The biological indicators and temporal spawning habits of wrasse (Family: *Labridae*) from Sunnhordland

Thesis in partial fulfilment of the degree Master of Science in Fisheries Biology and Management

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Abstract

The salmonid industry in Norway has grown exponentially. The greatest cost and danger to the salmonid industry are ectoparasitic sea lice (*Lepeophtheirus salmonis*). Sea lice attach to salmon causing damage and increasing health risks. Wrasse (Family: *Labridae*) provide a possible solution. Wrasse, specifically ballan, corkwing, goldsinny, and rock cook, are cleaner fish. They can be released into sea pens and will eat the sea lice off the salmon. This has been highly effective against sea lice. As a result wrasse have gone from a worthless fish (bony and not particularly tasty) to a highly desired multi-million kroner fishery.

The growth of the fishery raises serious concerns. As a result of wrasse being unimportant until recently little information is known about them, including their reproductive habits. To provide further information regarding spawning and the stock of wrasse this project was developed to study the four economically important wrasse: ballan, corkwing, goldsinny, and rock cook.

Over the space of two months in the spring/summer of 2014 I regularly participated in fishing expeditions with wrasse fisherman and research staff. The goal was to get a picture of the wrasse stock in Sunnhordaland and multiple sites were targeted. Data were collected in Austevoll (21 dates), Os (2 dates) and Sveio (3 dates). These 26 separate trips produced 4985 wrasse that were catalogued at sea. Of these, a sub-sample of 818 were euthanized and taken to the lab for analysis.

Data on place, date, length, sex (when possible), and spawning behavior were collected on all fish observed in the field. There were a number of analyses done with the primary interest being first to accurately map the spawning patterns across the summer and to see how spawning behavior differed by species, size (length), across time and place, and by sex. The second dependent variable considered was sexual maturity. Most of these analyses required using the laboratory facilities for the sub-sample brought to the Institute for Marine Research in Austevoll. In the laboratory these 818 fish were dissected to extract the gonads to determine both sex and whether the individual was sexually mature. Furthermore otolith dating was used to determine the age of each individual fish.

The spring of 2014 was warmer than average so spawning had already started for most species by the time I started collecting data in early May. Broadly speaking the data show spawning rising throughout May and into June, but then tapering off near the end of June and into July. As such the opening of the 2015 wrasse season for test fishing on July 1st seems appropriate.

In looking at the individual fish the patterns are largely consistent with the literature. There were some findings, however, that indicate there may be some stress on the stock. Chief among these were findings that both corkwing wrasse and goldsinny were noticeably smaller in size at maturity than what was predicted by the literature.

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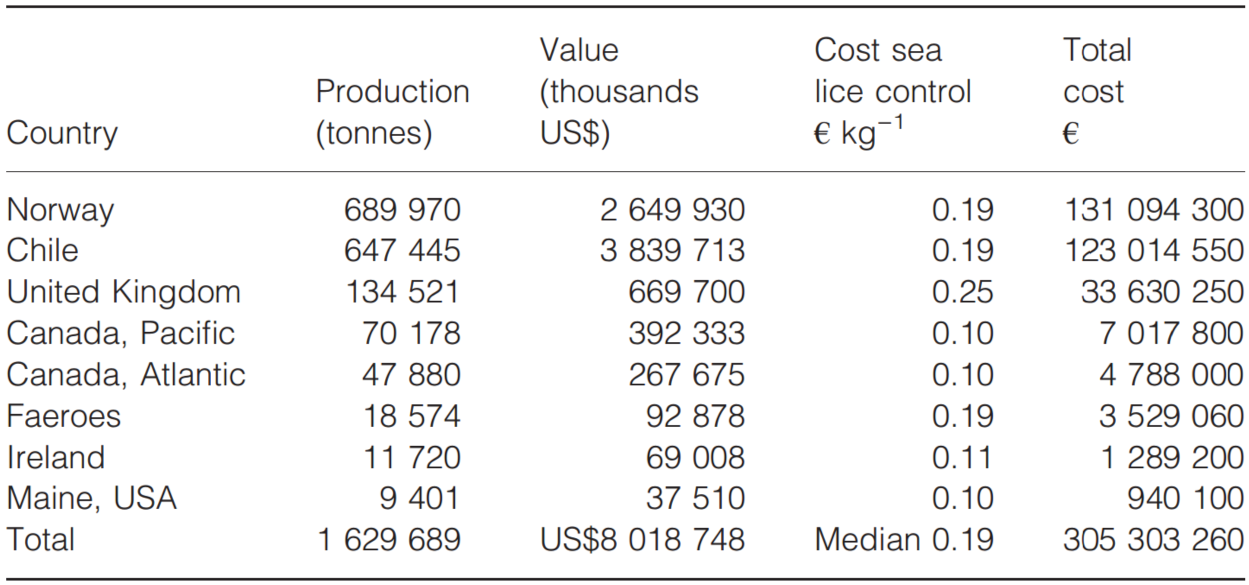
1. Introduction

The wrasse (family: *Labridae*) fishery is unique in that the fish harvested are not used for human or animal consumption. Wrasse were virtually untouched by fishermen until recently. They are bony fish that are not considered to be tasty, but within the last 25 years wrasse have become increasingly desirable. This is directly related to their utilization in salmon and trout farms and the increase in those industries.

1.1 Wrasse and Salmonid Farms

The salmon and trout farm industry has been growing exponentially worldwide since it became successful. The salmon industry is, however, faced with a serious threat, ecoparasitic copepods, also known as sea lice (*Lepeophtheirus salmonis*). Sea lice can damage salmon, which reduces the fish's market value, as well as increase the salmon's chances of getting a secondary infection (Costello, 1996; Muncaster, et al., 2010; Skiftesvik, et al., 2013; Treasurer & Feledi, 2014). Sea lice damage costs the industry worldwide hundreds of millions of euros each year. The costs of trying to control sea lice has risen to remarkable levels (table 1.1 (Costello, 2009)). In 2006 sea lice control specifically cost the Norwegian salmonid industry over 1 billion Norwegian kroner (Costello, 2009).

Table 1.1 The coast of sea lice on the Salmonid Industry worldwide from Costello, 2009.



Country	Production (tonnes)	Value (thousands US$)	Cost sea lice control € kg^{-1}	Total cost €
Norway	689 970	2 649 930	0.19	131 094 300
Chile	647 445	3 839 713	0.19	123 014 550
United Kingdom	134 521	669 700	0.25	33 630 250
Canada, Pacific	70 178	392 333	0.10	7 017 800
Canada, Atlantic	47 880	267 675	0.10	4 788 000
Faeroes	18 574	92 878	0.19	3 529 060
Ireland	11 720	69 008	0.11	1 289 200
Maine, USA	9 401	37 510	0.10	940 100
Total	1 629 689	US$8 018 748	Median 0.19	305 303 260

Wrasse are valued for their use as a cleaner fish in fish farms. Cleaning behavior has been commonly observed in tropical waters but is uncommon in fish found along the Norwegian coast (Costello M. J., 1996). Cleaning behavior is the act of removing unwanted particles from the host (Breen, 1996). It is a mutually beneficial symbiosis as the cleaner receives nourishment from the removed particles and the host are relieved of pests, some of which can be harmful, like the sea lice.

Cleaning behavior in wrasse was first observed by G. W. Potts (1973), a marine biologist working at the Plymouth aquarium in England. The behavior of removing sea lice from salmon by wrasse was first witnessed in 1987 (Costello M. J., 1996). Åsmund Bjordal (1988, 1990, 1991, 1992) later studied the effect of wrasse on removing sea lice in an aquaculture setting and found it to be an effective option. In Norway wrasse were first used as a means to rid salmon of their lice in 1988 (Bjordal, 1991). Since then it has been used extensively as a measure to control sea lice infestations (Treasurer, 1996; Kvenseth, 1996; Young, 1996; Skiftesvik, *et al.* 2013). Wrasse also perform a useful function by decreasing the instances of net fouling, which can cause decreased dissolved oxygen levels (Kvenseth, 1996). Sea pens with decreased dissolved oxygen levels can experience sluggish fish and increased mortality.

1.2 History of the wrasse fishery

The first fishery for goldsinny wrasse was opened in 1988, with others opening soon after (Bjordal, 1991; Gjøsæter, 2002). The fishery went from 1,000 fish registered caught in 1988 to 3.5 million in 1997 (Kvenseth, 1996; Gjøsæter, 2002). After a short drop at the turn of the century the catch has continued to grow as the Norwegian Directorate of Fisheries estimates the targeted wrasse fishery at over 20 million wrasse in 2014 (Norwegian Directorate of Fisheries statistics 2015) (figure 1.2). When the season is open the fishermen tend to exclusively devote their time to the wrasse fishery. Two wrasse fishermen that I spoke to, Tord Rabben (2015) and Håkon Jørgensen (2015), stated that they intend to set and pull 100 pods everyday during the open season. During the off season these fishermen tend to work either on the salmonid farms or they fish in other fisheries (Johannes Møkster 2014).

The initial solution used for the sea lice problem was using wrasse as cleaner fish. Eventually pharmaceutical solutions were developed and adopted in the mid-1990s. They were more effective and easier to manage than the wrasse. These were used effectively for several years resulting in a decrease in use of wrasse from 1998 to 2005 (Skiftesvik *et al.*, 2014). After only a few short years, however, by the mid-2000s, an increasing amount of sea lice were found to be resistant to the pharmaceutical solutions (Skiftesvik, *et al.*, 2013; Skiftesvik, et al., 2014A; Treasurer & Feledi, 2014). There have also been issues raised over the environmental impacts that the pharmaceutical solutions may have (Davies, et al., 2001; Muncaster, et al., 2010; Skiftesvik, *et al.*, 2013). This has caused the revival of a previous method of controlling sea lice, using cleaner-fish. Since 2007 the demand for wrasse has continued to increase in Norway, as seen in figure 1.1 (Fiskeridirektoratet, 2015). It is now a 200 million kroner industry and growing exponentially.

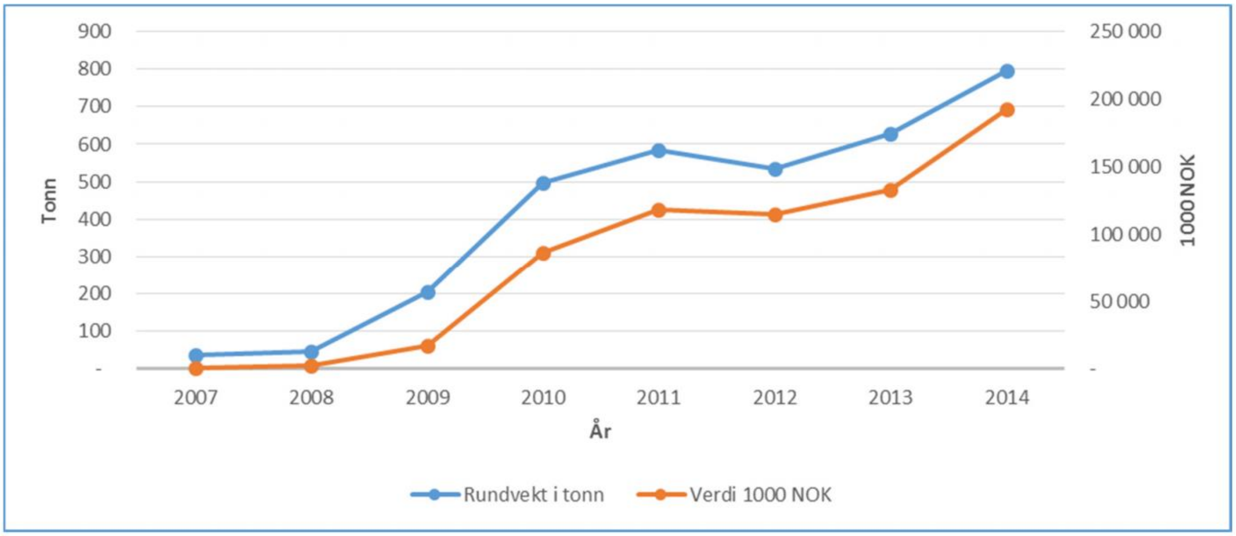


Figure 1.1 The amount of wrasse caught (blue line-in tons) and their worth (orange line- in 1000 nok) over a span of 8 years from 2007-2014. From Fiskeridirektoratet, 2015.

As a result of wrasse having no consumption value, and the pharmaceutical solution appearing to make the fish less relevant, the wrasse fishery has been loosely regulated. This general lack of data makes managing the fishery complicated. Additionally until this year (2015) hobby fishermen could also fish for and sell wrasse in a process completely outside the fishery regulation (Håkon Jørgensen 2015).

According to a case study done on wrasse in Hardangerfjord the catches were significantly underreported from 2000-2009 (Skiftesvik, et al., 2014A). Until 2006 wrasse were sold privately from fishermen to the fish farmers. After 2006 catches were registered through the Fisheries Sales Organization and by 2010 more accurate numbers were being reported for the individual species. Even with better reporting, however, the catches are most likely higher than reported as the fish that die during storage, transport, etc. go unreported (Gjøsæter, 2002; Skiftesvik, et al., 2014A).[1]

Several concerns arise from a poorly regulated fishery, particularly when little is known about the life-history characteristics. Especially with the exponential growth of the industry overfishing is more than just a concern, it is an inevitability (Figure 1.1). The removal of larger fish resulting in the breeding population favoring the smaller fish has been widely studied in bigger fisheries and is believed to be one of the main reasons that cod fishery in Canada collapsed and furthermore it is seen as an important reason why the cod fishery has failed to recover (Olsen, et al., 2004). There is also strong evidence indicating there are individual wrasse populations that are genetically isolated from others (Skiftesvik, *et al.,* 2014A). All these factors increase the chance that overfishing may become a real problem and as fishing pressure continues the size of individual wrasse will become smaller and smaller. As the nature of this fishery is not single species managed but uses a multi-species management system it is important for this project to explore all the species harvested in the wrasse fishery. It could be possible that there was relatively little pressure on one species but significant pressure on a different one under the same management guidelines.

The wrasse fishery is also important for the industry as well. Wrasse that are too small have a lower survival rate in salmon pens and only corkwing and ballan wrasse are considered big enough to be used in second year salmon pens (Skiftesvik, *et al.*, 2013).

1.3 Wrasse species found in Norway

Norway has six different wrasse species. Two of these species are not used for the aquaculture industry. The first being the scale-rayed wrasse (*Acantholabrus palloni*), which is rare. The second is the cuckoo wrasse (*Labrus mixtus*). This species is best known for sexual dimorphism (Jonsson & Semb-Johansson, 1992; Moen, 2004). The males are blue and the females are red. They do not show any interest in consuming sea lice and therefore are not important for the fishery. The other four are highly sought after by the salmon industry. They

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[1] This is almost certainly true as I observed on the fishing vessels I accompanied. Fish under the requested size limit were thrown back into the ocean. In theory, these fish are sent back to grow bigger and to be the stock for the next generation. In reality, they become food for the bird population that followed the boat everywhere it went. Smaller fish brought up are not included in catch estimates, but only a small proportion actually return to the ocean.

are ballan wrasse (*Labrus bergylta*), corkwing wrasse (*Symphodus melops)*, goldsinny wrasse (*Ctenolabrus rupestris*), and rock cook (*Centrolabrus exoletus*). Goldsinny and corkwing wrasse are the most commonly caught species; corkwing wrasse and ballan wrasse are the most desired (Figure 1.2).[2]

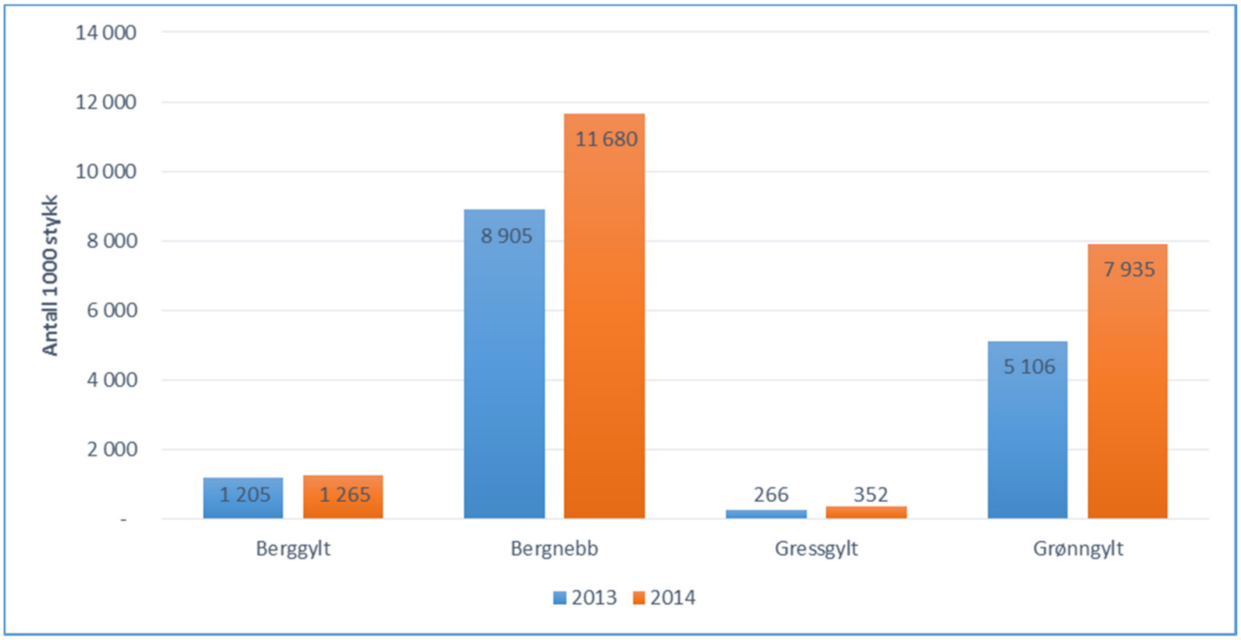

Figure 1.2 The total of wrasse based on species in 2013 and 2014 (From the left: ballan, goldsinny, rock cook, corkwing). From Fiskeridirektoratet, 2015

The ballan wrasse[3] (Table 1.2, Figure 1.3) is the largest and longest lived wrasse found along the Norwegian coast. Their maximum size is around 60 cm with a maximum age of 25 years old (Darwall, *et al.*, 1992; Muncaster, et al., 2010). As a result of their long life they mature far later than the rest of the wrasse, maturing around six to nine years of age. The females are 16 to 18 cm long at maturity, while the males are 28 cm. They are commonly found along rocky shores but juveniles can be found in the intertidal coastal areas (Quignard & Pras, 1986; Sayer & Treasurer, 1996). They are also protogynous fish, meaning the smaller younger fish are females and as they get older and larger they change from having female organs to having male organs (Dipper,

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[2] The Norwegian names are *berggylt* (ballan wrasse), *grønngylt* (corkwing wrasse*)*, bergnebb (goldsinny wrasse), gressgylt (rock cook).

[3] Though this fish is highly sought after and we did collect several specimens, they are rare and we did not recover sufficient numbers to be able to do any statistical analyses of them as a group.

Bridges, & Menz, 1977). The ballan wrasse is also the only wrasse species that exhibits synchronous spawning, which is the spawning of all individuals in unison (Darwall, *et al., 1992*).

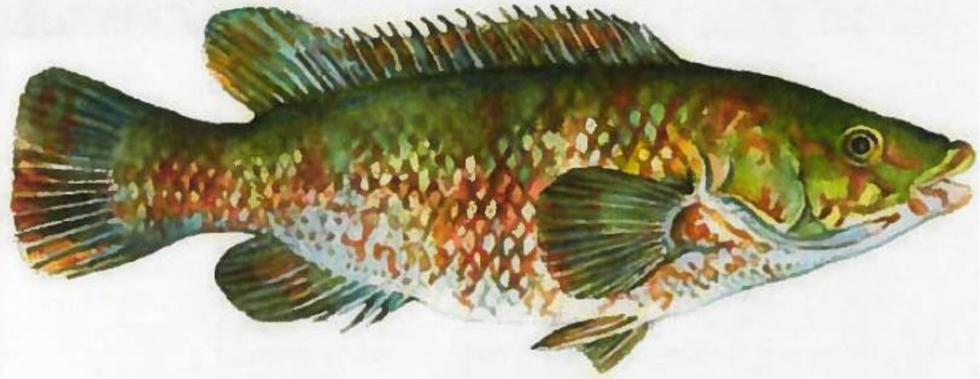

Figure 1.3 Ballan wrasse illustration by Stein Mortensen

Corkwing wrasse (Table 1.2, Figure 1.4) live to the age of nine (Sayer & Treasurer, 1996) and mature at the age of two or three (Darwall, et al., 1992). The corkwing wrasse matures at the length of 10 cm but can be as big as 28 cm. Corkwings are found along rocky shores, eel grass beds, and kelp forests (Sayer & Treasurer, 1996). They most commonly live at depths less than five meters (Uglem, *et al.*, 2001). The male builds and defends a nest and later provides paternal care (Darwall, *et al.*, 1992; Uglem, *et al.*, 2001). Often smaller corkwing males who cannot compete with the aggressive males for mates will adapt a female appearance in order to sneak in and spawn with a female in another male's nest; these are called sneaker males (Sayer & Treasurer, 1996; Uglem, et al., 2001). This social structure relies on a stable ratio of dominate males and sneakers. Fishing pressures could destabilize this social structure (Uglem, *et al.,* 2001; Potts, 1985). The corkwing wrasse are batch spawners (Darwall, *et al.*, 1992). This means spawning occurs in spurts and is not continious.

Figure 1.4 Corkwing wrasse illustration by Stein Mortensen. The male is on top of the picture and the female is on the bottom.

Goldsinny (Table 1.2, Figure 1.5) are one of the smaller wrasse averaging 10-12 cm in total length (Quignard & Pras, 1986; Sayer & Treasurer, 1996). The maximum age for male goldsinny has been observed to be fourteen while females can live up to twenty years (Sayer & Treasurer, 1996). This means they are a slow growing species. Their habitat tends to be rocky shores, allowing them to find hiding spots, as well as areas with dense brown algae (Hillden, 1978; Quignard & Pras, 1986; Sayer, Gibson, & Atkinson, 1993; Sayer & Treasurer, 1996;Gjøsæter, 2002). The goldsinny matures around two years and is the only wrasse species to have planktonic eggs (Darwall, et al., 1992; Costello, 1996). A mature goldsinny is around 9.5 cm or more (Darwall, *et al.*, 1992). Like the corkwing wrasse goldsinny are batch spawners (Darwall, *et al.*, 1992).

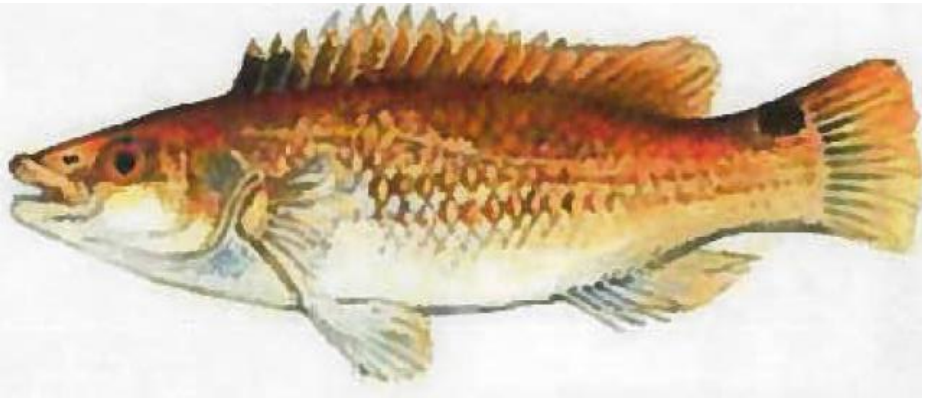

Figure 1.1 Goldsinny wrasse illustrated by Stein Mortensen

Rock cook (Table 1.2, Figure 1.6) is also a smaller wrasse averaging 10-14 cm in total length (Sayer & Treasurer, 1996). The oldest rock cook recorded was nine years old (Darwall, Costello, Donnelly, & Lysaght, 1992). Rocky shores are their preferred habitat but they have been observed above sandy bottoms with eelgrass. The fish matures around two years of age, but the size of maturity, as well as mode, is unknown(Costello, 1991; Darwall, *et al.*, 1992). Overall little is known about this species.

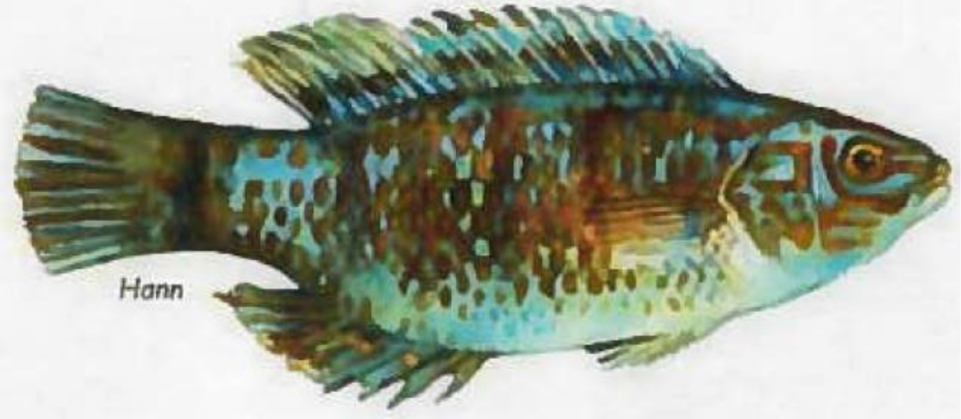

Figure 1.2 Rock cook illustration by Stein Mortensen. This is a male. Females tend to be lighter.

Table 1.1 Summary of life history for wrasse used in the salmon farm industry (adapted from Darwall,et al. (1992) additional information from Sayer & Treasurer (1996).

Species	Goldsinny	Corkwing	Rock cook	Ballan
Maximum age	M(14)/F(20)	9	9	25
Age at maturity (female)	2	2 to 3	2	6 to 9
Maximum size	18 cm	28 cm	16.5 cm	60 cm
Size at maturity	9.5 cm	10 cm	-	F (16.0-18.0 cm) M(28 cm)
Spawning season	April-Sept	April-Sept	May-Aug	April-Aug
Spawning place	Mid-water	Nest	-	Nest
Nest building	-	Male	-	Female
Spawning mode	Batch	Batch	-	Synchronous
Parental care	None	Male	-	Male
Egg type	Pelagic	Benthic	Benthic	Benthic
Sex Change	No	No	No	Yes
Territorial	Yes	Yes	Yes	Yes

1.4 Spawning overview

As the wrasse has become a significant fisheries object there has been increasing interest in their spawning cycles. Because this interest is quite recent, however, there is only limited research on the spawning times of wrasse.Darwall, *et al.* (1992) places the spawning time of all the wrasse, in Northern Europe, from late spring to late summer. Muncaster, *et al.* (2010), looking specifically at ballan wrasse, from the west coast of Norway, found the spawning period was from April to July, while Hilden (1978) observed a spawning time for goldsinny along the Swedish coast from May to June.

A study over several years along the Sunnhordaland coast measuring spawning behavior from June to August in the late 1990s found that the highest spawning period was in June and the proportion of spawners dropped by July, but did not end (Skiftesvik, *et al.*, 2014B). While, the corkwing wrasse appeared to be finishing its spawning season in June the rock cook wrasse continued spawning through July. This study shows the spawning period for wrasse appears to be long. It can continue for up to three months, with the last month having only a few spawners. A search for research on spawning behavior shows there has been a limited amount of research and much of it is dated especially as spawning behaviour does appear to be sensitive to water temperature.

The spawning times of wrasses coincide with the increased photoperiod as well as increasing water temperatures (Muncaster, et al., 2010). Peak spawning is generally completed by the summer solstice during a period where the water temperature continues to increase. It is common to find changes in photoperiod and temperature to cue reproduction in teleost fish (Peter & Crim, 1979). Differences in spawning times have also been observed depending on where the fish are located along the Norwegian coast. It is believed that each species has a different spawning period and time frame (Skiftesvik, Durif, Bjelland, & Browman, 2014).

As seen in table 1.2 goldsinny, corkwing, and rock cook mature around the age of two, while the ballan wrasse has a more complicated sexual lifestyle reaching maturity around the age of six to nine. Also the goldsinny size at maturity is stated as 9.5 cm, while the corkwing wrasse is 10 cm. No information is currently available for the rock cook, which hopefully this project will be able to shed some light on.

1.5 Importance and goals of the thesis

Knowing the spawning period of these fish is important for two reasons. Biologically it is important to allow fish to spawn before they are harvested out of the population in order to insure a stable population. A closing of the fishery during the spawning period would increase the chance that recruitment will be statisfactory for the next year (Mortensen & Skiftesvik, 2011). Another concern is if a male wrasse, who is protecting his eggs that have not hatched yet is fished up, what will happen to his eggs? As per my own observation we removed a male from his nest and the minute that happened several fish attacked his nest eating several eggs. This would be another reason to not have nets set during the period of spawning because if a male becomes caught in the net he cannot go back to protecting his eggs. This suggests that a more conservative line should be taken when setting the fishing season as not only do the eggs need to be fertilized, they must also be protected until they hatch which cannot happen if the males protecting their nests are harvested.

Second, the wrasse fishery is economically important as the fish farms do not desire spawning wrasse in their sea pens (Fiskeridirektoratet, 2015). There are several reasons why reproducing wrasse do not belong in sea pens.They often lack interest in eating sea lice and there are increased health risks during spawning (Fiskeridirektoratet, 2015). They are more susceptible to diseases and there is an increased mortality rate in spawning fish (Skiftesvik, et al, 2014). Therefore, the salmon farms are in support of opening the fishery after spawning, which is beneficial to the fishery as a whole. Currently there is “test fishing” during the start of the fisheries opening. One of the goals of the “test fishing” is to see if any of the fish are still spawning. If they are still spawning then the opening of the fishery may be postponed.

The primary goal of this research project is to pinpoint more accurately the spawning time of wrasse along the Sunnhordaland coast of Norway. This includes determining at what age the fish mature as well as their size at maturity. Size is essential as it is an easy marker that can be used on board the fishing vessels, but accurate tracking of the relationship between size and age can only be estimated via careful research projects such as this one. Previous research has provided estimates of age and size expectations for wrasse (Table 1.2) (Darwall, et al. 1992; Sayer & Treasurer, 1996).

Additionally this research project is important in order to gather as much information on the length of the spawning period as possible. This could be beneficial as it could give researchers and fisheries policymakers the ability to more appropriately set the time for opening this fishery. For example, it appears that corkwing wrasse started spawning in early June. If they spawn for a month then it would be safe to open the fishery in July.

Previous research has provided estimates of age and size expectations, along with the age of maturity for the majority of wrasse at two years - with the ballan wrasse, which has a much longer life span, around six to nine years old for sexual maturity in females, being the exception (Table 1.2) (Darwall, *et al.*, 1992; Sayer & Treasurer, 1996).

While this project only spans one summer the data compiled can be furthered utilized in other research projects, as several years of data would be needed for a more accurate view of when the fish spawn and what determines the start of the spawning season. This research project is based upon the expectation that the peak spawning period will be completed around the summer solstice, but some spawning occuring in July would not be surprising, especially in the rock cook (Darwall, *et al.*, 1992; Hilden (1978); Muncaster, et al., 2010; Skiftesvik, *et al.*, 2014B).

Ultimately the goal of this research project is to increase our knowledge so that one can evaluate if the current standards outlined by the Norwegian Fisheries Directorate are appropriate for the spawning habits of harvested wrasse. This study takes into consideration the wrasse fishery in Sunnhordaland and cannot speak to considerations beyond this area nor to the Fishery Directorates' management strategy beyond this area. According to the Norwegian Fisheries Directorate the 2015 fishery will open on the 1st of July in Hordaland allowing goldsinny and rock cook to be harvested at 11 cm, while corkwing wrasse must be at least 12 cm. It is expected, based on previous research, that these standards would allow the wrasse the opportunity to spawn once or twice in their lifetime, with the assumption that they are harvested once they reach the minimum harvest size (Darwall, *et al.*, 1992; Sayer & Treasurer, 1996).

2. Materials and Methods

2.1 Fish Identification

To be able to do an in depth study of the spawning behavior of the various wrasse I must first be able to correctly identify them. In the field identification happens primarily via visual inspection of the fish. In the laboratory fish are identified through a visual inspection as well as by an evaluation of their gonads.

The fishing gear did not exclusively catch wrasse and as such there was a significant amount of by-catch including cod, pollack, and too small wrasse. All of these species are distinctively different from the primary catch and as such there was little difficulty in identifying the wrasse.

