2006, the first Pacific oysters were detected on the Swedish west coast. Since then the population density has grown and now ranges between less than 1 to over 100 individuals/m^2, and in some areas over 1000 individuals/m^2 (Strand & Lindegarth, 2014). Oceanographic models and genetic studies show that the Pacific oysters found in Sweden most likely origins from the Danish coasts and today populations can be found widely spread along the Danish, Swedish and Norwegian coasts (Laugen, et al. 2015). The Pacific oyster can settle on most surfaces where wave activity is low but the water exchange rate is frequent. Dense populations are commonly found on soft bottoms at a depth of approx. 0.5-1.5 m. The optimal salinity for the Pacific oyster is around 25 ‰, but mature individuals can survive in salinity levels as low as 5‰ and in as high levels as over 40‰ (Strand & Lindegarth, 2014). Since the start of the monitoring of the oyster population in 2007, it has been observed that natural events such as extreme winters or disease outbreaks are most likely not able to eradicate the Pacific oyster from Swedish waters (Strand et al. 2012, Mortensen et al. 2016).

The Pacific oyster is today well established on the west coast of Sweden and showing no indications of extinction (Strand & Lindegarth 2014). The Pacific oyster can pose a serious threat to local ecosystems by e.g. competing with local species for space and food and by changing hydromorphological factors (Wrange, et al. 2010). Feral oysters can, however, be a potential resource. This has also lead to a growing interest of creating a commercial industry based on the Pacific oyster. Conflicts of interest appear between industrial exploitation and nature conservation due to the Pacific oyster's status as invasive, hence in-depth research is required to determine how to handle this new species. Exploitation of the Pacific oyster has, with the right infrastructure available, the potential to become a lucrative business in Sweden.

To initiate a market for fresh local oysters there are some knowledge gaps that need to be filled. The Pacific oyster can undertake many different shapes depending on the environment it lives in. The population density is on of the factors defining the shape of the oyster. In highly dense populations the oysters tend to grow to an oblong shape, while in low-density populations the oyster have space enough to take its typical rounder shape. Considering the market values, a sellable oyster should be as uniformly shaped as possible, have a shell length of 50-120 mm, and a width and length ratio no less than 45 % (see Appendix 1, Australian seafood cooperative research centre, 2009) (Fig. 1). To determine if there are Pacific oysters fulfilling the market values and in which population densities they can be found, I conducted a research during the summer of 2016 quantifying sellable oysters in different areas and densities along the Swedish west coast. Due to the growing interest of exploiting feral Pacific oysters for the Swedish market, my aim is that the information gained from the research could be used as an indicator of in which densities oysters can be harvested ensuring the largest catch by unit effort (CPUE).

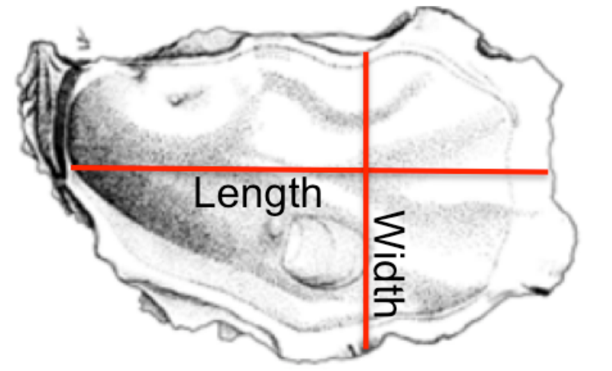

Figure 1 Width and length of the oyster shell

Another issue is to ensure a continuous supply of fresh oysters after harvesting. A storage system for the collected oysters would be required, where maintaining the preferred properties of the oyster would be essential. During the summer period as the water gets warmer the Pacific oyster produces large numbers of larvae, which reduces the quality of the oysters and thereby lowers the market value. To avoid this, the oysters can be stored at depth after collection, hence in colder water, thereby inhibiting reproduction. During the summer I conducted a research on an alternative for storing the oysters after collection, called live-storage. In my research I lowered the collected oysters to three different depths while analysing the development of the oysters throughout the summer months, from June until September. This method can be used for two different purposes, to maintain the quality of the collected oysters and to let smaller individuals grow to a desired size. Little is known about this method on the Swedish west coast, thus, my aim with this research is to establish in which depth the Pacific oysters has the most favourable living conditions considering the market aspects, and how the live-storage method influences the quality of the oysters in different depths.

2 Background

2.1 Invasive species

An invasive species is by definition, "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health" (NISC, 2006). Invasive species has transformed marine habitats all around the world, altering ecosystems by changing food webs or other fundamental processes, outcompeting local fauna or acting as disease spreaders, and unlike many other environmental impacts, these are often irreversible. Therefore, scientists and policy makers are increasingly recognizing invasive species as a major threat to the environmental and human wellbeing.

Ever since people begun using ships as means of transport, marine organisms and animals has unintentionally been carried to new regions. Today maritime transport handles more than 80 per cent of the total volume of global trade (UNCTAD, 2015), and although measures has been taken to reduce the amount of alien species transported, it is considered that globally at any given moment more than 10.000 species are being transported across bio-geographical regions in ballast tanks alone (Baxa, et al. 2003). Ballast tanks, although only one of many possible routes is usually considered to be the main issue. Fortunately, very few species survive the long voyage in the harsh conditions in these tanks, and of the ones that survive few manage to survive or settle in their new environment. Nonetheless, faster and larger ships are being built reducing the ships transit times, all the while environmental issues are being better managed in ports around the world, which may lead to alien species finding their new environments more and more favourable (Baxa, et al. 2003).

2.2 The Pacific oyster

The Pacific oyster is a bivalve mollusc with a solid, rough shell. The lower valve of the oyster is deeply cupped whilst the top valve is flat or slightly convex. The shape tends to be oblong but this varies highly depending on the environment. Although the Pacific oyster can be found in most habitats, their preferred habitat is firm bottom substrate such as rocks, shells or other debris. Growing in an area with a low density of oysters the larvae, after settling, has space enough to grow as a solitary oyster forming its typical shape, influenced mainly by the object it is attached to. Settling in a dense population of oysters it is normal that oysters grow attached to each other, forming clusters with oblong shaped oysters. However, clusters can also be found in low-density populations because older oysters provide a good surface for larvae to settle on. The Pacific oyster occurs in waters of 0 to 40 m depth; however the highest population densities are most commonly found in depths from 0-1 m. Under ideal conditions, the Pacific oyster grows quite rapidly (Fig. 2), up to 3-4 cm in length during the first year and 2-3 cm during the second year (Fey, et al. 2009), hence reaches market size in 18 to 30 months (FAO, 2016). This factor contributes to the steadily expanding aquaculture production, placing the Pacific oyster as one of the most popular oyster species around the world.

