Population Dynamics of the European Sea Bass (*Dicentrarchus labrax)* in Welsh Waters

Abi Carroll

MSc Marine Environmental Protection Thesis

Bangor University

2013 – 2014

Supervisors: Dr Ian McCarthy & Dr Giulia Cambiè

Contact email: abicarroll@googlemail.com

CONTENTS

FIGURES

<u>TABLES</u>

<u>APPENDICIES</u>

PRIFYSGOL
BANGOR
UNIVERSITY

i. DECLARATION

This work has not previously been accepted in substance for any degree and is not being currently submitted for any degree.

This dissertation is being submitted in partial fulfilment of the requirement of the M.Sc. in Marine Environmental Protection.

The dissertation is the result of my own independent work / investigation, except where otherwise stated.

Other sources are acknowledged by footnotes giving explicit references and a bibliography is appended.

I hereby give consent for my dissertation, if accepted, to be made available for photocopying and for inter-library loan, and the title and summary to be made available to outside organisations.

Signed:

Date:

ii. ACKNOWLEDGEMENTS

I would like to acknowledge the following people for their help along the way with this work: Dr Giulia Cambiè and Dr Ian McCarthy for their supervision, support and expertise; the fishers whose continued participation was vital for this projects success; all the research assistants in the EFF group at the School of Ocean Sciences who helped me with the lab work; Tom Clegg for his skills in R; Adam Suchley for his stats brains; Chris Carroll for using his PhotoShop expertise to create some brilliant diagrams; my parents for accepting I had no time for them this year; Lindo Edwards, for putting up without me for such a long time; all my friends who have supported me this year, including Katy Moorhead, Harriet Robinson, Kathryn Burt, Ben Butler, Faye Walker, Lauren Davies and Rachel Shiner.

This work is dedicated to my brother, Ben Carroll, who through tragic circumstances, will never read these words.

iii. List of Abbreviations

ANOVA – analysis of variance

Df – degrees of freedom

GSI – Gonadosomatic index

ICES – International Council for the Exploration of the Sea

MLS – Minimum landing size

SD – standard deviation

TAC – total allowable catch

TL – total length (cm)

VBG – von Bertalannfy growth

1.0 ABSTRACT

European sea bass (*Dicentrarchus labrax*) in Wales is a species of commercial, recreational and economic importance. Recent declines in landings have brought to light the need for increased management measures to enable sustainable exploitation of the stock. There is a lack of data on the sea bass population of Wales and this study forms part of a European Fisheries Fund project using data from bass collected by participating members of the fishing community. The aims were to estimate the growth parameters, size distribution and size at maturity of bass in Wales. Regional differences between the populations of sea bass around the coast of Wales were investigated. A total of 1979 fish caught in Welsh coastal waters between April 2013 and July 2014 were used in this study. In the laboratory, total length (cm) and weight (g) of the bass were recorded and the fish were dissected, the maturity stage was estimated based on the key by Pawson & Pickett (1996) and age was determined from scale analysis. It was evident that there are regional differences between some of the population parameters, most notably the sex ratio of male to female fish, which is higher in South Wales than in North Wales. The mean body size of fish in South Wales was higher than North Wales, but the difference in MLS between these areas coupled with gear selectivity likely influenced the result. The data lacked immature fish, therefore the size at which bass mature could not be estimated, nor could the von Bertalannfy growth parameters for the two regions of Wales. There is some evidence to suggest that there are regionally separate populations of sea bass in Wales, but there is not enough evidence as yet to advise whether regional or national management techniques should be adopted.

2.0 INTRODUCTION

2.1 General Introduction

The European sea bass *(Dicentrarchus labrax*) is a predatory species of fish found throughout the Mediterranean Sea and the Eastern Atlantic, ranging from Southern Morocco and the Canary Islands to the coastlines of Norway (Fritsch et al. 2007), including the Bay of Biscay, English Channel, Celtic Sea, Irish Sea and the North Sea (Figure 1). Recent climate change and warming of the sea is a likely cause of the sea bass occupying a wider, more northerly range and it is now found in the Solway Firth in the Irish Sea and into the North Sea (Pawson et al. 2007). Sea bass occupy a large range and make use of a broad range of habitats (Kelley 1987).

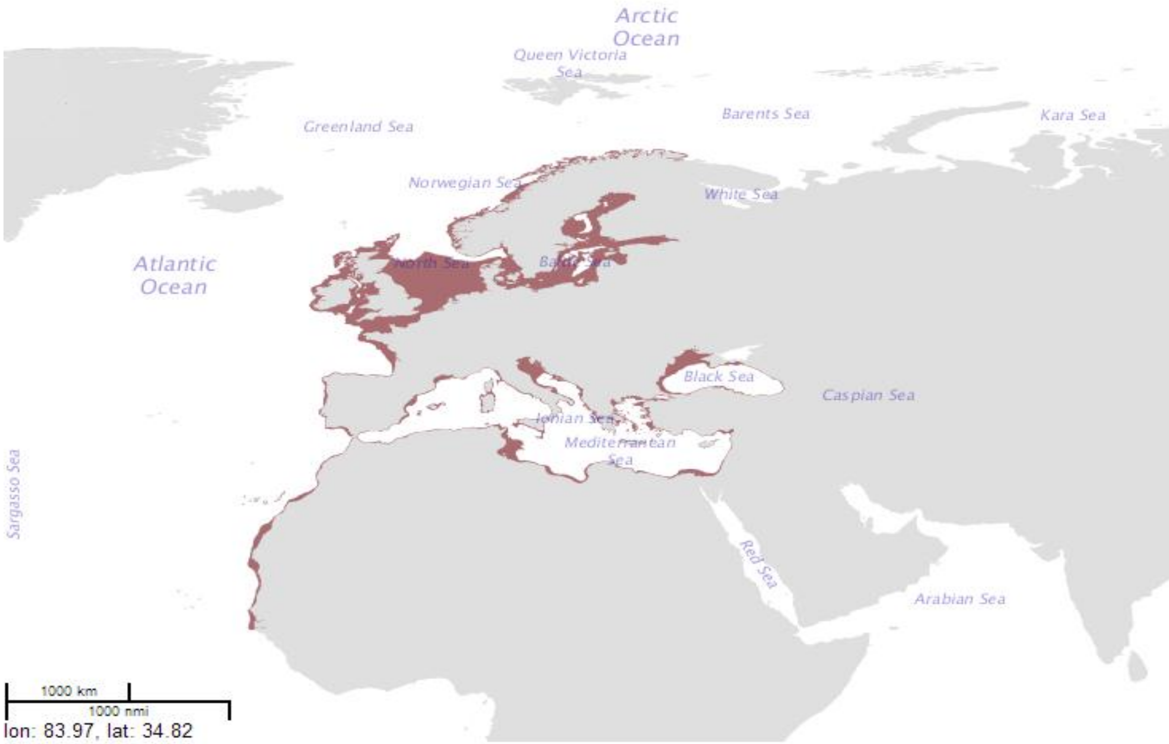

Figure 1. Distribution of European sea bass (Dicentrarchus labrax), based on 2012 landings information (FAO 2012).

In the 1970's sea bass in the UK shifted from primarily a sport fish to a commercially important species (Kelley 1988). The development of fishing technologies such as faster boats, sonar and nylon netting allowed fish to be located and caught more easily. Due to the historical lack of a sea bass fishery, there is little data and published literature on the species prior to relatively recent calls from ICES for accurate stock assessments (Pawson et al. 2005, ICES 2004). ICES have reported declining total catches of sea bass in recent years (Figure 2) which could be due to a combination of continued fishing pressures and numerous cold winters since 2008 reducing the survival of larval and juvenile fish (SeaFish 2011) or an increase in the magnitude of the recreational catch.

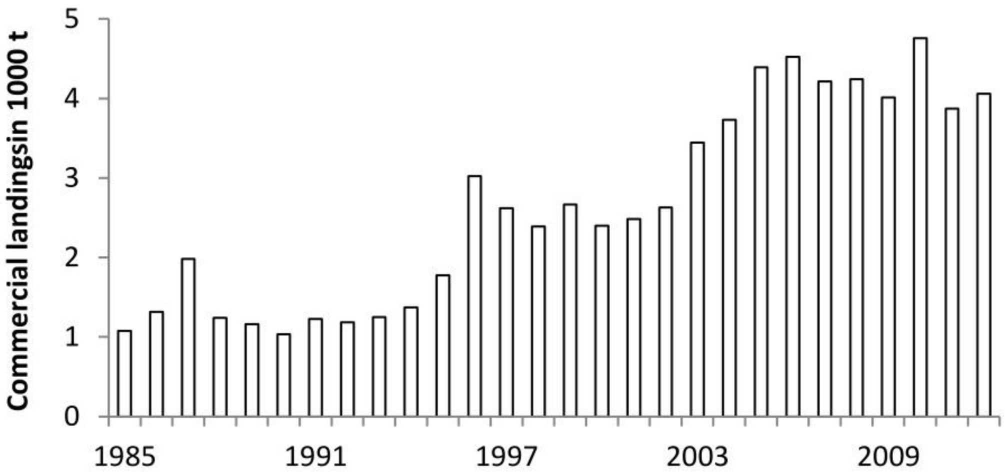

Figure 2. .Commercial landings (1000 tonnes) of European sea bass in Divisions IVbc, VIIa, and VIId–h for the year 1985-2012 (ICES 2013a).

2.2 Ecology and Biology of the European Sea Bass.

2.2.1 Life History

The sea bass life cycle (Figure 3) can be split into four broad phases: eggs and larvae, juvenile, adolescent and adult (Dando & Demir 1985). Sea bass reach maturity between 4 and 7 years of age (~35 and 42cm) and can continue to reproduce for up to 20 years (Pawson & Pickett 1987). The oldest sea bass recorded was thought to be 28 years old (ICES 2013a). Sea bass exhibit sexual growth dimorphism where female bass mature at a greater size and age than males (Kennedy & Fitzmaurice 1972). The juvenile stage occurs approximately 2 months after spawning (Kelley 1988) during which time larval bass remain in the plankton and are transported inshore by currents into post-larval habitats in estuaries and shallow coastal waters, where they arrive at a total length of around 10 – 15 mm (Jennings & Pawson 1992). Bass can tolerate brackish water habitats such as those in estuaries and river mouths where they spend much of their juvenile stage (Kennedy & Fitzmaurice 1972).

Fully mature bass undertake seasonal migrations from summer coastal feeding grounds to winter offshore spawning grounds (Pawson et al. 2007) coinciding with the decrease in coastal water temperature (Pawson & Pickett 1987) that generally occurs in October. Numerous tagging studies have shown that sea bass have a strong fidelity to summer feeding grounds, where they will return year on year (Claridge & Potter 1983, Pawson et al. 1987, Kelley 1988, Pawson, Pickett, et al. 2007). Some bass have been recaptured on the very same rock where they were first caught and tagged, but most recaptures have been within 80 km of their first release (Pickett et al. 2004, Quayle & Righton 2007).

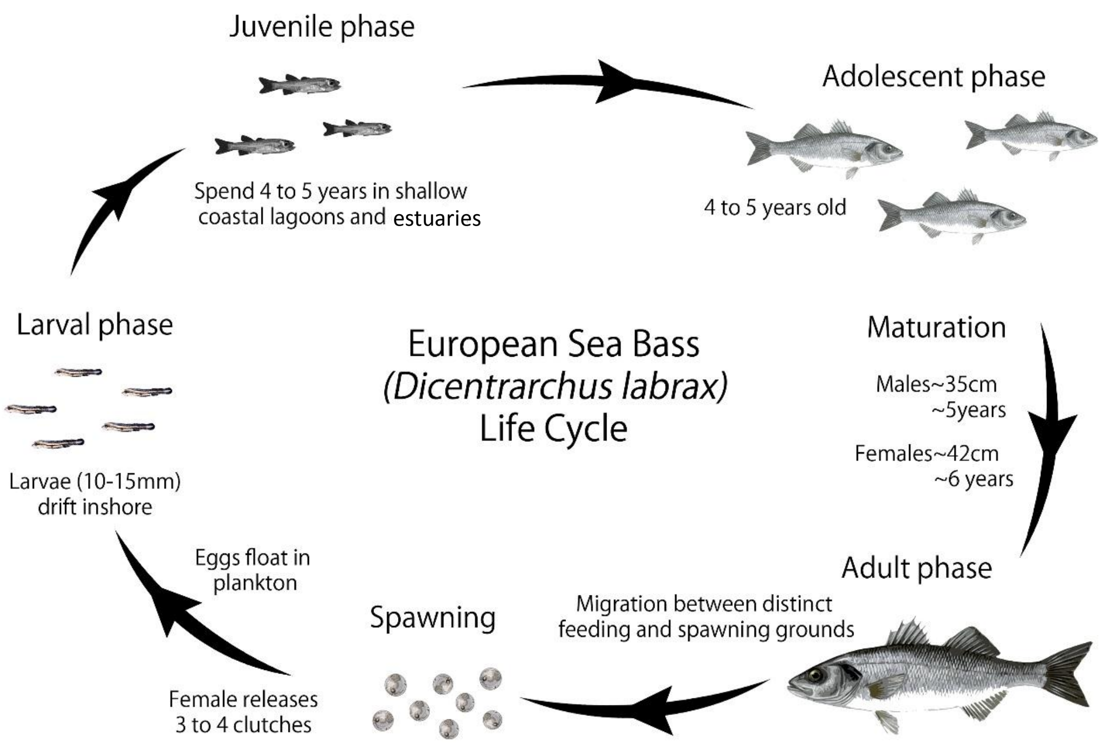

Figure 3.. Illustration of the European sea bass (Dicentrarchus labrax) life cycle (from Dando & Demir 1985, Pawson et al. 1987, Jennings et al. 1991, Pawson, et al. 2007).