The ballan wrasse's (Figures 1.3& 2.1) body, head, and fins are often brown-reddish or reddish, while some are greenish in colour. All have some kind of white marking, often spots but sometimes they can be stripes (Quignard & Pras, 1986). The gender is best identified by length as the first 14 years of a ballan wrasse's life is spent as female (Leclercq, *et al.*, 2014). Therefore, the smaller ballan tend to be females and the larger are males.

Figure 2.1 Ballan wrasse sex unidentified caught in Austevoll. (Photo credit: Emma Matland 2015)

The corkwing wrasse (Figures 1.4, 2.2) has sexual dimorphism, where the females and males look distinctly different. Females are brown or greenish-brown, while males are brightly coloured with grey-greenish and red colours. Both have sinuous stripes on the head, which on the male are red. The females also have a dark blue urogenital papilla as well as five spots on the dorsal fin (Quignard & Pras, 1986). Sneaker males mimic the female manners and coloring and look just like the female in Figure 2.2 (Uglem, *et al.*, 2001). By doing so they are usually misidentified as female in the field if they are not currently spawning. This is primarily because visual identification is the only way to quickly identify the wrasse in the field. If they are not spawning a correct identification would require opening them up and inspecting their gonads, which requires a laboratory.

Figure 2.2 Male and female corkwing wrasse, caught in Austevoll. (Photo credit: Emma Matland 2015)

The goldsinny (Figures 1.5, 2.3) can be brown or orange-red in colour. They have a black patch at the front of the dorsal fin as well as a dark patch close to the caudal fin (Quignard & Pras, 1986). They are longer and skinnier than the other wrasse species. Females have white bellies with multiple parallel bands, while males have dark red spots on their anterior (Moen, 2004; Jonsson & Semb-Johansson, 1992).

Figure 2.3 Male and female goldsinny wrasse, caught in Austevoll. (Photo credit: Emma Matland 2015)

The rock cook (Figures 1.6, 2.4) can be greenish, brownish, or purple on the back, while lighter colouring are found on the belly. The body and lower part of the head can be yellowish, orange, and striped blue. The caudal fin has a light band across it (Quignard & Pras, 1986). The different coloring between females and males becomes most apparent during the spawning period. Males specifically become a deep blue/purple color (Moen, 2004). As a result of this some of the fish caught early on did not have the distincitve coloring yet and could not be conclusively identified as being male or female.

Figure 2.4 Male and female rock cook wrasse, caught in Austevoll. (Photo credit: Emma Matland 2015)

2.2 Locations

In selecting venues for fish collection we wanted as wide a dispersion as possible, but with a realistic range. As I did not have independent funding for my project I was forced to seek assistance from other projects that were on going in the area. While this required using a convenience sample[4], there was significant diversity both with respect to locations and dates. Samples were taken from three separate locations in Sunnhordaland (Figure 2.5). The first location was the waters around the Institute of Marine Research (IMR) satellite in Austevoll, identified as Austevoll (Figure 2.6A). The second location was in Os located across the fjord

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[4] The other studies were collecting data from a variety of fisheries including some studies that included wrasse, this provided me the opportunity to collect data from the work they were doing.

from Krokeidet, where the ferry from Austevoll to Bergen docks (Figure 2.6B). The third location was about an hour south of Austevoll in Sveio municipality (Figure 2.6C).

Figure 2.5 Fishing locations relative to each location. Locations identified as A- Austevoll, B- Os, and C- Sveio (Maps adapted from Google Earth)

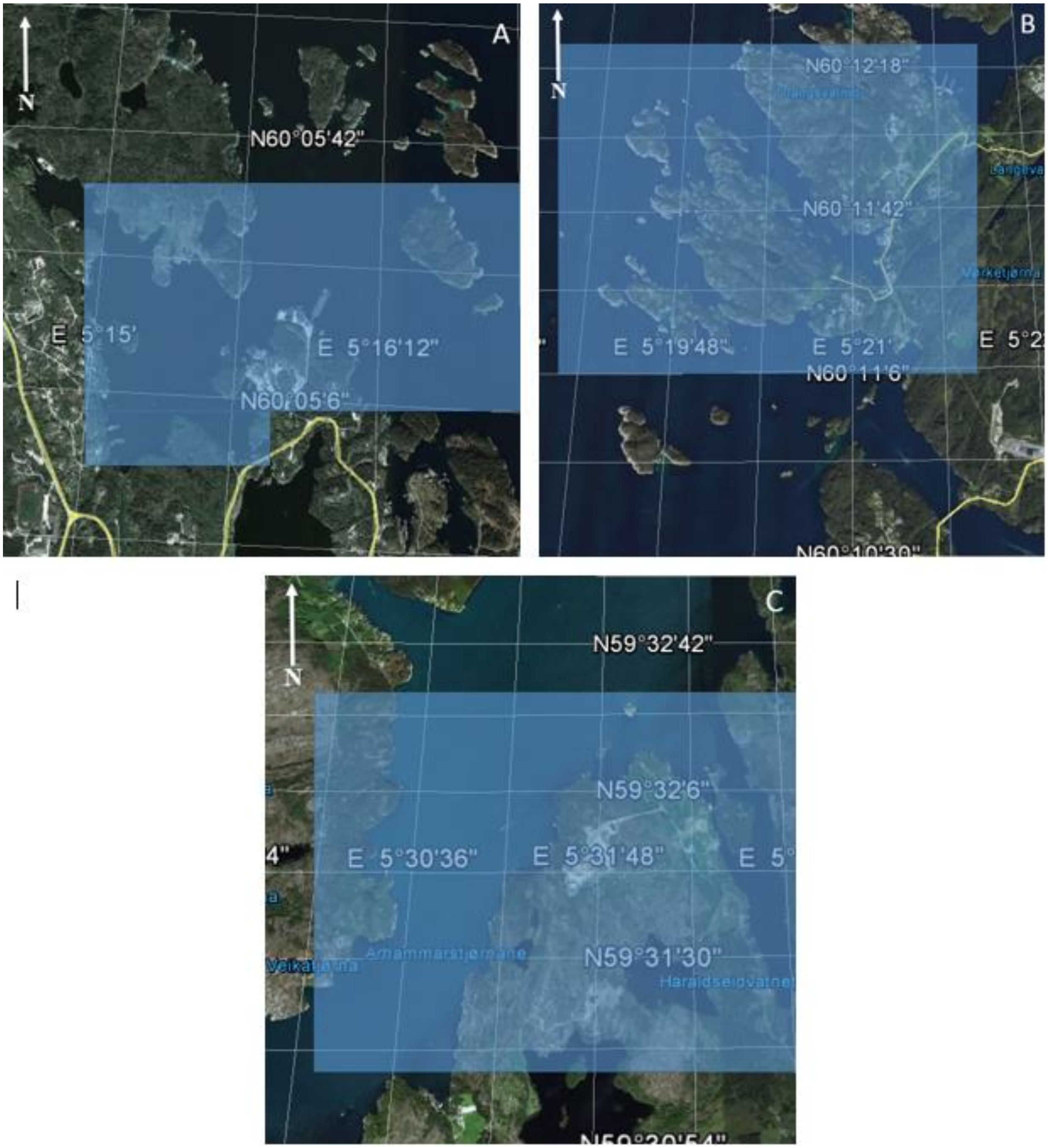

Figure 2.6 The highlighted areas are approximations of the exact locations fished in each location. A- Austevoll, B- Os, and C- Sveio (Maps adapted from Google Earth)

Samples collected in Austevoll were done simultaneously with Kim Halvorsen's work on his Ph.D project. Halvorsen's project involved tagging corkwing wrasse and he tended to work intensively when in Austevoll. Therefore, a number of my data collection days where I was working with Halvorsen, are consecutive. Fyke nets were either set by Halvorsen, my supervisors Reidunn Bjelland and Anne-Berit Skiftesvik, or me. The gear was set along the shore on various days from the start of May until mid-July.

The other two locations, Sveio and Os, were used in association with the Fisheries Ministry who were conducting a project in which they were testing the effect of a selection gate in the fyke nets on the composition of the fish collected. These nets were set by fishermen who would contact us prior to pulling the fyke nets in order for us to join them. As the locations were some distance from Austevoll and they were to contact us rather than the reverse we had fewer collection days in Sveio and Os than we would have liked.

Each of these sampling regions were covered by a different fishermen. In Sveio the fisherman was Dagfinn Lilland and in Os the fisherman was Lars Askvik. Both took an active interest in our work and were as interested in our research as we were in their observations as fishermen. We were able to collect samples from Sveio three times (May 20th, June 6th, and June 20th) and twice in Os (May 14th and June 13th). Initially we planned to gather samples from all three sites in the month of July. However, for a variety of practical reasons this was not possible.

2.3 Data collection

The fish were caught with eel fyke nets at all locations[5] (Figure 2.7). In Austevoll up to 15 fyke nets were set the day before collection and allowed to soak between 15 and 24 hours. The nets were set perpendicular from the shore line along the bottom (Figure 2.8). The fishermen in Sveio and Os set up to 30 fyke nets. Among the factors that could effect the gear selectivity were the amount of time the nets were allowed to soak, the mesh size of the nets, predation and fish behaviour. The fishermen reported that predator species, such as lobsters, had been caught in the fyke nets and may have caused death or injury to the wrasse found already inside the nets. Selectivity may also be effected by the avoidance of the nets by wrasse as a result of predators inside the net (Breen & Ruetz III, 2006). It is outside the scope of this project, however to evaluate the effectiveness of different fishing gear upon the sampling/wrasse. The only difference between the fyke nets utilized in Austevoll and those used in Sveio and Os were that half of the fyke nets utilized in Sveio and Os had two small escape hatches (15 mm x 70 mm).

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[5] The only exception to this was the first two samples in Austevoll which were caught with pods but these were primarily trial runs and at the time there were no fyke nets available. A total of 12 pods were set for a day with frozen shrimp as bait.

Figure 2.7 Placing of a fyke net in Austevoll (photo clipped from video filmed by Reidun Bjelland 2014)

Figure 2.8 Fyke net resting along the bottom in Austevoll (photo clipped from video filmed by Reidun Bjelland 2014)

2.3.1 Field Collection

At each location (Austevoll, Sveio, or Os) water temperature was noted as well as the weather conditions. When collecting data in the field, at the research station and with the fishermen, the fish caught were identified by species and sex, and were measured for total length (rounded off to the nearest 0.5cm). They were also checked for ripe eggs and milt by stripping the fish. In Austevoll all fish were returned to the water, unless they were going to the lab. With the fishermen fish that were too small to be harvested, or were spawning, were returned back into the water while the harvestable fish were put in the boats holding tank for the fisherman to later transport to the fish farms.

Each trip to Sveio and Os resulted in samples being taken to the lab as a sub-sample. In Austevoll we were out considerably more often as Halvorsen's doctoral dissertation project provided an opportunity for us to collect more data. Of the fish caught in Austevoll, a total of 281 corkwing wrasse were given to a bachelor's degree student who was working on a project about corkwing age and length. The data he collected, which included gonadal information, has been added to my project.

A statistical power calculation was used in order to assess the number of fish which should be collected for the sub-sample. Calculations indicated that we should aim for a sample of approximately 30 corkwing wrasse per day to insure sufficient statistical power to be able to detect differences across sampling sites and dates. Addtionally, before pulling the nets, random nets were targeted for total wrasse collection for inclusion in the laboratory samples. Other species, such as cod and lobster were excluded. At least three fyke nets would make up a laboratory sample in case the populations are genetically isolated within the specific locations (Skiftesvik, et al., 2014A)[6]. It would have been more appropriate to use a random number generator to identify which nets to pull for the lab sample, but the uncertanty of how many fish would be caught drove us not to go this route. Ultimately a good subsample, representative of the total population, was pulled for each area (Table 3.1).

After initial field information was collected on the fish those chosen to be included in the lab samplings were euthanized with high doses of anasthesia for transportation to the lab. The anasthesia was prepared by a lab technician from the Institute of Marine Research in Austevoll who is trained in the proper dosage for euthanizing. The fish caught were placed in a freezer at the Institute for Marine Research in Austevoll until it was time to analyze them in the lab. At no

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[6] This was checked for later in analysis and there did not appear to be an effect of the different specific locations within the areas of fishing.

point were the fish captured in the field marked in any way, making it impossible for the data collected in the lab on an individual to be linked with the field data collected on the same fish.

2.3.2 Sub-sample analysis

When I was ready to do the laboratory analyses the fish were thawed and looked at individually. All fish were given an identification number to which all data were attached. When our analyses were finished the fish were placed back into the freezer to be available for future research. The first step in the lab was to identify the species. After a total length (in cm) and total weight measurement (in grams) was taken the fish were carefully cut open and the fish's sex determined.

Fish were identified as male when they had testes and female when they had ovaries. Fish that were identified as female based on their coloring and visual inspection, but had male gonads, were identified as sneakers. These made up a small portion of the project. A simplified version of sexual maturity identification was used in order to keep an accurate record of the gonads identified by the bachelor degree student and by myself. Instead of separating the maturity stages of the gonads into four categories: immature, mature before spawning, mature during spawning, and mature after spawning, two categories were agreed upon: immature and mature. Mature male gonads were milky white and wider than immature gonads. They also tended to have a rubbery feel to them. Immature male gonads were transparent and thin. Sexually mature female gonads were most often identified by their color. Mature female gonads were a deeper pink/red color then the male gonads and often the oocytes could be observed. Furthermore, they often had distinct veins running along the gonads. Immature female gonads were small and often a dull pink color. The female gonads were gently removed with scalpels and tweezers to be weighed and recorded.

The last step in the laboratory analysis was to cut an incision into the fish's skull and remove the otoliths. The otoliths were stored in small containers filled with distilled water, so they could be cleansed before age identification. Each container was marked with the fish's id number. Genetic information was also collected but has yet to be analyzed.

2.4 Data Analysis

2.4.1 Gonadal Somatic Index (GSI)

Since the exact stages of maturity were not recorded another way of measuring the stages was needed. Previous research has shown that using the gonadal somatic index, or GSI, as an indicatior of spawning can be effective in other fish species (Hunter & Macewicz, 1985; Stahl & Kruse, 2008). This is because right before spawning the ovaries swell with water and slowly become smaller after each batch of eggs (Hunter & Macewicz, 1985). Currently there are no average GSI for each specific maturity stage in wrasse.

The gonado-somatic index (GSI) will be calculated using the formula below (Barber & Blake, 1991; Gunderson & Dygert, 1988):

$$GSI = \frac{Gonad\ weight}{Fish\ weight} \times 100$$

2.4.2 Otolith Ageing

Age structure is crucial in fisheries management as it allows for better understanding of the life history of the studied fish. Several methods have been used to age fish, but the most widely used and accepted form is otolith ring reading (Campana, 2001). The age of the fish is calculated based on rings in the otolith, similar to the way tree rings are read (Campana, 2001).There are errors that researchers need to be aware of, however, when using this form of age determination as age identification can vary up to a factor of three, depending on who is reading the otolith. Incorrect aging can be detrimental to the management of a species (Campana, 2001). Inaccuracy in otolith age reading is correlated with age so that there are more innacurate age readings for older fish than for younger fish. Wrasse do not have a long life span so the errors are likely to be limited. The one exception to this is the goldsinny which do live for a longer period of time than other wrasse species.

The collected otoliths were inspected under a Leica microscope (MZ 16 A) with a camera attached (DFC425 C). Using a black background and two or three drops of 96% ethanol inhanced the samples allowing one to more clearly read the rings. Different magnifications were utilized in accordance with the size of the otolith, and for ease of counting. In figure 2.9 the black rings seen in the picture are known as the hyaline ring and represents a winter season (figure 2.9). The ring is an indication of one year passed. The fish were identified by their number and the age was recorded.

Below in figure 2.9. are images that shows examples of otoliths for a three year old corkwing (Figure 2.9A), a six year old goldsinny (Figure 2.9B), and a two year old rock cook (Figure 2.9C). Of all the species the goldsinny were the hardest to read. Primarily because of their ablility to reach an older age and because their otoliths stay fairly small, which means the rings end up being tightly compacted. Ideally a second person would have independently calculated the ages and the two measures would have been compared, unfortunately I did not have the resources for such an undertaking.

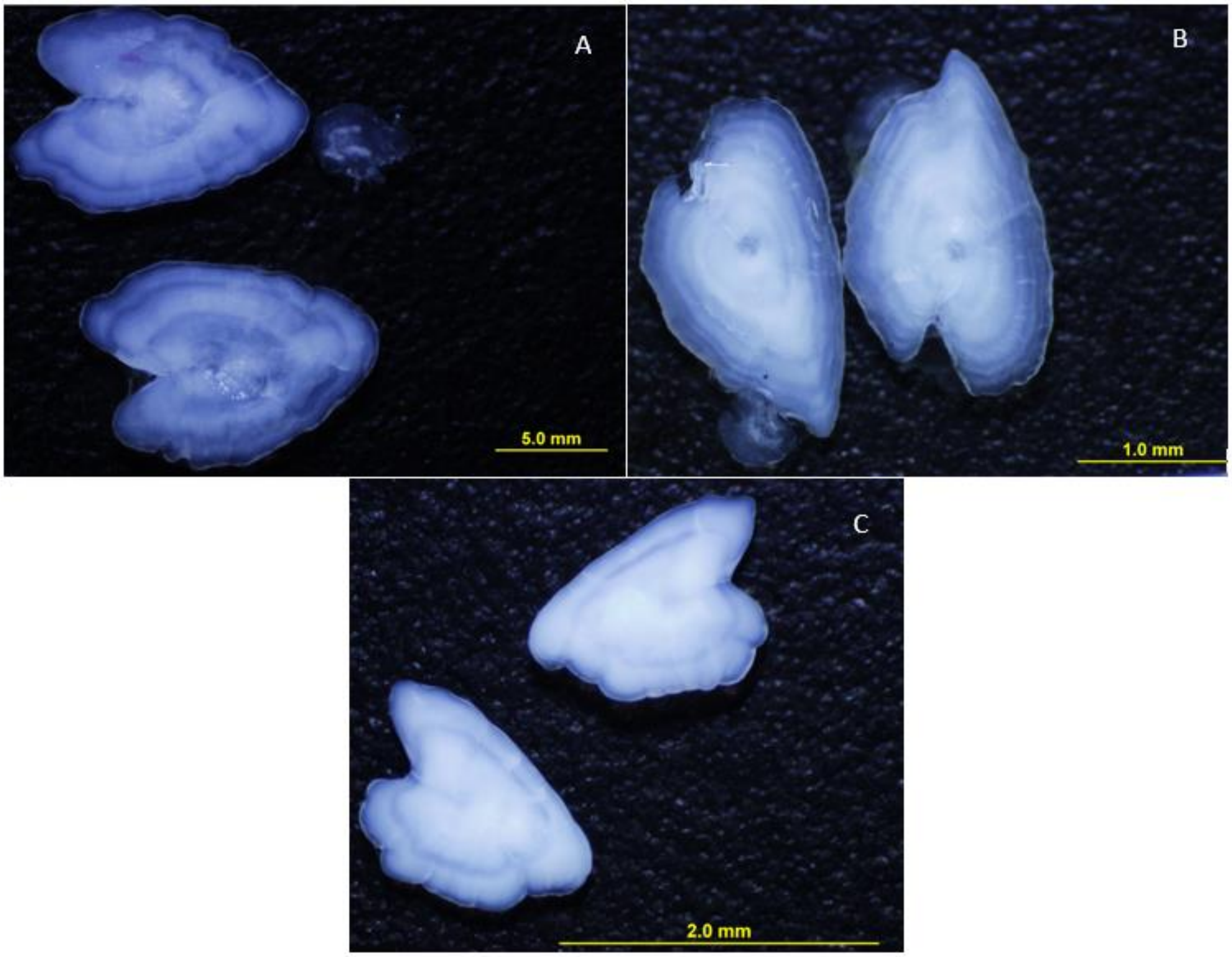

Figure 2.9 Images of some of the otoliths observed in the research. A-corkwing wrasse (three years old), B- goldsinny wrasse (six years old), C- rock cook wrasse (two years old).

2.4.3 Statistical Analysis

R software (version 3.2.0) and RStudio were used for the statistical analysis and graphing (The R Foundation, 2015). The data collected were separated into several categories. The first division was by species. All analyses described were within a single species and not across species. Within species the field data and sub-sample data from the lab are described separately. A liner model was used to test whether the sub-sample is a good representation of the population in each location. Lastly, the data were evaluated by location and lastly the fish were separated by gender.

It was important to compare locations to each other. Since the data was not collected on the same date at all locations only variables that would not be effected by daily or weekly changes were compared. The TukeyHSD test was used to see if the lengths and age of each species differ by location.

2.4.3.1 Field Analyses

A standard linear regression model was used to observe the direct effect of each factor (Table 2.1). For each species[7], a test was run in order to evaluate different factors that may indicate spawning: The independent variables tested against spawning include time elapsed (days), length (cm), and sex. These tests were carried out on the full species dataset and separated by location.

Lastly the species data set was separated by gender and time elapsed (days) and lengths (cm) were tested to see if they are a factor in spawning. Again these tests were carried out based on the full data set as well as separated by location. During the spawning season, fish may be sexually mature but not currently spawning at the time they were captured (a result of batch spawning), which may affect some conclusions. Consideration of the lab data allows us to at least partially mitigate this complication.

2.4.3.2 Sub-sample Analyses

Just like the field data the data analyzed in the lab were first separated by species. To insure the sub-sample was a good representation of the population as a whole the length data from the field was compared to the length data from the sub-sample of each location. These data

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[7] At no point were multiple species analyzed together.

show the subsample studied in the lab is a good match with the complete sample taken on the boats. For each species a linear model was tested in order to identify different factors that may indicate sexual maturity (Table 2.1). The independent variables tested against sexual maturity include age, length, and gender. Both specific locations and the combined data were analyzed. The data set was then separated by sex to see if the effect of age and length on sexual maturity is different based on the fishes sex.

The GSI of the female fish were tested with a linear model to see if time elapsed or sexual maturity had an effect (Table 2.1). The purpose of testing time elapsed is to get an idea of what maturity stage the fish are in (Hunter & Macewicz, 1985). The third is more of a check to see if GSI is an accurate way to identify sexual maturity (Hunter & Macewicz, 1985; Stahl & Kruse, 2008).

Table 2.1 The variables tested with a linear model. Test outputs can be found in the appendix.

	Independent Variable	Dependent Variable	Data Set
All	Age	Maturity	Sub-sample
	Length	Maturity	Sub-sample
	Length	Spawning	Field sample
	Time Elapsed	Spawning	Field sample
	Sex	Maturity	Sub-sample
	Sex	Spawning	Field sample
Female	Age	Maturity	Sub-sample
	Length	Maturity	Sub-sample
	Length	Spawning	Field sample
	Time Elapsed	Spawning	Field sample
	Time Elapsed	GSI	Sub-sample
	Maturity	GSI	Sub-sample
Male	Age	Maturity	Sub-sample
	Length	Maturity	Sub-sample
	Length	Spawning	Field sample
	Time Elapsed	Spawning	Field sample

3. Results

In all a total of 4,895 wrasse were evaluated for this project. Of these fish a sub-sample of 818 were taken to the lab for more extensive evaluation. Table 3.1 presents basic data on the fish collected for the project. Note the average lengths of each species in the lab data varies only marginally from the field data so it appears the subsample studied in the laboratory is a good representation of the field sample. To test this more formally, the lengths of each species in the sub-samples were tested against the length of the original data from each location to see whether the sub-sample was a good representation of the location. Of the nine tests carried out six show no significant differences, three produced, however, a significant difference between the data sets with the length of the subsample studied in the laboratory being smaller (corkwing from Austevoll p-value<0.001, Appendix 5.1; goldsinny from Os p-value<0.001, Appendix 5.2; rock cook from Os p-value=0.005, Appendix 5.3). Upon further inspection, however, the differences between the two data sets were all calculated between 0.5 and 0.6 cm. Since fish sizes were rounded to the nearest 0.5 cm when they came on board the ship, whereas they were measured more precisely in the lab some difference is inevitable, and this quite modest difference in the samples I consider negligible and undisturbing.

Note, however, the much larger differences in size among non-spawners and immature fish. A fish is defined as spawning when egg or milt is observed in the field. A fish is defined as sexually mature when the gonads inspected in the lab indicate maturity. Corkwing and goldsinny wrasse[8] are batch spawners meaning they spawn only periodically during the spawning period, as a result, they are often not observed spawning even if they are sexually mature. In the field a fish that is not spawning is identified as a non-spawner. In the lab, however, that fish is more accurately analyzed and those that are sexually mature but not spawning ended up being labelled as sexually mature, while those that truly were immature fish ended up in the immature category. This process leads to exactly the expected effect. Many of the larger fish that were labelled as not spawning were in fact sexually mature (and spawning this season), while the subset of those identified as not spawning who were genuinely immature tended to be the smaller fish as can be seen from the noticeable size difference between non-spawning fish from the complete sample and the immature fish based only on the subsample evaluated in the lab.

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[8] The spawning mode is unknown for rock cook.

When fishing for wrasse, fish under 11 cm were tossed back into the ocean, unless they were part of the sample to be collected for lab analysis. Approximately 1/3 of the catch was below the 11 cm barrier.   When the fish were stripped on board the boat approximately 50% were spawning with no significant variation across species. If the fish were spawning they were also returned to the ocean, unless they were part of the sample being collected for the lab. The fishermen do not desire spawning fish as the fish farms perceive them as less likely to survive in the pens. [In contrast the subsample evaluated in the laboratory showed that more than 75% of each species (except ballan) were sexually mature.]

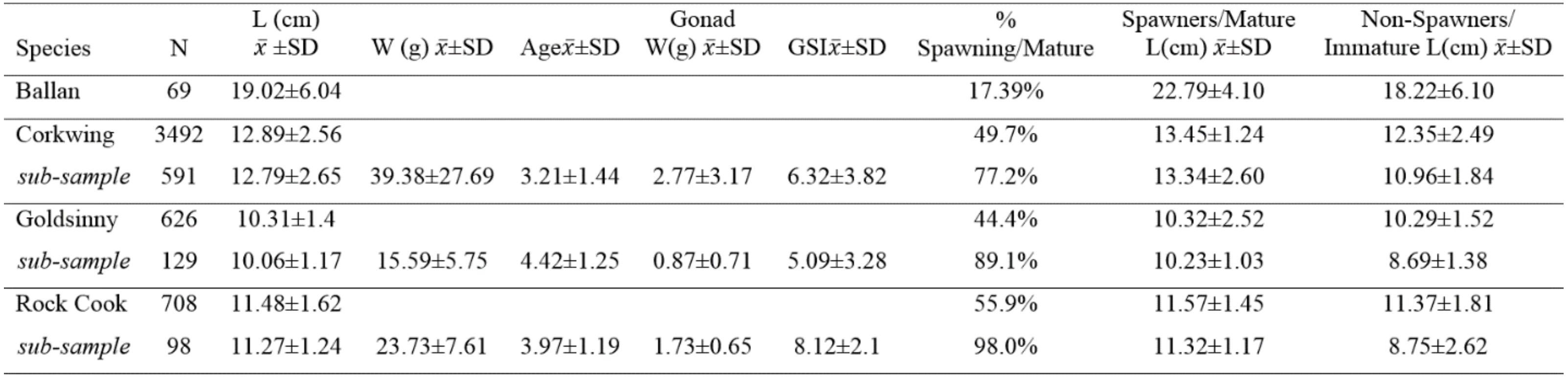
The ballan wrasse, while being one of the most desired wrasse in the fishery, was rarely observed. Only 69 were collected. The average size of the ballan wrasse caught was 19 cm. This is well past the minimum size of 14 cm set by the Fisheries Ministry for ballan wrasse harvest. Only 17.4% of the fish observed were spawning. The total catch of ballan wrasse was insufficient to create a sub-sample for lab inspection.

Corkwing wrasse dominated the sample, being fully 71% of the fish caught. The average size of the corkwing wrasse caught is just above 12 cm, which is the minimum size for harvesting corkwing wrasse. The average age was closest to three-years-old. During data collection only 49.7% of the fish were observed to be spawning, however 77.2% upon internal examination were found to be sexually mature. The average size of the spawning corkwing wrasse was above the minimum harvest size at 13 cm. The average of sexually mature corkwing was also above the minimum harvest size, 13 cm. The immature fish had an average size below the harvest size, 11 cm.

The goldsinny were on average the smallest fish observed (10 cm); however, they were the oldest (four-years-old). This average is below the minimum size requirement indicating that over 50% of the goldsinny caught are useless to the fishermen. Of the goldsinny sample in the field 44.4% were spawning, while 89.1% of the lab sub-sample were found to be sexually mature. The average size of spawning and mature goldsinny was about 10 cm, but the average size of immature goldsinny was about 9 cm, which is 2 cm below the required harvesting size.

The rock cook wrasse was observed to be spawning the most often. In fact of the sub-sample brought in to the lab 98% of the fish were sexually mature. Only two of the 98 fish evaluated in the lab were found to be immature. The average size of the rock cook was 11 cm, which was also the average size of the spawning and mature rock cooks. The immature rock cooks had an average size of around 9 cm, again around 2 cm below minimum harvest size.

Table 3.2 An overall view of the data collected for ballan, corkwing, goldsinny, and rock cook wrasse.



Species	N	L (cm) $\bar{x}$ ±SD	W (g) $\bar{x}$±SD	Age$\bar{x}$±SD	Gonad W(g) $\bar{x}$±SD	GSI$\bar{x}$±SD	% Spawning/Mature	Spawners/Mature L(cm) $\bar{x}$±SD	Non-Spawners/ Immature L(cm) $\bar{x}$±SD
Ballan	69	19.02±6.04					17.39%	22.79±4.10	18.22±6.10
Corkwing	3492	12.89±2.56					49.7%	13.45±1.24	12.35±2.49
sub-sample	591	12.79±2.65	39.38±27.69	3.21±1.44	2.77±3.17	6.32±3.82	77.2%	13.34±2.60	10.96±1.84
Goldsinny	626	10.31±1.4					44.4%	10.32±2.52	10.29±1.52
sub-sample	129	10.06±1.17	15.59±5.75	4.42±1.25	0.87±0.71	5.09±3.28	89.1%	10.23±1.03	8.69±1.38
Rock Cook	708	11.48±1.62					55.9%	11.57±1.45	11.37±1.81
sub-sample	98	11.27±1.24	23.73±7.61	3.97±1.19	1.73±0.65	8.12±2.1	98.0%	11.32±1.17	8.75±2.62

3.1 Ballan Wrasse

As previously stated, only a few ballan wrasse were caught. Table 3.2 shows that almost all days where ballan wrasse were observed there tended to be only one or two caught. After the 6th of June no more ballan wrasse were observed to be spawning. This can be further seen in figure 3.1. Figure 3.1 shows the 69 ballan wrasse caught divided into three categories: spawning females, spawning males, and non-spawning sex undetermined. The x-axis shows the number of days elapsed since the first day of sampling (May 9, 2014). As can be seen almost all the data points were of non-spawning fish, while the majority of the fish observed to be spawning were females. The non-spawning fish were not identified by gender as there is no way to externally determine their sex if they are not spawning.

There is some indication that the ballan wrasse spawn earlier than the other species, but as a result of insufficient data no statistical tests were done. There is also no laboratory subsample that would provide age or gonadal information to further explain what is happening with the ballan wrasse. I can note, however, that most of the ballan caught are well above the required size which does suggest there is not significant overfishing pressure on the ballan wrasse.