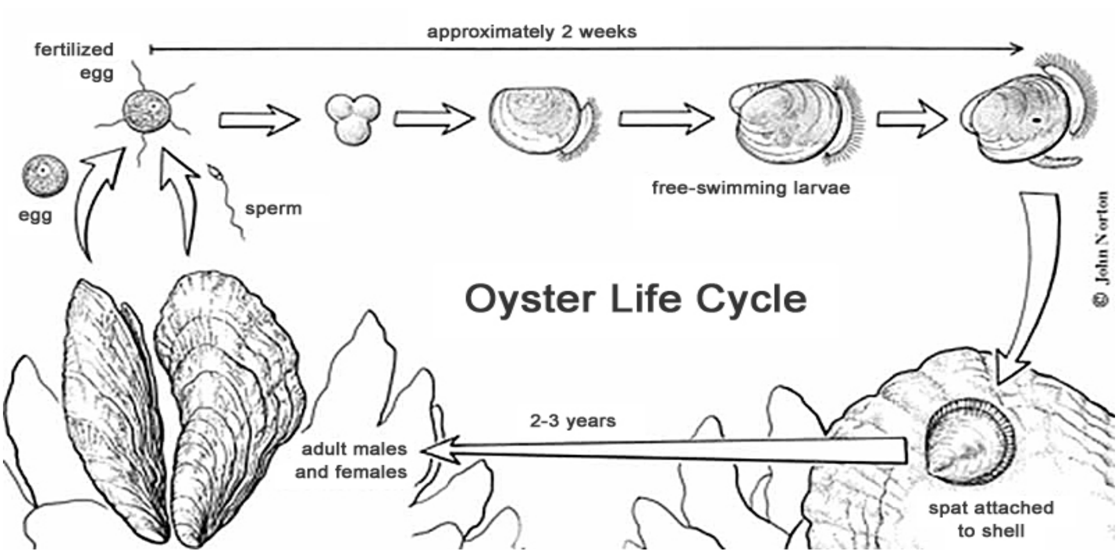

Figure 2 Pacific oysters life cycle (Pangea Shellfish & Seafood Company, 2016)

The Pacific oyster is native to the Pacific coast of Asia, Japan, and was and was named by the Swedish naturalist Carl Peter Thunberg in 1795. Not long after the species was introduced to Europe in the 1960's, the Pacific oyster dispersed from the farmed areas and healthy feral populations appeared along the European west coast, altering the general belief that the Pacific oyster would not be able to reproduce in the cold waters of Europe. During the 70's the pacific oyster was introduced in to Danish waters, and during the 80's and 90's the Pacific oyster was widely cultivated in Denmark. In the mid 00's feral populations appeared around Denmark and in just a few years the biomass increased dramatically. In Sweden and Norway small-scale cultivation trials were conducted in the 1970's but no reproduction activities were noted, although the growth rate was considered good. Since the end of the trials, very few encounters with the Pacific oyster had been reported in these areas up until 2007, when suddenly several reports were filed (Strand & Lindegarth, 2014). Based on genetic studies, there are no differences in the oysters on the Swedish west coast and the oysters found in Denmark. Combining this with oceanographic models (Laugen, et al. 2015), it is believed that the most plausible route of the Pacific oyster invasion of Sweden is through larvae following ocean currents from feral oyster populations in Danish waters.

2.3 Cultivation and feral oyster exploitation

Due to the Pacific oyster's ability to survive in a wide range of environments and its high growth rate, it quickly became a popular species for cultivation and today dominates the global shellfish aquaculture production. In 2014, the global aquaculture production of the Pacific oyster was 630 thousand tonnes, while the global capture production of feral oysters was 30 thousand tonnes (FAO, 2016). The producing countries domestic market, sometimes supplemented by import from other countries and trading partners, consume most of the produced oysters. A large-scale global trade is challenging due to the relatively short shelf life of the species, and due to consumers' preferences for live and fresh oysters. Canned, frozen or otherwise prepared oysters represent only a small proportion of the market (FAO, 2017). There is also a continuous market for hatchery-produced oyster seeds, particularly for triploid seed, which is a sterile oyster unable to produce gamete and therefore maintains a good market value regardless the changes in the temperature (Helm, et al. 2004).

In Sweden, the oyster production is concentrated on a few small producers and the market is mainly local. The feral oysters are captured through diving and handpicking, which is a more environmentally friendly harvest method compared to bottom trawling used in some countries. However, since the government forbids cultivation of the Pacific oyster, the aquaculture production in Sweden is focused on the local species European flat oyster, *Ostrea edulis*, which has a 3-5 times higher market value compared to the Pacific oyster (FAO, 2017). According to SCB (Statistics Sweden, 2016) there were only two oyster farmers registered in Sweden in 2015. All the while the consumption of oysters in Sweden is steadily increasing, and during the last decade the import of oysters has increased by 1300 per cent (Ostron Akademien, 2017).

2.4 Food, water quality and survival

Water temperature and the quality of the available food, and often the combination of these, are some of the most important factors influencing the physiology of the Pacific oyster (Flores-Vergara, et al. 2004). The Pacific oyster is a filter feeder, which natural diet mainly consists of particles of organic and inorganic matter, including phytoplankton (Miossec, et al. 2009). Consequently, the composition of the diet highly varies depending on the environment the oyster lives in. With the help of the gills, the oyster separates unwanted particles from the feed and transport the feed to its mouth. As a species the Pacific oyster is very tolerant to varying abiotic conditions, explaining the worldwide distribution of the species from the warm waters of the Medittarean sea to the cold conditions of the Northern sea. The optimal salinity level for The Pacific oyster is between 20–25 ppt (FAO, 2017) and generally occurs in regions with a surface seawater teperature ranging from 14-23 °C for the warmest month and -1.9 to 19.8 °C for the coldest month of the year, and respectively an atmospheric temperature ranging from 15 to 31 °C and -23 to 14 °C (Carrasco & Barón, 2009). A study conducted in Sweden by Strand et al. (2011) showed the Pacific oyster to be extremely tolerant to long time exposures in cold atmospehric temperature. In the study the oysters were exposed to -22 °C (representing winter temperature in Sweden) for 24, 48 and 72 hours and the result showed a survival rate of approximately 50% after 24h. Naturally, the Pacific oysters early life stages are not as resistant to extreme environmental conditions as the adults. An experiment by Child and Laing (1998) showed a high mortality level (>95%) on juvenile oysters exposed to 3 °C during a period of 3-7 weeks. On the other hand, all the juveniles in the experiment survived in 6 °C and 9 °C. Although the Pacific oysters are considered to be highly tolerant to cold temperature, Büttger et al. (2011) argues that the mass mortality of the Pacific oyster after the severe winter of 2009/2010 was partly due to the mechanical stress of the heavy ice masses.

The Pacific oyster is a protandrous hermaphrodite species, which usually are born as males and changes sex to females when suitable conditions occurs (FAO, 2017). The temperature is an important factor for the Pacific oysters' annual reproduction cycle. In temperate regions, the active phase of gametogenesis starts in spring when the water temperature rises. The species reaches maturity and spawning when the water temperature is above 19 °C (Fabiouxa, et al. 2005). During this time the oysters consume alot of energy on the maturation process, hence depleting its energy reserves (Samain & McCombie, 2008), which from a consumers perspective is undesirable.

2.5 Product quality and safety

There are a number of known diseases within the cultivation of the Pacific oyster, but historically no major disease outbreaks has been reported. However, during the last decades a syndrome known as "summer mortality" has increasingly been affecting the oyster production globaly, severely effecting the production and resulting in major economical losses. The syndrome has been assosiated with a virus called OsHv-1, Ostreid herpes virus, and bacteria of the genus *Vibrio* (Petton, et al. 2015). According to the European Union Reference Laboratory (EURL, 2012), summer mortalities usually starts appering after the water temperature reaches 16 °C, which is confirmed by a study conducted by Bruno et al. (2013), showing the optimal temperature for OsHv-1 disease transmission is between 16,2 - 21,9 °C. It is, however, still not fully understood what triggers these mass mortalities, since it seems to be a result of multiple factors or stressors (Flores-Vergara, et al. 2004).