The slow growing nature of sea bass along with the strong fidelity to specific locations means the species is vulnerable to over exploitation (Kelley 1988).

2.2.2 Feeding Behaviour

Sea bass exhibit opportunistic feeding behaviours and take a broad range of prey (Kelley 1987). The range of prey differs regionally, which can be attributed to the wide range of sea bed habitats around the coastline of the UK which in turn, are able to support a wide range of species. In Kelley (1987) 1225 bass were caught within 1 km from coastline using rod and line and beach-seine nets. The stomach contents of the fish were examined, and crabs, sand eels, prawns and shrimps were the dominant foods present, with lesser amounts of other fish. In a small study of sea bass in Cardigan Bay, west Wales, crabs up to 8cm as well as fish, prawns, shrimps, lugworms and algae were all present in the stomachs of 11 fish (Sant 1978). Both studies demonstrate the opportunistic and generalist feeding behaviours in bass, their ability to hunt for food at a variety of depths.

A study on bass in the Menai Strait, North Wales (Ward 2008) did not note any significant difference in diet between fish of differing 10 cm size classes. This is contrary to Kelley (1987) where bass had an increasing tendency for crabs and fish over prawns and shrimps with increasing size. Furthermore, in Kelley (1987), bass caught in North Wales had the least proportion of fish in their stomachs, contradicting the results of Ward

(2008) where fish were found to make up a dominant component of the bass diet. There is a rise in the overall intake of food with increasing size (Kelley 1987), but that is to be expected as a larger fish requires more energy. The larger fish caught in this study (Kelley 1987), (>68cm) tended to take fewer, larger prey. It was noted that male bass preferred less bulky foods when compared to female bass, probably due to the fact that males are smaller than females. Feeding is greatly reduced in the run up to, and during, spawning, but does not cease all together (Kelley 1987).

2.2.3 Growth

The European sea bass is characteristically a long lived and slow growing species (Kennedy & Fitzmaurice 1972). The bass exhibits sexually dimorphic growth, where females grow to a larger maximum size (~ 70 cm TL) than males (~ 60 cm TL) (Pawson & Pickett 1996). These differences in total length do not materialise until after the juvenile phase at around 35 cm (Pawson & Pickett 1996) where female bass have been shown to grow faster than males from age 5 onwards. Bass is an eurythermic species with a temperature tolerance of 5 – 33 °C, however, maximal somatic growth occurs between 22 and 24 °C (Vinagre et al. 2012).

A study by Claridge & Potter (1983) suggested a strong link between summer water temperatures and growth rate of the juvenile bass within the estuary. Bass > 100 mm standard length were infrequent in the estuary with the majority of fish in the o+ age class. Claridge & Potter (1983) obtained bass from the cooling-water intake screens at four power stations in Severn estuary and Bristol Channel in the years 1974 to 1976. The combination of ageing from otoliths and the length-frequency data allowed the growth rate of the bass to be determined. They found that growth occurred predominantly between May and September with a period of rapid growth (from 35 mm) in August, September and early October occurring when water temperatures are highest (14 – 21°C). The fish reached 55 mm in this time and once temperatures fell to 13°C in the autumn growth slowed dramatically. Very few adolescent bass were found in the estuary. Adolescent bass present were immature with low gonadosomatic indices, suggesting that the sea bass do not mature in the area and that spawning occurs in fully marine environments as opposed to an estuarine environment.

Fish are ectothermic organisms, so are highly dependent on temperature, which is an important factor for growth (Vinagre et al. 2009). The strength of a year class can be dependent on the temperature regime of the nursery or spawning area. Good growth years generally correspond with good hatch years and periods of warm weather-mild winters and warm summers (Sant 1978). Below average temperatures in the winters of 2010/11 and 2012/13 and a high number of extreme storm events in the winter of 2013/14 (MET 2013) may result in reduced survival of fish and weakened subsequent year classes.

In fish, photoperiod (number of daylight hours) acts a guide as to what time of year it is, and this coupled with seasonal changes in temperature likely stimulate the onset of migrations, spawning and maturation

(Pawson & Pickett 1996, Pawson et al. 2000, Vinagre et al. 2009). Light is also a fundamental factor in growth, and it has been found that longer photoperiods stimulate growth in larvae and juveniles (Vinagre et al. 2009) and that constant photoperiod can enhance growth overall (Rodrıguez et al. 2001). It has been argued that temperature controls the timing of spawning and that photoperiod is the regulating factor in maturation (Pawson et al. 2000, Rodrıguez et al. 2001, Bayarri et al. 2004). In a Portuguese study on water temperatures and photoperiod over a latitudinal gradient (Vinagre et al. 2009), it was found that there was an increasing trend in growth rates from North to South over a total of 4 degrees of latitude. The study observed that an increase in temperature is not the main trigger of spawning, and that spawning started generally when the temperature was decreasing. The study took place in Portuguese waters where the sea surface temperature rarely fell below 13 ° C, as opposed to the cooler waters around the UK where other studies have been focused (Pawson & Pickett 1996, Pawson et al. 2000, Fritsch et al. 2007). Warm water outflows from power stations are favoured by anglers as they seem to catch bigger bass (www.totalseamagazine.com). Anecdotal evidence from angling clubs suggests there is a relationship between warmer waters and enhanced growth in sea bass.

2.2.4 Maturation

In sea bass, maturation occurs at around 35 cm for males aged between 3 and 6 years (Pawson & Pickett 1996) and the latest stock assessment suggests females mature around 40 cm (40.65 cm) (ICES 2013b) aged between 4 and 7 years. Ripe adult (> 42cm) female bass around England and Wales have been found from January until May or June, and ripe adult male bass (> 34cm) from December until June.

The ambient temperature of water in winter may influence the onset of maturity in females (Pawson et al. 2000). In waters below 9 °C, bass experience delayed maturation, reduced growth and retardation of ovarian development (Pawson et al. 2000). Bass residing in Mediterranean waters do not have an extended adolescent stage like those in British waters and have been observed to mature earlier at 2 years (males) and at 3 years (females) (Kara 1997). It seems that the extended period of adolescence in female sea bass in British waters is a result of their environment and not due to their intrinsic species biology.

Temperature has been identified a major factor in the sex differentiation during the juvenile phase of sea bass (Koumoundouros et al. 2002), where the sex ratio of a population is defined. In general, the wild sea bass population is slightly biased towards females, but individual populations of varying geographical location are often dominated by either males or females (Diaz et al. 2011). Under experimental conditions during the critical temperature sensitive juvenile phase, higher temperatures yield more males than females within a population (Koumoundouros et al. 2002) and lower temperatures yield more females. In the case of the Portuguese coast, a trend of increasing temperature along a decreasing latitudinal gradient corresponds with the sex ratio of sea bass sampled in coastal waters (Vinagre et al. 2009).

2.3 Fisheries and Exploitation

The sea bass fishery in the UK is a commercially and economically important one. In an independent report commissioned by the CCW estimated commercial sea bass fishing in England and Wales yielded £35 million annually (Barclay 2011). The commercial fishery targets bass inshore in spring, fishing from vessels using gears such as trawls, longline and handline. Offshore, bass are generally caught using pelagic pair trawlers which target congregations of spawning bass between December and April (Pawson et al. 2007). Bass are also fished recreationally by anglers from boats and the shore, where they are caught with rod and line or fixed nets (ICES 2013a). In the UK the majority of the fishery activity takes place in the summer and autumn (ICES 2002). This seasonal practice is defined by the seasonal offshore movement of the bass and the increasing poor weather conditions in the winter months (Pawson et al. 2007). Some countries, including France, Spain, Portugal and to a lesser extent the UK continue to fish all year round, essentially following the bass on their seasonal migrations (ICES 2002). Recreational fisheries contribute at least 20 % of the total fishery production for sea bass, (ICES 2013a) and in 2010 it was estimated that the angling directly and indirectly contributes £140 million to the coasted economy of England and Wales (Barclay 2011). The limited recreational catch data that are available however, have not been included in the stock assessment which could thereby underestimate the current declining status of the population of sea bass by a substantial amount. Commercial landings in 2012 for UK and France combined totalled at 4060 t (24% bottom trawlers; 29% pelagic pair trawlers; 14% fixed/drift nets; 12% lines; 7% other gears. Other countries: 14% all gears) (ICES 2013a).

Under EU legislation, the official minimum landing size (MLS) for bass is 36 cm (EC Regulation 850/98). As well as this European restriction on landing size, there are other national restrictions in place including a larger MLS of 37.5 cm in South Wales and Cornwall, seasonal area closures, and weekly catch limits of 5 tonnes for UK and French trawlers landing bass to UK ports (Bennett 2013, ICES 2013c). South Wales Sea Fisheries Committee enforce a bylaw stipulating a gill net minimum mesh size of 100mm (Bennett 2013), whereas North Wales fishers use nets from 89 mm stretched mess size. The seasonal area closures [The Bass (Specified Areas) (Prohibition of Fishing) (Variation) Order 1999] came into force to protect the nursery areas of juvenile sea bass, where 37 nursery areas were designated in the UK. These nursery areas are shallow coastal waters comprising of river estuaries, harbours and power station outfalls where juvenile bass are more easily caught, particularly during the summer months (ICES 2002). The protection of juveniles has been effective and some recovery of the bass stock has been observed (Pawson et al. 2005). The species does not have a Total Allowable Catch (TAC) limit currently enforced at a European level (ICES 2013c).

As much as half of the fishing effort for all species in the Northeast Atlantic is carried out by trawl activity (ICES 2013a) which is a highly unselective fishing method and catches non-target organisms, as well as undersized target fish. The discard rate is assumed to be low in general in the sea bass fishery (ICES 2012a) although the quality and quantity of the discard data is low. A study by Walmsley & Pawson (2006) suggests that the trawl fisheries around the UK, and more specifically the English Channel, do catch undersize bass. Mesh size and fishing area influence the size composition of the catch with English Channel trawlers catching a high proportion of bass under 36 cm Walmsley & Pawson (2006).

Recently, there have been calls for an increase in the MLS from 36 cm to 45 cm (Bennett 2013). This would ensure that more females reach maturity and therefore have a chance to reproduce before they recruit into the fishery (Bennett 2013). A change in the MLS would increase the number of larger individuals in a population (Pawson et al. 2005). Larger fish are generally of more value within the stock in terms of spawning ability, (fecundity is directly related to size) as well as being of greater commercial and recreational value (Bennett 2013). In the short term, increasing the MLS could negatively impact fisheries, resulting in short term reduction in landings and therefore economic loss to commercial fishers. However, this may be the only method available other than a complete fishing ban to see the longer term recovery of the sea bass fishery in the UK.

2.4 Conclusion

The minimum length at which sea bass mature is as 35cm TL in males and has recently been suggested to be around 40cm TL in females. This means that the current MLS for sea bass in the UK and more specifically Wales, (36 cm in the North and 37.5cm in the South) allows the removal of immature bass from the stock, reducing potential spawning stock biomass. ICES advice suggests that there should be no more increase in fishing pressure. There is a growing amount of data available (ICES 2013b) on sea bass, but there are no management units or stock structures currently defined, therefore appropriate assessments by ICES cannot be performed. The temperature variation between North and South could be a limiting factor in the growth, maturity and reproduction of sea bass in Welsh waters.

There is little known about sea bass in Welsh waters and there is a need for more information in order to create appropriate management policy. The difference in water temperatures between North, Mid and South Wales may mean that the dynamics and population parameters vary between areas. If this is the case, adoption of regional policy may well be needed in order to adequately manage this valuable fisheries recourse.

In order to collect data on the exploited sea bass stock in Wales, the ongoing participation of key stakeholders is paramount. The stakeholders include commercial and recreational fishers, fish merchants and processors.

2.5 Aims and Objectives

This study forms part of a larger, ongoing project funded by the European Fisheries Fund on the "Sustainable use of fisheries in Welsh waters" and aims to add to the data available on sea bass in Welsh waters in order to assist the Welsh Government's decisions regarding management of the fishery and whether the creation of a single management plan for the whole of Wales is appropriate or if regional management plans should be adopted.

The three main objectives of this study are as follows:

a) Growth parameters for male and female bass will be estimated from the measurements of total length (cm), weight (g) and age (years) from scale analysis (by counting growth rings).

b) The size distribution and growth of sea bass will be estimated by sex, by area, by gear, and by season/year.

c) The size at maturity of sea bass will be estimated using the maturity scale as described by Pawson and Pickett (1996) and will be compared with previous studies.

2.6 Hypotheses

H1: There is a difference in the size distribution of the bass by area (North, Mid & South Wales), by gear (rod and line vs net) and season.

H2: There is a difference in the growth parameters of bass between North, Mid and South Wales.

H3: The size at first maturity changed with respect to the previous studies.

H4: There is a difference in the sex ratio by area (North, Mid or South) and by season.

H5: There are no changes in the population parameters over 20 years in North Wales (age/sex structure, growth, maturity).