Table 3.3 Ballan registration by date and location

Date	℃	Location	N	L (cm) $\bar{x}$ ±SD	% Spawning
14/05/2014	9.9	Os	36	20.56±5.41	30.56%
20/05/2014	10.6	Sveio	1	12.5	0.00%
06/06/2014	15.5	Sveio	7	16.93±10.12	14.29%
08/06/2014	15.6	Austevoll	1	10.7	0.00%
13/06/2014	13.6	Os	13	18.92±4.20	0.00%
20/06/2014	16.3	Sveio	7	16.61±7.50	0.00%
23/06/2014		Austevoll	1	18.8	0.00%
08/07/2014		Austevoll	2	16.5±0.71	0.00%
15/07/2014		Austevoll	1	16.5	0.00%
		Overall	69	19.02±6.04	17.39%

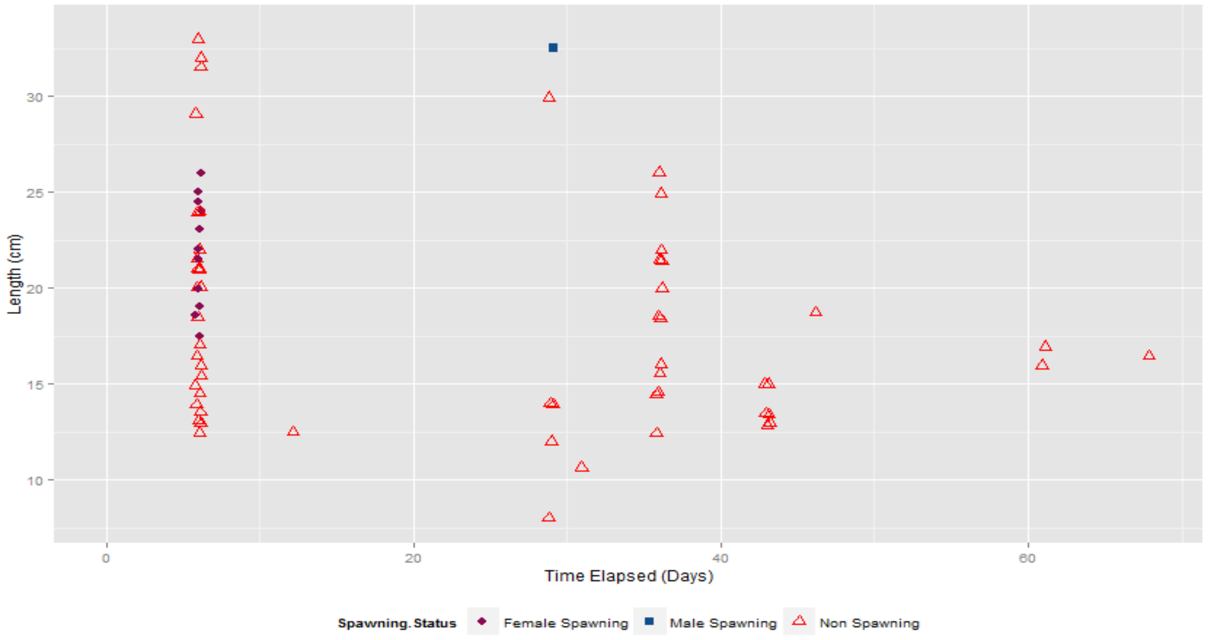


Figure 3.3 Ballan wrasse length relative to days elapsed since the first day of sampling (May 9, 2014). Divided into spawning status.

3.2 Corkwing Wrasse

Besides goldsinny, corkwing wrasse are the most commonly harvested fish in the wrasse fishery. Table 3.3 lists the 26 separate dates on which corkwing wrasse were collected along with the sub-sample data. From these data we can see the average length for each day of sampling ranged from 11.5 cm to 14.4 cm. At Os the main sample and the sub-sample had an average length well above that found in Austevoll or Sveio. Looking at the laboratory subsample exclusively, sexually mature corkwing range for average length was between 11.6 cm and 16 cm. The numbers were driven up by the sample from Austevoll on the 16th of May; but also, by the larger than average sample from Os. The range of average length of immature corkwing was 9.7 cm to 14.1 cm. The average age ranged from two years old to four years old. Again the sample from the 14th of May from Os proved to have several older larger fish than the other samples.

Corkwing wrasse were distinctive at each location (p-value<0.001, Appendix 4.1). The smallest corkwing were found in Sveio, with an average size of 12.1 cm. Austevoll corkwing were on average 1 cm larger than the ones found in Sveio. Lastly Os had on average the largest corkwing at 13.9 cm, almost 2 cm larger than the ones found in Sveio. The fish in Sveio and Austevoll were not significantly different in age (p-value=0.250, Appendix 4.1). They both on average had three-year-old fish. Os on the other hand had older fish, with an average age of four-years-old and was statistically different from both Sveio and Austevoll (p-value<0.001, Appendix 4.1).

Figure 3.2.1 shows the relationship between length and age at the three separate research sites with the sample separated based on maturity status. This means the sample is first separated by gender: female, male, or sneaker; then, they are identified as either mature or immature. The oldest observed corkwing wrasse was 8 years old. The youngest mature males and females were two-year-olds found in Austevoll and Sveio (Figure 3.2.1A & C). The youngest mature males and females in Os were at least three-years-old(Figure 3.2.1B). Even the sneakers were at least three in Os.

Females appear to be more dependent on age than length when it comes to sexual maturity. No female that is older than three is immature (Figure 3.2.1). Os did not have a single immature female, which might also be a result of no one or two year old female having been observed (Figure 3.2.1B). They seem to spawn as soon as physically possible, with little concern for their size. Figure 3.2.2 clearly shows that the size difference between spawning females and non-spawning females is almost non-existent as the spawning females are only marginally larger than non-spawning females.

Males do appear to be more affected by length instead of age (Figure 3.2.1). Several older males still have not reached sexual maturity. The oldest immature males were five-years-old, found in Austevoll (Figure 3.2.1A) and Os (Figure 3.2.1B). The sexually mature five-year-old males are all larger than the immature males of the same age. The size difference between spawning males and non-spawning males is clearly seen in Figure 3.2.2. It appears from figure 3.2.1 and 3.2.2 that spawning males have a minimum length of 15 cm. There are a few occasions where spawning/mature males are below the 15 cm threshold. It is also apparent that few males are non-spawning/immature beyond the 15 cm size.

The sneakers are the earliest to mature, as well as the smallest (Figure 3.2.1 and 3.2.2). No non-mature sneaker was observed in the sub-sample. All two-year-old s observed were sexually mature (Figure 3.2.1). No one-year-old sneakers were observed. Looking at figure 3.2.2 the sneakers were the smallest fish observed, with the exception of the fish identified as juveniles. Immature females seem to be in the same size group as sneakers but are younger than sneaker males.

Table 3.3 Corkwing registration by date and location

Date	°C	Location	N	L (cm) $\bar{x}$ ±SD	W (g) $\bar{x}$±SD	Age$\bar{x}$±SD	Gonad W(g) $\bar{x}$±SD	GSI$\bar{x}$±SD	% Spawning/ Mature	Spawners/ Mature L(cm) $\bar{x}$±SD	Non-Spawners/ Immature L(cm) $\bar{x}$±SD
9/05/2014	9.7	Austevoll	4	13.63±4.03					25.0%	14	13.5
sub-sample			4	13.6±3.99	45.8±38.45	2.75±1.26	3±3.97	7.12±7.76	75.0%	15±3.48	9.4
14/05/2014	9.9	Os	658	14.4±2.37					60.8%	14.59±2.11	14.09±2.70
sub-sample			82	15.23±2.14	71.53±30.1	4.31±1.29	8.03±3.41	11.04±1.94	89.0%	15.66±1.86	11.79±0.46
16/05/2014	9.7	Austevoll	8	12.5±2.55					25.0%	16±1.41	11.33±1.47
20/05/2014	11.7	Austevoll	90	13.25±1.91					68.9%	13.60±1.97	12.48±1.52
20/05/2014	10.6	Sveio	268	12.3±2.84					28.0%	13.47±1.96	12.30±1.66
sub-sample			44	13.1±2.57	46.38±28.41	3.36±1.1	4.64±3.23	10.34±2.04	97.7%	13.16±2.56	10.2
21/05/2014	13.3	Austevoll	82	12.7±2.12					59.8%	13.01±2.21	12.24±1.93
22/05/2014	10.8	Austevoll	88	13.78±2.49					88.6%	13.90±2.32	12.84±3.57
23/05/2014	11.8	Austevoll	50	13.70±2.68					60.0%	14±2.92	13.28±2.30
sub-sample			15	11.66±1.13	27.06±10.24	3±1.2	1.39±0.01	7.7±0.56	80.0%	11.58±1.75	11.71±0.58
24/05/2014	12.2	Austevoll	123	13.96±2.29					72.4%	14.21±2.28	13.31±2.22
1/06/2014	13.5	Austevoll	12	12.17±1.72					25.0%	12.27±2.71	12.13±1.50
6/06/2014	15.5	Sveio	845	11.76±2.58					45.1%	12.12±2.72	11.45±2.42
sub-sample			27	11.73±2.26	32.32±22.26	3.08±1.23	3.46±4.23	9.08±3.5	92.6%	11.74±2.34	11.6±1.27
8/06/2014	15.2	Austevoll	40	11.78±2.07					20.0%	12.73±3.11	11.54±1.71
sub-sample			2	12.15±0.35	30.45±2.76	3.5±0.71	1.92	5.93	50.0%	12.4	11.9
9/06/2014	15.1	Austevoll	123	13.48±1.92					38.2%	12.93±1.81	13.82±1.92
10/06/2014	15.7	Austevoll	145	13.37±2.03					67.6%	13.50±2.01	13.10±2.08
11/06/2014	15.2	Austevoll	103	13.66±1.93					72.8%	13.92±1.97	12.99±1.68
sub-sample			74	13.30±2.56	42.8±27.02	3.27±1.43	3.82±3.13	8.44±2.61	85.1%	13.59±2.57	11.671.86
12/06/2014	15.2	Austevoll	34	12.62±1.8					47.1%	12.66±2.19	12.59±1.43
sub-sample			18	12.7±1.73	31.87±13.05	2.83±1.25	1.78±1.17	5.87±2.32	72.2%	13.02±1.88	11.88±0.96
13/06/2014	13.6	Os	190	12.27±2.27					36.3%	13.10±2.04	11.80±2.27
sub-sample			42	11.32±2	25.43±12.78	3.37±1.09	1.65±0.62	6.33±1.35	81.0%	11.63±1.80	10.03±2.45
20/06/2014	16.3	Sveio	278	12.79±1.88					41.4%	13.47±1.96	12.30±1.66
sub-sample			56	12.28±2.13	33.5±17.66	3.07±1	1.7±0.88	5.33±1.97	83.9%	12.45±2.25	11.4±1.05
21/06/2014	14.1	Austevoll	85	12.48±2.53					43.5%	13.70±2.28	11.53±2.32
23/06/2014	13.3	Austevoll	40	13.49±2.24					37.5%	14.15±2.80	13.09±1.78
sub-sample			40	13.19±2.18	36.67±20.5	3.38±1.69	1.47±1.12	4.39±2.63	82.5%	13.34±2.30	12.5±1.39
25/06/2014	14.5	Austevoll	18	12.66±3.22					77.8%	13.39±3.10	10.10±2.47
sub-sample			20	13.56±4.16	46.10±46.49	3.55±2.24	1.98±1.78	6.45±3.28	80.0%	14.43±4.09	10.1±2.47
29/06/2014	14.8	Austevoll	22	11.09±1.57					63.6%	11.69±1.54	10.04±1.00
sub-sample			24	11.73±2.64	29.18±30.01	2.58±1.67	1.09±1.03	4.19±1.71	79.2%	12.27±2.68	9.68±1.11
2/07/2014	15.2	Austevoll	82	11.52±2.55					23.2%	12.77±2.67	11.14±2.41
sub-sample			82	11.52±2.55	24.92±17.12	2.09±1.04	0.39±0.59	1.57±1.35	43.9%	12.94±2.37	10.42±2.11
3/07/2014	13.3	Austevoll	21	13.07±1.23					23.8%	13.92±1.12	12.81±1.17
sub-sample			21	13.07±1.23	35.21±10.98	3.43±1.6	1±0.73	2.55±1.2	71.4%	13.29±1.35	12.53±0.67
8/07/2014	14.6	Austevoll	22	12.27±2.68					13.6%	15.17±4.31	11.82±2.17
15/07/2014	17.8	Austevoll	61	13.19±2.44					19.7%	14.46±2.91	12.88±2.23
sub-sample			40	12.24±2.48	31.90±19.34	3.35±1.29	0.38±0.26	1.33±0.45	72.5%	13.02±2.32	10.16±1.52
		Overall	3492	12.89±2.56					49.7%	13.45±1.24	12.35±2.49
		sub-sample	591	12.79±2.65	39.38±27.69	3.21±1.44	2.77±3.17	6.32±3.82	77.2%	13.34±2.60	10.96±1.84

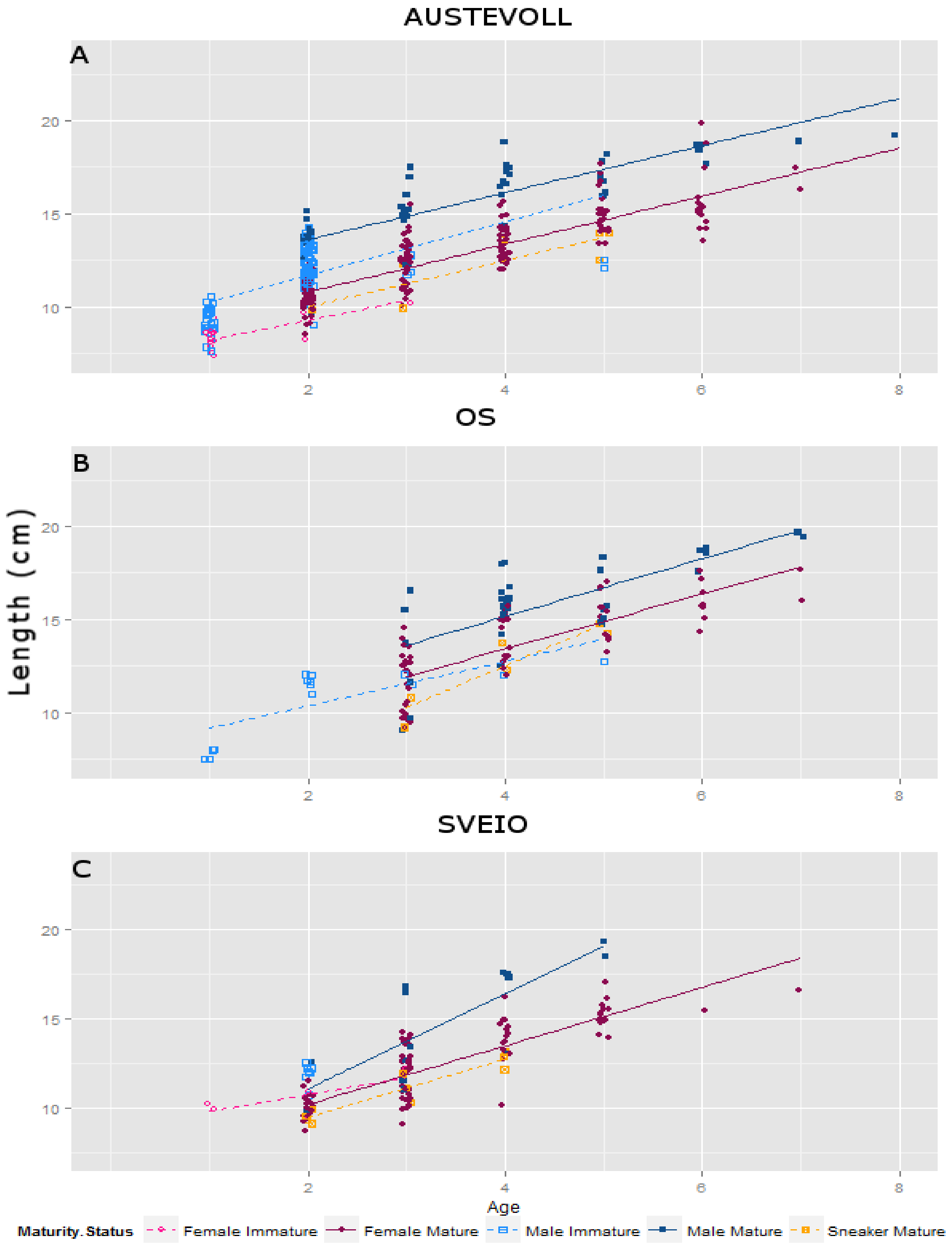


Figure 3.2.1 Corkwing wrasse length relative to age divided into maturity status of each sex. (Austevoll- Female Immature(N=18), Female Mature(N=180), Male Immature (N=88), Male Mature (N=47), Sneaker Mature (N=7). Os- Female Immature(N=0), Female Mature(N=64), Male Immature (N=17), Male Mature (N=37), Sneaker Mature (N=6). Sveio- Female Immature(N=5), Female Mature(N=90), Male Immature (N=7), Male Mature (N=15), Sneaker Mature (N=10).)

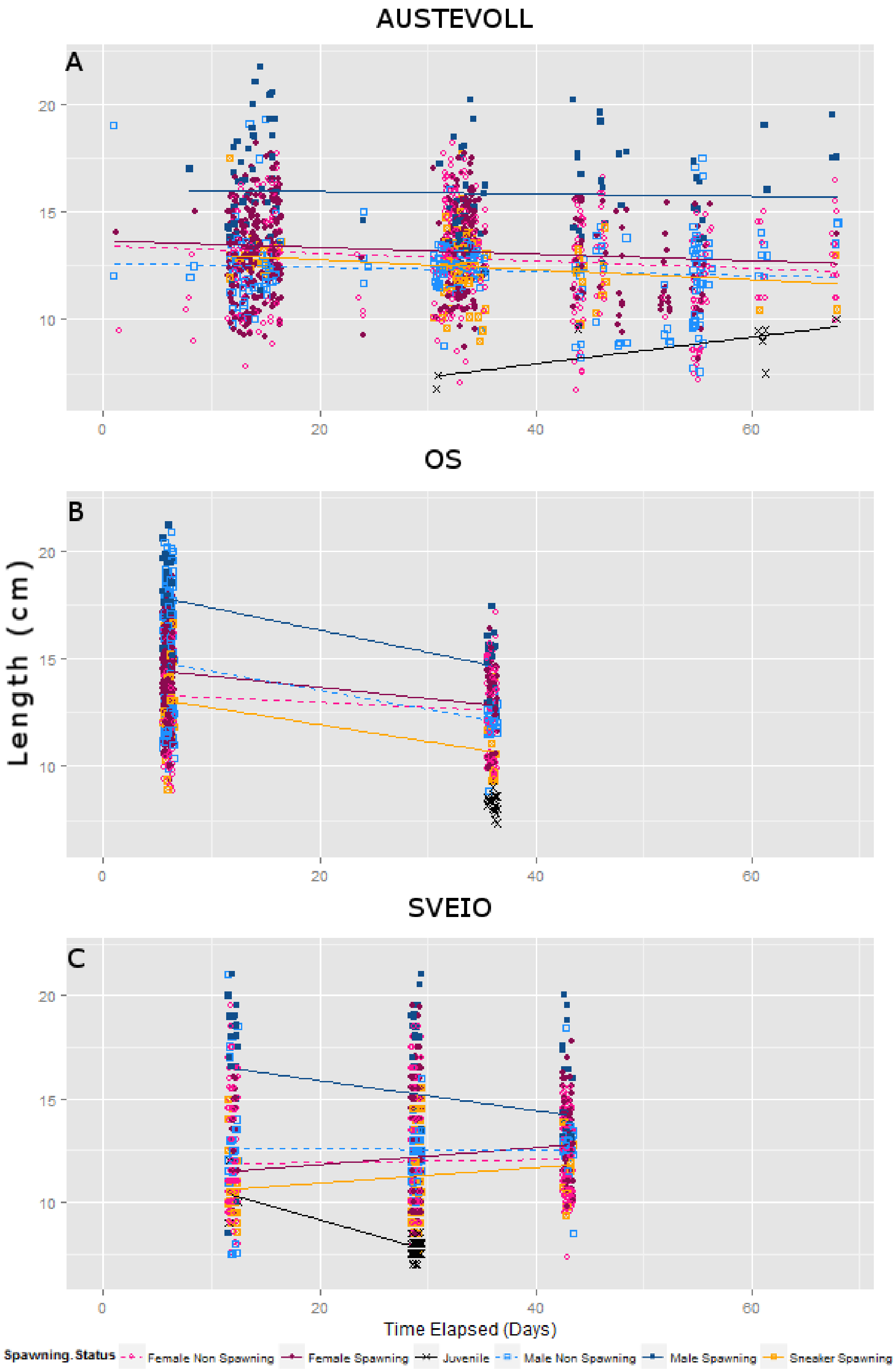


Figure 3.2.2 Corkwing wrasse length relative to time elapsed in days divided into spawning status of each sex. (Austevoll- Female Non-spawning(N=299), Female Spawning(N=430), Juvenile(N=14), Male Non-spawning (N=171), Male Spawning (N=103), Sneaker Spawning (N=92). Os- Female Non-spawning(N=188), Female Spawning(N=370), Juvenile(N=19), Male Non-spawning (N=172), Male Spawning (N=55), Sneaker Spawning (N=44). Sveio- Female Non-spawning(N=597), Female Spawning(N=384), Juvenile(N=65), Male Non-spawning (N=157), Male Spawning (N=93), Sneaker Spawning (N=91).)

Age always plays a factor in a species sexual maturity and the corkwing wrasse is no exception. Age was determined for the subsample studied in the lab using otolith ageing. The age at which the fish are mature varies by sex. As seen in Figure 3.3.1A-D none of the one year olds are sexually mature. The percentage of mature fish increases dramatically from age one to age two. Almost all females are sexually mature by age two and at the latest by age three. The story is a little different with males. A portion are mature by two but the majority stay immature until age three (figure 3.3.1). Specifically looking at figure 3.3.1 A and C both Austevoll and Sveio show a small percentage of sexually mature males at age 2. Os (figure 3.3.1B) does not have a single sexually mature male at two. By age three, however, almost all males are mature. Beyond three years of age, sexually immature fish were found but they were very rare. Figure 3.2.1 shows that these males were still small and most likely chose not to spawn this season because of their size. Statistically age has a positive significant effect on maturity in all permutations as expected (p-value<0.001: Appendix 1.1.1, 1.1.2, 1.1.3; Table 3.4).

Figure 3.3.1E-H shows the percentage of sexually mature fish based on length. Similar to age, length is known to have a strong connection with maturity status. The only location that did not show a statistically significant relation to maturity based on length was Sveio (p-value=0.086, Appendix 1.2.1), which is likely a result of the lack of immature fish captured (Figure 3.3.1G). Spawning was also evaluated against length. Table 3.4 shows corkwing are more likely to be spawning or mature the bigger they are (p-value<0.001, Appendix 1.2.1, 1.2.2, 1.2.3, 1.3.1, 1.3.2, 1.3.3).

If we define as a critical length the point at which 50% of the sample are sexually mature, females reach this critical length at 8.5 cm in Austevoll. For the sample as a whole this length is also met around 8.5 cm (Figure 3.3.1E and H). There is insufficient variation in the data from Os to evaluate the impact of length on sexual maturity in Os (there are no sexually immature females in the dataset). As seen in Figure 3.3.1G Sveio shows a weak effect of length on maturity(Appendix 1.2.2), although here too the data is problematic because of very few immature females (Table 3.4).

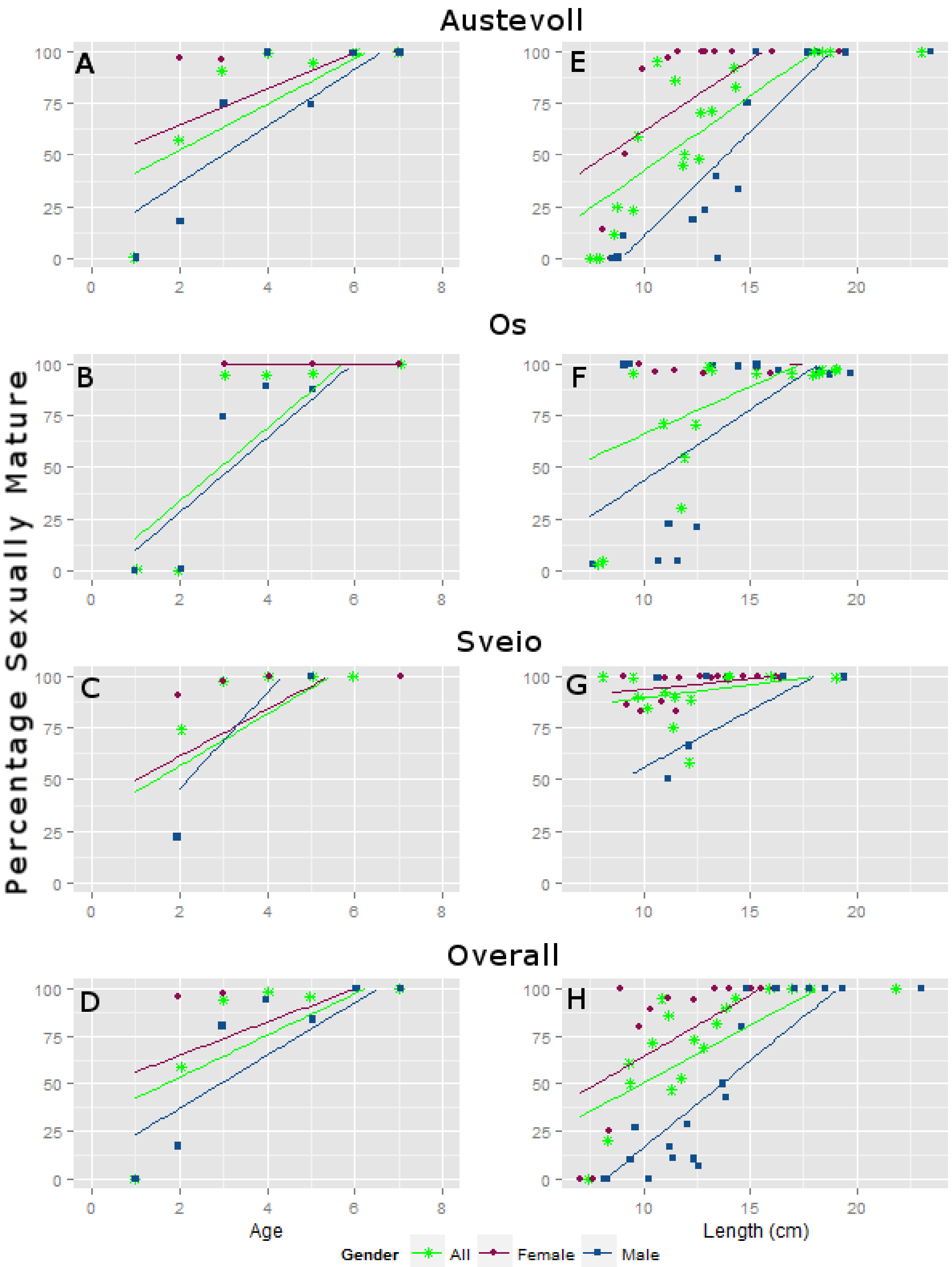


Figure 3.3.1 Percentage of sexually mature corkwing wrasse based on age and the fishes length. (Austevoll- All (N=340), Female (N=198), Male (N=135). Os- All (N=124), Female (N=64), Male (N=54). Sveio- All (N=127), Female (N=95), Male (N=22) Overall- All(N=591), Female(N=357), Male(N=211).)

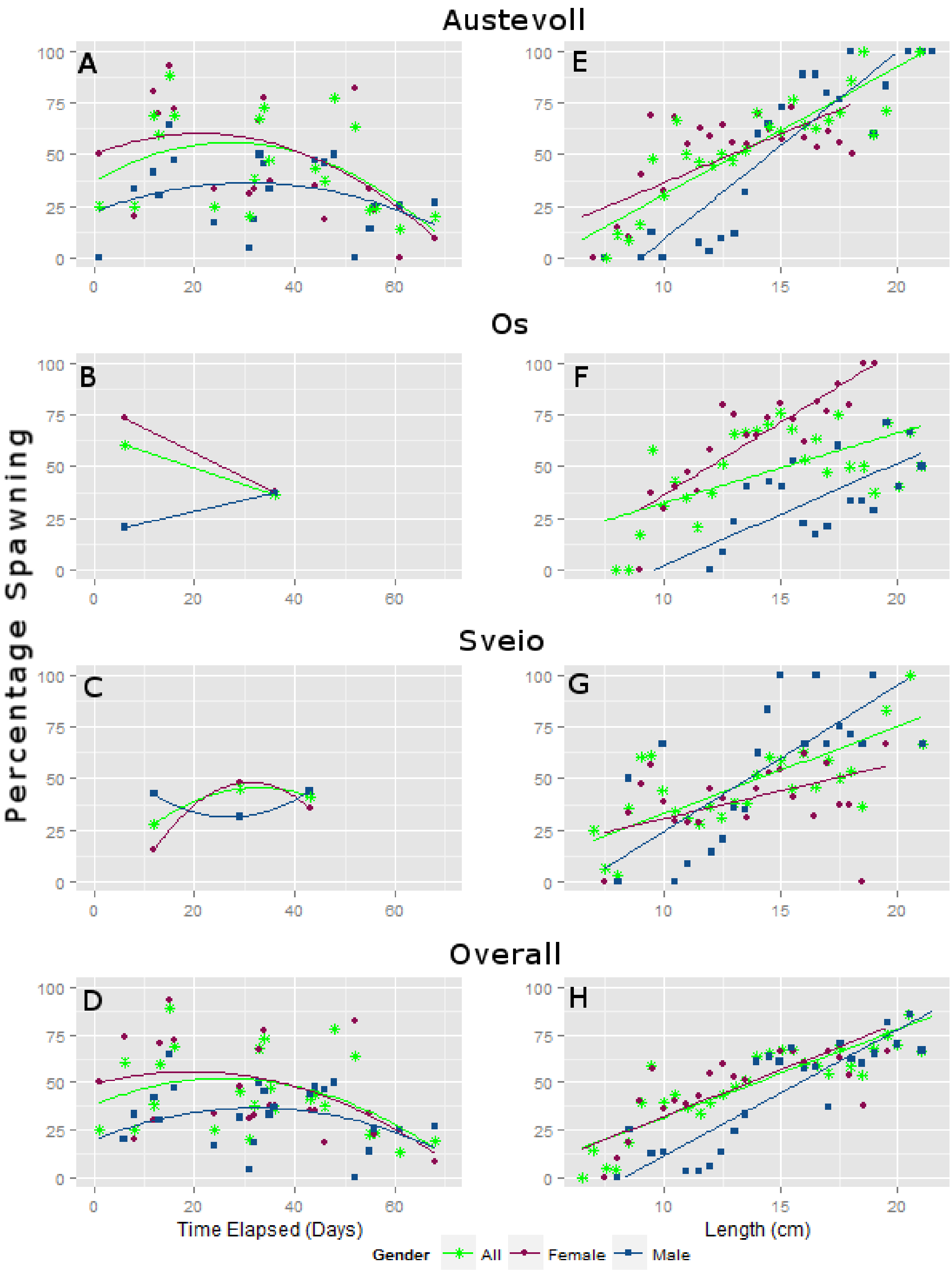


Figure 3.3.2 Percentage of spawning corkwing wrasse based on time elapsed since May 9th (first day of data collection) and the fishes length. (Austevoll- All (N=1253), Female (N=808), Male (N=338). Os- All (N=848), Female (N=558), Male (N=227). Sveio- All (N=1391), Female (N=981), Male (N=250). Overall- All(N=3492), Female(N=2347), Male(N=815))

The critical length for females, which divides the sample into half spawning and half not spawning, is observed to be ~12.5 cm in Austevoll, Os, and overall (Figure 3.3.2E, F, and H). The graphs underestimates spawning, however, as corkwing are batch spawners. The observed fish may not be spawning at the moment of observation. Even if they are not spawning when observed, however, this does not mean they will not spawn this season. This effect is best seen in Sveio, at no point did the proportion of female spawners surpass 50%. Therefore the critical length is 18 cm for Sveio, which is several cm greater than the point at which most corkwing wrasse are sexually mature. The effect of length on spawning was only observed to be statistically significant in Os and for the complete sample (p-value<0.001, Appendix 1.3.2) (Table 3.4).

The critical length where 50% of the fish were mature was different for each location. In Austevoll the data showed a 50% maturation rate in males around 13.5 cm (Figure 3.3.1E). The size in Os and Sveio is smaller, closer to 10-12 cm (Figure 3.3.1F and G). However, the observed spawners had a critical length of 15 cm in Austevoll, Sveio, and the total sample (Figure 3.3.2E, G, and H). In Os the length is much larger, ~18cm (Figure 3.3.2F). This information would indicate that males become sexually mature at a far larger size than females. Statistically length has a positive significant effect on sexual maturity in all locations for males (p-value<0.001: Appendix 1.2.3, 1.3.3,Table 3.4).

Age and length are closely related, as seen in figure 3.2.1. As Table 3.4 makes clear there are consistent statistical effects also. Length is positively and significantly related to sexual maturity for virtually all tests performed (19 of 22). For the three tests where the effect was not significant it is more the results of no variance in the data (lack of non-spawning females), than contradictory data. The same result is found with respect to age where the expected positive effect is found in 11 of 12 trials. In inspecting the data most females are sexually mature by the age of two, when they are approximately 10 cm long. Males, however, seem to take a bit longer. By the age of three, the majority of males are spawning, when they are approximately 14 cm long.

Table 3.4 Summary of statistical tests done on the corkwing wrasse.