As a filter feeder, the Pacific oysters will also indgests toxic algea during times these are present in the water. Although they present no danger for the oyster, these toxins might accumulate in the oysters tissues and become dangerous for human consumption. In the European waters there are essentially three kinds of toxins found, Paralytic Shellfish Poisoning (PSP), Amnesic Shellfish Poisoning (ASP) and Diarrhoetic Shellfish Poisoning (DSP), which can be harmful or even leathal for humans (Guéguena, et al. 2008), and poses a serious threath to the industry. Although the water of western Sweden is generally considered clean, during the spring of 2014, the County Administrative Board (Länssytrelsen) was forced to temporarily stop all harvesting of mussels and oysters in the area due to the high levels of PSP toxins found in the waters (Persson, et al. 2015). These toxins are not destroyed by heating or freezing, but the oysters are slowly detoxified by feeding on cleaner water.

3 Methodology

3.1 Quantification of sellable oysters

For the quantification of sellable Pacific oysters in different oyster densities I visited a total of eleven locations along the west coast, from Ellös in the south to Strömstad in the North (Fig. 3). These locations were known, from previous studies and through recommendations from locals, to contain oysters in a variation of densities.

Figure 3 Map of the locations visited

Pacific oyster occurrences were counted and recorded through a transect method. For each location, three transects were used (for example, see Fig. 4), extending from the shoreline until approx. a depth of 1m, or as far as oysters could be found. On each transect a square was dropped every 1-3 meter, depending of the size of the area, so enough data was collected to get a representative sample of the population. The square size used varied depending on the oyster population density, where a large square size was used where oysters were few and smaller square sizes the more abundant the oyster population was. The square sizes used varied from the largest being 100x100 cm and the smallest 20x20 cm. For each square dropped, the depth and time was noted, from which I later noted the true depth. The true depth was calculated comparing water level data from the Swedish Meteorological and Hydrological Institute (SMHI) with my depth measurements, at the given time of the measurement. All oysters, both dead and alive, situated within the square frame were recorded. For each individual, the shell length was measured. For the alive, solitary individuals which were between 50-120 mm long, representing the sellable length range (see Appendix 1, Australian seafood cooperative research centre, 2009), I also measured the width, as the width/length ratio should be no less than 45% for the individual to be considered a market sized oyster.

Figure 4 Transects drawn for the location Smalsundet

3.2 Live-storage

For the research on an alternative storage method, the live-storage, I collected approx. 450 oysters in the size range 50-60 mm, from areas near the Sven Lovén centre for marine infrastructure. These oysters were kept indoors, for a period of approx. four weeks, in containers with a constant flow of filtered surface water of natural temperature varying from 11-18 °C, until they were moved to the live-storage location near Uddevalla on the west coast of Sweden (58.304 °N, 11.784 °E).

The live-storage trial was set-up as follows: a total of 12 cages were divided into three different depths (4 cages per depth), hanging on top of each other. The cages were hanged in a location with a water depth of approx. 14m as following: The first set of cages was set so the lowest cage was at approx. 2.5m depth, the second set of cages at approx. 6.5m and the third at approx. 13.5m. The oysters were divided equally between the cages, 33 oysters per cage, making a total of 132 oysters per depth. Due to high mortality during the first weeks in the 2.5m and 6.5m depths, an additional 250 oysters in the size range 55-65mm were added to the live-storage four weeks after the initial set-up. These oysters were put separate from the previous oysters and distributed between the different depths, adding 100 new oysters to 2.5m and 6.5m, and 50 new oysters to 13.5m. A probe (Hoboware – Hobo Conductivity logger U24) was attached to the cages at each depth, measuring conductivity and temperature throughout the study. Of the initial 450 oysters, a start-pool of 30 oysters was taken back to the lab, to be measured and used as the base for the oyster development. After the initiation of the study I visited the location every second week collecting 15 live oysters per depth and all the dead ones. A new start pool of 30 oysters were collected from the new oysters and after adding the additional 250 oysters I collected 15 individuals of both the old and the new oysters every second week until no more oysters were left in the cages. At the lab, after each pick-up, I measured the shell length of all oysters, and the wet weight of the meat from the individuals alive.

Different degrees of fouling, i.e. organisms growing attached to the cages, were developed during the summer, which ultimately could have blocked the water flow in the cages. To prevent this the cages were cleaned with a brush during each visit.

In connection to each visit I collected water samples from each depth using a standard water sampler. The samples were analysed with a coulter counter (Beckman Coulter – Multisizer 3), to see how much particles, i.e. food, was available for the oysters. Each water sample was analysed three times of which the average result was used. I also measured the salinity level from each depth for later analyses regarding the environmental properties.

4 Data analysing and findings

All data collected on the field was stored in Excel and later imported to R 3.3.0 (R Core team 2017) for further analysing. Temperature readings were imported from the probes using Hobowares software and the graphs were drawn and analysed with Excel.

4.1 Sellable oysters

My aim for the quantification of sellable oysters study was to determine in which population densities most market sized Pacific oysters could be found, i.e. solitary oysters, and determine the amount of sellable solitary oysters found. In all 11 locations, I measured a total of 2174 individuals. Of these 1111 individuals were solitary and the remaining 1063 individuals was growing as clusters in varying numbers. Of the 1111 solitary oysters, 448 oysters were within the market length standard (50-120mm), of which 445 were above the minimum width/length ratio (45 %). Resulting in a total of 20,5 % of all the oysters is within the set market values, thus considered sellable oysters.

I plotted the proportion of the solitary oysters fulfilling the minimum market criteria regarding the shape and size of the oyster by calculating the width and length ratio of all solitary oysters found within the marketable length scale (50-120mm) (Fig. 5). The graph clearly shows that within the marketable oyster length criteria almost all solitary oysters are also above the minimum criteria for the width/length ratio. However, there seems to be a slight decrease of oysters fulfilling the correct width/length ratio in the longer individuals.

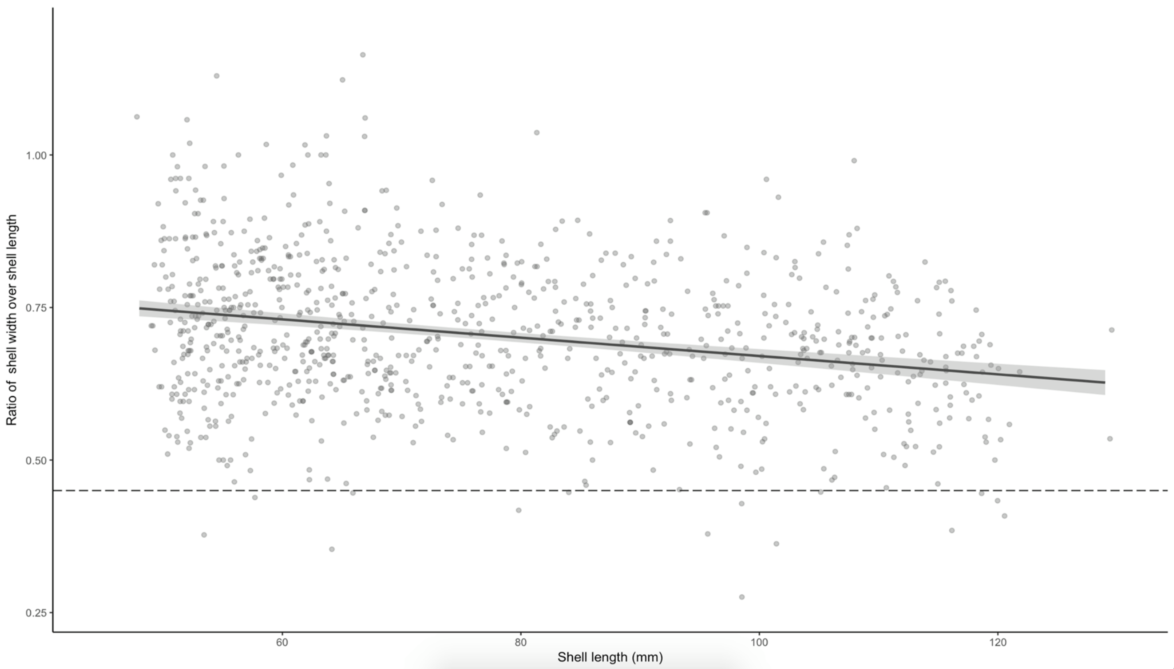

Figure 5 Width/length ratio plotted for the marketable 50-120 mm long solitary oysters. The dotted line represents the minimum width/length ratio of 45%.