3.0 MATERIALS AND METHODS

3.1 Collection of Sea Bass Specimens

Fish were collected from a number of different sources around Wales including commercial and recreational fishermen and fish processors. The majority of fish came from processors, who obtain bass from local commercial fishermen. In general, bass were purchased whole and frozen for analysis in the laboratory. Occasionally, and with the owner's permission, bass were analysed on the premises of fish processors. In this case, gonads were frozen and scale samples were taken and for later laboratory assessment. The current MLS of sea bass in North Wales is 36 cm and in south Wales is 37.5 cm, so this restricts the size range of bass available from the fishing industry. A licence was obtained from Welsh Government to retain undersize bass in order to increase the sample size of smaller fish and increase the breadth of data on the population dynamics of the sea bass at all its life history stages in Welsh waters. Undersize fish are also more likely to be immature, and so will add to the data used to estimate size at maturity.

3.2 Laboratory Work

Defrosted fish were analysed in the laboratory (Figure 4). Total length (cm ± 0.1 cm) was measured and total weight (g ± 0.1g) was recorded. A sample of 15 to 20 scales was removed from each fish from beneath the pectoral fin, using a knife held perpendicular to the fish and stored in a labelled envelope to dry. The fish was cut open using dissecting scissors. An incision was made from the anus in the direction of the head, the tips of the scissors were angled upwards to avoid cutting open the gonads.

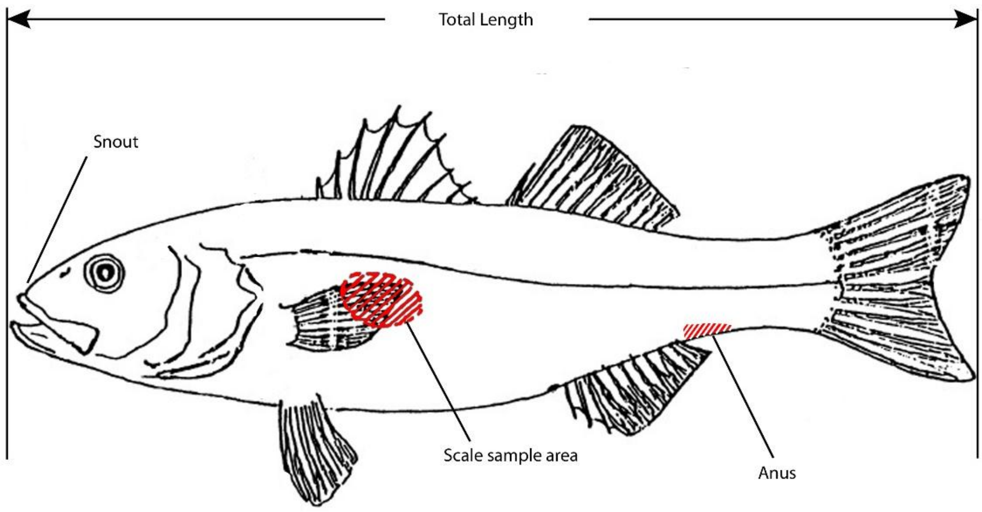

Figure 4. Diagram of a sea bass showing where the total length is measured from, scale sample is taken from and the anus where the incision is made for opening the ventral cavity (adapted from Pickett & Pawson 1994*).*

3.3 Maturity Staging

The maturity stage was estimated macroscopically based on the scale described by Pawson and Pickett (1996) (Table 1). A photograph of the gonads within the ventral cavity was taken, as well as one of the gonads once removed in order to catalogue the size of the gonads in relation to the ventral cavity (Figure 5) and to keep a pictorial record of the gonads.

Table 1. Maturity stages for male and female bass (Dicentrarchus labrax). Reproduced from (Pawson & Pickett 1996).

Maturity Stage		Female: Ovary	Male: Testes
I	Immature	Small thread-like ovary, reddish pink.	Small, colourless, thread-like: testis not practical to differentiate macroscopically <TL 20 cm.
II	Recovering Spent	Ovaries one-third length of ventral cavity, opaque, pink, with thickened walls and may have atretic eggs (Figure 5).	Testis one-third length of the ventral cavity, often bloodshot with parts dark grey (Figure 5).
III	Developing (early)	Ovaries up to one-half length of ventral cavity, orange-red, slight granular appearance, thin translucent walls.	Testes thickness 10-20 % of length, dirty white, tinged grey or pink.
IV	Developing (late)	Ovaries greater than one-third length of the ventral cavity, orange-red; eggs clearly visible, but none hyaline.	Testes flat-oval in cross section and thickness >20 % of length half to two-thirds of ventral cavity. White colour and milt expressed from vent if pressure applied to abdomen.
V	Gravid (ripe)	Swollen ovaries two-thirds length of ventral cavity, pale yellow-orange; opaque eggs clearly visible beneath thin almost transparent ovary wall, and expressed freely under light pressure.	Testes bright white and more rounded-oval in cross section. Only light pressure required to cause milt to flow from vent.
VI	Running	Ovaries very swollen; both opaque and larger hyaline eggs clearly visible beneath thin almost transparent ovary wall, and expressed freely with light pressure.	Testes becoming grey-white and less turgid. Milt extruded spontaneously.
VII	Spent	Ovary flaccid but not empty, deep red; very thick ovary wall; dense yellow atretic eggs may be visible	Testes flattened and grey, flushed with red or pink, larger than those at stage II or III.

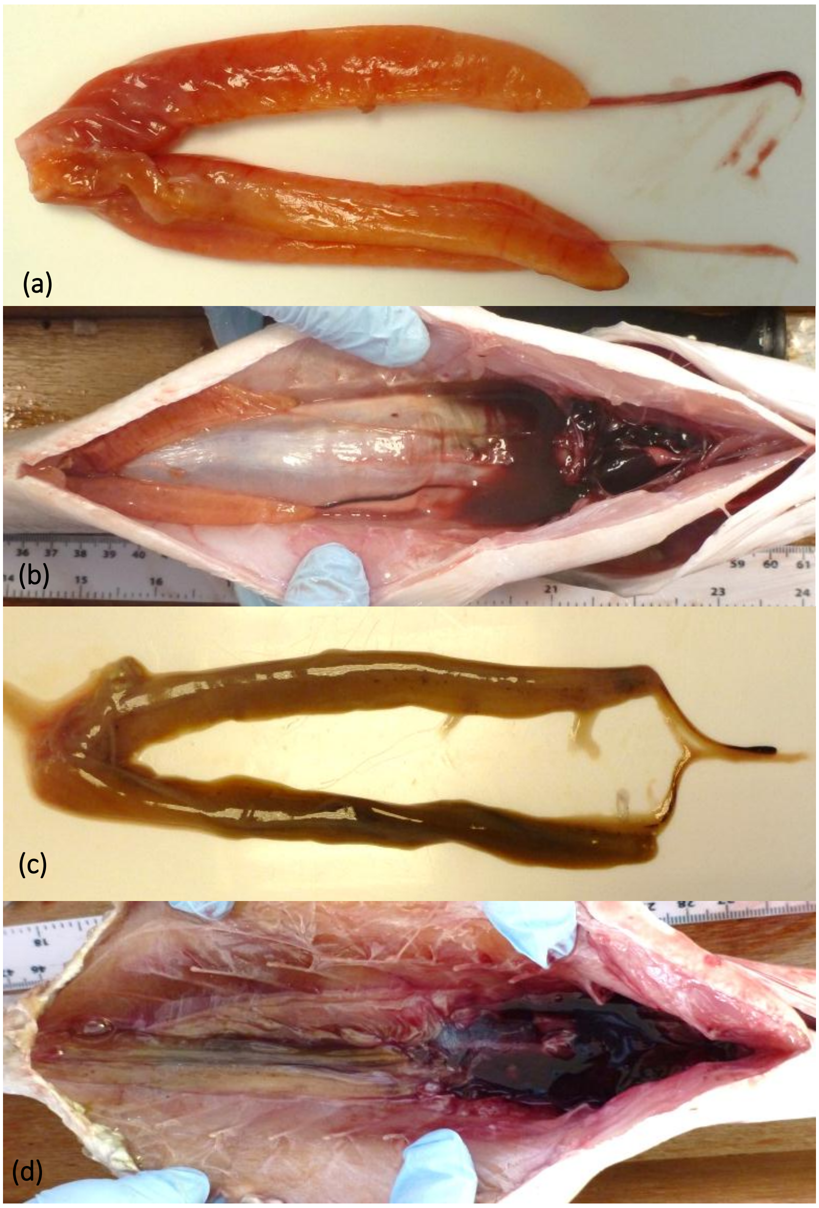

Figure 5. Example of sea bass gonads at stage II in a female (a & b) and a male (c & d) fish. Inspecting gonads within the ventral cavity in (b) and (d) assists in the identification of the maturity stage (Table 1).

3.4 Scale Ageing Analysis

Scales were removed from behind the pectoral fin and dried for at least 2 days in a paper envelope. The scales from behind the pectoral fin and closest to the head are generally the first to form (Kennedy & Fitzmaurice 1972) and are generally, but by no means always, the most regularly shaped, largest and easiest to age (Fritsch 2005). They are also the least likely to have been damaged or lost and replaced during a fishes lifetime (Fritsch 2005). Scales that have been replaced are difficult to age as there is often a large area of rapid regrowth that is without a complete set of annuli (Figure 6). Regrown scales cannot be aged and it is therefore important to retain a large enough sample of scales in order to find at least two with a complete set of annuli. A second scale confirms the reading from the first and as there can be 'false' years (partial annuli from a period of rapid seasonal growth (Fritsch 2005)) or one can be more difficult to age than the other. A photograph of each scale was taken with an *Amscope* digital camera (model MU900) mounted with a fixed microscope adaptor. The photographs were displayed directly onto a computer screen (using the software *Amscope x 86*) and the annuli were counted. This method of counting the annuli from a high quality digital photograph was found to be the most efficient and accurate.

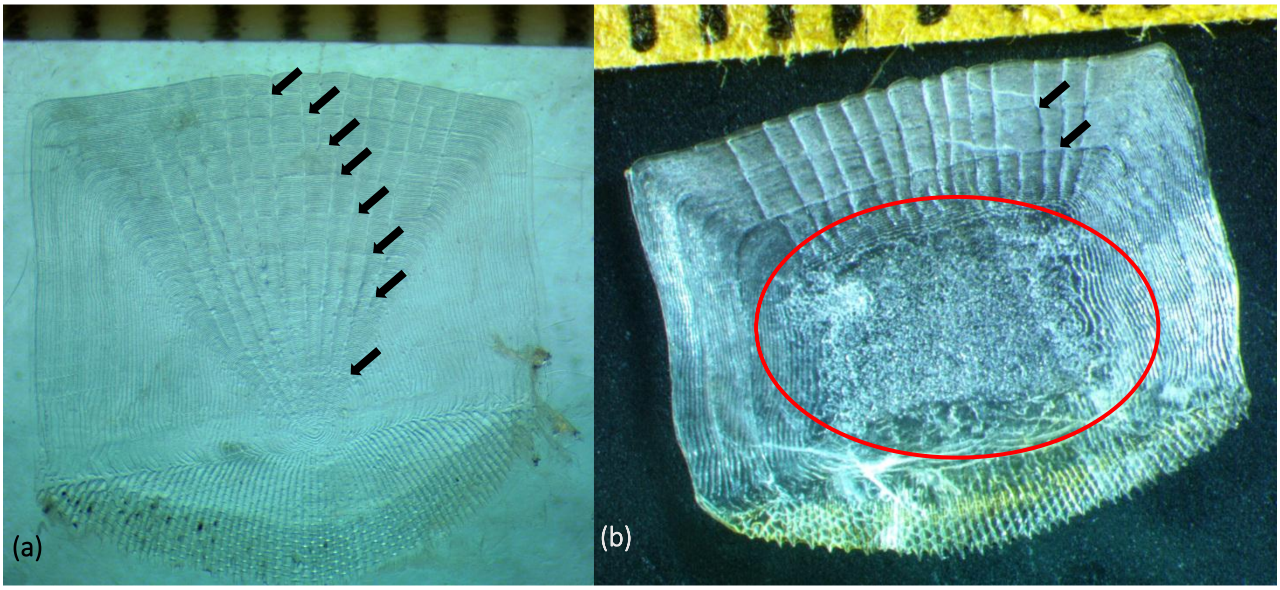

Figure 6. Example of a scale (a) from an 8 year old sea bass and a regrown scale (b) with only 2 clear annuli and a large area of regrowth shown within the red oval (arrows show clear annuli the scale bar shows mm).

3.5 Data Analysis

Throughout this study, where possible parametric analyses were applied to the data. Levene's and Bartlett's tests were used in order to ascertain if the variance of the data were homogeneous, and the Sharpiro Wilk test was applied to see if the data were normally distributed. Where parametric tests have been applied, the data met assumptions. Where the data failed the assumptions, equivalent non - parametric tests were applied.

Unless otherwise stated, the years 2013 and 2014 were combined in order to analyse the data, and the analyses were carried out using Excel 2013 and a number of packages in R Studio (R Core Team 2014) (Appendix 5).

For the catch at age matrices the two years were separated and undersized fish were removed prior to their construction as they are not representative of the commercial and recreational catch of Welsh fishers. The undersize fish are useful to 'calibrate' the growth curve and for estimation of size at first maturity. Catch at age matrices were constructed using the number or weight (kg) of fish per length (cm) and age (years) caught in 2013 and 2014. These matrices can be used to visualize the movement of cohorts of each age class of fish and assume a nominal birth date of January 1st of for each year class. Mean body size of fish was compared for North and South Wales using ANOVA.