			Austevoll			Os			Sveio			All		
	Independent Variable	Dependent Variable	DF	Effect	P-value	DF	Effect	P-value	DF	Effect	P-value	DF	Effect	P-value
All	Age	Maturity	338	positive	**<0.001**	119	positive	**<0.001**	124	positive	**<0.001**	585	positive	**<0.001**
	Length	Maturity	338	positive	**<0.001**	122	positive	**<0.001**	125	positive	0.086	589	positive	**<0.001**
	Length	Spawning	1248	positive	**<0.001**	845	positive	**<0.001**	1388	positive	**<0.001**	3487	positive	**<0.001**
	Time Elapsed	Spawning	1248	negative	**<0.001**	845	negative	**<0.001**	1388	positive	**<0.001**	3487	negative	**<0.001**
	Sex	Maturity	338	negative	**<0.001**	125	negative	**<0.001**	125	negative	0.137	589	negative	**<0.001**
	Sex	Spawning	1144	negative	**<0.001**	783	negative	**<0.001**	1229	negative	0.574	3160	negative	**<0.001**
Female	Age	Maturity	196	positive	**<0.001**	62	NA	NA	92	positive	**0.003**	354	positive	**<0.001**
	Length	Maturity	196	positive	**<0.001**	62	NA	NA	93	positive	0.063	355	positive	**<0.001**
	Length	Spawning	804	positive	0.066	555	positive	**<0.001**	978	positive	0.155	2343	positive	**<0.001**
	Time Elapsed	Spawning	804	negative	**<0.001**	555	negative	**<0.001**	978	positive	**<0.001**	2343	negative	**<0.001**
	Time Elapsed	GSI	194	negative	**<0.001**	60	negative	**<0.001**	91	negative	**<0.001**	351	negative	**<0.001**
	Maturity	GSI	195	positive	**<0.001**	62	NA	NA	93	positive	**0.003**	353	positive	**<0.001**
Male	Age	Maturity	133	positive	**<0.001**	49	positive	**<0.001**	20	positive	**<0.001**	206	positive	**<0.001**
	Length	Maturity	133	positive	**<0.001**	52	positive	**<0.001**	20	positive	**0.019**	209	positive	**<0.001**
	Length	Spawning	335	positive	**<0.001**	224	positive	**<0.001**	247	positive	**<0.001**	812	positive	**<0.001**
	Time Elapsed	Spawning	335	negative	0.268	224	positive	**<0.001**	247	positive	0.111	812	positive	**<0.001**

As noted in the introductory chapter, the primary goal of this research project was to observe at what time the fish were spawning. Figure 3.3.2D shows that most locations showed a significant negative effect between time and spawning, suggesting as time went on the proportion of fish spawning dropped (p-value<0.001, Appendix 1.3.1,Table 3.4). Sveio, on the other hand, showed a positive effect (p-value<0.001, Appendix 1.3.1; Table 3.4). It is important to note that a critical point of spawning was never observed in Sveio. It may indicate peak spawning occurred after the last collection date or during the days in between, when we did not collect data.

The males showed an odd effect of spawning in relation to time. There was never a critical point of spawning for males over time. Instead, they seemed to be spawning at a even rate at all times. Often the only non-spawning males were too small or too young to spawn (Figure 3.3.2E-H). The statistical tests show an overall significant positive effect of time on spawning in males for the sample as a whole, as well as in Os (p-value<0.001, Appendix 1.3.3) (Table 3.4). A non-significant effect, however, was found in Austevoll and Sveio (Appendix 1.3.3) (Table 3.4).

The females tend to control when spawning occurs; therefore, they are the most important to look at when trying to find out when corkwing spawn. It appears peak spawning occurs between May 9th to June 15th based on Figure 3.3.2A and D. This would indicate that peak spawning spans over a month. Os (Figure 3.3.2B) appears to have started peak spawning earlier than Austevoll (Figure 3.3.2A); however, lack of multiple day samples from Os make it hard to compare. All locations, besides Sveio, showed a significant negative effect of time on spawning (p-value<0.001, Appendix 1.3.2) (Table 3.4). Sveio (Figure 3.3.2C) showed a positive significant effect of time on spawning (p-value<0.001, Appendix 1.3.2) (Table 3.4). At no point is spawning observed to be above 50%. The effect in Sveio (and Os) must be seen as merely tentative as the lack of dates where data were collected at these sites make it very difficult to observe changes in spawning behavior over time.

One way to get around the difficulty caused by batch spawning making it difficult to identify whether fish are spawning this season is to evaluate the data on the GSI against time. First, a test was done to see if GSI was a good indicator for sexual maturity[9]. Figure 3.4A-D compares GSI with sexual maturity and as can be seen there is a strong relationship in all

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[9] The wrasse gonads were inspected and identified as immature (0) or mature(1).

locations (p-value<0.001, Appendix 1.5) with the exception of Os, where there were no immature wrasse to evaluate (Table 3.4, Appendix 1.5).

As expected all locations showed a negative significant effect of time on GSI (p-value<0.001, Appendix 1.4). Figure 3.4G suggests that in Sveio a significant amount of spawning occurred between the first and second sampling date. However, the greatest drop in GSI occurred between the second and third sampling date. This could indicate that more spawning occurred between the 6th of June and the 20th of June compared to the 20th of May to the 6th of June. Based on the limited data from Sveio and Os no peak spawning time frame can be given for these sites. The GSI data (Figure 3.4) does indicate the corkwing wrasse is still spawning at all locations by the end of June but based on the spawning data (Figure 3.3.2A-D) peak spawning has ended.[10] By the last day of sampling it appears that most ovaries were depleted based on the GSI. It would be safe to assume that little to no spawning occurred after the July15th. The GSI data also supports the idea that the majority of spawning occurred around the June 15th (Figure 3.4H).

It is apparent that sex has an effect on spawning behavior. This is seen in figures, 3.3.1, 3.3.2., When comparing across sex, we find females are more likely to be both sexually mature and spawning at a given age and a given size (i.e. holding size or age constant females are more likely to be sexually mature). The effect is significant in all locations except Sveio (p-value<0.001, Appendix 1.6;Table 3.4) where data limitations affect the analysis. Males tend to become mature at an age older and size larger than the females (3.3.1H).

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[10] June 30th was the 52nd day since the start of data collection.

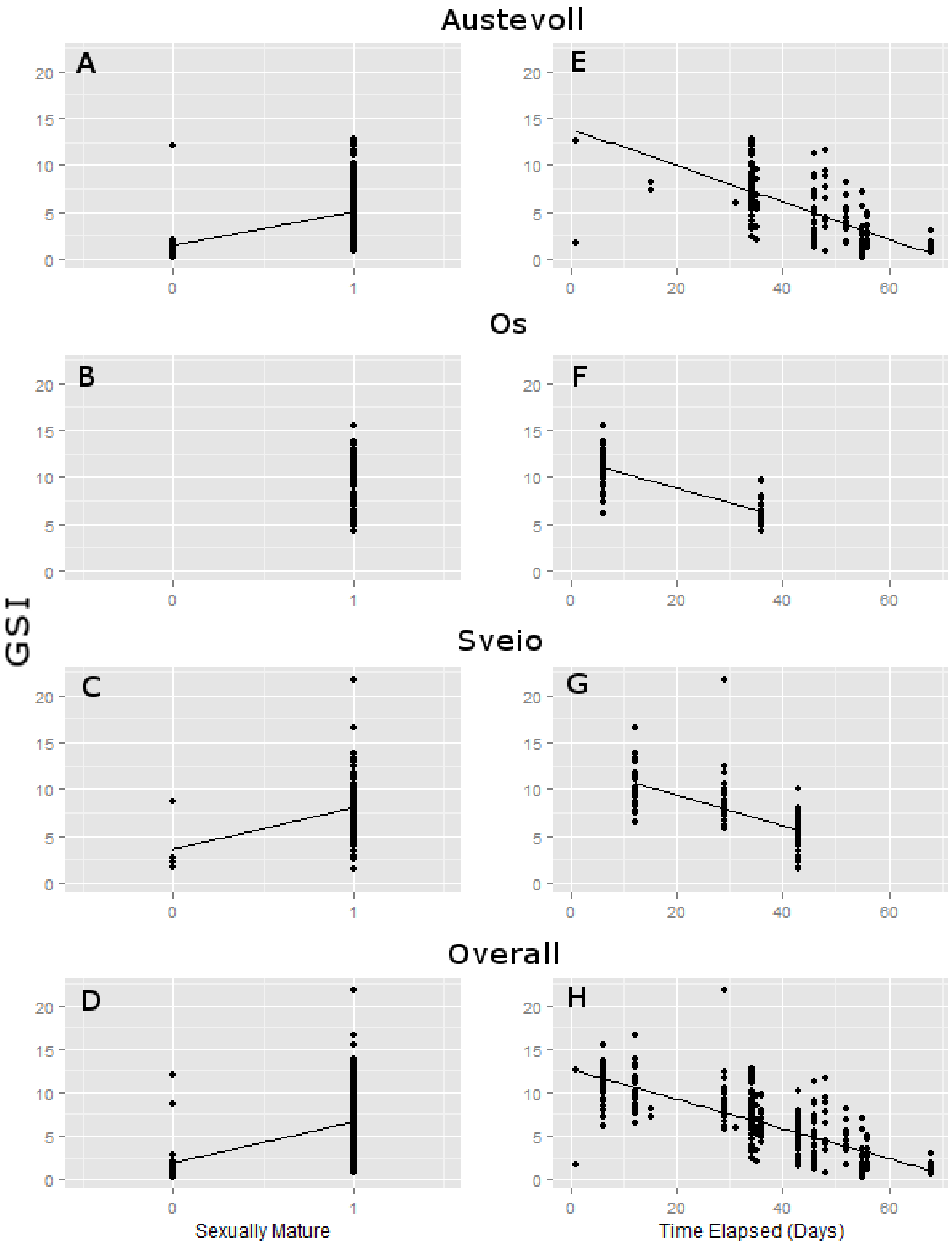

Figure 3.4 GSI of female corkwing wrasse based on maturity status of the fish and days elapsed since the first day of sampling (May 9th 2015). Austevoll (N=198), Os (N=64), Sveio (N=95), Overall (N=357).

3.3 Goldsinny Wrasse

Table 3.5 presents the basic data for the goldsinny. A total of 626 goldsinny were observed and a sub-sample of 129 were further analyzed in the lab. The average length of all the observed goldsinny was 10.3 cm (Table 3.5). Of these the spawning/mature fish had an average size range of 8.4 cm to 11.4 cm. The non-spawning immature fish had a slightly smaller average size range of 7.7 cm to 11.3 cm (Table 3.5). The goldsinny are a small group of fish but are also the oldest of the wrasse, excluding ballan wrasse. The average age of the goldsinny ranged from three-years-old to six-years-old. Looking at Table 3.5 we see the average GSI decreases markedly over the sixty days tracked(Table 3.5).

Based on the sub-sample of 129 fish taken to the laboratory, the oldest goldsinny observed was nine-years-old (Figure 3.5.1A). All the one and two-year-olds analyzed were immature. In addition, ages 3, 4, and 6 had at least one immature fish in the group. In Austevoll the immature three-year-old is the smallest of the observed three-year-old males. The immature females are on the smaller side among three-year-old females. Also the immature female that is four-years-old from Austevoll is the smallest in that group (figure 3.5.1A). This pattern does not continue in Sveio or Os. The observed immature males in Os are the largest in their age group (Figure 3.5.1B). Only one immature female was identified from Os. It was the largest female in its three-year-old age group (Figure 3.5.1B). The observed immature male in Sveio is the oldest male analyzed from that location and is slightly larger than the younger mature male (Figure 3.5.1C). No immature females were observed from Sveio (Figure 3.5.1C). It appears that most goldsinny are mature by 9 cm. In general few immature fish were observed. Of the 129 subsample brought to the lab, only 13 (5 Females,8 Males) were immature., This is possibly a result of the immature fish being too small to be caught by the fyke nets.

The goldsinny wrasse are small slow growing fish, which means even the slightest change is significant. In particular we are interested to see if pressure on the species is noticeably greater in some localities than others. Goldsinny from Os and Sveio were approximately the same but were statistically different from Austevoll (p-value<0.001 and p-value=0.014 respectively, Appendix 4.2). Goldsinny from Austevoll are approximately 0.5 cm smaller than the ones from Sveio and 0.6 cm smaller than the ones from Os. Considering the fact that measurements were rounded to the nearest 0.5 cm this effect may be more a result of the rounding than a difference in length by location. A different effect is shown when looking at the ages of the goldsinny. Austevoll and Os are on average the same age, while the fish in Sveio are significantly older (p-value=0.003 and p-value=0.013 respectively, Appendix 4.2). On average goldsinny from Austevoll and Os are four-years-old, while the fish from Sveio are on average between five and six-years-old.

The first impression Figure 3.5.2 produces is that the size of male and female goldsinny are homogenous (also apparent in Figure 3.5.1). The spawning fish from Austevoll (3.5.1A) and Sveio (Figure 3.5.1C) at most show females are on average larger than males by 0.5 cm. The non-spawning males at most are 0.5 cm larger than the females in Austevoll (3.5.1A) and Os (3.5.1B). Since goldsinny are slow growing it may appear that age is more of a factor for maturity than is length.

Table 3.5 Goldsinny registration by date and location

Date	°C	Location	N	L (cm) $\bar{x}$ ±SD	W (g) $\bar{x}$±SD	Age$\bar{x}$±SD	Gonad W(g) $\bar{x}$±SD	GSI$\bar{x}$±SD	% Spawning/ Mature	Spawners/ Mature L(cm) $\bar{x}$±SD	Non-Spawners/ Immature L(cm) $\bar{x}$±SD
14/05/2014	9.9	Os	71	10.57±1.06					64.8%	10.65±1.01	10.42±1.16
sub-sample			1	11	22.1	5	2.34	10.59	100.0%	11	
16/05/2014	9.7	Austevoll	9	10.28±1.06					33.3%	10.33±1.04	10.25±1.17
20/05/2014	11.7	Austevoll	40	10.04±1.55					55.0%	10.26±1.20	9.76±1.90
20/05/2014	10.6	Sveio	44	9.92±1.58					38.6%	11.38±0.85	11.16±1.03
21/05/2014	13.3	Austevoll	38	9.95±1.44					60.5%	10.37±1.25	9.31±1.52
22/05/2014	10.8	Austevoll	20	8.76±1.2					30.0%	8.40±0.58	8.91±1.37
23/05/2014	11.8	Austevoll	17	9.86±1.3					70.6%	10.01±1.20	9.50±1.60
sub-sample			5	10.04±1.27	16.54±5.84	3.5±0.58	0.95±0.87	6.1±5.53	100.0%	10.04±1.27	
24/05/2014	12.2	Austevoll	11	10.43±1.65					36.4%	10.05±1.45	10.64±1.83
1/06/2014	13.5	Austevoll	14	10.09±1.54					57.1%	10.21±1.31	9.92±1.91
6/06/2014	15.5	Sveio	35	10.43±1.88					37.1%	9.81±1.33	10.80±2.07
sub-sample			1	12.8	39.4	5	3.58	9.09	100.0%	12.8	
8/06/2014	15.2	Austevoll	21	10.20±2.02					57.1%	11.23±1.74	8.84±1.54
sub-sample			17	9.92±1.67	16.25±7.77	3.41±1.28	1.5±0.67	8.85±1.57	70.6%	10.75±1.12	7.92±0.83
9/06/2014	15.1	Austevoll	5	10.48±1.83					0.0%		10.48±1.83
10/06/2014	15.7	Austevoll	7	9.87±1.95					71.4%	9.30±1.57	11.30±2.69
11/06/2014	15.2	Austevoll	13	10.25±1.57					84.6%	10.32±1.66	9.85±1.20
12/06/2014	15.2	Austevoll	19	9.99±1.36					63.2%	9.68±1.30	10.54±1.39
13/06/2014	13.6	Os	135	10.62±1.03					36.3%	10.43±0.70	10.73±1.16
sub-sample			50	9.89±1.02	14.62±4.7	4.38±1.09	0.92±0.49	5.94±2.43	92.6%	9.90±1.01	9.78±1.35
20/06/2014	16.3	Sveio	34	11.24±0.97					35.3%	11.38±0.85	11.16±1.03
sub-sample			13	10.74±0.77	19.18±3.9	5.6±0.84	0.98±0.54	5.23±2.62	92.3%	10.72±0.80	11
21/06/2014	14.1	Austevoll	41	9.62±1.24					36.6%	10.03±1.36	9.38±1.12
23/06/2014	13.3	Austevoll	4	10.4±1.06					75.0%	10.90±0.44	8.9
sub-sample			4	10.2±1.17	15.38±5.55	4±0.82	0.8±0.62	4.96±2	75.0%	10.70±0.75	8.7
8/07/2014	14.6	Austevoll	12	11.5±1.15					16.7%	11.15±0.49	11.57±1.24
15/07/2014	17.8	Austevoll	36	10.57±1.12					8.3%	11.00±1.32	10.53±1.12
sub-sample			34	10.02±1.12	14.42±4.92	4.76±1.28	0.18±0.1	1.21±0.47	91.2%	10.24±0.89	7.73±0.67
		Overall	626	10.31±1.4					44.4%	10.32±2.52	10.29±1.52
		sub-sample	129	10.06±1.17	15.59±5.75	4.42±1.25	0.87±0.71	5.09±3.28	89.1%	10.23±1.03	8.69±1.38

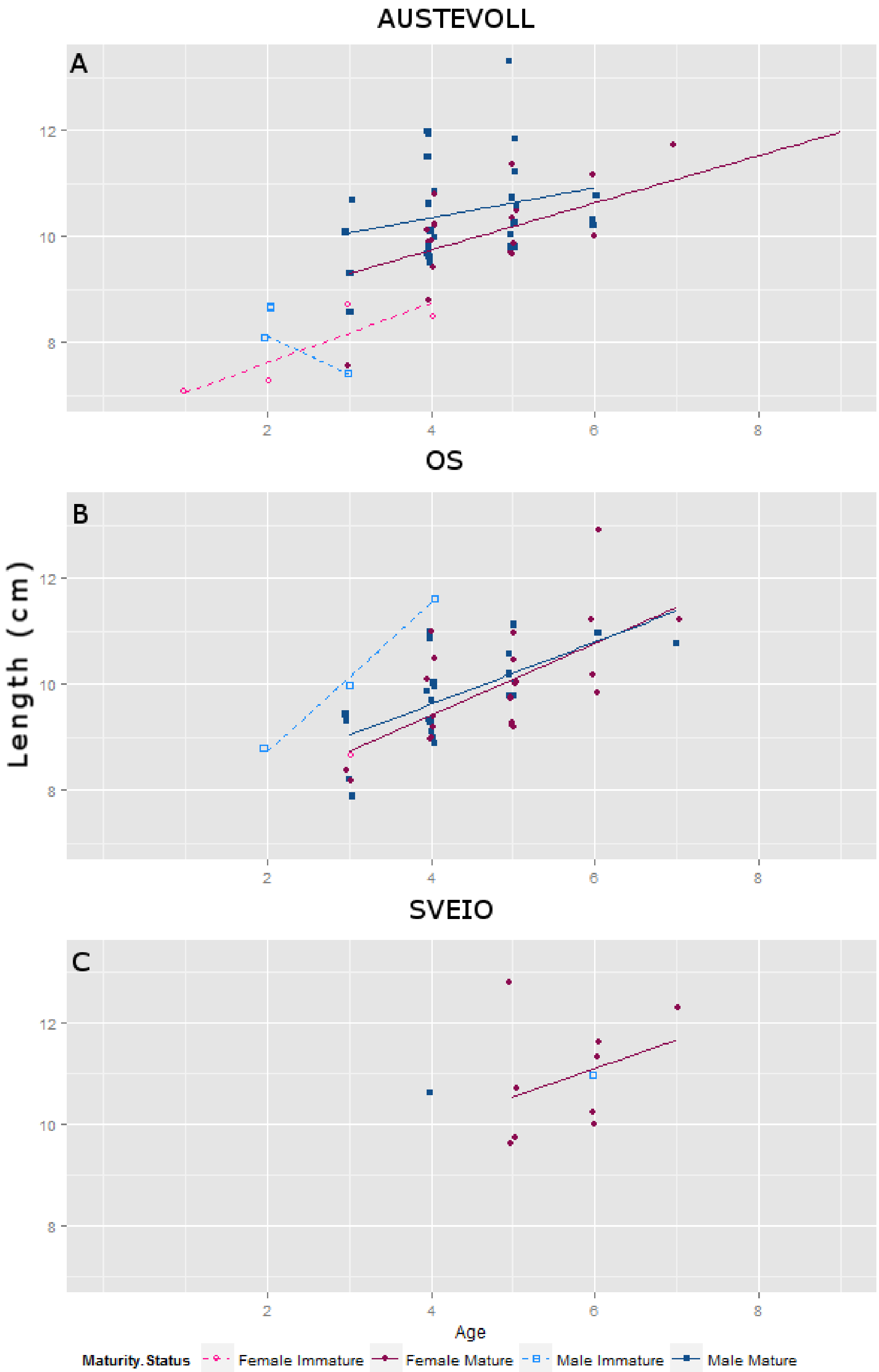

Figure 3.5.1 Goldsinny wrasse length relative to age divided into spawning status of each sex. (Austevoll- Female Immature (N=4), Female Mature (N=22), Male Immature (N=5), Male Mature (N=29). Os- Female Immature (N=1), Female Mature (N=25), Male Immature (N=3), Male Mature (N=26). Sveio- Female Immature (N=0), Female Mature (N=12), Male Immature (N=1), Male Mature (N=1).

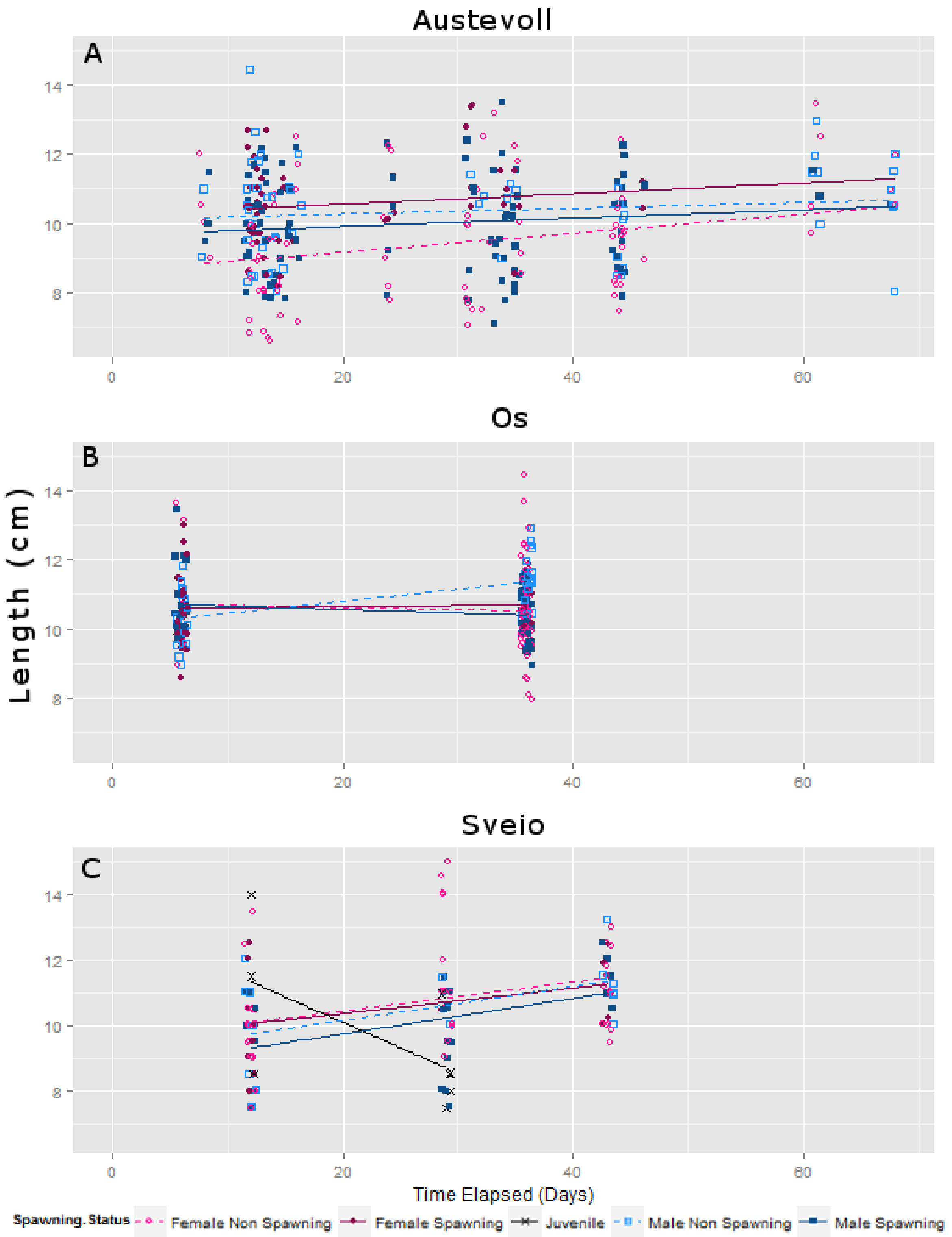

Figure 3.5.2 Goldsinny wrasse length relative to time elapsed in days divided into spawning status of each sex. (Austevoll- Female Non-spawning (N=97), Female Spawning (N=47), Juvenile (N=0), Male Non-spawning (N=69), Male Spawning (N=94). Os- Female Non-spawning (N=72), Female Spawning (N=32), Juvenile (N=2), Male Non-spawning (N=37), Male Spawning (N=63). Sveio- Female Non-spawning (N=48), Female Spawning (N=16), Juvenile (N=7), Male Non-spawning (N=15), Male Spawning (N=26).)

The goldsinny's age was tested to see if it affected maturity. Figure 3.6.1 shows that the majority of the observed fish were mature. The majority of the immature fish observed were below the age of three. At age three a big jump occurs and there are significantly more mature fish than immature fish (Figure 3.6.1C). Beyond three the goldsinny are overwhelmingly, but not exclusively, mature. The critical age for maturity in goldsinny appears to be three-years-old for both genders. The effect of age on maturity was found to be significant for the overall sample and in Austevoll (p-value<0.001, Appendix 2.1.1) (Table 3.6). There were too few goldsinny from Sveio to test them. Os showed a statistically significant effect of age on spawning in males (p-value=0.05, Appendix 2.1.3) (Table 3.6) but not in females (p-value=0.094, Appendix 2.12) (Table 3.6). The sample size in Os is likely the main reason for the failure to get a statistically significant effect. Only one of the 26 females observed in Os was immature.

The smallest mature goldsinny was a 7.5 cm female, while the smallest mature male was 8 cm. The largest immature female were 8.5 cm while the largest immature male was 11.5 cm. The critical length for maturity in goldsinny appears to be 8 cm in females and 9 cm in males (Figure 3.6.1H). The effect of length on maturity was found to be significant in Austevoll and the overall effect (p-value<0.001). However, in Os length showed no effect on maturity (p-value=0.79 Appendix 2.2.1) (Table 3.6). This was likely a result of the immature males from Os were large compared to the other locations and the lack of immature females. In total Os only had four observed immature goldsinny.

The information gathered on the subsample evaluated in the lab indicates that the majority of the fish observed in the field were sexually mature. Yet, looking at figures 3.6.2F-H females were rarely observed to be spawning at a 50% rate. The batch spawning intervals affect the data interpretation. As a result the critical length for spawning females is indeterminate, while males appear to have a critical length around 7 to 7.5 cm. Another odd effect observed is the decrease in spawning as the fish got larger, best seen in figure 3.6.2H. It is important to note, however, that this effect is not statistically significant. In most cases spawning was not significantly affected by length. The overall effect of length on spawning with all locations included showed little change (p-value=0.32, Appendix 2.3.1) (Table 3.6). We can unpack this a bit by looking across sex. Looking at the females for all the locations together (Figure 3.6.2E) we see a positive significant effect of length on spawning (p-value<0.001, Appendix 2.3.2)

(Table 3.6). This effect is driven by strong results from Austevoll (Figure 3.6.2E) where there is a significant positive effect of length on spawning (p-value<0.001, Appendix 2.3.2) (Table 3.6). The other sites show very little relationship between length and spawning behavior. Males, on the other hand, show a negative relationship between length and spawning. This was statistically only in Os (p-value=0.018, Appendix 2.3.3) and all locations together (p-value=0.018, Appendix 2.3.3) (Table 3.6), but it exists at all three sites (Figure 3.6.2F, G and H). This is the only condition under which length appears to have a significant negative effect on spawning. It is unclear what would cause this. There is some territorial behavior exhibited by goldsinny, which would indicate more spawning at a larger size.

The males are more readily available to spawn than the females. The observed data indicate that peak spawning occurred between Day 20 (May 28th) and Day 40 (June 17th), similar to the corkwing wrasse time frame. The effect of time elapsed on the goldsinny was observed to be significant in all locations (p-value<0.001, Appendix 2.4.1) except for Sveio (p-value=0.97, Appendix 2.4.1) (Table 3.6). Specifically the effect was more strongly associated with females (p-value<0.001, Appendix 2.4.2), than males. Only males from Austevoll showed an effect of time elapsed on spawning (p-value=0.015, Appendix 2.4.3). A possible reason behind males showing an effect of time on spawning in Austevoll compared to the other locations is that we have more complete data for Austevoll as sampling continued on into July, where little to no spawning was observed (Figure 3.6.2A).

The GSI of the female corkwing wrasse shows how spawning occurred over time. However, the data from Os (Figure 3.7F) and Sveio (Figure 3.7G) were not available for statistical tests as only one day per location had several data points. Time elapsed has a significant negative effect on the GSI (p-value<0.001, Appendix 3.5) (Table 3.6). Based on the GSI observed in Os and Sveio it would indicate that some spawning occurred after the last day of sampling. The last day of sampling in Austevoll indicates little to no spawning occurred after the 15th of July.

GSI was found to be a good indicator of maturity in goldsinny (p-value=0.05, Appendix 3.5) (Table 3.6) (Figure 3.7A, B, and D). Sveio was not tested as there were no immature females observed.

As previously seen in corkwing wrasse gender seems to play a factor in spawning and maturity. In goldsinny maturity was not significantly affected by gender (p-value=0.654, Appendix 3.6) (Table 3.6). The effect of gender on spawning is significant in all cases (p-value<0.001, Appendix 3.6) except for Os (p-value=0.2, Appendix 3.6) (Table 3.6). In general males were observed spawning far more often than females.

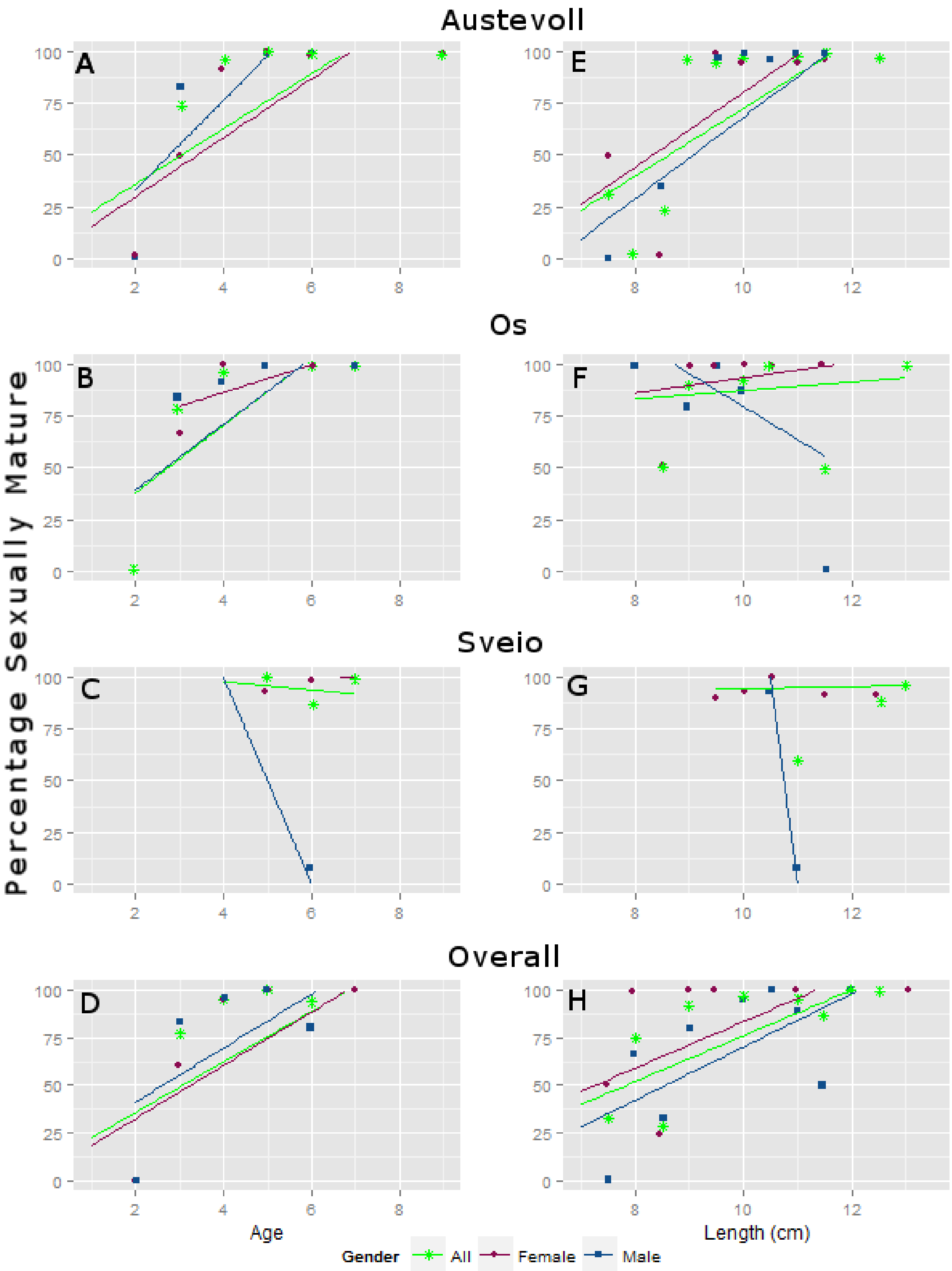

Figure 3.6.1 Percentage of sexually mature corkwing wrasse based on age and the fishes length. (Austevoll- All (N=60), Female (N=26), Male (N=34). Os- All (N=55), Female (N=26), Male (N=29). Sveio- All (N=14), Female (N=12), Male (N=2). Overall- All (N=129), Female (N=64), Male (N=65).)