To determine the effect of population density on the proportion of solitary oysters, I calculated an average population density per m^2 for each of the eleven visited locations, based on the amount of oysters found within the squares. Using simple linear regression, the effect of the population density on the proportion of solitary oysters was tested. As the independent value I used the calculated average population densities, and as the response variable the amount of solitary oysters (Fig. 6). The result shows that the population density of a given area seems to have a slight negative effect on the proportion of solitary oysters growing in that area, i.e. the higher density of an area the less solitary oysters can be found.

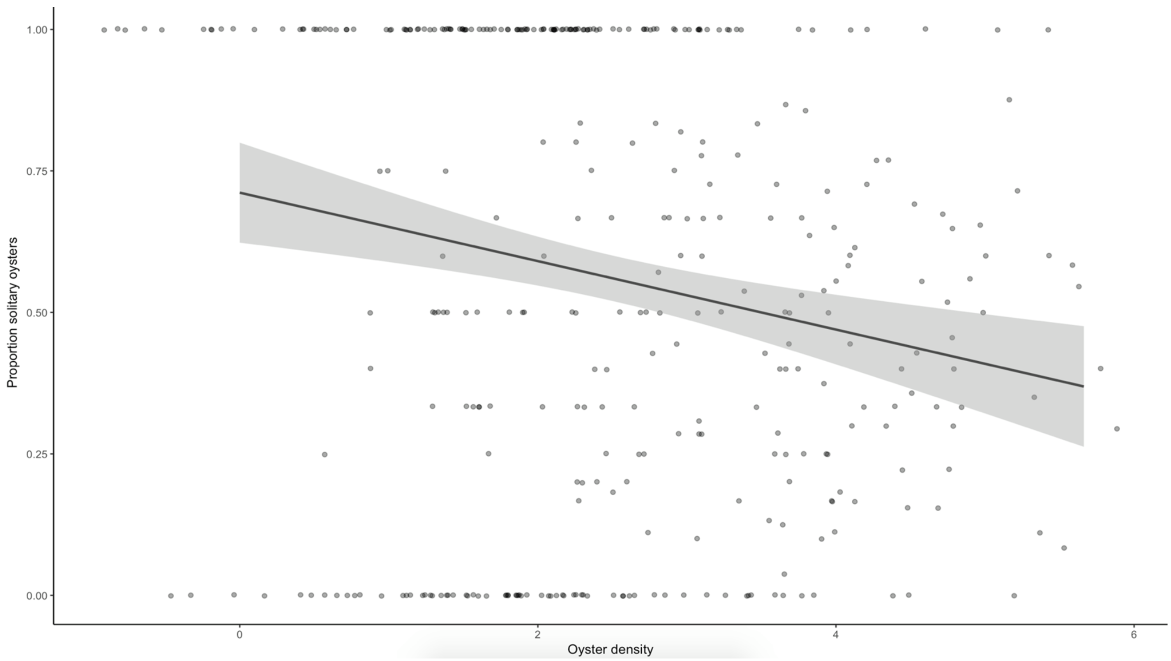

Figure 6: Simple linear regression of the effect of oyster population density on the amount of solitary oysters

4.2 Live-storage

In the live-storage experiment I followed the physical changes of the oysters during the summer and compared the development between the different depths and noted the mortality rate. The physical properties observed for this purpose was the changes in the oysters shell length and wet weight. The environmental properties observed were seawater temperature, salinity levels and the amount of particles in the water.

4.2.1 Length and wet weight development

For the Live-storage trial I measured a total of 658 oysters, of which 480 oysters where alive. To see the physical development of the live oysters, I visualized the results for each pick-up occasion and each depth, on a period of 18 weeks from June 23 to September 15th (see Figure 7 and 8).

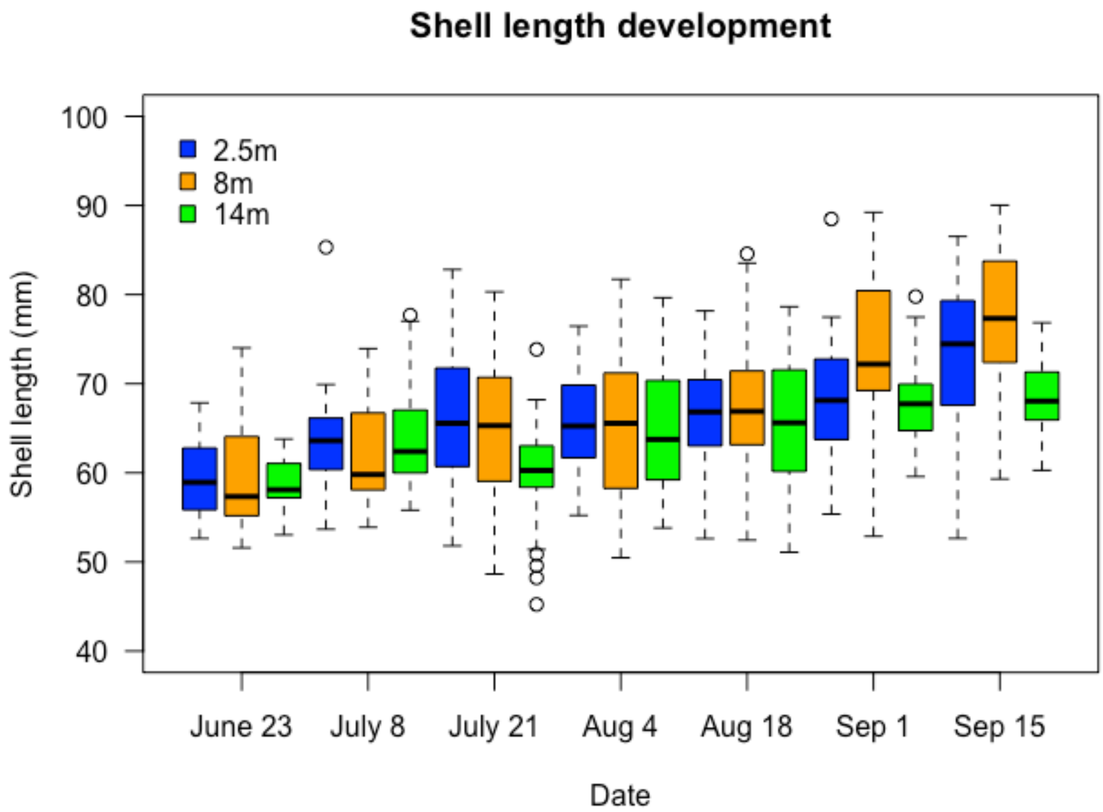

Figure 7 Shell length development during the Live-storage trial

The average shell length measured from the two start pools of a total of 60 individuals was 57.8 mm. Measured 18 weeks later the average shell length for the depths 2.5 m, 8 m and 14 m was; 72.5 mm; 76.7 mm; and 68.5 mm. Leading to an increase in length by 14.7 mm, 18.9 mm and 10.7 mm. The overall shell length increased at all depths (Fig. 7), indicating that the environment in all three depths were favourable for the oysters, i.e. correct salinity level, temperature and sufficient amounts of food. There were, however, some differences in the length increase between the different depths, towards the end of the observation period. During the two last measurement occasions, there was a sudden increase in length at the depth 2,5 m and 8 m, while the oysters stored at 14 m depth did not show such an increase.