To assess the overall growth rate of fish in Wales, as well as for male and female fish separately, the von Bertalanffy growth equation was fitted to the data (King 2013) :

$$Lt = L_{\infty} (1 - exp - K^{(t-t0)})$$

where L_{∞} is the theoretical maximum length a fish may grow (cm), K is the rate of growth (cm $year^{-1}$) and $t0$ is the theoretical age at length zero (years) (King 2013). The parameters of the growth curve were fitted using a nonlinear regression in *R.* For this analysis, fish over 70 cm were removed from the data set as these larger, older fish are difficult to accurately age from the scale analysis process (ICES 2013b).

Using data for both male and female fish split between North and South Wales, length weight relationships were analysed by fitting the data to the model (King 2013):

$$W = a L^{b}$$

using nonlinear regression, where W is weight (g), L length (cm) and a & b are parameters estimated by the analysis. Values given for b are used in subsequent analyses of the type of growth the bass exhibit (allometric vs. isometric). Linear regression was then performed on log transformed data and the intercept and slope were compared using a general linear model. A t-test was used in order to determine whether the fish exhibit allometric or isometric growth. If the b is significantly different from 3, growth is said to be allometric ($b < 3$ growth is negative, if $b > 3$ growth is positive). If b does not differ significantly from 3 then growth is said to be isometric (King 2013).

Fish caught in the months from March to May were to be used to estimate the size at maturity of the sea bass. Analysis was restricted to fish caught in these months as they are the peak spawning season (Pawson and Pickett 1996) and so any fish found to have a maturity stage of III will most likely be an immature fish that has not spawned before (ICES 2013b). Fish with gonads of stage III outside of these months should be excluded from the maturity analysis due to the ambiguity as to whether they may still mature (Pawson & Pickett 1996). Stages 2, 4, 5, 6 and 7 are classed as mature.

As this study did not sample juvenile fish, it subsequently found few immature fish, therefore the size at maturity could not be calculated.

The gonadosomatic index (GSI) was estimated using the expression:

$$GSI = (gonad\ weight / total\ weight) * 100$$

and expressed as a percentage of the total weight of the fish. The data were divided into seasons; spring (March, April & May), summer (June, July & August), autumn (September, October & November) and winter

(December, January & February) for comparison purposes. The arcsine transformed GSI for each season was compared by location using a Mann Whitney U test.

The data were divided into subsets by date of fish capture and by location. For each of these subsets, the sex ratio was calculated using the expression:

Sex ratio = number of males / (number of males + females)

This method gives a robust sex ratio and is based on the number of male fish as a ratio of the total number of fish (males and females combined) (Wilson & Hardy 2002). The sex ratio is expressed as the proportion of males for each sample. The sex ratio data was arcsine transformed and analysed using ANOVA or Mann Whitney to assess for differences by location. A binomial test was carried out to detect differences from an expected ratio. This is based on the hypothesis that there are equal numbers of males and females within a population or sample of fish and tests the statistical significance in the deviation from the theoretical expected proportion of 0.5 males to 0.5 females.

4.0 RESULTS

4.1 Data Composition

A total of 20 fishers were involved with the data collection for this study, 4 recreational, 9 commercial and 7 processors, each providing a varying number of sea bass (Appendix 1). The data consist of 1979 sea bass caught off the coast of Wales (Figure 7) during the 15 months from April 2013 to July 2014. Of the total number of fish, 1398 (71 %) were sourced from fish processors, 502 (25 %) from commercial fishers and 79 (4 %) from recreational anglers (Figure 8); of which, 842 were caught by net (both gill and trammel net), 965 were caught by rod & line (rod and line and long line from boats or from the shore) and 116 of the fish were caught by trawler. Throughout this section, the gear types are referred to as 'net', 'rod & line' and 'trawl' respectively.

Out of the total number of bass, gonads were retained for subsequent maturity staging from 802 fish, and scale ageing analysis was performed on 1172 fish. N varies throughout the analysis, due to the unavailability of some aspects of the data, for example there is a comprehensive length weight dataset, but fewer data were available for sex and age.

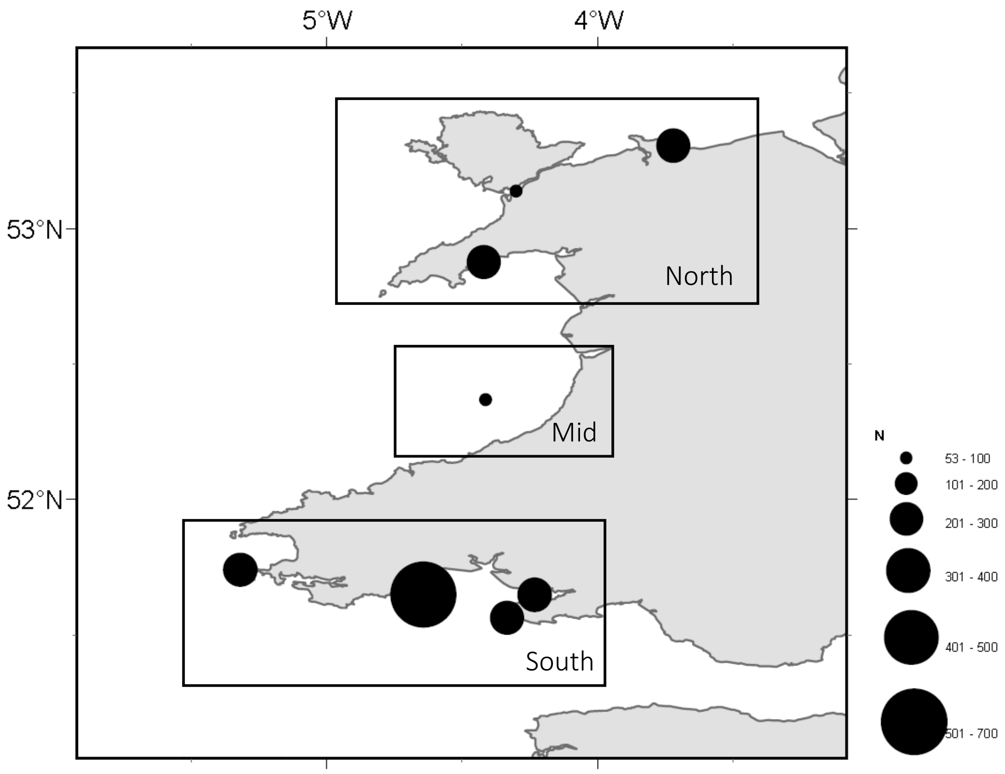

Figure 7. Map of Wales, showing sample size per location of fish capture. Locations grouped for illustration only. (Appendix 1, Appendix 2).

The sample sizes obtained varied between locations and gear type (Table 2) due to the variable availability of fish from the participating fishers. The sample size in Mid Wales was too small (n = 53) for many of the statistical comparisons and analyses to be performed, therefore mid Wales was excluded from analyses. The same applied to the fish caught by trawler (n = 116), as there were relatively few compared to other fishing methods and were only captured in South Wales.

Table 2. Sample size per gear type and location.

	Location		
Gear	North	Mid	South
Net	446	53	338
Rod & line	161	0	295
Trawl	0	0	116

Fish of length 40 – 44 cm were the most frequently caught by all 3 fisher types, making up 42.9 % of the catch. Recreational anglers tend to target larger fish as the sport dictates a competitive tendency to capture larger fish (Richardson et al. 2006). Figure 8 shows that the commercial fishers were the greatest contributor to the fish used in this study.

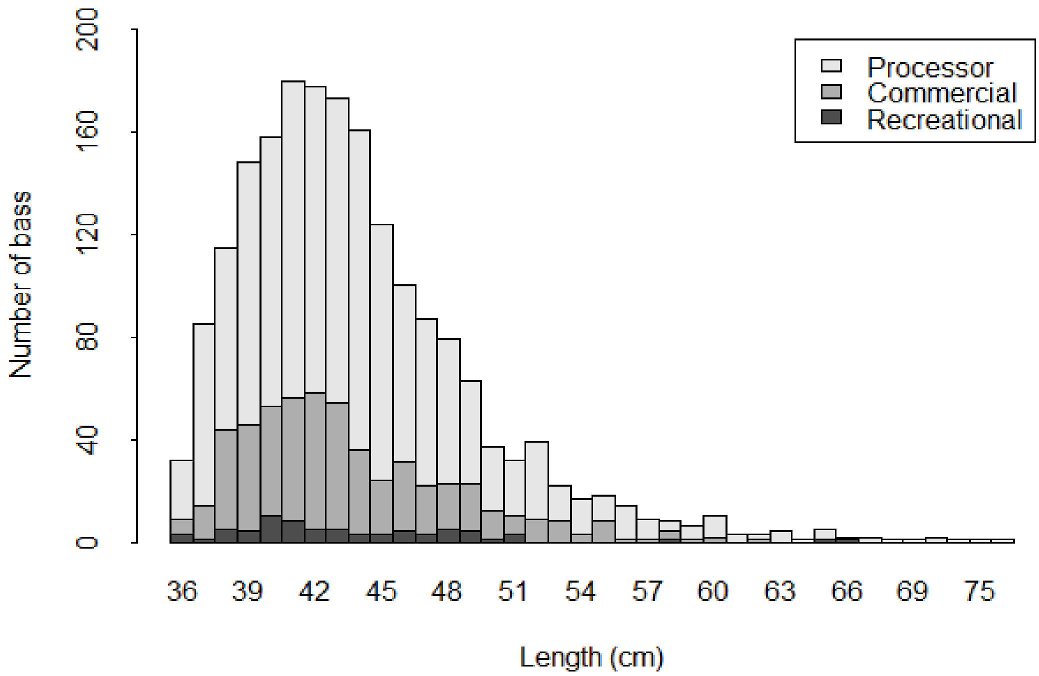

Figure 8. Length frequency distribution for bass caught by industry type for all of Wales. Undersize bass excluded from this plot.

4.2 Size, Age and Growth

The mean body size (TL) of net caught fish in North Wales (mean TL ± SD) (43.6 ± 4.9 cm, n = 445) was significantly smaller (Kruskal Wallis $p < 0.0001$) from those in South Wales (46 ± 5.6 cm, n = 319) (Figure 9). Fish caught by rod & line in North (41.5 ± 4.9 cm, n = 455) and South Wales (44.3 ± 5.6 cm, n =785) also exhibited significant differences in mean body size (Kruskal Wallis $p < 0.0001$) (Figure 9).

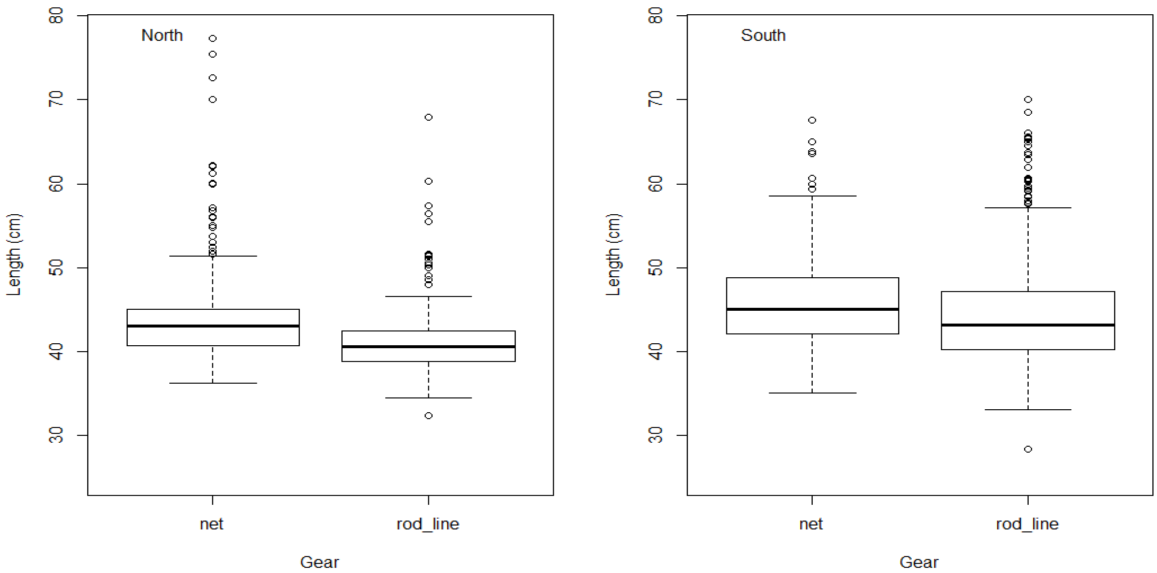

Figure 9. Distribution of body size (total length (cm)) of bass caught by fishing gear in North and South Wales.

When selecting fish greater than 37.5 cm (to account for the variation in MLS), the differences between North and South Wales [South net (46.3 ± 5.4 cm), North net (43.8 ± 4.9 cm), South rod & line (44.7 ± 5.4 cm), North rod & line (42.2 ± 4.9 cm)] were significant in all cases (Kruskal - Wallis $p > 0.0001$) with a consistently larger body size in South Wales. There were only 16 fish over 55 cm in this study, only 5 of which were male. The largest fish were females and caught by net in North Wales.