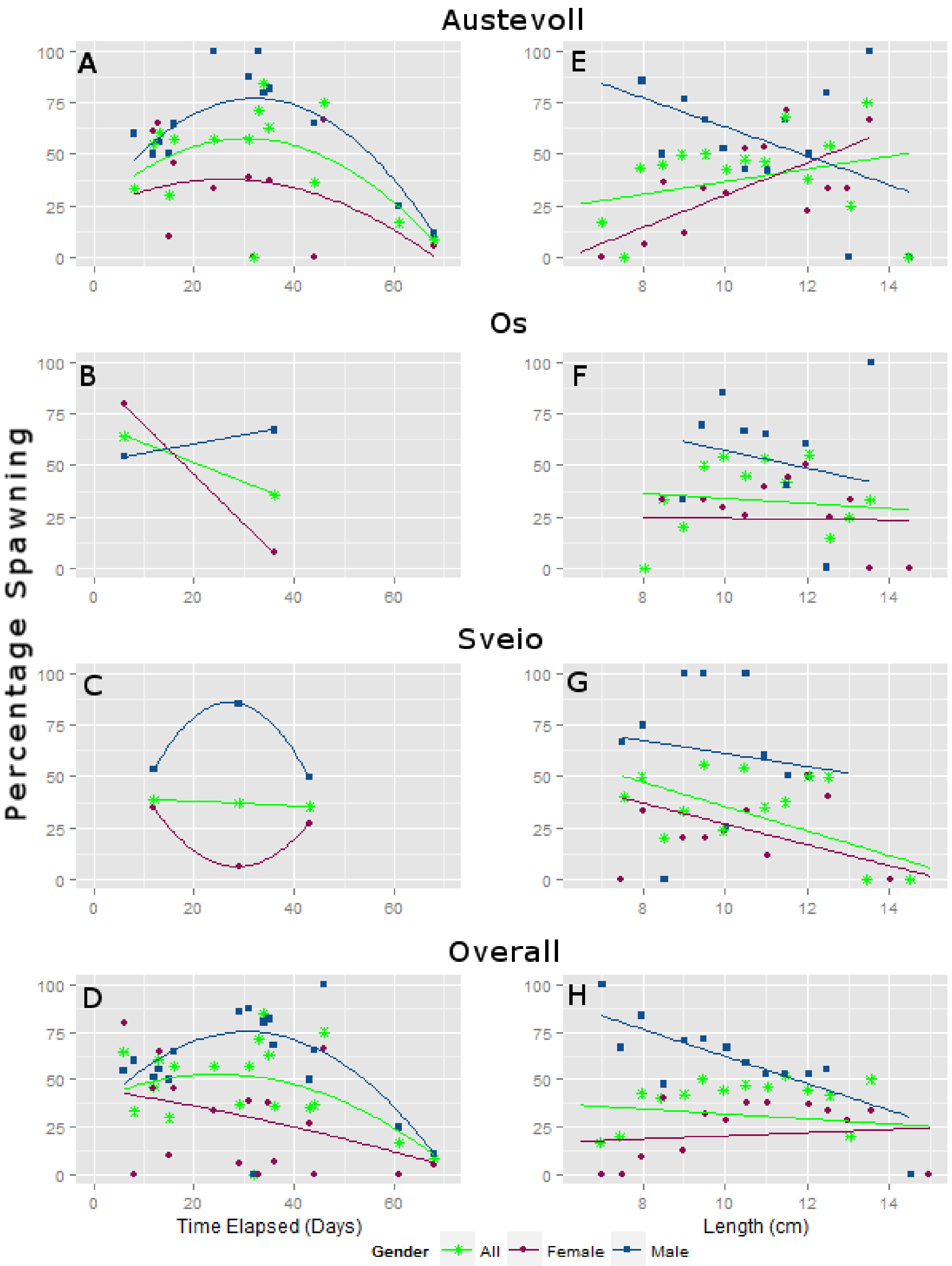

Figure 3.6.2 Percentage of spawning goldsinny wrasse based on time elapsed since May 9th (first day of data collection) and the fishes length. (Austevoll- All (N=194), Female (N=71), Male (N=100). Os- All (N=328), Female (N=88), Male (N=66). Sveio- All (N=186), Female (N=78), Male (N=86). Overall- All (N=708), Female (N=237), Male (N=252).)

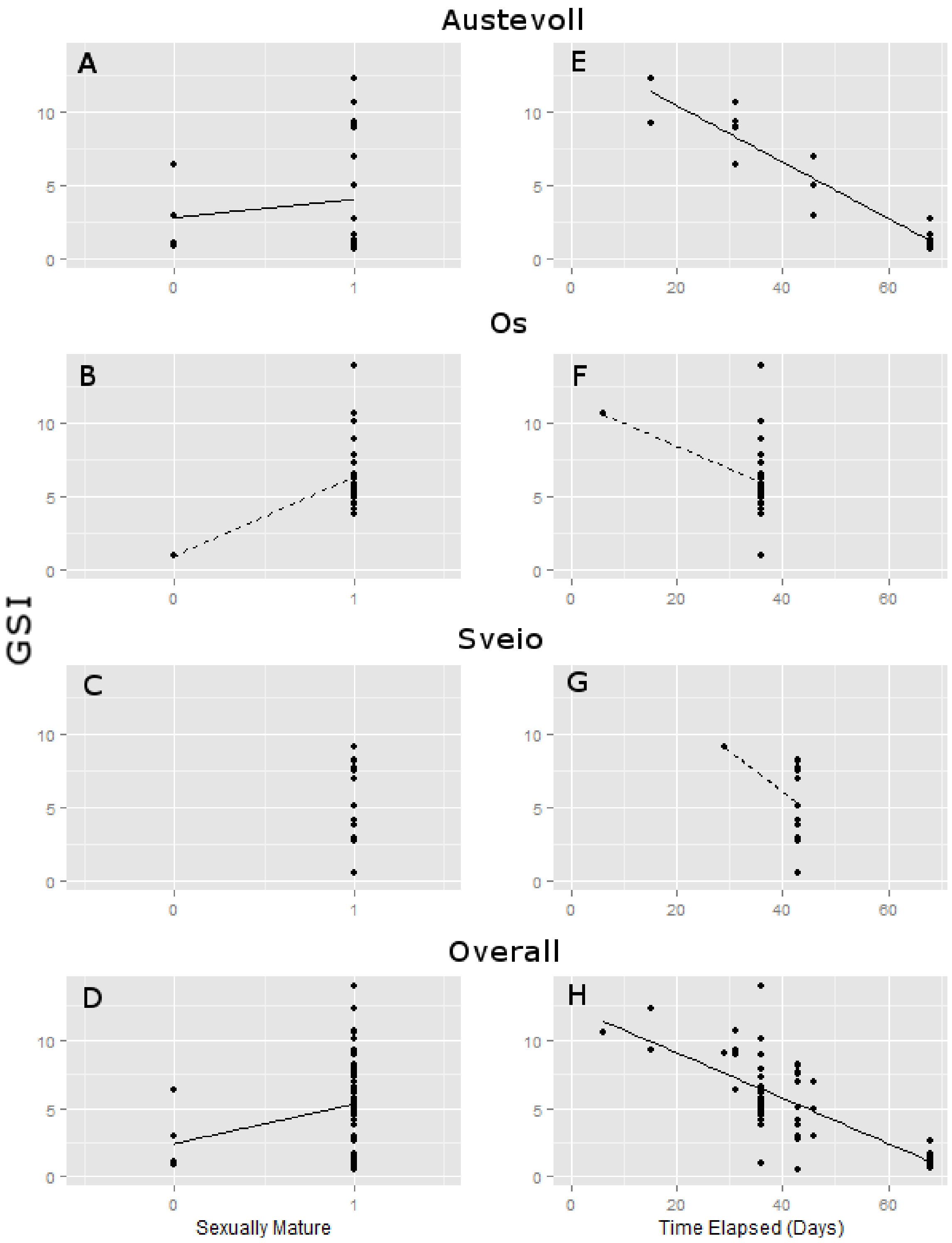

Figure 3.7 GSI of female goldsinny wrasse based on maturity status of the fish and days elapsed since the first day of sampling (May 9th 2015). Austevoll (N=144), Os (N=104), Sveio (N=64), Overall (N=312).

Table 3.6 Summary of statistical tests done on the goldsinny wrasse.

			Austevoll			Os			Sveio			All		
	Independent Variable	Dependent Variable	DF	Effect	P-value	DF	Effect	P-value	DF	Effect	P-value	DF	Effect	P-value
All	Time Elapsed	Spawning	304	negative	**<0.001**	203	negative	**<0.001**	110	positive	0.97	623	negative	**<0.001**
	Length	Spawning	304	positive	**0.015**	203	negative	0.441	110	negative	0.341	623	positive	0.32
	Sex	Spawning	305	positive	**<0.001**	202	positive	**<0.001**	103	positive	**<0.001**	615	positive	**<0.001**
	Length	Maturity	58	positive	**<0.001**	53	positive	0.792	NA	NA	NA	127	positive	**<0.001**
	Age	Maturity	56	positive	**<0.001**	49	positive	**0.006**	NA	NA	NA	118	positive	**<0.001**
	Sex	Maturity	58	positive	0.943	53	negative	0.363	NA	NA	NA	127	negative	0.274
Female	Time Elapsed	Spawning	141	negative	**<0.001**	101	negative	**<0.001**	61	negative	0.546	309	negative	**<0.001**
	Length	Spawning	141	positive	**<0.001**	101	positive	0.948	61	negative	0.801	309	positive	**<0.001**
	Time Elapsed	GSI	23	negative	**<0.001**	NA	NA	NA	NA	NA	NA	61	negative	**<0.001**
	Maturity	GSI	23	positive	**0.01**	23	positive	**0.032**	NA	NA	NA	61	positive	**0.05**
	Length	Maturity	24	positive	**<0.001**	24	positive	0.247	NA	NA	NA	62	positive	**<0.001**
	Age	Maturity	22	positive	**0.004**	22	positive	0.094	NA	NA	NA	55	positive	**<0.001**
Male	Time Elapsed	Spawning	160	negative	**0.015**	97	positive	0.118	38	positive	0.618	301	negative	0.177
	Length	Spawning	160	negative	0.135	97	negative	**0.018**	38	negative	0.357	301	negative	**0.018**
	Length	Maturity	32	positive	**<0.001**	27	negative	0.472	NA	NA	NA	63	positive	**0.005**
	Age	Maturity	32	positive	**<0.001**	25	positive	**0.05**	NA	NA	NA	61	positive	**<0.001**

3.4 Rock Cook Wrasse

A total of 708 rock cook were observed, of these subsample of 98 was taken. Table 3.7 shows a summary of the data broken down by date and location. The average size of the rock cook observed ranged from 9 cm to 13 cm. The spawning/mature rock cooks had a higher average size range, 10 cm to 13 cm; while, the non-spawning/immature rock cooks had an average length range of 7 cm to 12 cm. The average range of ages is high from two-years-old up to five-years-old. Most notably though is that over time neither the GSI nor the percent spawning seem to decrease.

Of the 98 individuals in the sub-sample only two were observed to be immature. Figure 3.8.1A shows that the immature female was one-years-old and the immature male was two-years-old. No immature rock cooks were observed in Os (Figure 3.8.1B) and Sveio (Figure 3.8.1C). The oldest rock cook observed was a female seven-years-old, from Sveio. It appears that most females and males are mature by the age of two; however, there were no two-year-old females observed in Austevoll or Os. Males tend to be the larger fish in their age group (Figure 3.8.1). Males appear to be approximately 0.5 cm larger than females on average (Figure 3.8.2). There is also little difference in length between spawning rock cooks and non-spawning rock cooks. Particularly both genders in Sveio (Figure 3.8.2C) and males in Austevoll (Figure 3.8.2A). This enforces the idea that these fish are sexually mature, as seen in the sub-sample (Figure3.8.1) but may be between spawning batches when observed, assuming they are batch spawners (Figure 3.8.2).

As stated in section 2, early in the season rock cook are harder to identify by gender. This mostly caused issues with the data from Os, as seen in Figure 3.8.2B. Almost all non-spawning fish were not identified by gender. It is likely that the spawning period had just started by the time the rock cook were observed on the 14th of May.

Rock cook from Os were significantly larger than the ones found in Austevoll and Sveio (p-value<0.001, Appendix 4.3). The average size of rock cook from Austevoll and Sveio were both 11 cm, while the average size in Os was 12 cm. The ages of goldsinny from Sveio and Os were also significantly different from each other (p-value=0.038, Appendix 4.3). Sveio had younger fish than Os, which would support the fact that Os had larger fish than Sveio. Austevoll's rock cook population may grow slower than the ones found in Os as the population is about the same age.

Table 3.7 Rock cook registration by date and location

Date	°C	Location	N	L (cm) $\bar{x}$ ±SD	W (g) $\bar{x}$±SD	Age$\bar{x}$±SD	Gonad W(g) $\bar{x}$±SD	GSI$\bar{x}$±SD	% Spawning/ Mature	Spawners/ Mature L(cm) $\bar{x}$±SD	Non-Spawners/ Immature L(cm) $\bar{x}$±SD
14/05/2014	9.9	Os	284	12.06±1.17					38.0%	11.79±0.95	12.23±1.26
sub-sample			18	11.78±0.89	27.23±5.4	4.33±0.91	1.69±0.52	7.05±1.09	100.0%	11.78±0.89	
20/05/2014	11.7	Austevoll	21	9.53±1.74					47.6%	10.53±1.45	8.63±1.51
20/05/2014	10.6	Sveio	77	10.70±1.61					74.0%	10.96±1.54	9.95±1.59
sub-sample			9	11.46±1.55	25.22±9.92	3.33±1.12	1.16±0.82	6.19±2.78	100.0%	11.46±1.55	
21/05/2014	13.3	Austevoll	26	10.87±1.91					73.1%	11.22±1.70	9.90±2.25
22/05/2014	10.8	Austevoll	11	11.68±1.31					81.8%	11.78±1.39	11.25±1.06
23/05/2014	11.8	Austevoll	6	11.62±1.41					83.3%	11.44±1.50	12.5
sub-sample			3	10.87±1.12	22.37±8.94	3±1	1.34±1.25	5.68±4.89	66.7%	11.00±1.56	10.6
24/05/2014	12.2	Austevoll	12	11.98±1.19					50.0%	12.77±0.58	11.20±1.14
01/06/2014	13.5	Austevoll	7	10.71±1.68					57.1%	10.95±1.61	10.40±2.08
06/06/2014	15.5	Sveio	43	11.16±1.49					48.8%	11.55±1.77	10.80±1.10
sub-sample			2	9.5±0.14	13.2±1.56	2±0	1.28	8.95	100.0%	9.50±0.14	
08/06/2014	15.2	Austevoll	27	10.95±2.2					55.6%	11.69±2.08	10.02±2.05
sub-sample			23	11.64±0.87	27.34±5.7	4.7±0.88	2.25±0.44	8.78±0.9	100.0%	11.64±0.87	
09/06/2014	15.1	Austevoll	1	9					0.0%		9
10/06/2014	15.7	Austevoll	5	12.68±1.33					80.0%	12.98±1.34	11.5
11/06/2014	15.2	Austevoll	6	11.2±2.02					66.7%	12.5±0.22	8.6±0.14
12/06/2014	15.2	Austevoll	18	10.04±2.38					55.6%	11.13±1.36	8.68±2.75
13/06/2014	13.6	Os	44	12.14±1.61					84.1%	12.23±1.72	11.64±0.63
sub-sample			13	10.91±1.75	21.95±9.85	4.08±1.04	1.55±0.44	9.83±2.87	100.0%	10.91±1.75	
20/06/2014	16.3	Sveio	66	11.15±1.41					71.2%	11.27±1.49	10.87±1.19
sub-sample			6	10.93±1.35	21.7±7.61	3.83±1.94	1.96±0.77	8.69±0.43	100.0%	10.93±1.35	
21/06/2014	14.1	Austevoll	16	11.78±1.72					87.5%	11.93±1.34	10.75±4.31
23/06/2014	13.3	Austevoll	18	11.69±0.89					72.2%	11.68±1.04	11.72±0.37
sub-sample			17	11.24±0.85	20.65±4.98	3.76±1.03	1.32±0.2	7.02±1.18	100.0%	11.24±0.85	
08/07/2014	14.6	Austevoll	13	10.73±2.17					61.5%	11.63±1.53	9.30±2.41
15/07/2014	17.8	Austevoll	7	10.79±1.8					71.4%	11.20±0.57	9.75±3.89
sub-sample			7	10.2±1.58	17.03±6.96	2.86±1.07	0.81±0.7	5.15±4.09	85.7%	10.75±0.69	6.9
		Overall	708	11.48±1.62					55.9%	11.57±1.45	11.37±1.81
		sub-sample	98	11.27±1.24	23.73±7.61	3.97±1.19	1.73±0.65	8.12±2.1	98.0%	11.32±1.17	8.75±2.62

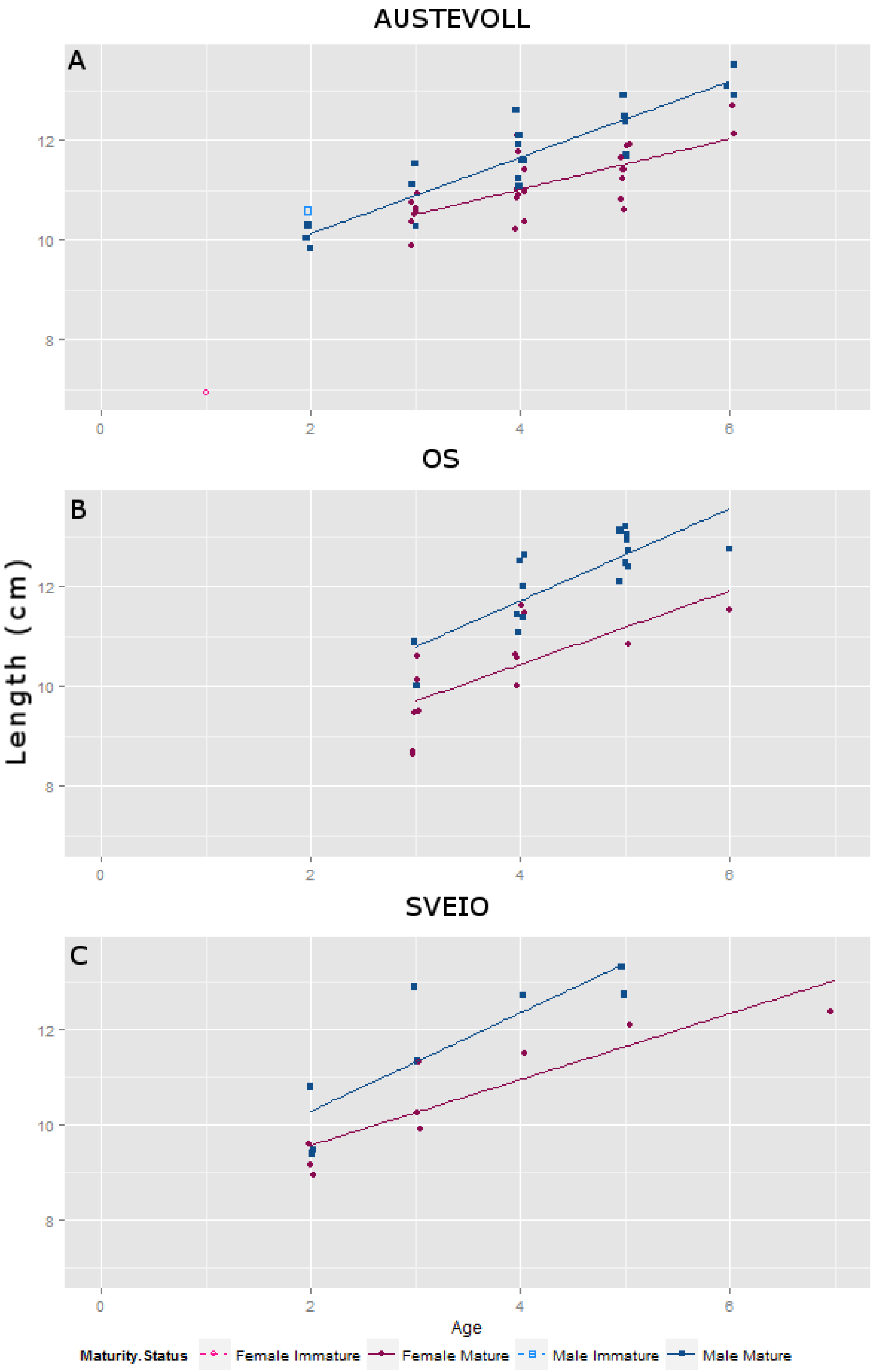

Figure 3.8.1 Rock cook wrasse length relative to age divided into spawning status of each sex. (Austevoll- Female Immature (N=1), Female Mature (N=28), Male Immature (N=1), Male Mature (N=20). Os- Female Immature (N=0), Female Mature (N=13), Male Immature (N=0), Male Mature (N=18). Sveio- Female Immature (N=0), Female Mature (N=9), Male Immature (N=8), Male Mature (N=0).

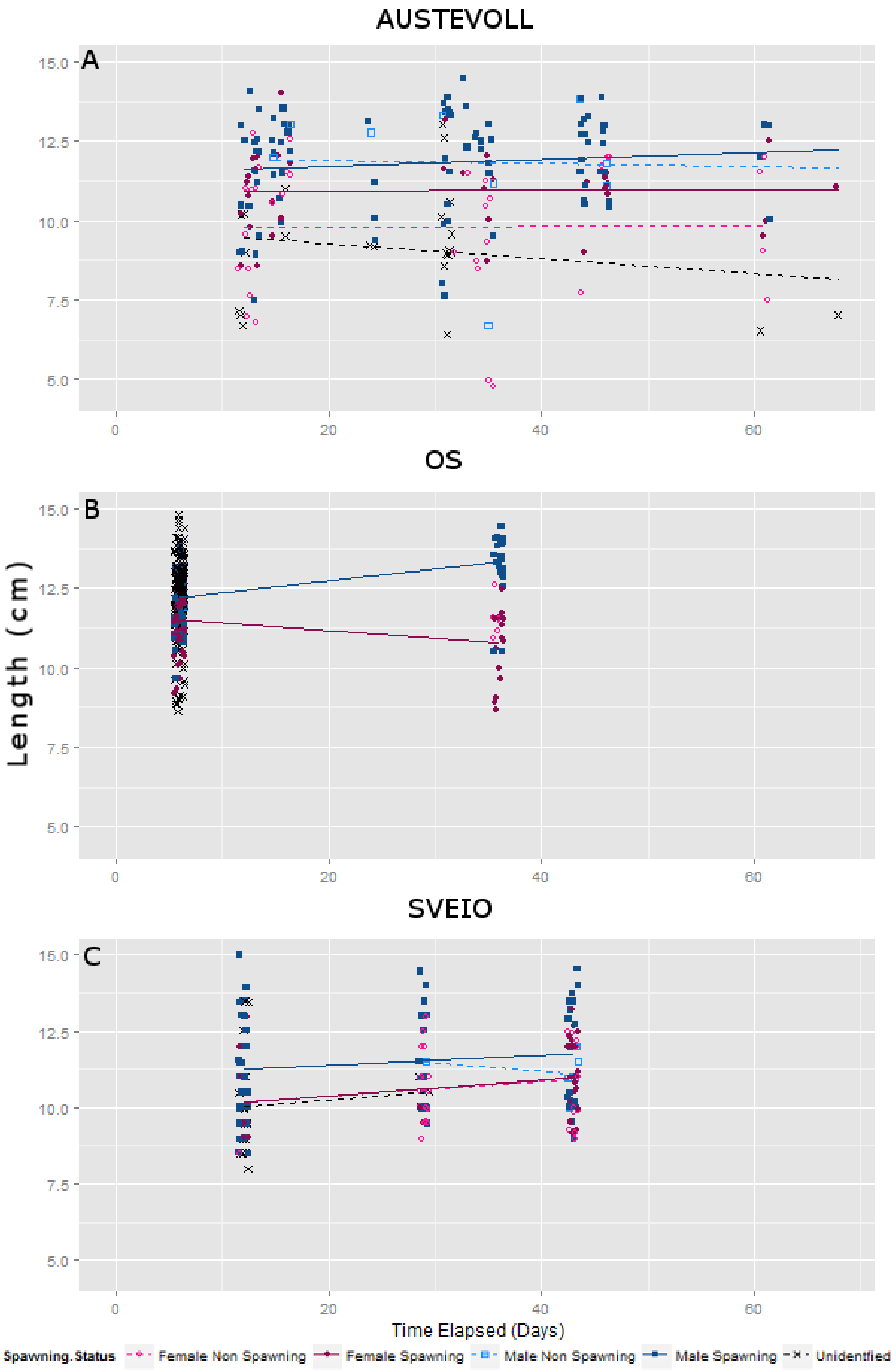

Figure 3.8.2 Rock cook wrasse length relative to time elapsed in days divided into spawning status of each sex. (Austevoll- Female Non-spawning (N=35), Female Spawning (N=36), Male Non-spawning (N=10), Male Spawning (N=90), Unidentified (N=23). Os- Female Non-spawning (N=7), Female Spawning (N=81), Male Non-spawning (N=2), Male Spawning (N=64), Unidentified (N=174). Sveio- Female Non-spawning (N=33), Female Spawning (N=45), Male Non-spawning (N=6), Male Spawning (N=80), Unidentified (N=22).

As previously seen in figure 3.8.1, 98% of the rock cook sub-sample were sexually mature. This is further explored in figure 3.9.1. With the lack of immature fish the conclusions drawn may be a little skewed. The critical age for sexual maturity is two-years-old for both genders. Two-year-olds can be immature, at least in males; however, the majority of the observed fish were mature. Age has a positive significant effect on all locations (p-value=0.003, Appendix 3.1.1) (Table 3.8)[11]. Looking specifically at gender, age had a significant effect on maturity in females (p-value=0.01, Appendix 3.1.2) but not males (p-value=0.088, Appendix 3.1.3) (Table 3.8). A likely reason for this is the immature male is two-years-old and does not show a clear difference from the other males observed, while the immature female was one-years-old and there were no mature one-year-olds.

Length, being the only measure of age when fishing, shows the critical length of spawning in males to be around 7.5 cm, while in females its about 9.5 cm (Figure 3.9.2). However, when looking at maturity the critical length is 9 cm for males and 8.5 cm for females (Figure 3.9.1). This is more likely a factor of which data has the smallest fish instead an accurate view of the critical length of spawning rock cooks. The lack of immature/non-spawning fish makes drawing conclusions like this difficult. There was an overall positive significant effect of length on spawning (p-value<0.001, Appendix 3.3.1) and maturity (p-value=0.003, Appendix 3.2.1) (Table 3.8). Os shows a few issues. There is a significant negative effect of length on spawning, when looking at the data not separated by gender (p-value=0.013, Appendix 3.3.1). A significant negative effect is found when looking at the females from Os (p-value=0.043, Appendix 3.3.2). A possible reason for this is that the larger females were faster to be ready to spawn and so they were identified during the first sampling round. During the second sampling round, the smaller females could be identified, drawing down the size of females spawning. Looking at males spawning (p-value=0.474, Appendix 3.3.3) and maturity (p-value=0.264, Appendix 3.2.3) were not driven by length. Also females from Sveio did not have a significant effect of length on spawning (p-value=0.907, Appendix 3.3.2).

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[11] No test was run with a dependent variable being maturity on Sveio and Os as each location had only mature fish, meaning the statistical test would show nothing.

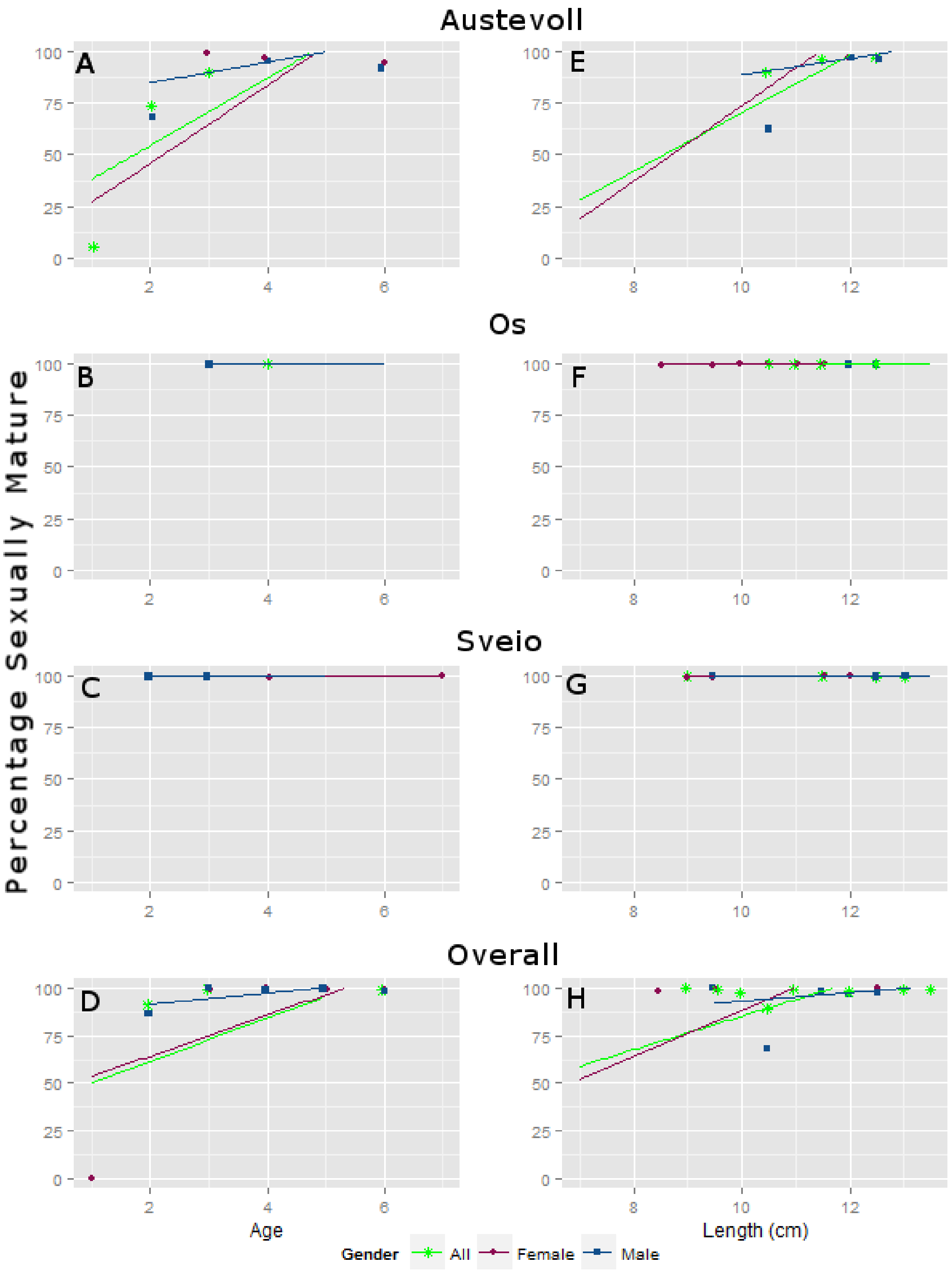

Figure 3.9.1 Percentage of sexually mature corkwing wrasse based on age and the fishes length. (Austevoll- All (N=50), Female (N=29), Male (N=21). Os- All (N=31), Female (N=13), Male (N=18). Sveio- All (N=17), Female (N=9), Male (N=8). Overall- All (N=98), Female (N=51), Male (N=47).)