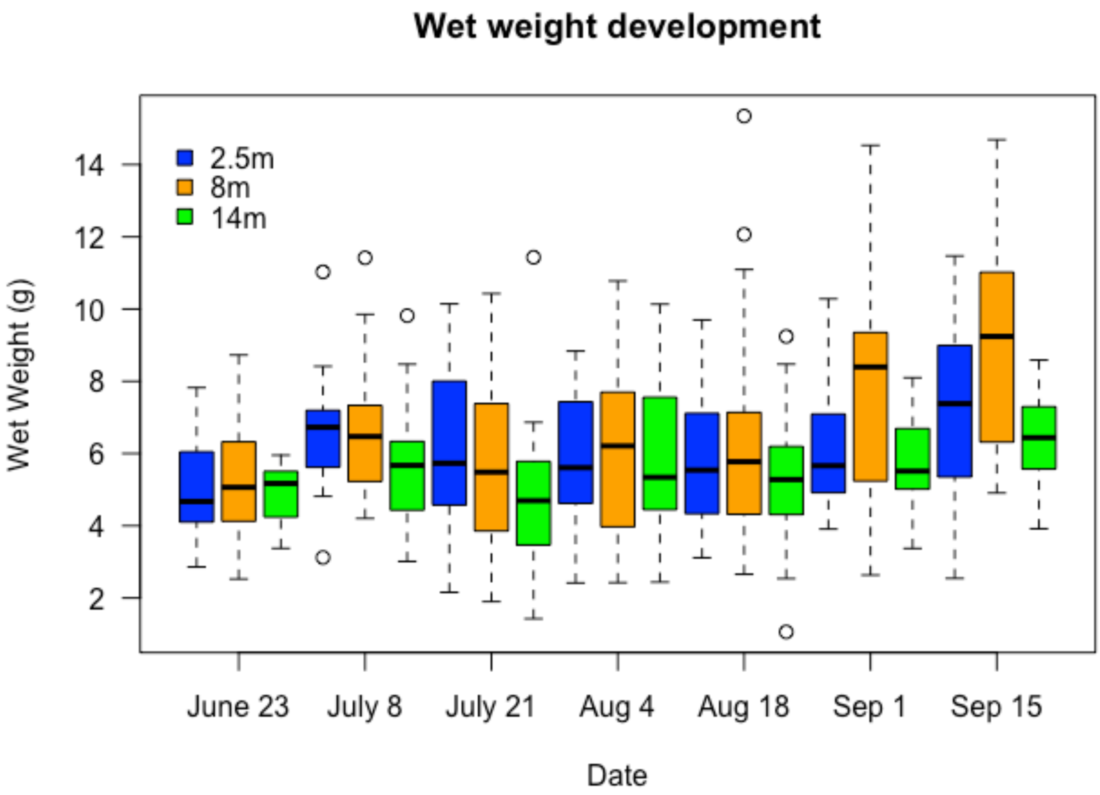

Figure 8 Oyster wet weight development during the Live-storage trial

The average wet weight of the oysters meat calculated from the two start pools was 4,4 grams. At the end of the trial the average wet weight for the different depths was measured 7,2 g; 9,0 g; and 6,4 g, an increase of 2,8 g, 4,6 g, and 2,0 g respectively. During the trial period the wet weight development fluctuated to some degree (Fig. 8), but generally the weight increased in all depths. Similar to the length development, the wet weight also increased more rapidly for the 2,5 m and 8 m depth during the last two measurement occasions, while the wet weight at 14 m depth did not.

4.2.2 Mortality

During the trial the mortality was high during three occasions, June 23rd; July 8th; and August 4th (Fig 9). On the other occasions the mortality was low (maximum one dead individual). Of the total 178 dead individuals the highest mortality rate was found at the 2,5 m depth with a total of 25,8 %, compared to 8 m and 14 m depth; 20,1 % and 6,9 %.

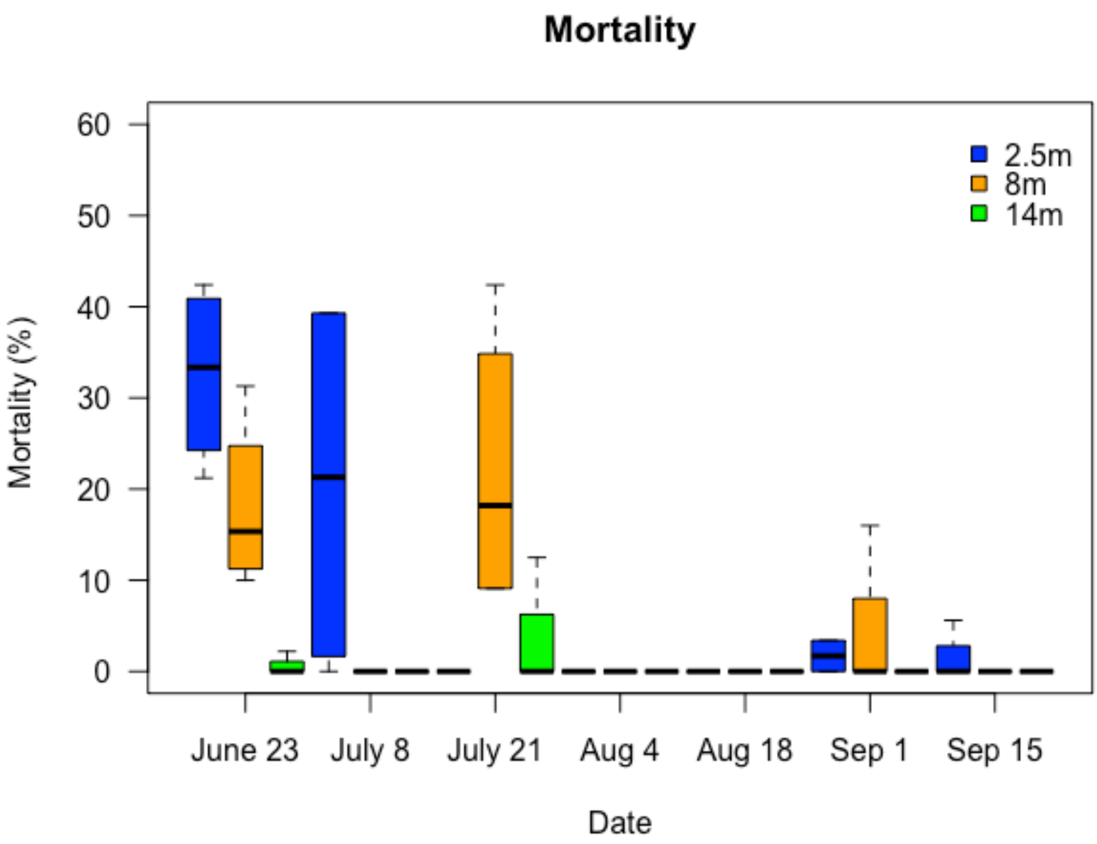

Figure 9 Mortality (%) per date and depth

4.2.3 Temperature

Throughout the Live-storage trial the temperature fluctuations for each depth was recorded with one-hour intervals (see Appendix 2). For the first two depths (2.5m and 7m) the temperature was quite stable from 17 °C to 19 °C all through the summer, with a peak from mid July to mid August (Fig. 10) and was from the start constantly above the threshold of 16 °C for Ostreid herpes virus (OsHv-1). For the lowest depth (14m) the 16 °C threshold was reached for short intervals during a few occasions, with the longest interval from late July to mid August.