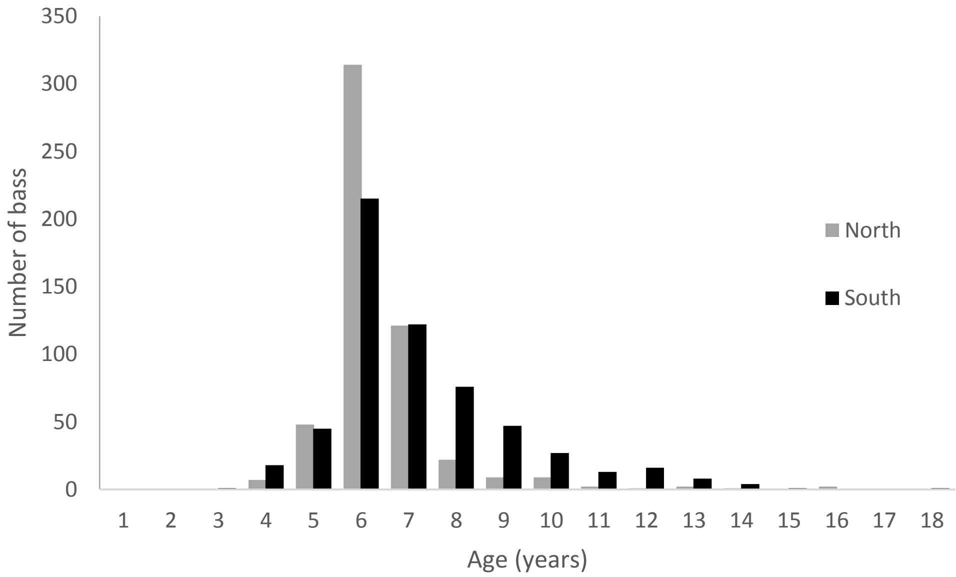

Figure10. Age-frequency of fish in North and South Wales.

The age range of fish in this study was 3 to 18 years (Figure 10). Females numerically outnumbered males in most age classes, except at ages 3 and 11, however only at age 6 in both 2013 and 2014 was there a significantly greater number of females than males (χ^2 $p < 0.001$) (Appendix 3, Appendix 4). Overall, fish aged 6 and 7 were the most frequently caught (Figure 11). There was only 1 fish caught less than 4 years old.

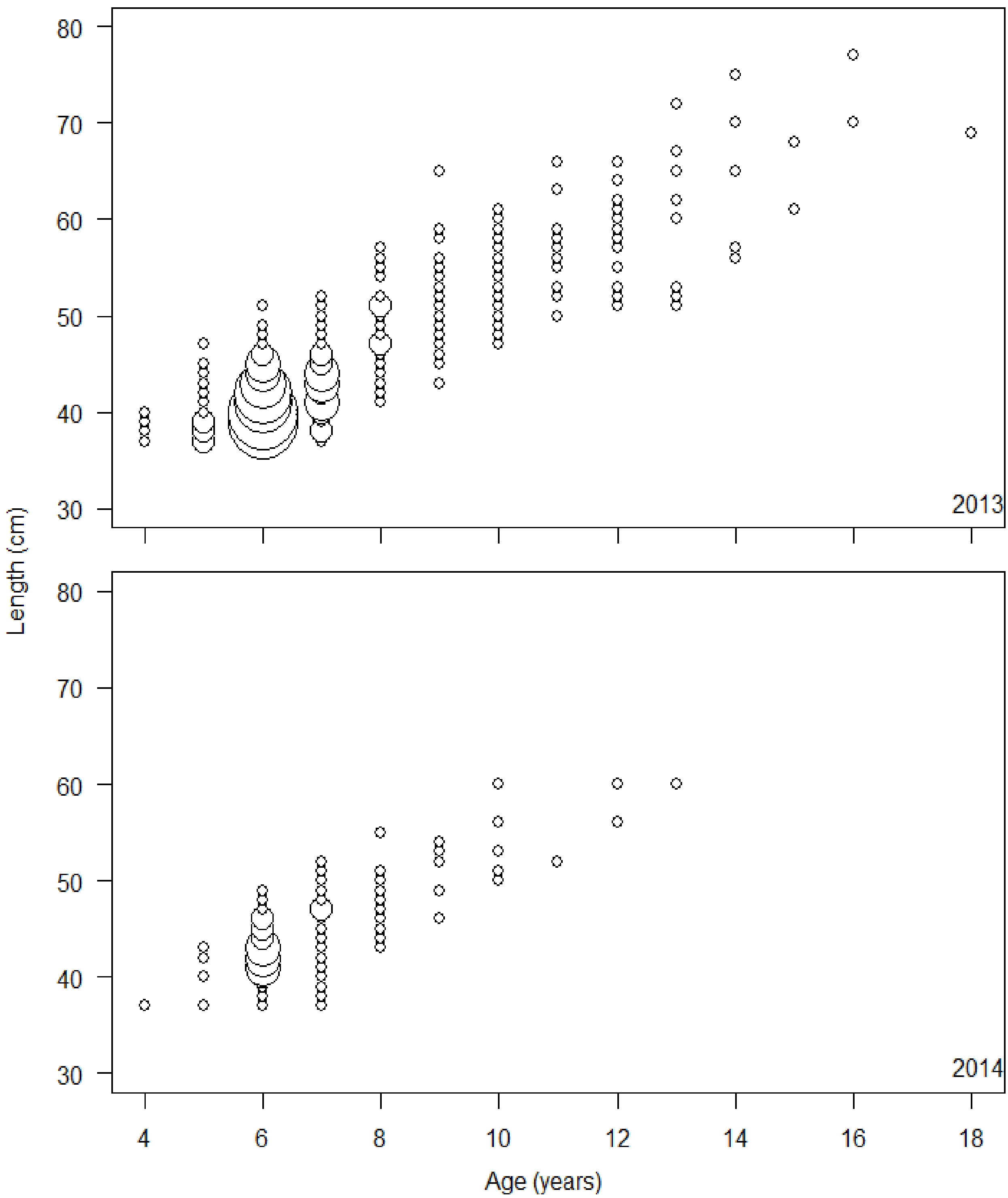

Figure 11. Catch at age plot for the years 2013 and 2014. Circles are representative of, and proportionate to the number of bass caught per age/length category per year (2014 consists only of 7 months from January-July). Undersized fish excluded. (Appendix 6, 7, 8 & 9).

4.2.1 Von Bertalanffy Growth

The von Bertalanffy growth curve could only be fitted for male (Linf = 96.08, K = 0.06) and female (Linf = 72.62, K = 0.124) (Figure 13) bass when the data for the whole of Wales were combined due to a lack of small and large fish. VBG Parameters for all of Wales (both sexes) were also estimated (Linf = 84.65, K = 0.077) (Figure 12).

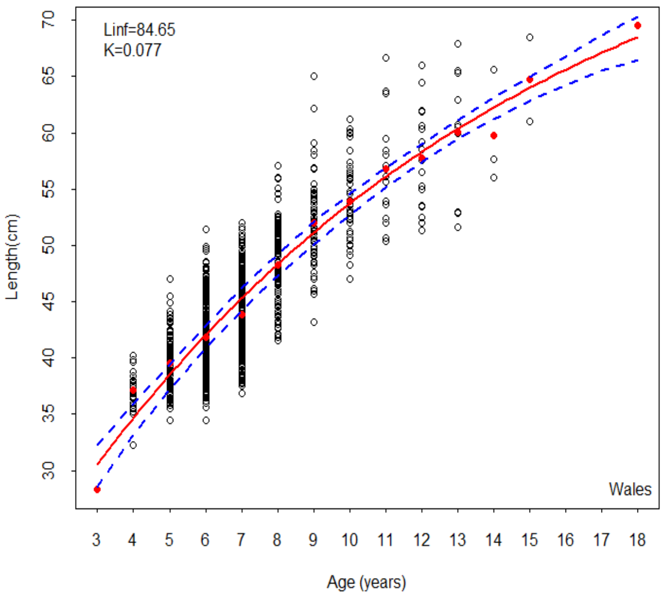

Figure 12. Von Bertalanffy growth curve for all of Wales (combined sexes). Black circles = raw data, red dots= mean, blue dashed line= upper and lower confidence intervals.

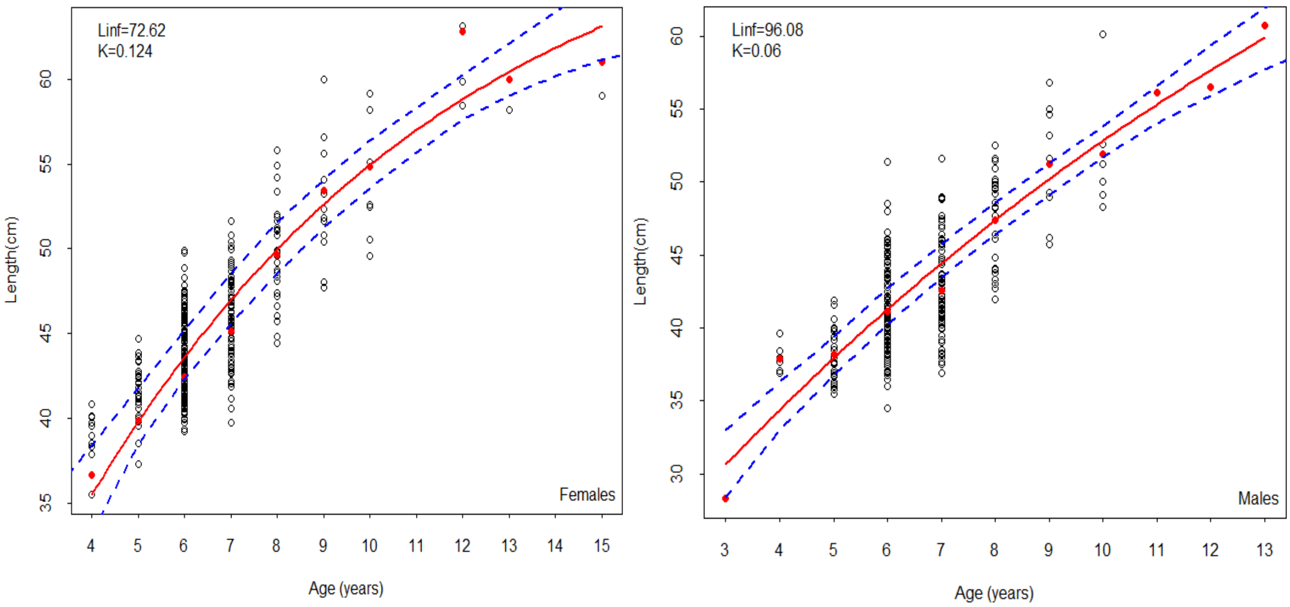

Figure 13. Von Bertalanffy growth curves for females and males for bass from all of Wales. Black circles = raw data, red dots = mean, blue dashed line = upper and lower confidence intervals.

Unfortunately there were not enough smaller (below MLS) or larger fish > 55cm for accurate, representative statistical comparisons to be drawn and subsequently, comparison of growth rates between North and South Wales (the second hypothesis of this study) could not be analysed.

4.2.2 Length – Weight Relationship

When considering the data from the whole of Wales, location had no significant effect on length weight (LW) relationship (ANOVA $p > 0.05$) (Figure 14). ANOVA, to a certain extent, is robust to unbalanced samples but not necessarily to a sample double that of the other (Dytham 2011). The number of samples in South Wales ($n = 1190$) is almost that of North Wales ($n = 621$) Wales which may influence the result. If the data are considered by area and by gear, net caught fish in North ($n = 446$) did not exhibit a different length weight relationship to those in the South ($n = 338$, ANOVA $p = 0.551$). For fish caught by rod & line however, there was a significant effect of location (North/South) on the LW relationship (ANOVA $p < 0.05$). Again, there is an unbalanced number of samples from each location; North $n = 795$ and South $n = 161$. This significance is therefore perhaps the result of the sample size and not of a difference in real terms.

Fish in North Wales ($b = 2.824$, t test $p < 0.0001$) and South Wales ($b = 2.788$, t test $p < 0.0001$) both exhibit negative allometric growth (Figure 14). A summary of the seasonal differences in the LW relationships between the areas North and South Wales can be seen in Table 3. The significance between North and South for rod & line caught fish in autumn may be a result of the greatly unbalanced sample size between North and South Wales and should be viewed cautiously.

Table 3. LW relationships of male and female fish combined, by season, gear and location. ANOVA compared each season and gear type between North and South Wales following linear regression of log transformed data. NA = lack of comparable data.