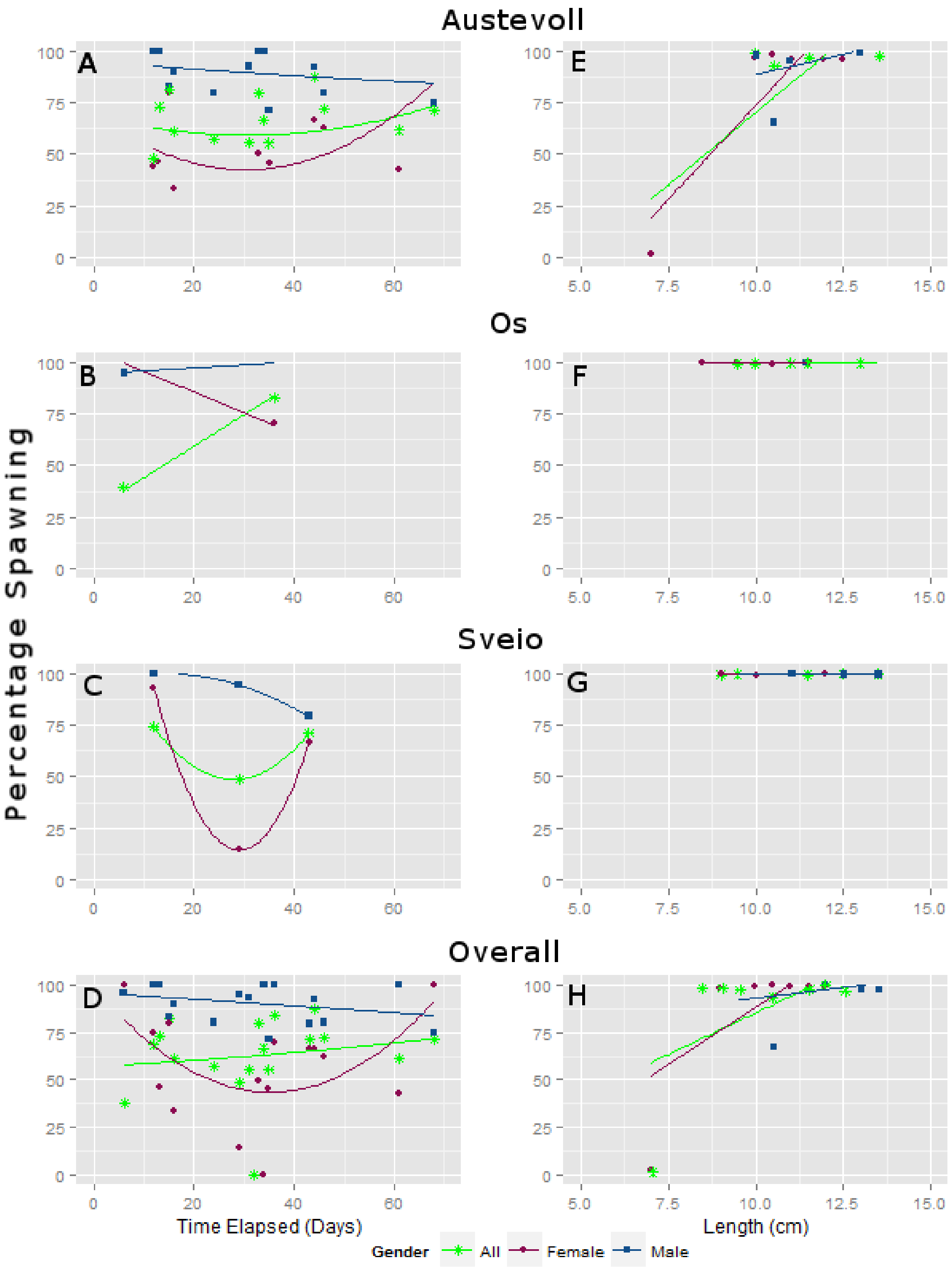

Figure 3.9.2 Percentage of spawning rock cook wrasse based on time elapsed since May 9th (first day of data collection) and the fishes length. (Austevoll- All (N=307), Female (N=144), Male (N=163). Os- All (N=206), Female (N=104), Male (N=100). Sveio- All (N=113), Female (N=64), Male (N=41). Overall- All (N=626), Female (N=312), Male (N=304).)

Unlike the other observed fish, rock cook always seemed to be spawning and almost none of the analyzed fish in the sub-sample were immature. This makes pinpointing the time of peak spawning next to impossible. Overall there appears to be a significant positive effect of time on spawning (p-value<0.001, Appendix 3.4.1) (Table 3.8). The effect is not significant in Sveio (p-value=0.326, Appendix 3.4.1) or Austevoll (p-value=0.737, Appendix 3.4.1), specifically. There are only four occasions where spawning, all genders included, dips below 50% (Figure 3.9.2A-D). Two of these days (June 6th in Sveio (Figure 3.9.2C) and 20th May in Austevoll (Figure 3.9.2A)) are 1% or 2% away from 50%.

Spawning for females seems to slow down in early June but it does pick up. While Sveio and Austevoll do not show an effect of time on spawning, Os (p-value<0.001, Appendix 3.4.2) and the locations together (p-value<0.001, Appendix 3.4.2) have a negative significant effect (Table 3.8). The males appear to slowly spawn less over time(Figure 3.9.2A-D); however, this effect is only significant in Sveio (p-value=0.001, Appendix 3.4.2) and a combination of all the locations (p-value=0.008, Appendix 3.4.3)

It is important to note that figure 3.9.2B is misleading, as most of the non-spawners were not identified by gender during the first initial sampling. This may also obscure the significant effects observed in Os and possibly the data overall.

The previous species were able to use GSI to paint a clearer picture as what how spawning was progressing over time and the hope was to use the same theory on the rock cook. First the test checking whether GSI was a good measure for maturity showed a significant effect (p-value<0.001, Appendix 3.5) (Figure 3.10A and D). Austevoll (Figure 3.10E) shows a decrease in GSI over time, which is statistically significant (p-value=0.02, Appendix 3.5) (Table 3.8). However the overall effect (Figure 3.10H) shows no decrease in GSI over time. In fact no significant effect of time on GSI was observed (p-value=0.708, Appendix 3.5) (Table 3.8). The observed effects are; however, dictated by only a few points and if the project had gone out through July and August maybe a decrease in the GSI would have been observed. Not enough data points were available for Os (Figure 3.10F) and Sveio (Figure 3.10G).

Sex had an effect on whether spawning would be observed. Males were more likely to be spawning than females at all locations (p-value<0.001, Appendix 3.6) (Table 3.8). It did not have an effect on whether the analyzed fish would be sexually mature (p-value=0.954, Appendix 3.6) (Table 3.8).

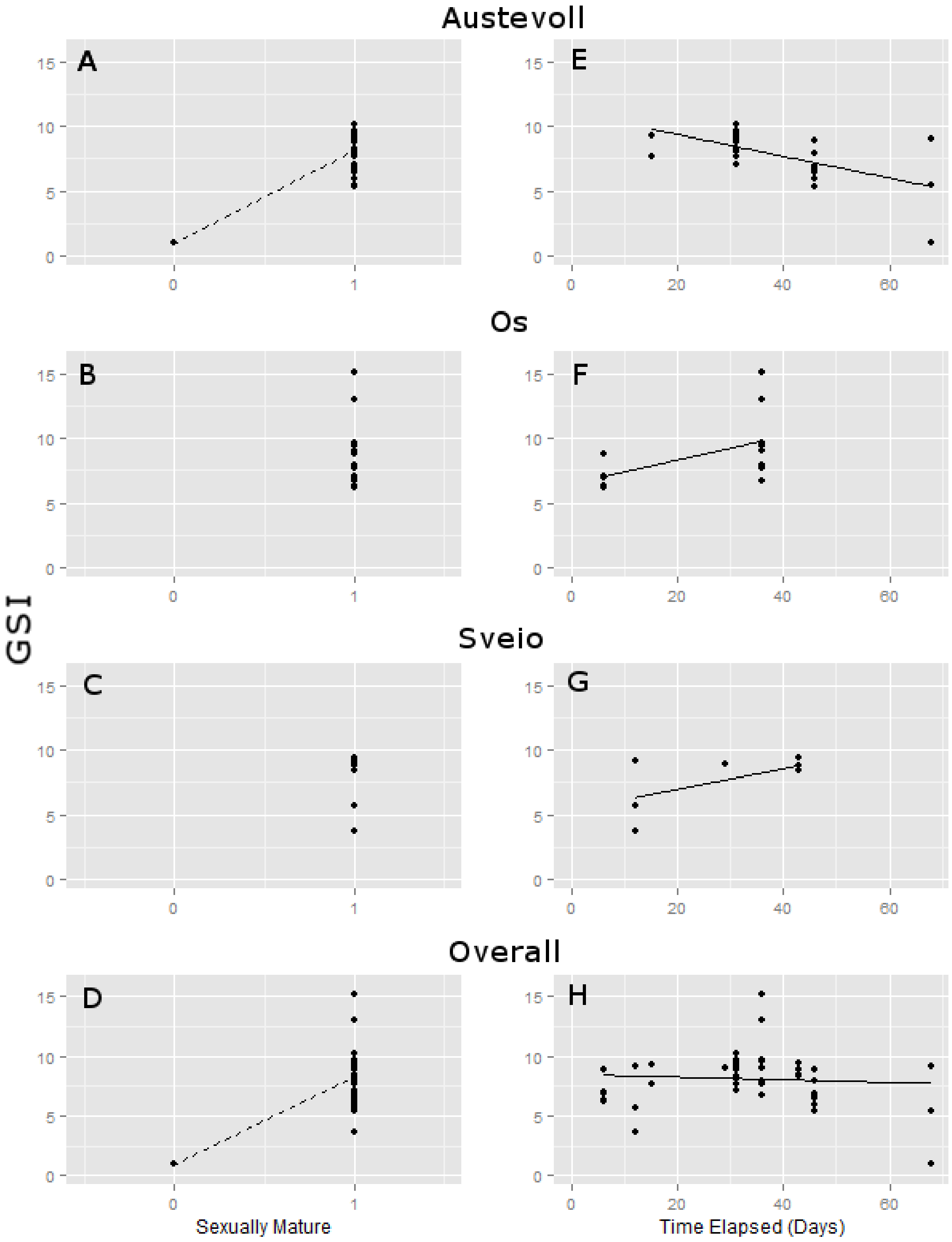

Figure 3.10 GSI of female rock cook wrasse based on maturity status of the fish and days elapsed since the first day of sampling (May 9th 2015). Austevoll (N=29), Os (N=13), Sveio (N=9), Overall (N=51).

Table 3.8 Summary of statistical tests done on the rock cook wrasse.

			Austevoll			Os			Sveio			All		
	Independent Variable	Dependent Variable	DF	Effect	P-value	DF	Effect	P-value	DF	Effect	P-value	DF	Effect	P-value
All	Time Elapsed	Spawning	191	positive	0.737	325	positive	**<0.001**	183	negative	0.326	705	positive	**<0.001**
	Length	Spawning	191	positive	**<0.001**	325	negative	**0.013**	183	positive	**0.005**	705	positive	**<0.001**
	Sex	Spawning	192	positive	**<0.001**	326	positive	**<0.001**	184	positive	**<0.001**	706	positive	**<0.001**
	Length	Maturity	48	positive	**<0.001**	NA	NA	NA	NA	NA	NA	96	positive	**0.003**
	Age	Maturity	48	positive	**0.001**	NA	NA	NA	NA	NA	NA	96	positive	**0.003**
	Sex	Maturity	48	negative	0.82	NA	NA	NA	NA	NA	NA	96	negative	0.954
Female	Time Elapsed	Spawning	68	positive	0.564	85	negative	**<0.001**	75	negative	0.47	234	negative	**<0.001**
	Length	Spawning	68	positive	**0.007**	85	negative	**0.043**	75	positive	0.907	234	positive	**0.001**
	Time Elapsed	GSI	26	negative	**0.02**	NA	NA	NA	NA	NA	NA	48	positive	0.708
	Maturity	GSI	26	positive	**<0.001**	NA	NA	NA	NA	NA	NA	48	positive	**<0.001**
	Length	Maturity	27	positive	**<0.001**	NA	NA	NA	NA	NA	NA	49	positive	**<0.001**
	Age	Maturity	27	positive	**0.002**	NA	NA	NA	NA	NA	NA	49	positive	**0.01**
Male	Time Elapsed	Spawning	97	negative	0.33	63	positive	0.23	83	negative	**0.001**	249	negative	**0.008**
	Length	Spawning	97	positive	0.914	63	negative	0.452	83	positive	0.449	249	positive	0.474
	Length	Maturity	19	positive	0.325	NA	NA	NA	NA	NA	NA	45	positive	0.264
	Age	Maturity	19	positive	0.134	NA	NA	NA	NA	NA	NA	45	positive	0.088

4. Discussion

The wrasse fishery is unique in that the fish captured are not killed or used for human consumption, but are instead transported to salmon farms and used as cleaner fish. It is important for both the sustainability of the fisheries and the economic value for the salmon farms, to have a clear picture of when the cleaner fish are spawning and factors that may influence this. These companies also do not desire spawning fish as they are believed to have a higher mortality rate and do not desire to eat sea lice (Fisheries Ministry 2015).

Wrasse that are 11cm are worth 6 kr a piece, while wrasse 13cm or above are worth 10 kr a piece (Håkon Jørgensen 2015). High cost makes it important to harvest the most productive specimens. Any smaller fish are considered to have too high a mortality or escape rate (Sjøtrol og Lerøy, 2014). Some companies may have more specific instructions as to size accepted, but this is the general instructions from the salmon farmers to the fishermen. The 2015 Fisheries Department regulations for wrasse require the fish be a minimum of 11 cm for goldsinny and rock cook, 12 cm for corkwing wrasse, and 14 cm for ballan wrasse. The Fisheries Ministry has not set any quota limits. Some companies, however, provide the fishermen's with quotas more as an order sheet of how many wrasse they need rather than a quota based on overall concerns for the carrying capacity of the species (Tord Rabben 2015).

The fishery is usually opened in early July. This is based upon the assumption that this date is after the peak wrasse spawning season. This project strove to strengthen the scientific data supporting these regulations and if necessary suggest alternatives. This thesis focused on at what size and age these fish are spawning and the time frame during which they spawn. This chapter reviews those findings and discusses how a follow up project could be designed to compensate for the weaknesses in this research project. Finally I discuss the results regarding present wrasse fishery management.

4.1 Ballan Wrasse

Originally, the ballan wrasse, along with the corkwing wrasse, was to be the focus of this project. It quickly became apparent, however, during the sampling process that we were both neither going to catch enough ballan wrasse during the duration of this project, but that they were at the end of their spawning period as we started sampling (Figure 3.1). A total of 69 ballan wrasse were caught and observed in the field. The last registered spawning ballan wrasse was on the 6th of June in Sveio. Only 17% of the ballan wrasse observed were spawning. Since these fish are the most desired of the wrasse it could be beneficial to assess which conditions are best for catching ballan wrasse. Fishermen in Austevoll believe that a strong current and deeper set gear is necessary to catch ballan wrasse (Haakon Jorgensen 2015).

Based on the data obtained there is little concern that the ballan wrasse would be spawning during the fishing period. However, there is concern that because the ballan wrasse exhibits protogyny (Quignard & Pras, 1986), where the smaller younger fish are females and the larger ones are males the size limits set could be problematic. Based on previous research females do not become mature until they are a minimum of 16 cm and males are not mature until 28 cm (Darwall, *et al.*, 1992; Sayer & Treasurer, 1996). This would indicate that the minimum size for harvest set by the Fisheries Ministry is too small to allow the fish the opportunity to spawn. It has also been shown to be problematic when protogynous fish do not get the opportunity to become males (Heppell, Heppell, Coleman, & Koenig, 2006). Males are an important part of reproduction and lack of males result in less reproduction because of sperm limitation (Heppell, *et al.,* 2006). A much larger harvesting size should be considered (~30cm). Not only would this policy be unpopular with the fishermen, however, but also companies have a cut off size for ballan wrasse at 30 cm, as it is believed these wrasse may eat the eyes of the salmon (Marine Harvest 2014).

4.2 Corkwing wrasse

Corkwing wrasse spawning habits were analyzed in the project. A general picture of the corkwing's spawning time frame is shown in table 4.1. One important item observed in the field was that while a female was mature enough to spawn at the time of catch; she did not exhibit spawning behavior, an effect of batch spawning.

Previous studies on the spawning time of corkwing wrasse have shown they spawn primarily during the month of June (Skiftesvik, *et al.,* 2014B). While in 2013 the wrasse did not begin spawning until late June/early July and in 2015 spawning seems to have started three weeks later than the year I used (personal conversation, Anne Berit Skiftesvik, 2013 and 2015). The data collected for the project suggests that corkwing wrasse started spawning by early May in 2014 (Figure 3.2.2, Figure 3.3.2). Based on this data the main spawning period of the corkwing wrasse was from mid-May to mid-June, even though some spawning occurred in July.

Limited spawning was observed in early-May, but there were a few observations. Possibly signifying the start of the spawning season but not the main event.

Table 4.1 The summarized conclusion on mature corkwing wrasse

	Minimum Mature L	50% Mature L	Minimum Mature Age	50% Mature Age	Peak Spawning	Most likely sex spawning
Female	8 cm	9 cm	2	2	End of May to mid-June	Female
Male	8.5 cm	14 cm	2	3		

Based on the field spawning data and the GSI data from Austevoll there were two peak times where spawning occurred for the corkwing wrasse. The first being the end of May and the second in mid-June (Figure 3.3.2E). After this the percentage of corkwing wrasse observed as spawning in the field dropped off, especially by July. The GSI of these fish show a similar pattern (Figure 3.4A). The largest average GSI observed was on June 11th and the second largest was on May 23rd, correlating with the field data (Table 3.3). After these dates the GSI declines, but it is not until July that the average GSI is small enough that one could assume that most of the observed ovaries were depleted. With this information it would be safe to assume the corkwing wrasse spawned from May to June and the few fish producing milt or eggs in July were not actively spawning.

Os, with only two sample dates clearly shows that spawning occurred from the first day of sampling (May 14, 2014) to the second day of sampling (June 14, 2014). Figure 3.4F best shows that spawning occurred while sampling did not occur, with the GSI dropping overtime by a significant amount. It is not clear if the majority of this happened in May or June, but it would be safe to assume that the fish had not finished spawning. Spawning would most likely continue out to the end of the month similar to the fish in Austevoll.

No clear conclusion could be drawn from the data points collected from Sveio on the spawning patterns of corkwing wrasse, because of the observed spawning instances being mostly below 50% at each time point. Figure 3.3.2C shows a positive association with time on spawning, which indicates they have clearly started spawning by June 6th, but had not completed spawning by June 20th. I believe Sveio may have continued to spawn a week into July as a result of this. Figure 3.4G and table 3.3 show that the GSI from Sveio did not largely change between the first day of sampling (May 20th) and the second day of sampling (June 6th); however, by June 20th the GSI has dropped noticeably. This would indicate that between May 20th and June 6th not much spawning occurred, but from June 6th and June 20th substantial spawning did occur. If Sveio follows the pattern Austevoll did, spawning in Sveio would most likely continue for at least a week more, possibly a few days in July.

Previous studies have found that female corkwing wrasse are mature at 10.5 cm (Darwall, *et al.* 1992; Sayer & Treasurer 1996). The Fisheries Ministry have set the minimum length at harvest for corkwing wrasse to be 12 cm. It is important to find out if fish that are 12 cm have had the opportunity to spawn. Insuring the fish’s ability to spawn at least once in their lifetime insures future cohorts (Mortensen & Skiftesvik, 2011).

The smallest sexually mature fish observed was 8 cm for females and 8.5 cm for males. However, the majority of females were sexually mature at 9 cm. This puts the female size at maturity being 1 cm smaller than what was recorded in the early 1990s (Darwall, *et al.*, 1992; Sayer & Treasurer, 1996). However, it is not until females reach the size of 9 cm and males 14 cm that the majority of their size group is mature (Table 4.1). This would indicate that the females would most likely have at least two years of spawning before being harvested, while many males might never get the opportunity to spawn.

The fact that smaller fish were observed to be sexually mature, could mean three things. First the fish in Sunnhordaland are smaller than the ones summarized in Darwall, *et al.* (1992) and Sayer & Treasurer (1996), where the information on size at maturity came from. This is a reasonable assumption, based upon the fact that the fish observed in this study and those they observed are not geographically close, and it is believed that the different wrasse populations are genetically isolated (Skiftesvik, *et al.* 2014A). Another factor could be that the fishing pressures have driven the fish to be smaller as predicted in Skiftesvik, *et al.* (2014A). As stated before fish becoming sexually mature at a smaller size is a sign of overfishing and should raise concern (Olsen, et al., 2004). Lastly, it could be a result of simply not enough data collected, with the larger fish either not being caught or not in the observation area.

Length and age are closely related, and therefore a possible method to calculate age based on a simple field measurement of length. Previous studies have shown that two-year-old fish were sexually mature (Darwall, *et al.* 1992; Sayer & Treasurer 1996). Overall 60% of the two year olds observed in this study were sexually mature, with the majority being female. Two-year-olds were exclusively collected from Austevoll and Sveio. The limited sample from Os did not include a single two year old.

The average length of the mature female two-year-old is 10.5 cm, with the critical length of maturity being 9 cm. This means that some of the sexually mature fish will only spawn once before being caught for the fish farms, but the majority of them will get the opportunity to spawn a second time as they are too small for the sea cages/pods.

Males on the other hand are slower to mature. The critical age for maturity in male corkwing is three-years-old. Some of the observed two-year-old males were mature but the majority were immature. The average size of a two-year-old male is 13 cm and the average size of a three-year-old male is 14 cm. Both of these sizes are above harvest limits, meaning many males may not get the opportunity to spawn. Only the slower growing corkwing males, which spawn at a younger age and smaller size, may get the opportunity to spawn. As a result this could drive the sizes of corkwing wrasse to go down. Another issue with removing the dominate males is the chance of destabilizing the social structure created by the corkwing wrasse mating habits (Uglem, *et al.,* 2001; Potts, 1985).

In general, the majority of the observed spawning fish were females. In fact the majority of fish observed were females. This is most likely a result of the spawning male corkwing wrasse spending more time guarding their nests then swimming around, decreasing the chances that they may be caught (Uglem, *et al.,* 2001; Potts, 1985).

The effect of gender on spawning habits is most apparent in corkwing wrasse. Females tend to spawn as soon as possible, while males take a longer time to mature to the age of spawning (Figure 3.2.1). The reason males wait until they are larger to spawn is a result of the corkwing mating habits. Corkwing wrasse exhibit paternal care on his fertilized eggs, inside a nest that he built (Potts, 1985). The competition for females often becomes aggressive, which encourages males to grow big and fast before they start spawning (Uglem, Galloway, Rosenqvist, & Folstad, 2001). Because of this behavior, sneaker males are also an important dynamic in the corkwing mating habits. These fish can be even smaller than the spawning females (Figure 3.2.2).

The standards set by the Fisheries Ministry are appropriate for female corkwing wrasse, as the majority will have the opportunity to spawn twice. However, the minimum size for corkwing wrasse is too small to accommodate for the delayed maturing of male corkwing wrasse. If possible, it would be advised to set the male minimum harvest size at 14 cm. It is important to keep the larger males in the population in order not to disturb the homeostasis of the corkwing social structure.

The size at maturity for female corkwing has decreased by 10% in the last 20 years. The fishing pressure on corkwing wrasse is a likely cause; therefore, developing a quota for the wrasse fishery based on scientific principles rather than market needs will be important in the future (Bianchi, et al., 2000; Birkeland & Dayton, 2005; Olsen, et al., 2004).

4.3 Goldsinny wrasse

Goldsinny are the second most common wrasse caught in the wrasse fishery. Although they are abundant, they can be small and are slow growing. Often the average size of the catch was smaller than the minimum harvest size (Table 3.5).

Table 4.2 The summarized conclusion on mature goldsinny wrasse

	Minimum Mature L	50% Mature L	Minimum Mature Age	50% Mature Age	Peak Spawning	Most likely sex spawning
Female	7.5	8	3	3	End of May to mid-June	Male
Male	7	9	3	3		

The exact spawning time frame of goldsinny is unclear. Spawning often does not begin until the end of May and it appears to be completed by July, at least in Austevoll. According to Figure 3.6.2, spawning occurred around the same time as the corkwing wrasse, from the end of May to mid-June, with less goldsinny spawning over time.

Goldsinny wrasse from Austevoll shows a similar pattern to spawning as the corkwing wrasse from Austevoll. In that, there are two main spawning events. The first event is at the end of May and the second in mid-June (figure 3.6.2A). The GSI graphs show a decrease in GSI over time (figure 3.7E) which indicates that more spawning occurred between the 8th of June to the 13th of June, than between the 23rd of May and 8th of June (Figure 3.7E). With the spawning decreasing by mid-July (Figure 3.6.2A, 3.7E).

The spawning data from Sveio is inconclusive. The males were the only fish to be observed to be spawning over 50% during sampling. Figure 3.7G also has inconclusive data on the spawning habits of goldsinny in Sveio. Looking at the GSI in Figure 3.7G, a conclusion based off the pattern seen in Austevoll would assume that spawning in Sveio has occurred during the span of the project and the goldsinny will continue to spawn. However, due to the low sampling numbers no conclusive conclusions can be drawn from the data.

With the first sampling in Os on May 14th, it appeared that the goldsinny were spawning and by the second sampling on June 13th, the fish were towards the end of their spawning period. The average GSI on the last day of sampling in Os was about three points higher than the GSI found in Austevoll on the last day of sampling. I suspect this can reasonably be taken as an indication that goldsinny from Os were not done spawning but would continue for at least another week.

The goldsinny wrasse is one of the longest living wrasse species; however, unlike the ballan wrasse whose maximum size is 60 cm, the goldsinny has a maximum size of 18 cm (Darwall, *et al.*, 1992; Sayer & Treasurer, 1996). With a long life span and a small maximum size, these fish tend to be slow growing and small for their age compared to other fish. Some salmon farms require goldsinny to be 13 cm because they are slim fish and the 11 cm fish are considered too small to not escape from the sea pens (Dafinn Lilland, 2014).

Many of the goldsinny were observed to be spawning even though they are smaller than the desired harvest size. The smallest spawning goldsinny was observed at 7 cm; while the smallest sexually mature fish observed was 7.5 cm. The majority of the goldsinny are sexually mature by the time females are 8 cm and the males are 9 cm long. This would indicate that most of the fish would have the opportunity to spawn at least once if not multiple times before being harvested.

Unlike the corkwing wrasse no two-year-old goldsinny were observed to be sexually mature. Previous studies have shown that two-year-old goldsinny are sexually mature (Darwall, *et al.*, 1992; Sayer & Treasurer, 1996), this study identified only five two-year-olds and none of them were mature (figure 3.5.1). Five cases is insufficient, however, to suggest previous work may no longer be relevant. Sexual maturity did not occur until they were at least three-years old. With some of the sexually mature fish being below 11cm and up to six years old. The average size for three-year-old mature females is 7.5 cm and for males, it is 9.5 cm. The age of a fish with the average size above the minimum length is seven- years-old. This indicates that the slow growing nature of goldsinny allows them the opportunity to spawn multiple years before reaching minimum harvest size.

Goldsinny do not have the same mating habits as the corkwing wrasse. The competition between males is not as aggressive as in the corkwing wrasse. This can be seen when looking at the differences in the effect of length on male spawning propensity. The effect is relatively weak among goldsinny, but is quite strong among corkwing wrasses (figure 3.6.2).

The standards set by the fisheries ministry are appropriate for both male and female goldsinny, as it is likely that all goldsinny would have the opportunity to spawn prior to be fished up based on the minimum required size.

The size at maturity for female goldsinny has decreased by 1.5 cm in the last 20 years, which is a decrease of 16% (Darwall, *et al.*, 1992; Sayer & Treasurer, 1996) (Table 1.2). The extreme fishing pressure on goldsinny wrasse may be a cause of this decrease and a quota for the wrasse fishery may protect the goldsinny from the fishing pressures (Birkeland & Dayton, 2005; Bianchi, et al., 2000; Olsen, et al., 2004).

4.4 Rock cook wrasse

The rock cook is the most elusive, other than the ballan wrasse, and least desired of the observed wrasse (Figure 1.2, Fisheries Ministry Report 2015). Many fish farms view rock cooks as fragile and they are considered to have a high mortality rate (Dagfinn Lilliand 2014, Sjøtroll/Lerøy 2014). As a result, many companies do not desire rock cooks, but there are still some fish farms that accept them.

Table 4.3 The summarized conclusion on mature rock cook wrasse

	Minimum Mature L	50% Mature L	Minimum Mature Age	50% Mature Age	Peak Spawning	Most likely sex spawning
Female	8.5 cm	8.5 cm	2	2	Unknown	Male
Male	7.5 cm	9 cm	2	2		

One of the interesting things observed in this study was that only spawning/mature rock cook's were captured. Specifically when fishing in Austevoll. Individuals may leave the region, possibly for deeper waters, when done spawning. In fact, only two out of 98 fish were observed in the lab as immature. In examining figure 3.9.2 and figure 3.10E-H there appears to be little change in the percentage of spawners and the GSI. This information indicates that the rock cook never stops spawning. Rock cook in a previous study done in the Lysefjord area showed a similar effect of little change in percentage of spawning over time (Skiftesvik, *et al.,* 2014B). It is only when rock cook are not captured that the spawning percentage is below 50%.[12]

It is important to note that the first sampling day (May 14th) in Os, where the majority of rock cooks were not identified by gender, was likely the very start of spawning for the rock cook in Os. This assumption is drawn as a result of a few fish spawning but the majority of the fish not presenting the proper coloring, which becomes stronger during the spawning period and allows the researcher to identify sex of the fish in the field.

The effect of time on the GSI in Austevoll showed a decrease in GSI over time. This Indicates that spawning was slowly progressing in Austevoll, but it did not show the rock cook were close to finishing spawning (Figure 3.10E). The overall effect seen in figure 3.10H shows no change in GSI over time, which is consistent with figure 3.92A-D where no significant change in spawning is observed.

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[12] In discussing this finding with Anne Berit Skiftesvik (2015) she suggested that the rock cook may come to shallower waters to spawn and then return to deeper waters where they are less likely to be fished up.

The smallest observed spawning rock cook was 7.5 cm. Like all the previous species, this is several cementers smaller than the desired minimum size. The only fish observed to be immature were a female at 7 cm and a male at 10.5 cm. This suggests that all fish have the opportunity to spawn at least once before being harvested. Since there were so few sexually, immature fish observed it makes the data a little skewed. Having more fish that are immature would increase the plausibility of this data, but we can reasonably expect more immature fish to be both younger and shorter than the existing sexually mature fish. If this is true the ministries' standards would present limited pressure on these fish.

The only immature fish observed were one-years-old, the female, and two-years-old, the male. There were a total of nine two-year-olds who were observed to be sexually mature. The average size of a mature two-year-old female is 9 cm; while a sexually mature female three-year-old average length is 10 cm. Females are around four-years-old before they are large enough to be harvested. In contrast, mature males at the age of two have an average size of 10 cm, but at the age of three, they are on average 11 cm. This does allow the majority of the rock cooks to spawn at least twice before being harvested.

While aboard the boat a large number of fish were identified as non-spawning, among those that were brought back to the laboratory, overwhelmingly the fish that were not observed to be spawning on the boat were observed to be sexually mature in the lab (96 of 98). Previous research has not conclusively identified a spawning mode for the rock cook. The pattern in my data does suggest the rock cook may be a batch spawner. The corkwing and goldsinny are both batch spawners and followed a similar pattern with a large number of the fish initially identified on board the boad as non-spawning actually being sexually mature and spawning once they were analyzed in the lab. .