The temperature threshold for spawning (19 °C) was for the lowest depth reached only for a short period in early august, while otherwise the low temperature would hinder or slow down the sexual maturation process throughout the summer. For the two other depths, 18 °C was reached in late June, while 19 °C was exceeded in mid July, indicating positive environmental properties for sexual maturation.

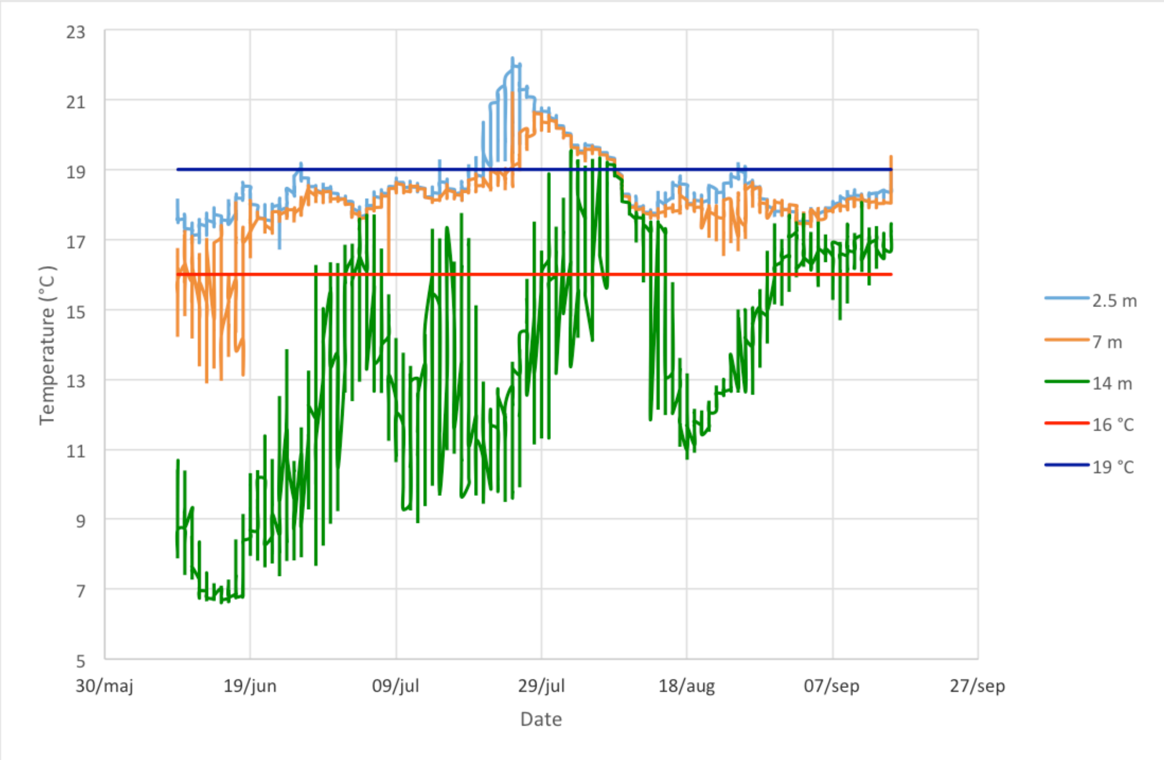

Figure 10 Temperature fluctuations for each depth. The red and blue lines represent the threshold temperature for the Ostreid herpes virus (16 °C) and oysters spawning (19 °C), respectively.

4.2.4 Salinity

The salinity (ppt) level did not vary significantly between the different depths and throughout the trial time (Fig. 11), and was observed to be within the optimal salinity level (20-25 ppt) for the Pacific oyster in all three depths.

Depth (m)	Average Salinity (ppt)	Max	Min
2,5	21,8	23,3	20,9
7	21,9	23,8	20,9
14	24,7	26,5	21,3

Figure 11 Average salinity (ppt) per depth.

4.2.5 Particles in the water

The amount of particles counted in the water represents the amount of food available for the oysters. The graph shows that the availability of food was similar at all depths throughout the summer but for one occasion in mid August, where the concentration of particles was higher at 2,5 m depth compared to the other depths.

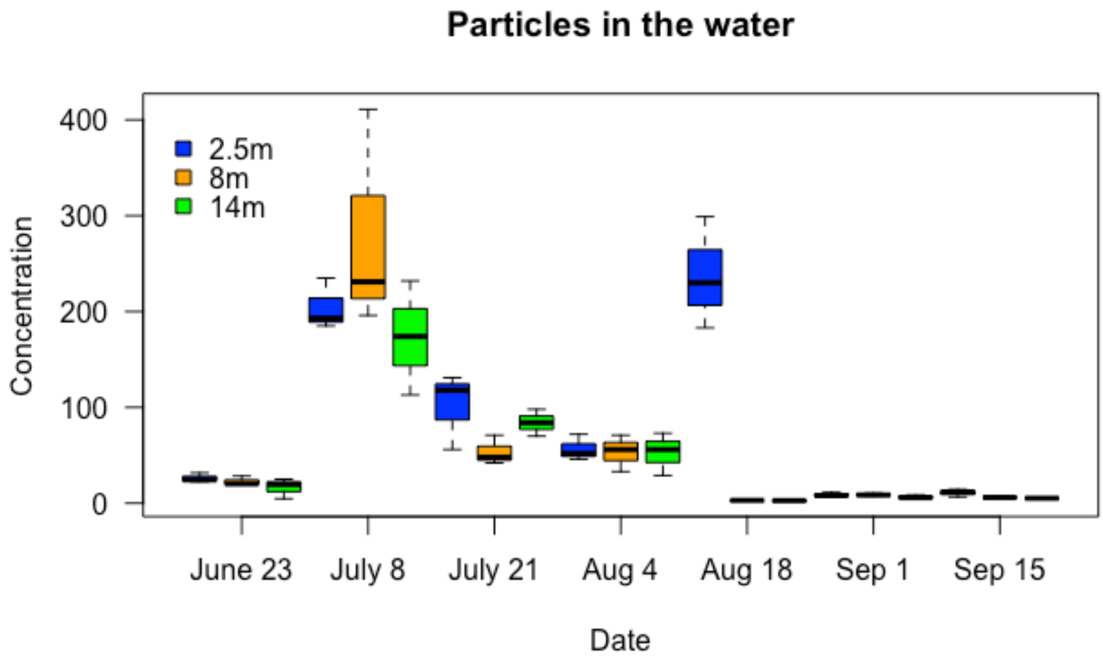

Figure 12 The amount of food available

5 Discussion

The issue of invasive species is a global problem, but it does not necessary involve only negative impacts in all areas. In this research I set out to study the utilization possibilities of the Pacific oyster on the Swedish west coast, a non-native species that possibly will become more abundant and could even be found further north in the future due to climate change resulting in warmer temperatures. Because of its status as an invasive species, it is not allowed to cultivate the Pacific oyster in Sweden, hence there is a conflict of interest between nature conservation, and the fishermen willing to initiate such an industry. To solve this conflict, and allow the utilization of this new resource, in-depth research is required to determine the species long-term impacts on the local environment and on how to handle the species.

There are a few actors within the oyster industry in Sweden who focus on the local species, the European flat oyster, which, although a higher market value, is considered more demanding to cultivate. Through my personal discussions with a couple of local fishermen, I understand that the opinions are somewhat divided between the Pacific oyster being a nuisance destroying the local species or a welcomed opportunity as a new resource.