Season	Gear	Location	Length (cm)	N	a	b	r^2	ANOVA
Summer	net	North	36.3-77.3	95	0.013	2.93	0.955	$p < 0.05$
	net	South	36.5-67.7	157	0.055	2.56	0.937	
Spring	net	North	39.1-62	99	0.004	3.193	0.8401	$p > 0.05$
	net	South	35-60.7	139	0.009	3.02	0.919	
Autumn	net	North	36.3-60	213	0.04	2.667	0.898	$p > 0.05$
	net	South	37.3-57	42	0.057	2.569	0.918	
Winter	net	North	38.8-53	39	0.0275	2.754	0.8356	NA
Summer	Rod_line	North	36-67.9	113	0.0236	2.781	0.8686	$p < 0.05$
	Rod_line	South	33.1-70	336	0.007	3.084	0.9451	
Spring	Rod_line	North	32.3-51	33	0.018	2.840	0.796	$p > 0.05$
	Rod_line	South	28.3-47.6	7	0.003	3.323	0.991	
Autumn	Rod_line	North	34.5-44.8	15	0.053	2.583	0.778	$p < 0.05$
	Rod_line	South	34.9-65	373	0.028	2.739	0.907	
winter	Rod_line	South	37.6-55.3	79	0.049	2.608	0.9036	NA

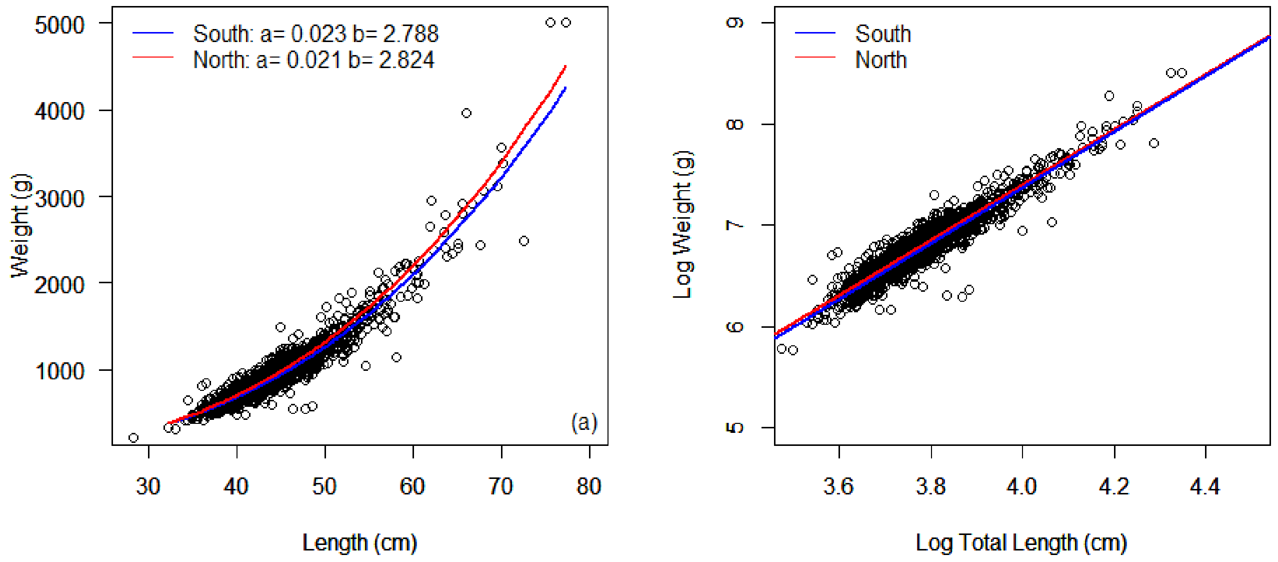

Figure 14. Exponential (a) and log transformed (b) length weight relationship for fish caught by all gear types in North (n = 612) and South (n = 1190) Wales.

4.3 Sex Structure and Maturity

4.3.1 Sex Ratio

There was no difference in the sex ratio between North (mean ± SD) (0.3 ± 0.29) and South Wales (0.42 ± 0.35) for the arcsine transformed data of net caught fish (Kruskal Wallis χ^2 = 0.252, df = 1, p = 0.62) (Figure 15). However, when considering the arcsine transformed data for rod & line caught fish, the sex ratio of fish in North Wales (0.26 ± 0.32) differed significantly from those in South (0.67 ± 0.41) (Kruskal Wallis χ^2 = 0.8544, df =1, p = 0.003). The binomial test (Table 4) proved that for each subset of gear and location there was a difference from the hypothesised 0.5 ratio, except for that of net caught fish in South Wales. For those that exhibited a significant deviation from the 0.5 ratio, there was an excess of females in the North for both gears, and an excess of males in the sample of fish caught by rod & line in the South.

Table 4. Summary of sex ratio by gear and location and the binomial test result. Sex ratio is expressed as the proportion of males per total males and females in a sample.

Location	Gear	Sex ratio (mean ± SD)	Binomial test	Notes
South	Net	0.42 ± 0.35	p = 1	No difference
North	Net	0.3 ± 0.29	p < 0.0001	Excess of females
South	Rod_line	0.67 ± 0.41	p < 0.001	Excess of males
North	Rod_line	0.26 ± 0.32	p < 0.0001	Excess of females

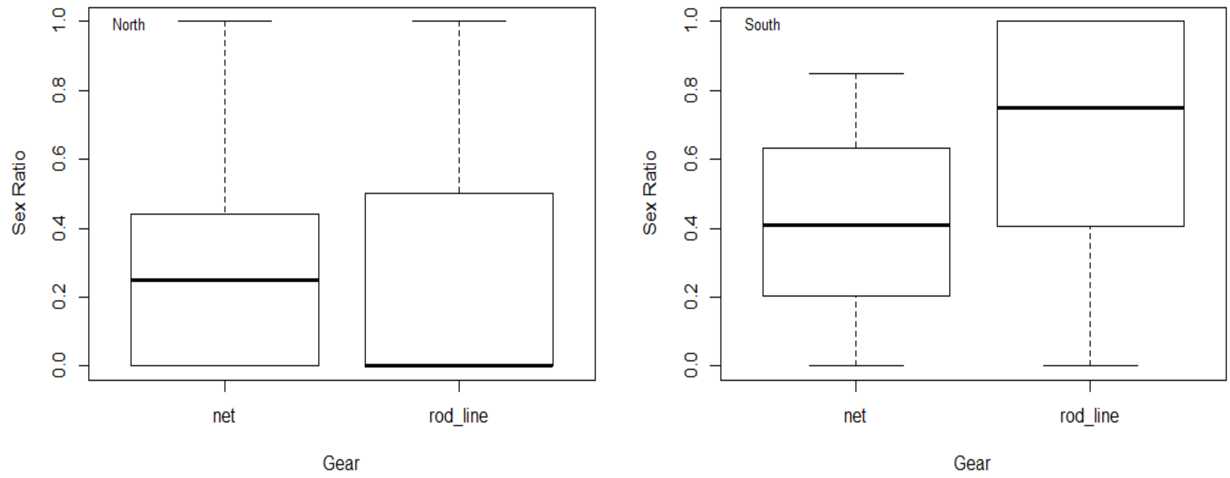

Figure 15. Boxplots of sex ratio by gear type for North and South Wales. Sex ratio is expressed as the proportion of males per total males and females in a sample.

4.4 Gonadosomatic Index

The GSI for North and South Wales follows a similar trend (Figure 16 & Figure 17). For both female and male bass, there was a peak in GSI in March followed by a declining trend through until June in North and July in South Wales. There were no fish caught in January in South Wales or in February in both North and South Wales. Although both sexes follow a similar trend, male fish tend to have a consistently lower GSI throughout the year with the exception of December, where male and female averages are very similar. Female fish (mean ± SD, 2.81 ± 3.39) in South Wales exhibit a significantly higher GSI than those in the North (2.34 ± 2.99, Kruskal Wallis, $p = 0.03$). This is also true for male fish in South Wales (1.05 ± 1.62) which have a higher average GSI than those caught in North Wales (1.68 ± 2.21, Kruskal Wallis, $p < 0.0001$).

For female fish in both North and South Wales, the GSI in spring (March, April & May) is significantly higher from that in all other seasons (Kruskal Wallis, $p < 0.0001$). Similar differences were detected in the GSI of male fish in North Wales where all seasons differ significantly from spring (Kruskal Wallis, $p = 0.01$). The average female GSI was highest in the South in March (12.57 ± 4.78) and was considerably higher than the same month in the North (8.12 ± 3.62).

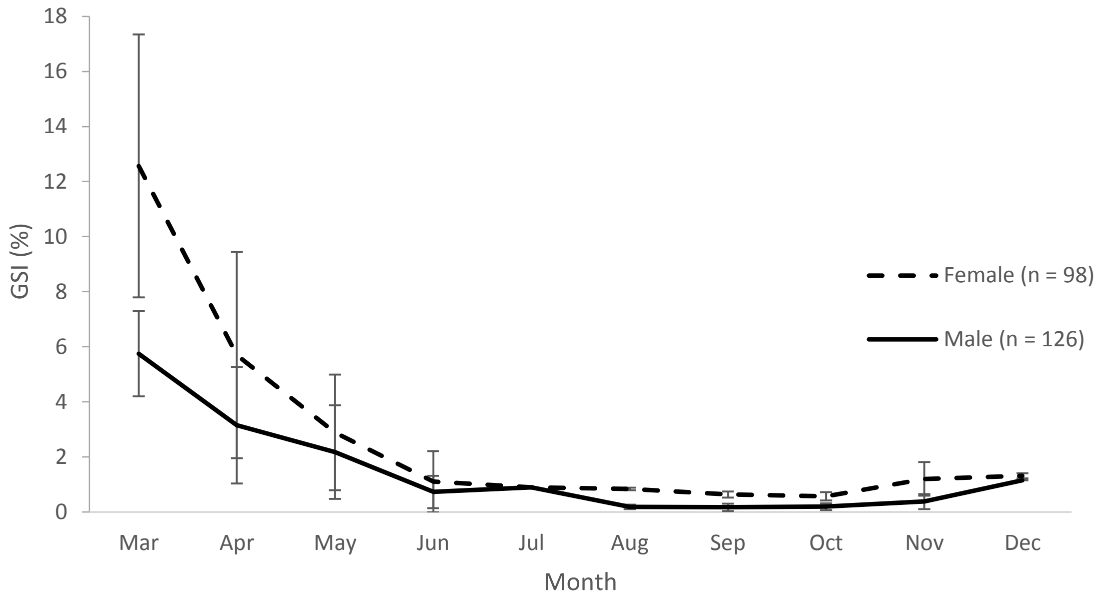

Figure 16. Mean gonadosomatic index by month for male and female fish caught in South Wales. Error is standard deviation.

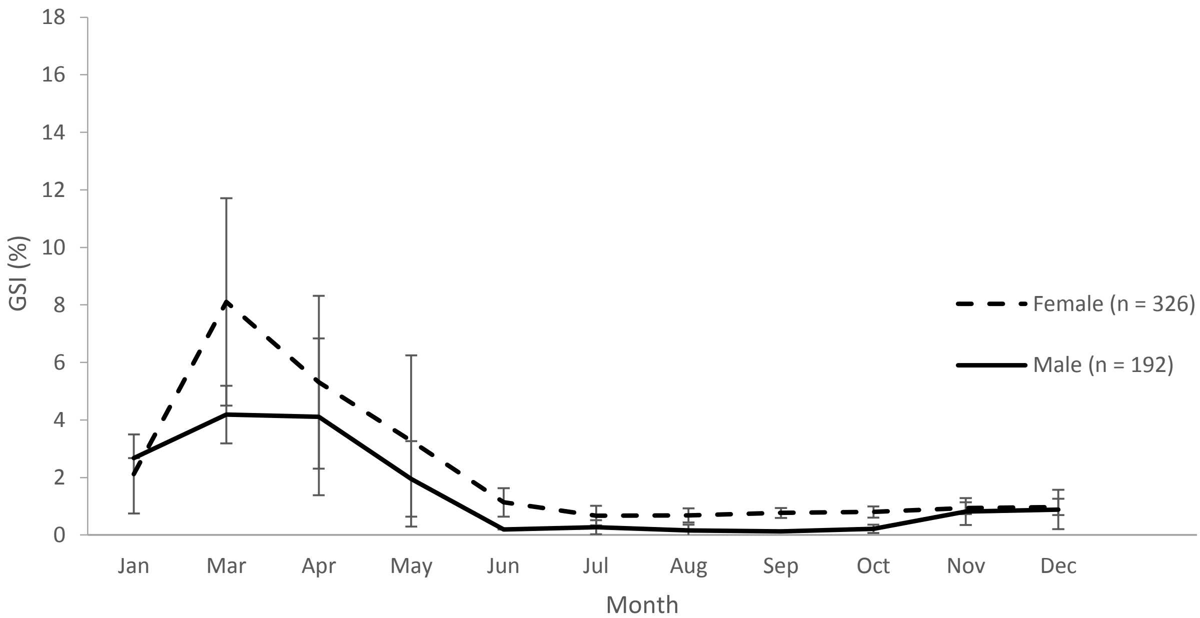

Figure 17. Mean gonadosomatic index by month for male and female fish caught in North Wales. Error is standard deviation.

4.5 Size at Maturity

There were no fish (male or female) caught with stage I (immature, Pawson & Pickett 1996) gonads, and very few fish exhibiting stage III gonads (caught in the months of March, April or May) that could be described as immature. There were only 5 female fish caught in these 3 months with gonads at stage III (length range 36.6 – 41.9 cm) and 4 males (length range 36 – 43.3 cm) (Figure 18). It was therefore not possible to estimate the size at maturity by computing the maturity ogives as planned. However, when considering all the maturity data across the whole year, the majority of female fish < 40 cm exhibited gonads that were developing (stage III).