In the corkwing, males tend to grow faster and bigger than the females, driven by their social structure and competition for female mates (Potts, 1985). Rock cook appear to have the same goal in mind. The males grow larger and faster, unlike the females. This may indicate some competition in their mating behaviors, based off what is seen in the corkwing wrasse. This is supported by the fact that the only immature male was the bigger of the two immature. Little is still known about the mating habits of rock cook.

The standards set by the Fisheries Ministry are appropriate for both male and female rock cook. Based on the available data most rock cook would have the opportunity to spawn at least twice (Table 4.3). It is unclear whether size at maturity has changed in the last decades but based on available data, females mature around length 8.5 cm and males mature around 9 cm.

4.5 Recommendations for future research projects

4.5.1 Limitations of project and improvements

The data collected was in association with three separate projects. Therefore, the time of data collection was determined by the needs of other researchers and was not designed to the questions raised in this thesis. Several limitations came as a result of this.

The project did not stretch from May to September, which would have been optimal. Furthermore, samples were not pulled as frequently as desired from some sights, nor as evenly as desired. As a result, only a few samples were taken in Sveio and Os. Ideally, samples should have been taken from all locations every one or two weeks from mid-April to mid-August. This would not only have shown a clear picture of the spawning habits of all four fish: ballan, corkwing, goldsinny, and rock cook; it would also have allowed for a comparison of the different locations. Additionally, the ability to identify the effects of temperature and weather on each species spawning patterns would have been useful. For example, after several days of storms do the females stop spawning and wait for calmer weather? Nevertheless, substantial data were collected and there are a number of interesting and important findings in these data.

Another issue with the lack of consistent data between locations made comparing each location difficult but the differences are important to note. The wrasse fishery is already separated into three geographic regions based on the idea that these fish have different spawning schedules (southern Norway, western Norway, or northern Norway). The three locations studied in the project, Austevoll, Sveio, and Os, are geographically nearby but it is infeasible that the wrasse would travel between these areas. While the difference between spawning at the different locations were not recorded, it is clear that the locations have different populations. Specifically Os appears to have the largest oldest populations. Further studying the localized wrasse populations could be beneficial. More specifically exploring the idea of location specific management goals could help protect wrasse populations.

Not nearly, enough ballan wrasse were observed in the sampling. This resulted in no possible conclusions being drawn from the available information. Future projects should look into setting gear that targets areas where ballan wrasse are more likely to be found, as well as, starting the project earlier to catch the ballan wrasse spawning. It appeared that the sample days were at the tail end of ballan wrasse spawning.

The sub-samples of goldsinny and rock cooks observed from Os and Sveio were lower than desired. This resulted in several statistical tests not being able to be completed. Ideally, at least 30 fish of each species for each day and location would have been taken back to the lab. This did not happen, which left holes in the data. Future projects should strive to fill them.

The biggest limitation to this project was the time limit. The most accurate way to observe when a fish may spawn would be to have a project that spans over the entire spawning season and over several years. Likewise, the impact that environmental factors have on when a fish spawns were not considered in this study as such analysis would require several years of environmental data, such as temperature, salinity, and current patterns.

Lastly, a bachelor's student looked at several of the corkwing wrasse dissected in the lab in a separate location. Therefore, a simplified identification of the gonads was agreed upon. Instead of having several levels of sexual maturity, the fish were either identified as immature or mature. Ideally, the gonads would have been identified as immature and then three stages of mature. The first being sexually mature but not currently spawning, sexually mature and currently spawning, and sexually mature and spawning completed. This would have allowed for a more accurate view of how the spawning proceeds over the season. It would have also allowed one to combine the GSI data with the gonad maturity status in order to achieve a GSI baseline that could indicate spawning stages for future projects.

4.5.2 Wrasse in fish farms

The only reason these fish are constantly being harvested is the high mortality and escape rate of the wrasse from fish farms. They are necessary for salmon lice removal and therefore are of huge economic importance to the salmon farmers. It could be financially beneficial and biologically helpful to improve upon the salmon farm formula to better suit both salmon and wrasse. Projects driven by decreasing wrasse mortality in sea cages and possibly over wintering would be beneficial.

Possibly usage of wrasse from aquaculture instead of wild wrasse could reduce the pressure on the current population caused by the fishing efforts. A previous study showed that the origins of the wrasse, wild or cultured, did not affect their efficiency in removing lice (Skiftesvik , *et al.*, 2013). It may be highly lucrative and could make the wrasse industry sustainable as a cultured population that could expand as the salmon industry expands, while it is unclear what may happen to wild populations with the continued growing pressure.

4.5.3 Wrasse fishing's effect on the populations as whole

Often when larger fish are removed from the breeding stock, it drives the fish's sizes to be smaller (Bianchi, et al., 2000; Birkeland & Dayton, 2005; Olsen, et al., 2004). It can also affect the fecundity and as a direct result, the recruitment rates for future cohorts (Birkeland & Dayton, 2005). A project looking into the long-term effect of fishing on size could be interesting. As this project, concluded most of the fish will be able to spawn at least once, if not twice before being caught. Moreover, there might not be an effect on the overall size of the fish caught, at least not because of spawning. Something that might happen is that the amount of fish that reach ages four and older may disappear as they are fished out. A project looking at the age distribution because of fishing pressures could also be interesting.

4.5.4 Wrasse by-catch

As stated in section three 1/3 of the catch was too small to be harvested and were put back into the ocean. One massive concern is the mortality rates of wrasse by-catch. Some fishermen are good at releasing the wrasse near the area they were caught, but many just toss them out as they sort their catch. The transition from boat back into the water can be a dangerous time for the wrasse. Many of these boats have a following of gulls just waiting for their next meal (Figure 4.1). I also observed larger fish like pollock and cod grab wrasse as they swam back to their rock to hide. Encouraging fishermen to adapt releasing habits that increases the smaller wrasses survivability is necessary. There is no use to not harvest the caught fish if they are only going to be eaten the minute they are released from the boat. A possible solution could be to use a tunnel from the sorting table to a submerged exit. This would decrease deaths as a result of birds but does not protect the wrasse from larger predators in the water. More research should be done to find the best method to decrease mortality in by-caught fish could be beneficial.

Figure 4.1 Gulls following a wrasse boat in Drøno (Photo credit: clip from video filmed by Emma Matland, 2014)

4.6 Interesting Observations

Throughout this project, I personally observed over 5,000 fish in several different locations. Many of these fish did not directly pertain to my project and therefore they were not mentioned. I am going to take a little time here to address some of the more interesting observations.

While catching fish in Austevoll we discovered rock cooks that were covered in a black tar like substance (Figure 4.2). The tar like substance can be found on the scales as well as fusing the fins together into black clumps. A vet, who specializes in fish health, came in to look at the fish but we only had frozen samples for him, which would not give him a good sample to study. From what we could figure out nothing is known about what causes this or even what it is. In addition, it is unclear how it effects the rock cooks but large amounts of them were observed to have this substance on them. Further research would be needed to understand this skin condition.

Figure 4.2 Female rock cook observed with black tar like substance on its fins and scales. (Photo credit: Emma Matland, 2015)

The most exciting discovery in the field was sneaker cuckoo wrasse. As previously stated these fish are sexually dimorphic. The males are blue and the females are red. While in the field, we discovered sneaker males. In my limited research done on cuckoo wrasse, I only found one reference where it indicated that some red fish had male gonads but they did not participate in spawning (Moen, 2004). These males were clearly participating in spawning as they produced milt. Cuckoo wrasse do not have any economic value as they are the only wrasse species that do not show any cleaning fish habits but it would be interesting to study this further. It might possibly be a localized phenomenon as it was only observed in Austevoll and Os.

4.7 Concluding Remarks

The age at maturity, as observed in this project, stayed consistent with previous studies (Darwall, *et al.*, 1992; Sayer & Treasurer, 1996). However, the size at maturity had decreased for both corkwing wrasse and goldsinny wrasse. No information was available for size at maturity of rock cooks, but this project found rock cook to be mature by 8 cm. In addition, with the exception of the rock cook, it was quite apparent that this year's fish spawned mostly during the month of June, so as long as the fishery opens in early or mid-July the majority of the fish would have completed spawning (table 4.1, 4.2, 4.3).

An important factor that was identified in this experiment that could be beneficial to wrasse fishermen is that females may be spawning even if when stripped they do not provide eggs. If significant portions of the males caught are providing milt it would be safe to assume that the females are spawning, they just are not releasing eggs at the minute of capture. Lilliand (2014) mentioned that he was docked money by the fish farming company he delivered his fish to because his females were spawning upon delivery. To avoid this it could be useful for the fishermen to be aware of the male spawning habits.

In reference to the standards set by the fisheries ministry only one proposal may be supported, which is an increase in minimum size for male corkwing wrasse. All other wrasse, excluding ballan because of lack of information, have the opportunity to spawn at least once, possibly even twice. The majority of males seem to become mature around 14 cm. This is 2 cm larger than the minimum catch size.

The wrasse fishery opened the 22nd of June, which correlates well with the end of peak spawning for corkwing and goldsinny wrasse. In 2014, the majority of spawning occurred during the two thirds of June. It may be advisable to wait until mid-July if the fish farms desire absolutely no spawning wrasse in their sea cages.

This does not mean that the fishery will always be ready to open on the 22nd of June in Sunnhordaland. As stated before this year's (2015) opening of the wrasse fishery will be the 15th of July. The wrasse this year started spawning three weeks later compared to 2014 (observation, Anne Berit Skiftesvik, 2015), which would indicate, based off data from 2014, the fishery may open during peak spawning. This is where test fishing becomes important. One of the purposes of this is to ensure that the wrasse are done spawning.

In contrast to 2014 and 2015, the wrasse in 2013 did not start spawning until late June/July, meaning the (observation, Anne Berit Skiftesvik, 2013). The most likely cause of these period differences come from the warmer waters that the 2014 fish experienced. The effect of temperature on triggering spawning has been observed in multiple species and wrasse (Darwall, *et al.*, 1992). Higher temperatures tend to result in earlier spawning, which is consistent with the differences of spawning times through the years.

The most important change for fishing standards of the wrasse is the lack of a quota. A few changes have recently been made to limit the amount of wrasse caught in the year but there is still no quota. I would argue that the growth of the fishery is already out of control and some sort of quota is needed to decrease the impact of fishing on the wild population. As seen in the corkwing wrasse and goldsinny size at maturity has already decreased, a clear sign of overfishing.

Work Cited

Bianchi, G., Gislason, H., Graham, K., Hill, L., Jin, X., Koranteng, K., . . . Zwanenburg, K. (2000). Impact of fishing on size composition and diversity of demersal fish communities. *ICES Journal of Marine Science*(57), 228-571.

Birkeland, C., & Dayton, P. K. (2005). The importance in fishery management of leaving the big ones. *Trends in Ecology and Evolution*, 356-358.

Bjordal, Å. (1988). Cleaning symbiosis between wrasses (Labridae) and lice infested salmon (Salmon salar) in mariculture. *International Council for the Exploration of the Sea, Mariculture Comittee, 1988/F, 17*, 8.

Bjordal, Å. (1990). Sea lice infestation of farmed salmon: possible use of cleaner fish as an alternative method for delousing. *Canadian Technical Reports in Fisheries and Aquatic Sciences, 1761*, 85-89.

Bjordal, Å. (1991). Wrasse as cleaner fish for farmed salmon. *Progress in Underwater Science, 16*, 17-29.

Bjordal, Å. (1992). Cleaning symbiosis as an alternative to chemical control of sea lice infestation of Atlantic salmon. I J. E. Thrope, & F. A. Huntingford, *The Importance of Feeding Behaviour for the Efficient Culture of Salmonid Fishes* (ss. 53-60). World Aquaculture Workshops, No. 4: World Aquaculture Society.

Breen, M. (1996). Field observations of the cleaning of ballan wrasse and torment feeding.

Breen, M. J., & Ruetz III, C. R. (2006). Gear bias in fyke netting: evaluating soak time, fish density, and predators. *North American Journal of Fisheries Management*, 32-41.

Campana, S. E. (2001). Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. *Journal of Fish Biology*(59), 197-242.

Costello, M. J. (1991). Review of the biology of wrasse (Libridae: Pices) in Northern Europe.

Costello, M. J. (1996). Development and future of cleaner-fish technology and other biological control techniques in fish farming.

Costello, M. J. (2009). The global economic cost of sea lice to the salmonid farming industry. *Journal of Fish Diseases*(32), 115-118.

Darwall, W. R., Cotello, M. J., Donnelly, R., & Lysaght, S. (1992). Implications of life-history strategies for a new wrasse fishery. *Journal of Fish Biology, 41*(Supplement B), 111-123.

Davies, I. M., Rodger, G. K., Redshaw, J., & Stagg, R. M. (2001). Targeted environmental monitoring for the effects of medicines used to treat sea-lice infestation on farmed fish. *ICES Journal of Marine Science, 58*, 477-485.

Dipper, F. A., Bridges, C. R., & Menz, A. (1977). Age, growth and feeding in the ballan wrasse Labrus bergylta Ascanius 1767. *Journal of Fish Biology*(11), 105-120.

Fiskeridirektoratet. (2015). Regulering av fisket etter leppefisk i 2015. 1-18.

Gjøsæter, J. (2002). Distribution and density of goldsinny wrasse (Ctenolabrus rupestris) (Labridae) in the Risør and Arendal areas along the Norwegian Skagerrak coast. *Sarsia, 87*, 75-82.

Gunderson, D. R., & Dygert, P. H. (1988). Reproductive effort as a predictor of natural mortality rate. *J. Cons. Int. Explor.*(44), 200-209.

Heppell, S. S., Heppell, S. A., Coleman, F. C., & Koenig, C. C. (2006). Models to compare management options for a protogynous fish. *Ecological Applications, 1*(16), 238-249.

Hillden, N.-O. (1978). On the feeding of the goldsinny, Ctenolabrus rupestris L. *Ophelia, 17*(2), 195-198.

Hunter, J. R., & Macewicz, B. J. (1985). fishes, Measurement of spawning frequency in multiple spawning. I R. Lasker, *An egg production method for estimating spawning biomass of pelagic fish: Application to the northern anchovy, Engraulis mordax* (ss. 79-99). NOAA Tech.

Jørgensen, H. (2015). Austevoll Wrasse Fishermen. (E. Matland, Intervjuer)

Kvenseth, P. G. (1996). Large-scale use of wrasse to control sea lice and net fouling in salmon farms in Norway. I M. D. Sayer, J. W. Treasurer, & M. J. Costello, *Wrasse: Biology and Use in Aquaculture* (ss. 196-203). Oxford: Blackwell Science Ltd.

Leclercq, E., Grant, B., Davie, A., & Miquad, H. (2014). Gender distribution, sexual size dimorphism and morphometric sexing in ballan wrasse Labrus bergylta. *Journal of Fish Biology*, 1842-1862.

Lilliand, D. (2014, June). Sveio Wrasse Fisherman. (E. Matland, Intervjuer)

Moen, F. E. (2004). *Marine fish & invertebrates of Northern Europe.* Kristiansun, Norway: KOM.

Mortensen, S., & Skiftesvik, A. B. (2011). Fangst og bruk av leppefisk - innenfor bærekraftige rammer? *Havforskningsnytt, 6*.

Muncaster, S., Andersson, E., Kjesbu, O. S., Taranger, G. L., Skiftesvik, A. B., & Norberg, B. (2010). The reproductive cycle of female Ballan wrasse Labrus bergylta in high latitude, temperate waters. *Journal of Fish Biology*, 1-18.

Olsen, E. M., Heino, M., Lilly, G. R., Morgan, M. J., Brattey, J., Ernade, B., & Dieckmann, U. (2004). Maturation trends indicative of rapid evolution preceded the collapse of northern cod. *Nature*(428), 932-935.

Peter, R. E., & Crim, L. W. (1979). Reproductive Endocrinology of Fishes: Gonadal Cycles and Gonadotropin in Teleosts. *Annual Review of Physiology*(41), 323-335.

Potts, G. W. (1973). Cleaning symbiosis among British fish with special reference to Crenilabrus melops (Labridae). *Journal of the Marine Biological Association of the United Kingdom, 53*, 1-10.

Potts, G. W. (1985). The Nest Structure of the Corkwing Wrasse, Crenilabrus Melops (Labridae: Telostei). *Journal of the Marine Biological Association of the United Kingdom, 2*(65), 531-546.

Quignard, J. P., & Pras, A. (1986). Labridae. I P. J. Whitehead, M. L. Bauchot, J. C. Hureau, J. Nielson, & E. Tortonese, *Fishes of the north-eastern Atlantic and the Mediteranean* (ss. 919-942). Paris: UNESCO.

Rabben, T. (2015, May). Austevoll Wrasse Fisherman. (E. Matland, Intervjuer)

Sayer, M. D., & Treasurer, J. W. (1996). North European wrasse: identification distribution and habitat. I M. D. Sayer, & J. W. Treasurer, *Wrasse: Biology and Use in Aquaculture* (ss. 3-12). Oxford: Blackwell Science Ltd.

Sayer, M. D., Gibson, R. N., & Atkinson, R. J. (1993). Distribution and density of populations of goldsinny wrasse (Ctenolabrus rupestris). *Journal of Fish Biology, 43*(Supplement A), 157-167.

Skiftesvik, A. B., Bjelland, R. M., Durif, C. M., Johansen, I. S., & Browman, H. I. (2013). Delousing of Atlantic salmon (Salmo salar) by cultured vs. wild ballan wrasse (Labrus bergylta. *Aquaculture*, 113-118.

Skiftesvik, A. B., Blom, G., Agnalt, A.-L., Durif, C. M., Browman, H. I., Bjelland, R. M., . . . Mortensen, S. (2014A). Wrasse (Labridae) as cleaner fish in salmonid aquaculture- The Hardangerfjord as a case study. *Marine Biology Research, 10*(3), 289-300.

Skiftesvik, A., Durif, C. M., Bjelland, R. M., & Browman, H. I. (2014B). Distribution and habitat preferences of five species of wrasse (Family Labridae) in a Norwegian fjord.

Stahl, J. P., & Kruse, G. K. (2008). Classification of Ovarian Stages of Walleye Pollock (Theragra chalcogramma). *Resiliency of Gadid Stocks to Fishing and Climate Change Alaska Sea Grant College Program*, 1-23.

The R Foundation. (2015). The R project for statistical computing [Online]. Vienna, Austria. Hentet fra http://www.r-project.org/

Treasurer, J. W. (1996). Wrasse (Libridae) as cleaner-fish of sea lice on farmed Atlantic salmon in west Scotland. I M. D. Sayer, J. W. Treasurer, & M. J. Costello, *Wrasse: Biology and Use in Aquaculture* (ss. 185-195). Oxford: Blackwell Science Ltd.

Treasurer, J., & Feledi, T. (2014). The Physical Condition and Welfare of Five Species of Wild-caught Wrasse Stocked under Aquaculture Conditions and when Stocked in Atlantic Salmon, Salmo salar, Production Cages. *Journal of the World Aquaculture Society, 45*(2), 213-219.

Uglem, I., Galloway, T. F., Rosenqvist, G., & Folstad, I. (2001). Male dimorphism, sperm traits and immunology in the corkwing wrasse (Symphodus melops L.). *Behav Ecol Sociobiol, 50*, 511-518.

Young, C. M. (1996). Wrase as cleaner-fish: the Shetland experiance. I M. D. Sayer, J. W. Treasurer, & M. J. Costello, *Wrasse: Biology and Use in Aquaculture* (ss. 204-210). Oxford: Blackwell Science Ltd.

Appendices

Appendix 1: Corkwing Wrasse

Appendix 1.1.1 Maturity by Age

Complete Sample:

Lm(formula= Maturity~Age)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-1.0470 -0.1997  0.1058  0.2586  0.4113 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.283	0.036	7.89	<0.001
Age	0.153	0.01	14.99	<0.001

```
Adjusted R-squared:0.276, F-statistic:224.7 on 1 and 585 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula= Maturity~Age)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-1.0338 -0.3615  0.1343  0.3024  0.4704 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.193	0.46	4.18	<0.001
Age	0.168	0.014	12.03	<0.001

```
Adjusted R-squared:0.298, F-statistic:144.6 on 1 and 338 DF, p-value:<0.001
```

Sample from Os:

Lm(formula= Maturity~Age)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.9996 -0.1221  0.1230  0.2455  0.2455 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.387	0.086	4.51	<0.001
Age	0.123	0.02	6	<0.001

```
Adjusted R-squared:0.226, F-statistic:35.95 on 1 and 119 DF, p-value:<0.001
```

Sample from Sveio:

Lm(formula= Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.88697  0.01114  0.11303  0.11303  0.21491
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.581	0.076	7.69	<0.001
Age	0.102	0.023	4.52	<0.001

```
Adjusted R-squared:0.135, F-statistic:20.46 on 1 and 124 DF, p-value:<0.001
```

Appendix 1.1.2 Female Only Maturity by Age

Complete Sample:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.90901 -0.04224  0.09099  0.09099  0.15761
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.709	0.032	22.02	<0.001
Age	0.067	0.009	7.58	<0.001

```
Adjusted R-squared:0.137, F-statistic:57.47 on 1 and 354 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.89102 -0.05004  0.10898  0.18849  0.18849
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.653	0.045	14.43	<0.001
Age	0.08	0.013	6.24	<0.001

```
Adjusted R-squared:0.161, F-statistic:38.91 on 1 and 196 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Maturity~Age)

```
Residuals:
   Min     1Q Median     3Q    Max
     0      0      0      0      0
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	1	0	Inf	<0.001
Age	0	0	NA	NA

```
Adjusted R-squared:NaN, F-statistic:NaN on 1 and 62 DF, p-value: NA
```

Sample from Sveio:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.93175  0.00671  0.06825  0.06825  0.12979
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.747	0.068	10.9	<0.001
Age	0.062	0.02	3.09	0.003

```
Adjusted R-squared:0.084, F-statistic:9.54 on 1 and 92 DF, p-value:0.003
```

Appendix 1.1.3 Male Only Maturity by Age

Complete Sample:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.95007 -0.27851 -0.05466  0.27378  0.72149
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.169	0.054	-3.12	0.002
Age	0.224	0.017	13.38	<0.001

```
Adjusted R-squared:0.462, F-statistic:179.1 on 1 and 206 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.88032 -0.24641 -0.03511  0.22533  0.75359
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.176	0.062	-2.82	0.005
Age	0.211	0.022	9.74	<0.001

```
Adjusted R-squared:0.412, F-statistic: 94.89 on 1 and 133 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.95009 -0.24592  0.04991  0.25408  0.45826 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.071	0.138	-0.513	0.611
Age	0.204	0.034	6.02	<0.001

```
Adjusted R-squared:0.414, F-statistic:36.27 on 1 and 49 DF, p-value:<0.001
```

Sample from Sveio:

Lm(formula=Maturity~Age)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.3636 -0.3636  0.0000  0.3182  0.6364 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.273	0.241	-1.13	0.27
Age	0.318	0.076	4.18	<0.001

```
Adjusted R-squared:0.44, F-statistic:17.5 on 1 and 20 DF, p-value:<0.001
```

Appendix 1.2.1 Maturity by Length

Complete: Sample:

Lm(formula= Maturity~Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.8620 -0.1261  0.1380  0.2821  0.4862 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.003	0.079	0.044	0.965
Length	0.6	0.006	9.91	<0.001

```
Adjusted R-squared:0.142, F-statistic:98.23 on 1 and 589 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula= Maturity~Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.8215 -0.4177  0.1486  0.3505  0.6122 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.248	0.113	-2.19	0.029
Length	0.075	0.009	8.44	<0.001

```
Adjusted R-squared:0.172, F-statistic:71.31 on 1 and 338 DF, p-value:<0.001
```

Sample from Os:

Lm(formula= Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.79993 -0.02668  0.06976  0.18573  0.39293
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.138	0.144	0.96	0.339
Length	0.052	0.01	5.14	<0.001

```
Adjusted R-squared:0.171, F-statistic:26.45 on 1 and 122 DF, p-value: 0.086
```

Sample from Sveio:

Lm(formula= Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.90653  0.04771  0.08775  0.13159  0.16591
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.668	0.139	4.793	<0.001
Length	0.019	0.011	1.73	0.086

```
Adjusted R-squared:0.016, F-statistic: 3 on 1 and 125 DF, p-value: 0.086
```

Appendix 1.2.2 Female Only Maturity by Length

Complete Sample:

Lm(formula=Maturity~Length)

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.9234 -0.0363  0.0473  0.1309  0.2312
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.003	0.079	0.044	0.965
Length	0.6	0.006	9.91	<0.001

```
Adjusted R-squared:0.154, F-statistic:65.77 on 1 and 355 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.82131 -0.05788  0.06575  0.17259  0.31911
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.162	0.095	1.71	0.089
Length	0.062	0.008	8.02	<0.001

```
Adjusted R-squared:0.243, F-statistic: 64.26 on 1 and 196 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Maturity~Length)

```
Residuals:
   Min     1Q Median     3Q    Max
     0      0      0      0      0
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	1	0	Inf	<0.001
Length	0	0	NA	NA

```
Adjusted R-squared:NaN, F-statistic:NaN on 1 and 62 DF, p-value: NA
```

Sample from Sveio:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.94632  0.01201  0.04555  0.08823  0.12482
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.698	0.134	5.2	<0.001
Length	0.02	0.011	1.88	0.063

```
Adjusted R-squared:0.026, F-statistic:3.55 on 1 and 93 DF, p-value:0.063
```

Appendix 1.2.3 Male Only Maturity by Length

Complete Sample:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.63891 -0.29263 -0.03541  0.22573  1.04394
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.09	0.108	-10.04	<0.001
Length	0.116	0.008	14.74	<0.001

```
Adjusted R-squared:0.507, F-statistic:217.3 on 1 and 209 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Maturity~Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.6182 -0.2713 -0.0067  0.1695  1.0534 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.21	0.129	-9.34	<0.001
Length	0.12	0.01	12.33	<0.001

```
Adjusted R-squared:0.53, F-statistic: 152 on 1 and 133 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.51651 -0.31369  0.00001  0.20288  0.85101 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.745	0.204	-3.65	<0.001
Length	0.0993	0.014	7.19	<0.001

```
Adjusted R-squared:0.489, F-statistic:51.71 on 1 and 52 DF, p-value:<0.001
```

Sample from Sveio:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.56214 -0.47733  0.04211  0.38940  0.66400 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.447	0.451	-0.993	0.333
Length	0.081	0.032	2.56	0.019

```
Adjusted R-squared:0.209, F-statistic:6.55 on 1 and 20 DF, p-value:0.019
```

Appendix 1.3.1 Spawning by Date and Length

Complete Sample:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.8696 -0.4541 -0.2371  0.4785  0.7965 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.105	0.048	2.19	0.028
Date	-0.004	0.0006	-6.72	<0.001
Length	0.0375	0.003	11.44	<0.001

```
Adjusted R-squared:0.058, F-statistic: 108.5 on 2 and 3487 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-1.0319 -0.4812  0.2001  0.4148  0.8547 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.241	0.085	2.85	0.005
Date	-0.008	0.0008	-9.61	<0.001
Length	0.042	0.006	7.28	<0.001

```
Adjusted R-squared:0.119, F-statistic:85.44 on 2 and 1248 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.7994 -0.5240  0.3166  0.4036  0.7173 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.227	0.107	2.11	0.0345
Date	-0.006	0.001	-4.312	<0.001
Length	0.029	0.007	4.1	<0.001

```
Adjusted R-squared:0.059, F-statistic:27.36 on 2 and 845 DF, p-value:<0.001
```

Sample from Sveio:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.6444 -0.4119 -0.3111  0.5485  0.7569
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.039	0.072	-0.543	0.587
Date	0.004	0.001	3.18	<0.001
Length	0.027	0.005	5.31	<0.001

```
Adjusted R-squared:0.027, F-statistic:20.02 on 2 and 1388 DF, p-value:<0.001
```

Appendix 1.3.2 Female Only Spawning by Date and Length

Complete Sample:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.8147 -0.4768  0.2415  0.4508  0.8169
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.278	0.063	4.43	<0.001
Date	-0.006	0.001	-9.16	<0.001
Length	0.031	0.004	7.18	<0.001

```
Adjusted R-squared:0.065, F-statistic:82.95 on 2 and 2343 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.8458 -0.4929  0.2226  0.4146  0.8413
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.724	0.11	6.58	<0.001
Date	-0.011	0.001	-10.24	<0.001
Length	0.014	0.008	1.84	0.066

```
Adjusted R-squared:0.124, F-statistic:58.03 on 2 and 804 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.9134 -0.4343  0.2011  0.2927  0.7718 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.148	0.137	1.08	0.279
Date	-0.01	0.002	-6.1	<0.001
Length	0.046	0.009	4.91	<0.001

```
Adjusted R-squared:0.128, F-statistic:41.86 on 2 and 555 DF, p-value:<0.001
```

Sample from Sveio:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.5320 -0.3957 -0.2669  0.5900  0.7521 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.07	0.091	0.77	0.441
Date	0.007	0.002	4.58	<0.001
Length	0.01	0.007	1.42	0.155

```
Adjusted R-squared:0.022, F-statistic: 12.01 on 2 and 978 DF, p-value:<0.001
```

Appendix 1.3.3 Male Only Spawning by Date and Length

Complete Sample:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.8857 -0.2649 -0.1200  0.3050  1.2304 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.05	0.085	-12.3	<0.001
Date	0.005	0.001	5.51	<0.001
Length	0.089	0.005	16.7	<0.001

```
Adjusted R-squared:0.255, F-statistic:140 on 2 and 812 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max
-1.0224 -0.2484 -0.1207  0.2332  1.1065
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.15	0.116	-9.96	<0.001
Date	-0.001	0.001	-1.11	0.268
Length	0.114	0.008	15.12	<0.001

```
Adjusted R-squared:0.413, F-statistic:119.4 on 2 and 335 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Spawning~Date+Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.60592 -0.29548 -0.03421  0.14445  0.85859
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.961	0.153	-6.29	<0.001
Date	0.011	0.002	5.19	<0.001
Length	0.071	0.009	7.62	<0.001

```
Adjusted R-squared:0.22, F-statistic: 32.87 on 2 and 224 DF, p-value:<0.001
```

Sample from Sveio:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max
-1.0078 -0.3112 -0.1778  0.3181  1.1764
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.03	0.172	-5.97	<0.001
Date	0.004	0.003	1.6	0.111
Length	0.095	0.11	8.98	<0.001

```
Adjusted R-squared:0.241, F-statistic:40.41 on 2 and 247 DF, p-value:<0.001
```

Appendix 1.4 GSI by Date and Maturity

Complete Sample:

Lm(formula= GSI~Date+Maturity)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-8.3346 -1.4239 -0.3031  1.1709 13.9441 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	10.14	0.604	16.77	<0.001
Date	-0.164	0.007	-22.73	<0.001
Gender	2.43	0.511	4.76	<0.001

```
Adjusted R-squared:0.630, F-statistic:302 on 2 and 352 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula= GSI~Date+ Maturity)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-9.7043 -1.7774 -0.2481  1.4102  6.9269 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	11.53	0.960	12.02	<0.001
Date	-0.187	0.014	-13.2	<0.001
Gender	2.15	0.618	3.48	<0.001

```
Adjusted R-squared:0.512, F-statistic:103.7 on 2 and 194 DF, p-value:<0.001
```

Sample from Os:

Lm(formula= GSI~Date+ Maturity)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-4.9264 -0.9137 -0.0131  1.1669  4.5504 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	9.87	1	9.988	<0.001
Date	-0.142	0.016	-9.08	<0.001
Age	0.441	0.194	2.24	0.029

```
Adjusted R-squared:0.645, F-statistic:113.9 on 1 and 61 DF, p-value:<0.001
```

Sample from Sveio:

Lm(formula= GSI~Date+ Maturity)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-4.3249 -1.4105 -0.2449  0.9152 13.6898 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	9.34	1.24	7.52	<0.001
Date	-0.16	0.02	-8.73	<0.001
Gender	3.26	1.09	2.99	0.004

```
Adjusted R-squared:0.492, F-statistic:46.55 on 2 and 92 DF, p-value:<0.001
```

Appendix 1.5 Spawning/Maturity by Sex

Complete Sample:

Lm(formula=Spawning~Gender)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.5215 -0.5215 -0.3227  0.4785  0.6773 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.72	0.027	27.06	<0.001
Gender	-0.199	0.02	-9.95	<0.001

```
Adjusted R-squared:0.030, F-statistic:98.93 on 1 and 3160 DF, p-value:<0.001
```

Lm(formula= Maturity~Gender)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.8928  0.1072  0.1072  0.1072  0.6646 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	1.17	0.043	26.9	<0.001
Gender	-0.279	0.028	-9.9	<0.001

```
Adjusted R-squared:0.141, F-statistic:97.95 on 1 and 589 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Spawning~Gender)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.5817 -0.5817  0.4183  0.4183  0.6598 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.823	0.043	19	<0.001
Gender	-0.241	0.032	-7.64	<0.001

```
Adjusted R-squared:0.048, F-statistic:58.33 on 1 and 1144 DF, p-value:<0.001
```

Lm(formula= Maturity~Gender)

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.8746 -0.4494  0.1254  0.1254  0.9759
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	1.3	0.063	20.7	<0.001
Gender	-0.425	0.041	-10.39	<0.001

```
Adjusted R-squared:0.24, F-statistic:108 on 1 and 338 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Spawning~Gender)

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.6631 -0.2423  0.3369  0.3369  0.7577
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	1.084	0.05	21.9	<0.001
Gender	-0.421	0.036	-11.6	<0.001

```
Adjusted R-squared:0.146, F-statistic:134.5 on 1 and 783 DF, p-value: <0.001
```

Lm(formula= Maturity~Gender)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.92635  0.07365  0.07365  0.07365  0.19967
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.989	0.062	16.02	<0.001
Gender	-0.063	0.042	-1.5	0.137

```
Adjusted R-squared:0.01, F-statistic:2.237 on 1 and 125 DF, p-value: 0.137
```

Sample from Sveio:

Lm(formula=Spawning~Gender)

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.3914 -0.3914 -0.3720  0.6086  0.6280
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.411	0.044	9.38	<0.001
Gender	-0.019	0.035	-0.563	0.574

```
Adjusted R-squared:-0.001, F-statistic:0.317 on 1 and 1229 DF, p-value: 0.574
```

Lm(formula= Maturity~Gender)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.92635  0.07365  0.07365  0.07365  0.19967 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.989	0.062	16.02	<0.001
Gender	-0.063	0.042	-1.5	0.137

```
Adjusted R-squared:0.01, F-statistic:2.237 on 1 and 125 DF, p-value: 0.137
```

Appendix 2: Goldsinny Wrasse

Appendix 2.1.1: Maturity by Age

Complete Sample:

Lm(formula= Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-1.07858 -0.07858  0.04473  0.16805  0.29136 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.339	0.096	3.53	<0.001
Age	0.123	0.021	5.9	<0.001

```
Adjusted R-squared:0.221, F-statistic:34.79 on 1 and 118 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula= Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.80818 -0.13517  0.02833  0.19182  0.35531 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.154	0.128	1.21	0.231
Age	0.163	0.0288	5.69	<0.001

```
Adjusted R-squared:0.355, F-statistic:32.32 on 1 and 56 DF, p-value:<0.001
```

Sample from Os:

Lm(formula= Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.88402  0.02023  0.02023  0.11598  0.21173
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.501	0.15	3.33	0.002
Age	0.096	0.033	2.88	0.006

```
Adjusted R-squared:0.127, F-statistic:8.286 on 1 and 49 DF, p-value: 0.006
```

Sample from Sveio:

Not enough samples to run a test.