However, researchers seem to agree that the Pacific oyster has arrived to Sweden to stay and will probably increase both in geographical distribution and biomass. The Pacific oyster is globally the most cultivated and consumed oyster species mainly due to the species tolerance to a wide range of environmental conditions. The rising demand for oysters shows that there is a need for suppliers of fresh oysters in Sweden.

5.1 Conclusions and future perspectives

Quantification of sellable oysters

My study shows that on the Swedish west coast there is an abundance of solitary oysters fulfilling market standards, and thus is in this context considered sellable oysters. Somewhat less than 50 % of all the solitary oysters measured were within the correct length interval and almost all of these met the requirement for the width and length ratio. It should however be taken in consideration that a part of the solitary oysters found will be attached to stones in various sizes, old shells or other debris, and is not always possible to remove without destroying the oyster.

Further, it was shown that sellable oysters were found in all visited locations, with a slight decrease of correct sized individuals in higher population densities. It needs to be pointed out that the analyses are somewhat simplified, and that analyses looking closer at differences between the sites will be done at a later stage. All the locations visited had oysters growing within a depth range accessible by foot from the shoreline, and some even accessible without waterproof equipment during low tide. This would probably make handpicking the most convenient harvesting method, and compared to the harvesting of European flat oysters, does not require scuba diving equipment. However, handpicking as a method is considered slow and thus difficult to support large quantities for an oyster market based on feral oysters. Future studies could concentrate on finding more suitable harvesting methods ensuring the best catch per unit effort (CPUE).

Live-storage

During the 18 weeklong live-storage trial both the shell length and the wet weight of the Pacific oysters increased in all three depths (2.5 m, 8 m, 14 m). The environmental properties measured during the trial showed favourable conditions for both survival and growth. The salinity level was within the optimal range and a sufficient amount of food was available in all depths. What set the different depths apart was the water temperature, a very important environmental property for the life cycle of the Pacific oyster. The temperature for the first two depths was almost identical, around 18 degrees Celsius throughout the summer with a peak of +20 degrees from mid July to mid August. This temperature interval indicates both the possibility for the existence of Ostrea Herpes Virus (OsHv-1), which grows in water exceeding 16°C, and taking into account the other physical properties, indicates good environmental properties for the oysters to reach sexual maturity and start spawning. From a marketable point of view the later is something to avoid since the oysters uses its energy to produce gonads, and the consistency of the meat becomes undesirable. At the 14 m depth the temperature, with a few exceptions, stayed beneath 16 °C and reached 19 °C only at one occasion. This might have had considerable effects on the species life cycle by hindering the sexual maturation process, while the other environmental properties ensured the oysters to be able to survive and even grow. In addition to this the mortality rate was significantly lower at 14 m compared to the two other depths, which might be due to the low temperature limiting the occurrence of the OsHv-1 virus at that depth.

My study shows that a live-storage method similar to the one I conducted, is possible to use on the Swedish west coast. According to the result, the environmental properties of the 14 m depth was ideal for storing oysters, maintaining their good physiological condition throughout the summer months, and even increasing their size and quality. The findings can be an important aspect for successfully developing an industry for fresh Pacific oyster in Sweden. It should be pointed out that regular maintenance of the equipment is required due to fouling growing on the cages, and thus hindering the water flow through the cages which influences the amount of food available for the oysters.

To have a closer look at the physiological development of the oysters and determining the maturation level, histology tests has been taken from tissue samples collected during the summer. However, the tests are not yet fully completed, but are an aspect of the result that should be analysed later on. Also, to fully exclude the occurrence of OsHv-1 at 14 m and determine whether the virus was a primary cause of death in the other depths, a histopathology test from the tissue samples collected should also be taken.

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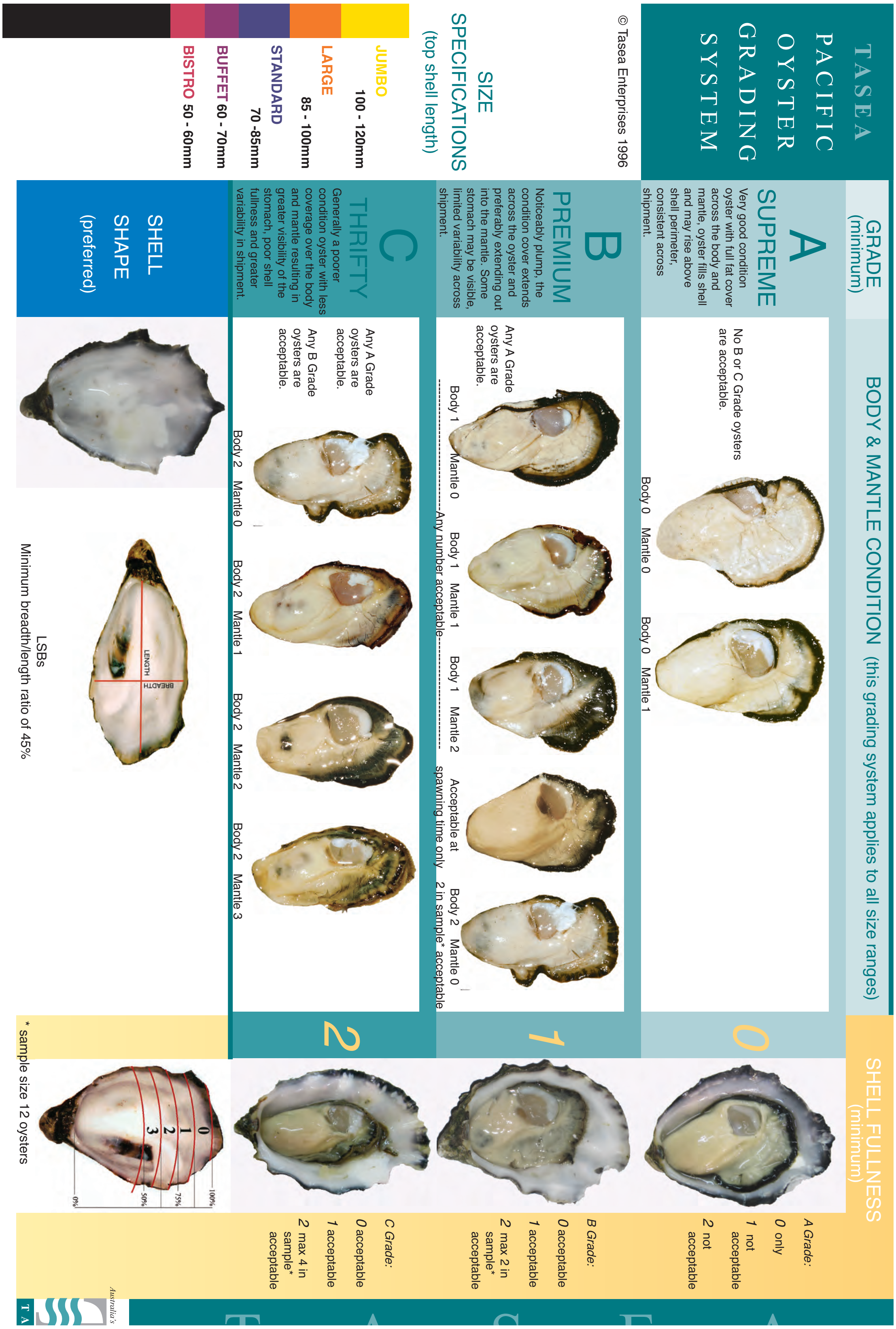
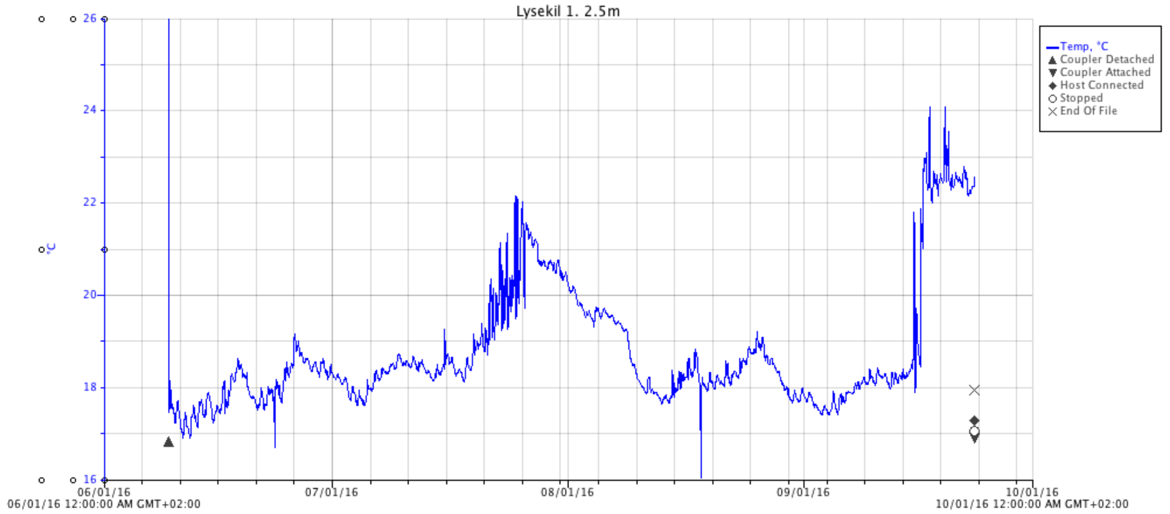
Appendix 1