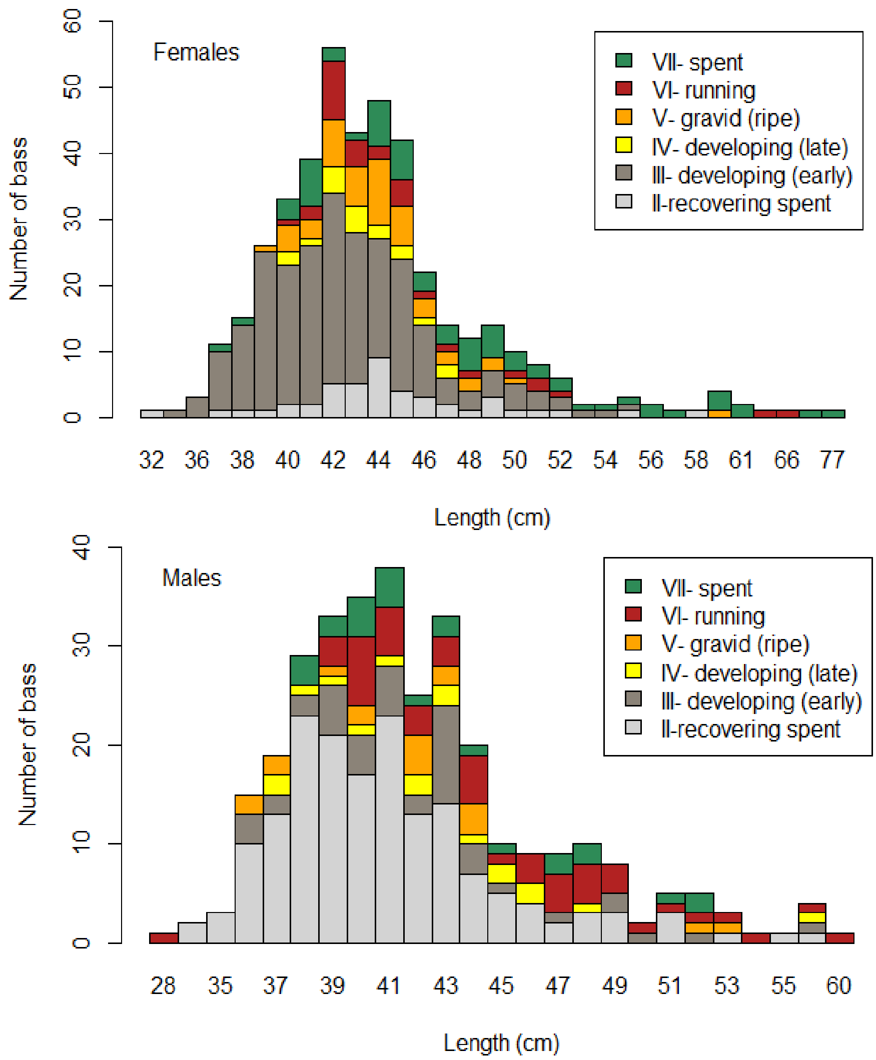

Figure 18. Frequency distribution of maturity stage per 1 cm length categories for female (n = 445) and male (n = 334) fish for all of Wales.

There is monthly variation in frequency of each maturity stage (Figure 19) something that can also be seen in the GSI monthly trend (Figure 16 & Figure 17). Running bass at stage VI were found in the months March, April and May and to a lesser extent in June. Bass exhibiting gonads at stage VI, were in their spawning stage at the time of capture. Spent (stage VII) females were found as late as September and spent males were not found after July, with the exception of 1 found in August. There majority of males were found with stage II gonads and females with stage III gonads.

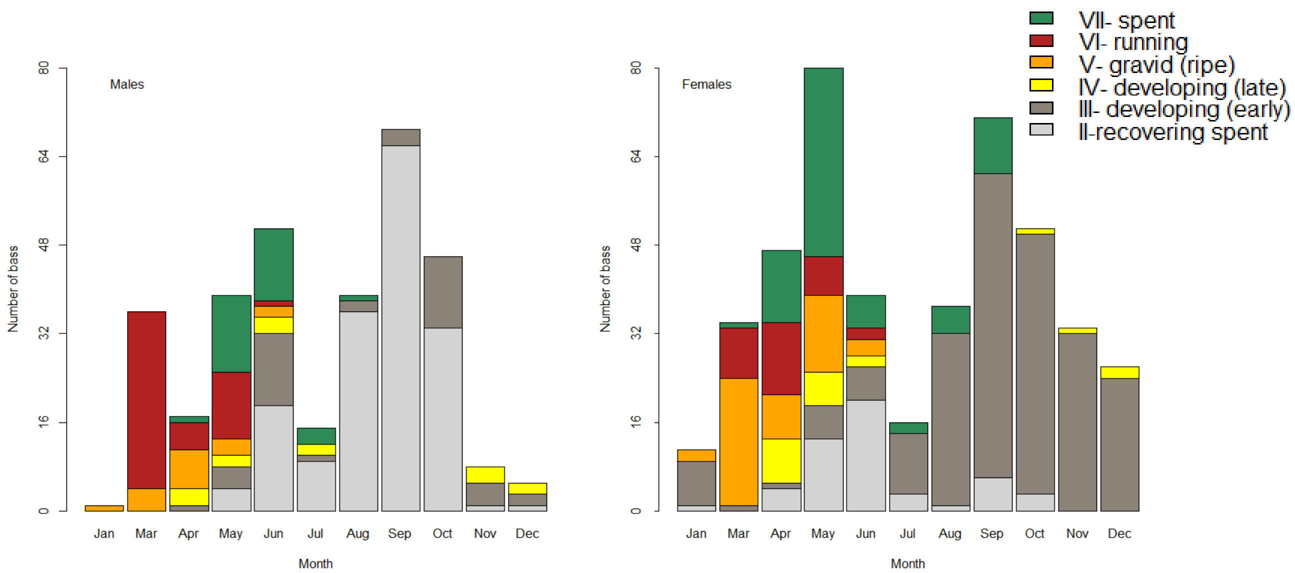

Figure 19. Frequency of fish caught at each maturity stage for males and females per month for all of Wales.

5.0 DISCUSSION

This study forms part of an ongoing detailed assessment of the sea bass population in Welsh coastal waters and provides an insight into the population parameters and how they compare between different parts of Wales. The samples of sea bass available varied in numbers between industry and gear type. There was an abundance of length and weight data, but less so for the sex, maturity and age data. Length and weight information was in part, gathered by participating fishers without the need to purchase fish or for researchers to travel to where the fish were landed. For dissection of the fish and the retention of gonads, bass had to be purchased. As bass fetch a high market price this was expensive and therefore sample sizes were somewhat limited.

There is very little information on the exact location of fish capture. If GPS coordinates of where the fish were caught were available, then they could be classed as onshore in shallower waters or offshore in deeper waters. Many fisheries target the fish as they move on their seasonal migrations to feeding or spawning grounds (Pawson et al. 2007). If these could be identified by making a link between the location of fish capture and the maturity stage of the gonads then more information about the fish population movements and dynamics would have been available. There is also some evidence that males may spend more time, or be more numerous in offshore areas (Kelley 1988) and if this is the case in the Welsh sea bass population then it could introduce a sampling bias as most of the fish caught in this study were in coastal (onshore) waters.

The difference in MLS in North (36 cm) and South (37.5 cm) Wales likely drives a difference in the mean body size between the two locations, therefore the observed differences are to be expected, and are likely not to be wholly representative of the Welsh sea bass population. However, when considering fish greater than 37.5 cm, there were significantly larger fish in the South when compared to those in the North, for both net and rod & line caught fish. Even when selecting the data in this way, it is difficult to account for gear selectivity as the minimum net mesh size in South Wales is larger (100 mm) than that of the North (89 mm), therefore a greater number of smaller fish will be caught by nets in the North thus potentially distorting the data in favour of larger fish in the South and smaller fish in the North. The fish caught by rod & line however, are not restricted by net mesh size and may well be representative of the sea bass population, which displays a larger mean TL in the South. There is some evidence to suggest that fish in warmer waters will to a certain extent attain a larger body size than those in cooler waters (Vinagre et al. 2009), for example fishermen target the large bass in warm water outflows from power stations such as that at Milford Haven and very large bass > 8 kg have been landed in the Bay of Biscay, where water temperatures are higher than in Welsh coastal waters (ICES 2004). The lower latitude of South Wales and the warmer waters (CEFAS 2014) could explain the larger body size of fish caught there.

The current study found there to be a difference in the sex ratio between North and South Wales. The population in the North was dominated by females and in South by males. The sex of sea bass is not genetically predetermined (Blazquez et al. 1999), but is defined during the juvenile stage and is largely influenced by temperature (Pawson et al. 2000, Koumoundouros et al. 2002, Díaz et al. 2013). Sexual differentiation begins at around 8.3 – 9.5 cm total length (Saillant et al. 2003) or up to 10.2 cm standard length (Koumoundouros et al. 2002) at around 168 days (~ 6 months) post fertilisation (Saillant et al. 2003). It is thought that a higher temperature during this critical period of sex differentiation will result in a population dominated by males whilst lower temperatures will result in a greater proportion of females (Koumoundouros et al. 2002, Vandeputte et al. 2012). In a laboratory experiment investigating temperature and its influence on the sex determination of sea bass, Koumoundouros et al. (2002) found that the incidence of female bass decreased with increasing temperature, whilst the opposite was observed for males. Vandeputte et al. (2012) reviewed data covering much of sea bass' natural range and compared the sex ratios of 13 population samples. It was found that there were fewer male fish per population sample in the North Atlantic where waters are cooler, and more in Mediterranean and South Atlantic samples, where the sea is generally warmer (Koumoundouros et al. 2002, Vandeputte et al. 2012). Interestingly Kennedy and Fitzmaurice (1972) observed that females outnumbered males in Irish waters by 2:1 in their study of sea bass biology.

This study lacks primary temperature data for Welsh coastal waters during the period of the fish capture, however, data available for 2012 shows average annual temperature for South Wales (taken at Skomer Island) was (mean ± SD) 12.03 ± 2.65 ° C and North Wales (taken at Moelfre, North East Anglesey) was 11.35 ± 3.7 ° C (CEFAS 2014). There is a difference between the annual means of 0.68 ° C between the North and the South. This 2012 temperature data along with latitudinal difference between North (53 ° N) and South (51 ° N) suggests there is an environmental gradient that may be influencing the populations of sea bass. It has been observed that the relatively small latitudinal gradient (similar to that of Wales) of the Portuguese coast between 37 ° N and 41 ° N (Vinagre et al. 2009) does indeed play a role in the variation in population parameters of the sea bass. Vinagre et al. (2009) observed a trend of increasing growth with decreasing latitude and that spawning started earlier at lower latitudes. However, it is difficult to isolate the effect of day length and temperature between latitudes, as the two are inherently connected (Vinagre et al. 2009).

Through the collaboration with fishers this study focussed on bass of the MLS or above, meaning that most of the fish were considered to be in their adult stage (~ 36 cm TL, Pawson et al. 2007). There is only information available on the general location of capture so it is difficult to define the location at which the fish spent their juvenile years. With no information on where the fish spent this critical temperature sensitive phase, it is difficult to state that the temperature of North and South Wales was the defining factor that resulted in the sex ratio difference evident in the sample population, but could well play a role in the sex structure of the populations.

Kennedy and Fitzmaurice (1972) identified 13 year classes in their study of bass in Irish waters and defined three year classes as "good brood years". Fish in the three good brood year classes were present in greater numbers than any other year class. The population of fish in these year classes was dominated by females (66% female) (Kennedy & Fitzmaurice 1972, Vandeputte et al. 2012). The 6 year old fish (caught in 2013) in the current study were born in a year of mild temperatures (MET 2012) which could explain this particularly strong year class. The dominance of females in this year class could also be linked to the mild temperature (Koumoundouros et al. 2002) in British waters during their first year of life.

The most recent stock assessment (ICES 2013b) estimated the von Bertalanffy growth parameters in ICES area VII_{AFG} (Wales, the Irish Sea and the Bristol Channel) to be *Linf* 81.87 cm and *K* 0.09 cm^{-1year}. The growth rate *(K)* was slightly lower in the current study (0.077 cm^{-1year}), with slightly higher theoretical maximum length (*Linf)* of 84.65 cm. As the bass analysed in the current study were only from Welsh waters, the rate of growth may be lower than fish in the South of England due to the higher latitude from which they originate. As mentioned previously, lower latitudes are associated with a higher rate of growth (Vinagre et al. 2009). Ward (2008) found the theoretical maximum sizes for fish in North Wales (female 61 cm, male 70.6 cm) to be relatively low in comparison to other studies (e.g. 82.5 cm in North Wales (Hargreaves 1992)) as well as the current study 84.65 cm in Wales.

The current study observed that the GSI of female fish was consistently higher than that of male fish, but both sexes have a low GSI from July to October with an increasing trend over the winter months and a peak in March. The increase in GSI over winter months is representative of the increase in the size of gonads during the development of ovaries and testes in the run up to spawning (Pawson & Pickett 1996). A similar trend was recorded in Pawson and Pickett (2006), where the GSI was lowest from July to September and peaked between January and April with the highest GSI of 22.13% for a female bass caught in South Wales in April, similar to the highest in the present study for which was also a female caught in South Wales in March with a GSI of 17.6 %. An increase in GSI becomes evident in December, when most bass in this study displayed stage III and stage IV (developing early and late) gonads. This onset of gonad development has been linked to a change in the day length around mid-winter, where the daylight hours begin to increase (Rodrıguez et al. 2001). Spermiation (the release of sperm from the testis) in males lasts longer than spawning (release of eggs from the ovaries) in females (Rodrıguez et al. 2001). The current study found that the majority of males in March were running (stage VI), whereas the majority of females in the same month were gravid (stage V).

It has been shown in experimental manipulation of sea bass that photoperiod (day length) and temperature are important influencers in the timing and onset of spawning (Prat et al. 1999, Bayarri et al. 2004, Vinagre et al. 2009). External environmental information made available by changes in seasonal photoperiod and temperature are thought to be the main cues that determine the time at which reproduction in fish occurs (Prat et al. 1999). In sea bass, photoperiod appears to be the main control in the timing of spawning (Devauchelle & Coves 1988). At lower latitudes, spawning occurs earlier in the year and can begin in December (Prat et al. 1999).