Appendix 2.1.2: Female Only Maturity by Age

Complete Sample:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.82812 -0.05124  0.06032  0.17188  0.28343
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.382	0.124	3.08	0.003
Age	0.112	0.025	4.44	<0.001

```
Adjusted R-squared:0.25, F-statistic:19.67 on 1 and 55 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.77139 -0.07549  0.09346  0.22861  0.36377
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.231	0.199	1.16	0.26
Age	0.135	0.042	3.2	0.004

```
Adjusted R-squared:0.287, F-statistic:10.24 on 1 and 22 DF, p-value: 0.004
```

Sample from Os:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.84140  0.00459  0.02170  0.09015  0.15860
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.636	0.189	3.37	0.003
Age	0.068	0.039	1.75	0.094

```
Adjusted R-squared:0.082, F-statistic:3.06 on 1 and 22 DF, p-value:0.094
```

Sample from Sveio:

Not enough samples to run a test.

Appendix 2.1.3: Male Only Maturity by Age

Complete Sample:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-1.12974  0.01458  0.15889  0.15889  0.30321
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.264	0.155	1.71	0.093
Age	0.144	0.036	3.98	<0.001

```
Adjusted R-squared:0.193, F-statistic:15.81 on 1 and 61 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.62869 -0.05228 -0.05228  0.15952  0.37131
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.007	0.17	-0.039	0.969
Age	0.212	0.04	5.24	<0.001

```
Adjusted R-squared:0.445, F-statistic:27.43 on 1 and 32 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.87597  0.00775  0.12403  0.12403  0.24031 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.411	0.239	1.72	0.098
Age	0.116	0.056	2.06	0.05

```
Adjusted R-squared: 0.111, F-statistic:4.25 on 1 and 25 DF, p-value:0.05
```

Sample from Sveio:

Not enough samples to run a test.

Appendix 2.2.1: Length by Maturity

Complete Sample:

Lm(formula= Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-1.05961 -0.01597  0.09313  0.14768  0.37680 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.206	0.218	-0.944	0.347
Length	0.109	0.022	5.07	<0.001

```
Adjusted R-squared:0.162, F-statistic:25.65 on 1 and 127 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula= Maturity~Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.6014 -0.1443  0.0938  0.1700  0.6082 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.06	0.272	-3.88	<0.001
Length	0.191	0.027	7.06	<0.001

```
Adjusted R-squared:0.453, F-statistic:49.77 on 1 and 58 DF, p-value:<0.001
```

Sample from Os:

Lm(formula= Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.94302  0.06302  0.07279  0.07838  0.09141
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.835	0.349	2.39	0.02
Length	0.009	0.035	0.265	0.792

```
Adjusted R-squared:-0.018, F-statistic:0.07 on 1 and 53 DF, p-value:0.792
```

Sample from Sveio:

Not enough samples to run a test.

Appendix 2.2.1: Female Only Length by Maturity

Complete Sample:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.76574 -0.03611  0.07204  0.12612  0.35323
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.175	0.247	-0.71	0.48
Length	0.108	0.024	4.48	<0.001

```
Adjusted R-squared:0.232, F-statistic:20.06 on 1 and 62 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.62377 -0.11964  0.08619  0.15169  0.58206
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-1	0.43	-2.34	0.028
Length	0.187	0.043	4.34	<0.001

```
Adjusted R-squared:0.416, F-statistic:18.84 on 1 and 24 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.90816  0.00090  0.04044  0.07108  0.11161
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.564	0.337	1.68	0.107
Length	0.04	0.033	1.19	0.247

```
Adjusted R-squared:0.016, F-statistic:1.41 on 1 and 24 DF, p-value: 0.247
```

Sample from Sveio:

Not enough samples to run a test.

Appendix 2.2.1: Male Only Length by Maturity

Overall Sample:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-1.03598  0.02844  0.11434  0.16803  0.36131
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.21	0.372	-0.563	0.575
Length	0.107	0.037	2.9	0.005

```
Adjusted R-squared:0.103, F-statistic:8.381 on 1 and 63 DF, p-value: 0.005
```

Sample from Austevoll:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.58114 -0.17090  0.07768  0.16541  0.43835
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.12	0.363	-3.08	0.004
Length	0.195	0.036	5.47	<0.001

```
Adjusted R-squared: 0.467, F-statistic:29.92 on 1 and 32 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.94447  0.07021  0.08978  0.11425  0.16806
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	1.38	0.659	2.09	0.046
Length	-0.049	0.067	-0.729	0.472

```
Adjusted R-squared:-0.017, F-statistic:0.532 on 1 and 27 DF, p-value:0.472
```

Sample from Sveio:

Not enough samples to run a test.

Appendix 2.3.1: Time Elapsed and Length by Spawning

Complete Sample:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.6388 -0.4229 -0.2234  0.4840  0.8272
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.492	0.145	3.4	<0.001
Date	-0.007	0.001	-5.78	<0.001
Length	0.014	0.014	0.995	0.32

```
Adjusted R-squared:0.0479, F-statistic:16.72 on 2 and 623 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.8011 -0.4532 -0.2059  0.4631  0.8169
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.227	0.187	1.21	0.227
Date	-0.007	0.001	-5.07	<0.001
Length	0.046	0.019	2.45	0.015

```
Adjusted R-squared:0.08, F-statistic:14.22 on 2 and 304 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.6873 -0.3785 -0.3158  0.3973  0.6717 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.97	0.35	2.77	0.006
Date	-0.009	0.002	-4	<0.001
Length	-0.025	0.032	-0.779	0.441

```
Adjusted R-squared:0.067, F-statistic:8.41 on 2 and 203 DF, p-value:<0.001
```

Sample from Sveio:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.4583 -0.3834 -0.3356  0.6021  0.6891 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.672	0.303	2.22	0.029
Date	0.0001	0.004	0.038	0.97
Length	-0.029	0.03	-0.956	0.341

```
Adjusted R-squared:-0.009, F-statistic:0.502 on 2 and 110 DF, p-value: 0.607
```

Appendix 2.3.2: Female Only Time Elapsed and Length by Spawning

Complete Sample:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.7452 -0.3015 -0.1702  0.4097  1.1805 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.073	0.163	0.447	0.655
Date	-0.012	0.001	-8.3	<0.001
Length	0.055	0.016	3.52	<0.001

```
Adjusted R-squared:0.191, F-statistic:37.63 on 2 and 309 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Spawning~Date+Length)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.77024 -0.30081 -0.07735  0.38322  1.03665
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.409	0.215	-1.9	0.059
Date	-0.01	0.002	-5.46	<0.001
Length	0.105	0.022	4.84	<0.001

```
Adjusted R-squared:0.233, F-statistic:22.74 on 2 and 141 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Spawning~Date+Length)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.79920 -0.07225 -0.07048  0.20434  0.92952
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.92	0.294	3.13	0.002
Date	-0.024	0.002	-10.87	<0.001
Length	0.002	0.027	0.066	0.948

```
Adjusted R-squared:0.53, F-statistic:59.17 on 2 and 101 DF, p-value:<0.001
```

Sample from Sveio:

Lm(formula=Spawning~Date+Length)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.32022 -0.26588 -0.21373  0.03209  0.80990
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.423	0.379	1.12	0.268
Date	-0.003	0.004	-0.61	0.546
Length	-0.009	0.037	-0.253	0.801

```
Adjusted R-squared:-0.022, F-statistic:0.312 on 2 and 61 DF,  p-value: 0.733
```

Appendix 2.3.3: Male Only Time Elapsed and Length by Spawning

Complete Sample:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.7908 -0.5431  0.3151  0.4027  0.6016 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	1.22	0.231	5.28	<0.001
Date	-0.002	0.002	-1.35	0.177
Length	-0.053	0.022	-2.39	0.018

```
Adjusted R-squared:0.022, F-statistic:4.353 on 2 and 301 DF, p-value:0.014
```

Sample from Austevoll:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.7506 -0.5182  0.2922  0.4056  0.7064 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	1.162	0.287	4.05	<0.001
Date	-0.005	0.002	-2.47	0.015
Length	-0.042	0.028	-1.5	0.135

```
Adjusted R-squared:0.046, F-statistic:4.89 on 2 and 160 DF, p-value:0.009
```

Sample from Os:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.8308 -0.5465  0.2329  0.3603  0.8357 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	1.85	0.562	3.3	0.001
Date	0.005	0.003	1.58	0.118
Length	-0.127	0.053	-2.41	0.018

```
Adjusted R-squared:0.054, F-statistic:3.83 on 2 and 97 DF, p-value:0.025
```

Sample from Sveio:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.7383 -0.5709  0.2900  0.3803  0.4599 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	1.12	0.566	1.98	0.055
Date	0.003	0.007	0.503	0.618
Length	-0.057	0.061	-0.933	0.357

```
Adjusted R-squared:-0.029, F-statistic:0.439 on 2 and 38 DF,  p-value:0.648
```

Appendix 2.4: Time Elapsed and Maturity by GSI

Complete Sample:

Lm(formula=GSI~Date+Maturity)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-4.8650 -1.1978 -0.1953  1.3858  7.3880 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	10.54	1.21	8.70	<0.001
Date	-0.163	0.016	-9.93	<0.001
Maturity	1.87	0.937	2.00	0.050

```
Adjusted R-squared:0.628, F-statistic:54.12 on 2 and 61 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=GSI~Date+Maturity)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-2.3753 -0.4853 -0.1636  0.5765  2.1106 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	13.06	0.720	18.14	<0.001
Date	-0.193	0.010	-19.09	<0.001
Maturity	1.47	0.521	2.83	0.010

```
Adjusted R-squared:0.936, F-statistic:185.1 on 2 and 23 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=GSI~Date+Maturity)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-2.4093 -1.2611 -0.4830  0.2371  7.7889 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	6.26	3.55	1.76	0.091
Date	-0.148	0.076	-1.94	0.065
Maturity	5.22	2.29	2.28	0.032

```
Adjusted R-squared:0.226, F-statistic:4.655 on 2 and 23 DF, p-value: 0.020
```

Sample from Sveio:

Not enough samples to run the test.

Appendix 2.5 Spawning/Maturity by Sex

Complete Sample:

Lm(formula=Spawning~Gender)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.6020 -0.3045 -0.3045  0.3980  0.6955 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.007	0.06	0.116	0.908
Gender	0.297	0.038	7.76	<0.001

```
Adjusted R-squared:0.089, F-statistic:60.23 on 1 and 614 DF, p-value:<0.001
```

Lm(formula= Maturity~Gender)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.92188  0.07813  0.07813  0.13846  0.13846 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.982	0.087	11.3	<0.001
Gender	-0.06	0.055	-1.1	0.274

```
Adjusted R-squared:0.002, F-statistic:1.206 on 1 and 127 DF, p-value: 0.274
```

Sample from Austevoll:
Lm(formula=Spawning~Gender)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.5767 -0.3264 -0.3264  0.4233  0.6736 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.077	0.089	0.854	0.394
Gender	0.25	0.055	4.52	<0.001

```
Adjusted R-squared:0.06, F-statistic:20.45 on 1 and 305 DF, p-value:<0.001
```

Lm(formula= Maturity~Gender)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.8529  0.1471  0.1471  0.1538  0.1538 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.839	0.155	5.4	<0.001
Gender	0.007	0.095	0.072	0.943

```
Adjusted R-squared:-0.017, F-statistic:0.005 on 1 and 58 DF, p-value:0.943
```

Sample from Os:

Lm(formula=Spawning~Gender)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.6300 -0.3077 -0.3077  0.3700  0.6923 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.015	0.104	-0.14	0.889
Gender	0.322	0.066	4.85	<0.001

```
Adjusted R-squared:0.0999, F-statistic:23.53 on 1 and 202 DF, p-value:<0.001
```

Lm(formula= Maturity~Gender)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.96154  0.03846  0.03846  0.10345  0.10345 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	1.03	0.114	9.01	<0.001
Gender	-0.065	0.071	-0.917	0.363

```
Adjusted R-squared:-0.003, F-statistic:0.84 on 1 and 53 DF, p-value:0.363
```

Sample from Sveio:

Lm(formula=Spawning~Gender)

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.6341 -0.2500 -0.2500  0.3659  0.7500
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.134	0.135	-0.996	0.322
Gender	0.384	0.091	4.2	<0.001

```
Adjusted R-squared:0.138, F-statistic:17.66 on 1 and 103 DF, p-value:<0.001
```

Not enough samples to run the test against maturity.

Appendix 3: Rock Cook Wrasse

Appendix 3.1.1: Maturity by Age

Complete Sample:

Lm(formula= Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.90855 -0.01677  0.01930  0.05538  0.09145
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.836	0.48	17.35	<0.001
Age	0.036	0.012	3.09	0.003

```
Adjusted R-squared:0.082, F-statistic:9.60 on 1 and 96 DF, p-value: 0.003
```

Sample from Austevoll:

Lm(formula= Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.80800 -0.03374  0.04150  0.09794  0.19200
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.658	0.092	7.18	<0.001
Age	0.075	0.022	3.44	0.001

```
Adjusted R-squared:0.181, F-statistic:11.81 on 1 and 48 DF, p-value: 0.001
```

Sample from Os:

Not enough samples to run a test.

Sample from Sveio:

Not enough samples to run a test.

Appendix 3.1.2: Female Only Maturity by Age

Complete Sample:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.85693 -0.02826  0.01457  0.05740  0.10023
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.814	0.065	12.47	<0.001
Age	0.043	0.016	2.66	0.011

```
Adjusted R-squared:0.108, F-statistic:7.06 on 1 and 49 DF, p-value:0.011
```

Sample from Austevoll:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.66991 -0.05519  0.04113  0.04113  0.13745
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.574	0.117	4.89	<0.001
Age	0.096	0.28	3.45	0.002

```
Adjusted R-squared:0.281, F-statistic:11.91 on 1 and 27 DF, p-value: 0.002
```

Sample from Os:

Not enough samples to run a test.

Sample from Sveio:

Not enough samples to run a test.

Appendix 3.1.3: Male Only Maturity by Age

Complete Sample:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.91682 -0.00680  0.02319  0.05318  0.08318
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.857	0.073	11.74	<0.001
Age	0.030	0.017	1.74	0.088

```
Adjusted R-squared:0.042, F-statistic:3.04 on 1 and 45 DF, p-value:0.0882
```

Sample from Austevoll:

Lm(formula=Maturity~Age)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.84332 -0.01090  0.04496  0.10082  0.15668
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.732	0.148	4.94	<0.001
Age	0.056	0.036	1.57	0.134

```
Adjusted R-squared:0.068, F-statistic:2.46 on 1 and 19 DF, p-value:0.134
```

Sample from Os:

Not enough samples to run a test.

Sample from Sveio:

Not enough samples to run a test.

Appendix 3.2.1: Length by Maturity

Complete Sample:

Lm(formula= Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.95704 -0.01768  0.01601  0.04296  0.11032
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.600	0.127	4.74	<0.001
Length	0.034	0.011	3.02	0.003

```
Adjusted R-squared:0.077, F-statistic:9.105 on 1 and 96 DF, p-value:0.003
```

Sample from Austevoll:

Lm(formula= Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.90268 -0.02937  0.03616  0.07984  0.16722
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.023	0.262	-0.089	0.929
Length	0.087	0.023	3.77	<0.001

```
Adjusted R-squared: 0.212, F-statistic:14.18 on 1 and 48 DF, p-value:<0.001
```

Sample from Os:

Not enough samples to run a test.

Sample from Sveio:

Not enough samples to run a test.

Appendix 3.2.1: Female Only Length by Maturity

Complete Sample:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.73128 -0.03113  0.01450  0.04709  0.15790
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.282	0.172	1.64	0.108
Length	0.065	0.016	4.09	<0.001

```
Adjusted R-squared:0.239, F-statistic:16.69 on 1 and 49 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.39148 -0.06865  0.03010  0.08654  0.18529
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.582	0.247	-2.36	0.026
Length	0.141	0.022	6.29	<0.001

```
Adjusted R-squared:0.580, F-statistic:39.59 on 1 and 27 DF, p-value:<0.001
```

Sample from Os:

Not enough samples to run a test.

Sample from Sveio:

Not enough samples to run a test.

Appendix 3.2.1: Male Only Length by Maturity

Overall Sample:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.95167  0.00017  0.01622  0.03655  0.07401
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.725	0.226	3.21	0.002
Length	0.021	0.019	1.13	0.264

```
Adjusted R-squared:0.006, F-statistic:1.28 on 1 and 45 DF, p-value:0.264
```

Sample from Austevoll:

Lm(formula=Maturity~Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.90388  0.00394  0.04542  0.07308  0.13300
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.415	0.534	0.778	0.446
Length	0.046	0.046	1.01	0.325

```
Adjusted R-squared:0.001, F-statistic:1.02 on 1 and 19 DF, p-value: 0.325
```

Sample from Os:

Not enough samples to run a test.

Sample from Sveio:

Not enough samples to run a test.

Appendix 3.3.1: Time Elapsed and Length by Spawning

Complete Sample:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.9399 -0.4856  0.2517  0.4780  0.6143
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.085	0.136	0.623	0.534
Date	0.007	0.001	6.42	<0.001
Length	0.029	0.011	2.53	0.012

```
Adjusted R-squared:0.056, F-statistic:21.97 on 2 and 705 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.9551 -0.4093  0.1492  0.3169  0.7273
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.524	0.187	-2.81	0.006
Date	0.0006	0.002	0.335	0.738
Length	0.105	0.016	6.44	<0.001

```
Adjusted R-squared:0.172, F-statistic:21.08 on 2 and 191 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.9004 -0.3835 -0.3050  0.5641  0.7212 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.919	0.255	3.60	<0.001
Date	0.015	0.003	6.11	<0.001
Length	-0.052	0.021	-2.50	0.013

```
Adjusted R-squared:0.111, F-statistic:21.51 on 2 and 325 DF, p-value:<0.001
```

Sample from Sveio:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.8703 -0.5734  0.2402  0.3658  0.4932 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.041	0.250	0.162	0.871
Date	-0.002	0.003	-0.986	0.326
Length	0.064	0.023	2.83	0.005

```
Adjusted R-squared:0.033, F-statistic:4.176 on 2 and 183 DF, p-value:0.017
```

Appendix 3.3.2: Female Only Time Elapsed and Length by Spawning

Complete Sample:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-0.8929 -0.5073  0.1547  0.3504  0.6620 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.122	0.234	0.521	0.603
Date	-0.007	0.002	-4.08	<0.001
Length	0.068	0.021	3.31	0.001

```
Adjusted R-squared:0.110, F-statistic:15.6 on 2 and 234 DF, p-value:<0.001
```

Sample from Austevoll:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.7119 -0.5036  0.1956  0.4112  0.6877
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.485	0.351	-1.38	0.172
Date	0.002	0.003	0.579	0.564
Length	0.090	0.032	2.78	0.007

```
Adjusted R-squared:0.0815, F-statistic:4.10 on 2 and 68 DF, p-value:0.021
```

Sample from Os:

Lm(formula=Spawning~Date+Length)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.69803 -0.02777 -0.00042  0.05428  0.38402
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	1.70	0.312	5.44	<0.001
Date	-0.011	0.002	-5.68	<0.001
Length	-0.055	0.027	-2.05	0.043

```
Adjusted R-squared:0.263, F-statistic:16.52 on 2 and 85 DF, p-value:<0.001
```

Sample from Sveio:

Lm(formula=Spawning~Date+Length)

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.6404 -0.5521  0.3513  0.4506  0.4661
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.636	0.494	1.29	0.202
Date	-0.004	0.005	-0.726	0.470
Length	0.006	0.047	0.117	0.907

```
Adjusted R-squared:-0.019, F-statistic:0.266 on 2 and 75 DF, p-value:0.768
```

Appendix 3.3.3: Male Only Time Elapsed and Length by Spawning

Complete Sample:

Lm(formula=Spawning~Date+Length)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.99210  0.02667  0.05431  0.09516  0.19965 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.907	0.126	7.19	<0.001
Date	-0.003	0.001	-2.68	0.008
Length	0.008	0.010	0.717	0.474

```
Adjusted R-squared:0.021, F-statistic:3.73 on 2 and 249 DF, p-value:0.025
```

Sample from Austevoll:

Lm(formula=Spawning~Date+Length)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.93139  0.06755  0.09593  0.12107  0.17191 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.934	0.234	3.99	<0.001
Date	-0.002	0.002	-0.979	0.330
Length	0.002	0.019	0.109	0.914

```
Adjusted R-squared:-0.011, F-statistic:0.479 on 2 and 97 DF, p-value:0.621
```

Sample from Os:

Lm(formula=Spawning~Date+Length)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.95945  0.01112  0.03222  0.04889  0.07390 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	1.15	0.267	4.30	<0.001
Date	0.002	0.002	1.21	0.230
Length	-0.017	0.022	-0.757	0.452

```
Adjusted R-squared:-0.008, F-statistic:0.757 on 2 and 63 DF, p-value:0.473
```

Sample from Sveio:

Lm(formula=Spawning~Date+Length)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.90124 -0.01219  0.01280  0.11750  0.22137 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.947	0.190	4.97	<0.001
Date	-0.007	0.002	-3.30	0.001
Length	0.012	0.016	0.761	0.449

```
Adjusted R-squared:0.096, F-statistic:5.53 on 2 and 83 DF, p-value:0.006
```

Appendix 3.4: Time Elapsed and Maturity by GSI

Complete Sample:

Lm(formula=GSI~Date+Maturity)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-4.3236 -1.0795  0.0589  0.9512  6.8743 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.063	2.25	0.028	0.978
Date	0.013	0.019	0.686	0.496
Maturity	7.78	2.00	3.90	<0.001

```
Adjusted R-squared:0.214,F-statistic:7.81 on 2 and 48 DF, p-value:0.001
```

Sample from Austevoll:

Lm(formula=GSI~Date+Maturity)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-2.3053 -0.9925  0.2650  0.7582  2.5393 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	4.41	1.75	2.52	0.018
Date	-0.051	0.019	-2.74	0.011
Maturity	5.62	1.35	4.15	<0.001

```
Adjusted R-squared:0.591, F-statistic:21.22 on 2 and 26 DF, p-value:<0.001
```

Sample from Os:

Not enough samples to run the test against maturity.

Sample from Sveio:

Not enough samples to run the test against maturity.

Appendix 3.5 Spawning/Maturity by Sex

Complete Sample:

Lm(formula=Spawning~Gender)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.99705 -0.07880  0.00295  0.00295  0.46208
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.079	0.020	3.94	<0.001
Gender	0.459	0.015	30.41	<0.001

```
Adjusted R-squared:0.567, F-statistic:924.8 on 1 and 706 DF, p-value:<0.001
```

Lm(formula= Maturity~Gender)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.98039  0.01961  0.01961  0.02128  0.02128
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.982	0.045	21.7	<0.001
Gender	-0.002	0.029	-0.058	0.954

```
Adjusted R-squared:-0.010, F-statistic:0.003 on 1 and 96 DF, p-value: 0.954
```

Sample from Austevoll:
Lm(formula=Spawning~Gender)

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.91039 -0.04517  0.08961  0.08961  0.52222
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.045	0.061	0.745	0.457
Gender	0.433	0.039	11.12	<0.001

```
Adjusted R-squared: 0.389, F-statistic:123.6 on 1 and 192 DF, p-value:<0.001
```

Lm(formula= Maturity~Gender)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.96552  0.03448  0.03448  0.04762  0.04762 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.979	0.086	11.37	<0.001
Gender	-0.013	0.057	-0.229	0.820

```
Adjusted R-squared:-0.020, F-statistic:0.053 on 1 and 48 DF, p-value:0.820
```

Sample from Os:

Lm(formula=Spawning~Gender)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-1.16864 -0.07546 -0.07546 -0.07546  0.37795 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.075	0.018	4.22	<0.001
Gender	0.547	0.017	31.69	<0.001

```
Adjusted R-squared:0.754, F-statistic:1005 on 1 and 326 DF, p-value:<0.001
```

Not enough samples to run the test against maturity.

Sample from Sveio:

Lm(formula=Spawning~Gender)

```
Residuals:
     Min       1Q   Median       3Q      Max 
-0.95423 -0.09380  0.04577  0.04577  0.47599 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.094	0.060	1.56	0.12
Gender	0.430	0.040	10.8	<0.001

```
Adjusted R-squared: 0.385, F-statistic:116.7 on 1 and 184 DF, p-value:<0.001
```

Not enough samples to run the test against maturity.

Appendix 4: TukeyHSD Test

Appendix 4.1 Tukey HSD Corkwing Wrasse

TukeyHSD(aov(Length~Location))

Locations	Difference	Lower	Upper	p-value
Os vs. Austevoll	0.817	0.561	1.07	0
Sveio vs. Austevoll	-1.04	-1.26	-0.811	0
Sveio vs. Os	-1.85	-2.10	-1.60	0

TukeyHSD(aov(Age~Location))

Locations	Difference	Lower	Upper	p-value
Os vs. Austevoll	1.05	0.702	1.39	0
Sveio vs. Austevoll	0.230	-0.109	0.571	0.250
Sveio vs. Os	-0.817	-1.23	-0.402	0.00001

Appendix 4.2 Tukey HSD Goldsinny Wrasse

TukeyHSD(aov(Length~Location))

Locations	Difference	Lower	Upper	p-value
Os vs. Austevoll	0.556	0.263	0.848	0.00003
Sveio vs. Austevoll	0.428	0.071	0.786	0.014
Sveio vs. Os	-0.128	-0.508	0.252	0.710

TukeyHSD(aov(Age~Location))

Locations	Difference	Lower	Upper	p-value
Os vs. Austevoll	0.168	-0.380	0.716	0.747
Sveio vs. Austevoll	1.32	0.383	2.26	0.003
Sveio vs. Os	1.15	0.205	2.10	0.013

Appendix 4.3 Tukey HSD Rock Cook Wrasse

TukeyHSD(aov(Length~Location))

Locations	Difference	Lower	Upper	p-value
Os vs. Austevoll	1.09	0.769	1.42	0
Sveio vs. Austevoll	-0.009	-0.377	0.359	0.998
Sveio vs. Os	-1.10	-1.43	-0.774	0

TukeyHSD(aov(Age~Location))

Locations	Difference	Lower	Upper	p-value
Os vs. Austevoll	0.206	-0.427	0.838	0.719
Sveio vs. Austevoll	-0.667	-1.44	0.110	0.107
Sveio vs. Os	-0.872	-1.708	-0.038	0.038

Appendix 5: Field sample vs. sub-sample

Appendix 5.1 Field sample vs. sub-sample Corkwing Wrasse

Sample from Austevoll:

Lm(formula=Length~Sample)

```
Residuals:
    Min      1Q  Median      3Q     Max
-6.5967 -1.5967 -0.0967  1.4033 10.9824
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	13.10	0.068	194.9	<0.001
SampleLab	-0.579	0.145	-3.98	<0.001

```
Adjusted R-squared:0.009, F-statistic:15.88 on 1 and 1589 DF, p-value:<0.001
```

Sample from Os:

Lm(formula=Length~Sample)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-6.4198 -1.9198  0.0802  1.5802  8.0919 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	13.92	0.087	159.3	<0.001
SampleLab	-0.012	0.245	-0.048	0.962

```
Adjusted R-squared:-0.001, F-statistic:0.002 on 1 and 970 DF, p-value:0.962
```

Sample from Sveio:

Lm(formula=Length~Sample)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-5.0665 -2.0665 -0.5665  1.4335  8.9335 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	12.07	0.068	178.0	<0.001
SampleLab	0.380	0.234	1.62	0.105

```
Adjusted R-squared:0.001, F-statistic:2.63 on 1 and 1516 DF, p-value:0.105
```

Appendix 5.2 Field sample vs. sub-sample Goldsinny Wrasse

Sample from Austevoll:

Lm(formula=Length~Sample)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-3.5391 -1.0391 -0.0391  0.9609  4.4609 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	10.04	0.083	120.34	<0.001
SampleLab	-0.034	0.206	-0.165	0.869

```
Adjusted R-squared:-0.003, F-statistic:0.027 on 1 and 365 DF, p-value:0.869
```

Sample from Os:

Lm(formula=Length~Sample)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-2.6019 -0.6019 -0.1019  0.3981  3.8981 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	10.60	0.072	146.82	<0.001
SampleLab	-0.695	0.157	-4.42	<0.001

```
Adjusted R-squared:0.066 F-statistic:19.5 on 1 and 259 DF, p-value:<0.001
```

Sample from Sveio:

Lm(formula=Length~Sample)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-2.9779 -0.9779  0.0221  0.8682  4.5221 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	10.48	0.146	71.64	<0.001
SampleLab	0.408	0.441	0.926	0.356

```
Adjusted R-squared:-0.001 F-statistic:0.857 on 1 and 125 DF, p-value:0.356
```

<u>Appendix 5.3 Field sample vs. sub-sample Rock Cook Wrasse</u>

Sample from Austevoll:

Lm(formula=Length~Sample)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-5.9588 -0.9588  0.0412  1.2690  3.5412 
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	10.96	0.129	84.96	<0.001
SampleLab	0.297	0.285	1.04	0.298

```
Adjusted R-squared:0.0004, F-statistic:1.088 on 1 and 242 DF, p-value:0.298
```

Sample from Os:

Lm(formula=Length~Sample)

```
Residuals:
    Min      1Q  Median      3Q     Max 
-3.5716 -0.5716 -0.0716  0.9284  2.9284
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	12.07	0.069	175.08	<0.001
SampleLab	-0.656	0.235	-2.79	0.005

```
Adjusted R-squared:0.019, F-statistic:7.81 on 1 and 357 DF, p-value:0.005
```

Sample from Sveio:

Lm(formula=Length~Sample)

```
Residuals:
   Min     1Q Median     3Q    Max 
-2.957 -0.957 -0.457  1.043  4.043
```

	Estimate	Std. Error	t-value	p-value
(Intercept)	10.96	0.111	98.28	<0.001
SampleLab	0.084	0.385	0.219	0.827

```
Adjusted R-squared:-0.005, F-statistic:0.048 on 1 and 201 DF, p-value:0.827
```