TASEA PACIFIC OYSTER GRADING SYSTEM
© Tasea Enterprises 1996
SIZE SPECIFICATIONS
(top shell length)
JUMBO 100 - 120mm
LARGE 85 - 100mm
STANDARD 70 -85mm
BUFFET 60 - 70mm
BISTRO 50 - 60mm
GRADE
(minimum)
A
SUPREME
Very good condition oyster with full fat cover across the body and mantle, oyster fills shell and may rise above shell perimeter, consistent across shipment.
B
PREMIUM
Noticeably plump, the condition cover extends across the oyster and preferably extending out into the mantle. Some stomach may be visible, limited variability across shipment.
C
THRIFTY
Generally a poorer condition oyster with less coverage over the body and mantle resulting in greater visibility of the stomach, poor shell fullness and greater variability in shipment.
SHELL SHAPE
(preferred)
BODY & MANTLE CONDITION (this grading system applies to all size ranges)
No B or C Grade oysters are acceptable.
Body 0 Mantle 0
Body 0 Mantle 1
Any A Grade oysters are acceptable.
Body 1 Mantle 0
Body 1 Mantle 1
Body 1 Mantle 2
Acceptable at spawning time only
Body 2 Mantle 0
Any number acceptable
2 in sample* acceptable
Any A Grade oysters are acceptable.
Any B Grade oysters are acceptable.
Body 2 Mantle 0
Body 2 Mantle 1
Body 2 Mantle 2
Body 2 Mantle 3
LENGTH
BREADTH
LSBs
Minimum breadth/length ratio of 45%
SHELL FULLNESS
(minimum)
0
1
2
A Grade:
0 only
1 not acceptable
2 not acceptable
B Grade:
0 acceptable
1 acceptable
2 max 2 in sample* acceptable
C Grade:
0 acceptable
1 acceptable
2 max 4 in sample* acceptable
0 1 2 3
100% 75% 50% 0%
* sample size 12 oysters
Australia's
TASEA

Appendix 2



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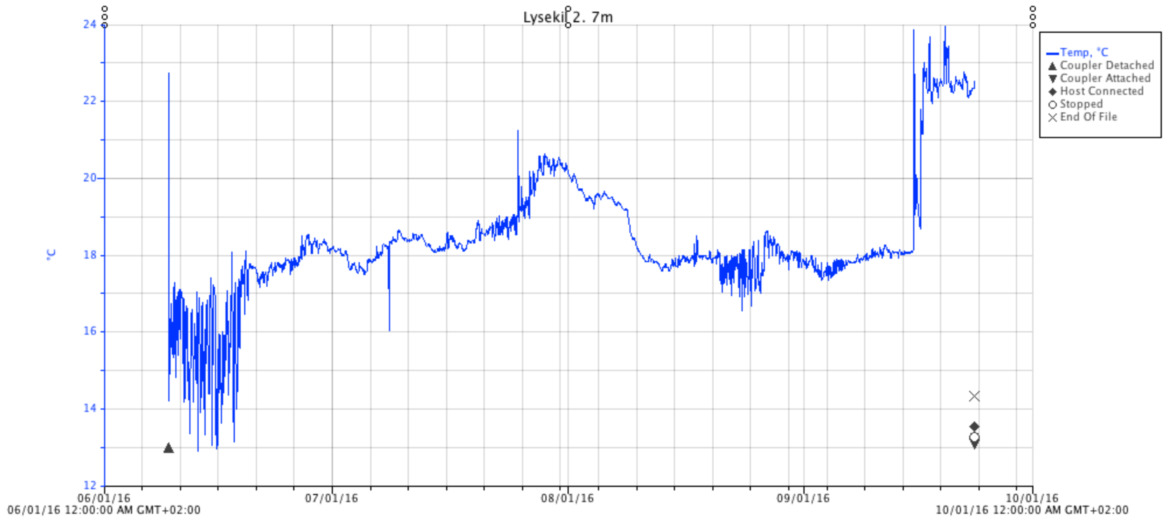

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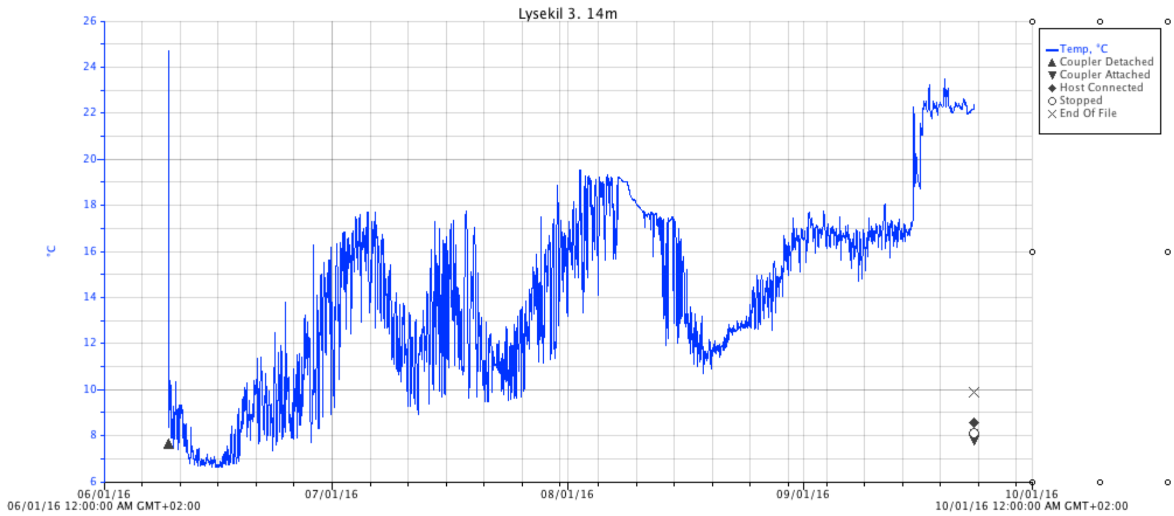

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