Analysis of fish greater than 37.5 cm showed those in South Wales were larger on average than those in North Wales. It is known in many fish species that fecundity in fish, especially that of females is directly related to size (Wootton 1998), where larger fish produce more eggs or sperm and therefore one would expect a larger gonad size. The larger average GSI that was observed in fish caught in South Wales could be a direct result of the larger average body size.

Stage V (gravid, ripe) gonads were found in both male and female bass in the months from January to June (no data for February), consistent with that of Pawson and Pickett (2006) who also observed this, as well as ripe males in December. Pawson and Pickett (1996) reported no ripe or mature females < 42cm total length which has been the accepted size at maturity for female sea bass. ICES reports a reduction in the size at maturity of females in the most recent (2013) stock assessment to 40.65 cm (ICES 2013b). The current study could not estimate size at maturity due to very few immature fish in the data, but did observe four spent (mature) females under 40 cm in length (between 37.5 and 40 cm), however of the few immature females the range in length was 36.6 to 46.2 cm. There is some overlap in the length range between the mature and immature fish, demonstrating the complex nature of sea bass biology. In Ward's 2008 thesis, which sampled bass in North Wales only, length at maturity was estimated at 39.7 cm for males and 38.9 cm for females. However, Ward used only stage I as immature fish, not stage III for the months of March to May as in this study and in the latest stock assessment (ICES 2013b) so the results may not be comparable. For males ICES estimate a 34.67 cm size at maturity (ICES 2013b). Size at maturity in Ward (2008) is lower than the ICES most recent estimates as well as that of older studies (Pawson & Pickett 1996) which could confirm that the size at maturity is now less than it was in the 1980's – early 2000's.

This recent evidence that there may be a declining trend in the size at maturity is concerning. A change over time in the age or size at which maturation occurs can be interpreted as a sign of evolutionary change within a species (Law 2007). Fishing is generally size – selective, and life history traits that are related to size like maturation, growth and reproduction can be subject to the effects of fisheries induced evolution (Ernande 2008). It can be difficult to distinguish between natural evolution of a fish stock following a change in environmental conditions, and any effect fishing pressure may be exerting. Evidence in cod stocks suggests that change can occur on evolutionary short timescales such as those spanned by the modern fishing era (Law 2007). If this is the case in the Welsh sea bass stock, then fishing pressure must be reduced in order to allow the population to recover (Law 2007).

5.1 Management Recommendations

The current 36 cm MLS in force in North Wales allows immature females to be removed from the population. The population of North Wales is dominated by females and there is a large amount of evidence that female bass do not reach maturity until 42 cm in length (Pawson & Pickett 1996), with more recent evidence suggesting that female maturation may now occur at around 41 cm in length (ICES 2013b). If fish are removed below the size at which maturation and subsequent reproduction occurs, then the population will inevitably see a reduction in numbers and may reach a point of collapse (King 2013). The MLS of 36 cm is aimed at protecting juvenile bass which predominate inshore (ICES 2001). Even the higher MLS that applies to South Wales (37.5 cm) allows the sea bass fishery to land immature fish. This therefore should be the first change in terms of management at a Welsh level, where an increase in MLS with immediate effect would allow the protection of immature and maturing fish and give them a chance to spawn at least once before they recruit into the fishery. A call to raise the MLS to a precautionary 45 cm in the past has been disregarded by policy makers (ICES 2001).

Currently fishing effort that targets offshore spawning aggregations is largely unregulated (Pickett et al. 1995, ICES 2013b). If the location at which Welsh sea bass spawn can be identified, a management option would be to restrict fishing of these aggregations (King 2013), thereby protecting the spawning adults. This could implemented by enforcing closed areas during the spring spawning season or a ban on fishing in the months preceding spawning and the spawning season itself- i.e. restrict or ban fishing from December to May in Welsh Waters. There is a voluntary closed season from February to mid-March in Brittany for longline and handline bass fisheries (ICES 2013b), proving with the correct implementation techniques and the education of fishers, measures of this kind can be successful.

Management measures introduced in the 1990's have been effective in the protection of juveniles (Pawson et al. 2007) and the MLS continues to be enforced in Wales, but a decline in recent landings (ICES 2012b) of sea bass suggests that more robust management measures are required to secure the sustainability and resilience of this stock into the future. It is obvious from the economic value of sea bass, its commercial fishery, its anglers and all the associated economic benefits to coastal communities that a closure of this fishery would be catastrophic to the livelihoods of many people in Wales. Management measures need to be sympathetic to the fishing community as well as environmentally responsible.

5.2 Limitations and Future Work

This study was unable to meet the aim to estimate the size at maturity and to compare this with previous studies due to a lack of immature fish caught by the fishers involved in the data collection. Dispensation was granted allowing undersized fish to be landed, however this did not result in a large enough sample of smaller fish to estimate the size at maturity. The size at which fish in Wales mature is a vital population parameter that may well influence the formulation of future management strategies, especially a change in the MLS. There is still a need to focus on the capture of fish under the MLS in all of Wales. Net mesh size is restricted so that fish below the MLS are not caught and therefore landing of undersize bass is somewhat limited to rod & line and longline sector of the fishery. In the light of this, more participation from the line fishing sector of the industry could assist in the collection of smaller fish. The study is ongoing and so the sample of immature fish should increase with the continued sampling effort of the fishers involved and the fisheries scientists at Bangor University. A greater number of smaller fish would also allow the von Bertalanffy growth parameters to be estimated and subsequently compared for North and South Wales. The growth parameters would provide information on the rate of growth, and if this proved different between the 2 areas of Wales then it would contribute further to a decision on whether Welsh sea bass should be treated as one 'stock' or if the North and South should be subject to different management policies.

Tagging and recapture studies could be conducted on Welsh sea bass such as those carried out by CEFAS in the English Channel and the North Sea (Quayle & Righton 2007). Studies of this kind would provide information on the behaviour and migratory movements of bass from season to season and could locate potential areas where management measures should be implemented, for example restricting fishing on spring spawning aggregations.

Whilst it is evident from this investigation that differences in some of the sea bass population parameters between North and South Wales do exist, some key parameters could not be estimated. It therefore remains unclear as to whether the sea bass population of Wales should be managed differently based on location or as a whole stock. What is clear from the literature, is that the current MLS is indeed too low to protect the spawning stock biomass of sea bass in Wales. More work is needed to provide further, more detailed data on the sea bass in Welsh waters in order to reach a decision as to whether the adoption of regional or national management policies is most appropriate.

6.0 REFERENCES

Barclay C (2011) Sea Bass Fishing. House Commons Libr

Bayarri MJ, Rodríguez L, Zanuy S, Madrid J a, Sánchez-Vázquez FJ, Kagawa H, Okuzawa K, Carrillo M (2004) Effect of photoperiod manipulation on the daily rhythms of melatonin and reproductive hormones in caged European sea bass (*Dicentrarchus labrax*). Gen Comp Endocrinol 136:72–81

Bennett O (2013) Seabass fishing SN/SC/745 Last. House Commons Libr

Blazquez M, Carrillo M, Zanuy S, Piferrer F (1999) Sex ratios in o ff spring of sex-reversed sea bass and the relationship between growth and phenotypic sex differentiation. J Fish Biol:916–930

Claridge PN, Potter IC (1983) Movements, abundance, age composition and growth of bass, *Dicentrarchus labrax*, in the Severn Estuary and inner Bristol Channel. J Mar Biol Assoc UK:871–879

Dando PR, Demir N (1985) On the spawning grounds and nursery grounds of bass, *Dicentrarchus labrax,* in the Plymouth area. J Mar Biol Assoc UK 65:159–168

Devauchelle N, Coves D (1988) Sea bass (*Dicentrarchus labrax*) reproduction in captivity: gametogenesis and spawning. Aquat Living Resour:215–222

Diaz N, Ribas L, Piferrer F (2011) Growth and sex differentiation relationship in the European sea bass (*Dicentrarchus labrax*). Indian J Sci Technol 4:69–70

Díaz N, Ribas L, Piferrer F (2013) The relationship between growth and sex differentiation in the European sea bass (*Dicentrarchus labrax).* Aquaculture 408-409:191–202

Dytham C (2011)Choosing and Using Statistics: A Biologists Guide, Third Edit. Wiley-Blackwell

Ernande B (2008) Fisheries-induced evolution of maturation schedule in exploited stocks: Empirical and theoretical evidence, expected demographic implications and potential mitigation measures. In: Society for Experimental Biology Annual Main Meeting 6th – 10th July 2008, Marseille, France.

Fritsch M (2005) Biological features and usage of the Bass (*Dicentrachus labrax)* in French fisheries in the Channel and Bay of Biscay

Fritsch M, Morizur Y, Lambert E, Bonhomme F, Guinand B (2007) Assessment of sea bass *(Dicentrarchus labrax,* L.) stock delimitation in the Bay of Biscay and the English Channel based on mark-recapture and genetic data. Fish Res 83:123–132

Hargreaves T (1992) The Bass Fishery of Anglesey and the Menai Straits. Bangor University

ICES (2001) Advisory Committee on Fishery Management ICES CM 2001 / ACFM : 25 Report of the study group on sea bass.

ICES (2002) Advisory Committee on Fishery Management:Report of the Study Group on Sea Bass.

ICES (2004) Report of the STUDY GROUP ON BASS. ICES

ICES (2012a) Report of the Inter-Benchmark Protocol on New Species (Turbot and Sea bass; IBPNew 2012).

ICES (2012b) ICES WGNEW REPORT 2012 Assessment of New MoU Species (WGNEW) Report of the Working Group on.

ICES (2013a) Advice June 2013 Celtic Sea and West of Scotland + North Sea European sea bass in Divisions IVbc , VIIa , and VIId – h (Irish Sea , Celtic Sea, English Channel, and southern North Sea). Book 5:1–8

ICES (2013b) ICES WGCSE Report. Annex 2 : Stock Annexe 10.1.

ICES (2013c) ICES WGNEW REPORT 2013 Report of the Working Group on Assessment of New MoU Species (WGNEW). :18–22

Jennings S, Pawson MG (1992) The origin and recruitment of bass, *Dicentrarchus labrax*, larvae to nursery areas. J Mar Biol Assoc United Kingdom 72:199

Kara MH (1997) Sexual cycle and fecundity of seabass, *Dicentrarchus labrax*,of Annaba Gulf. Cah Biol Mar 38:161–168

Kelley DF (1987) Food of bass in U.K. waters. J Mar Biol Assoc United Kingdom 67:275

Kelley DF (1988) The importance of estuaries for sea-bass , *Dicentrarchus labrax* (L.). J Fish Biol 33:25–33

Kennedy M, Fitzmaurice P (1972) The biology of the bass, *Dicentrarchus labrax*, in Irish waters. J Mar Biol Assoc UK 52:557–597

King M (2013) Fisheries Biology, Assessment and Management. Blackwell Science

Koumoundouros G, Pavlidis M, Anezaki L, Kokkari C, Sterioti A, Divanach P, Kentouri M (2002) Temperature sex determination in the European sea bass, *Dicentrarchus labrax* (L., 1758) (Teleostei, Perciformes, Moronidae): critical sensitive ontogenetic phase. J Exp Zool 292:573–9

Law R (2007) Fisheries-induced evolution: present status and future directions. Mar Ecol Prog Ser 335:271–7

MET (2013) MET Office Anomaly Data.

Pawson MG, Kelley DF, Pickett GD (1987) The distribution and migrations of bass, *Dicentrarchus labrax* L., in waters around England and Wales as shown by tagging. J Mar Biol Assoc United Kingdom 67:183–217

Pawson MG, Kupschus S, Pickett GD (2007a) The status of sea bass *(Dicentrarchus labrax)* stocks around England and Wales , derived using a separable catch-at-age model , and implications for fisheries management. ICES J Mar Sci 64:346–356

Pawson MG, Kupschus S, Pickett GD (2007b) The status of sea bass *(Dicentrarchus labrax)* stocks around England and Wales , derived using a separable catch-at-age model, and implications for fisheries management. ICES J Mar Sci 64:346–356

Pawson MG, Pickett GD (1987) The bass (*Dicentrarchus labrax*) and management of its fishery in England and Wales. MAFF Direct:37

Pawson MG, Pickett GD (1996) The Annual Pattern of Condition and Maturity in Bass, *Dicentrarchus Labrax*, in Waters Around England and Wales. J Mar Biol Assoc United Kingdom 76:107

Pawson MG, Pickett GD, Leballeau J, Brown M, Fritsch M (2007) Migrations, fishery interactions, and management units of sea bass *(Dicentrarchus labrax*) in Northwest Europe. ICES J Mar Sci 64:332–345

Pawson MG, Pickett GD, Smith MT (2005) The role of technical measures in the recovery of the UK sea bass *(Dicentrarchus labrax)* fishery 1980–2002. Fish Res 76:91–105

Pawson M, Pickett GD, Witthames P. (2000) The influence of temperature on the onset of first maturity in sea bass. J Fish Biol 56:319–327

Pickett GD, Eaton DR, Cunningham S, M.R.. D, S.D P, Whitmarsh D (1995) An appraisal of the UK bass fishery and its management. MAFF Dir Fish Res:1–85

Pickett G., Kelley D., Pawson M. (2004) The patterns of recruitment of sea bass, Dicentrarchus labrax L. from nursery areas in England and Wales and implications for fisheries management. Fish Res 68:329–342

Pickett GD, Pawson MG (1994) Sea Bass, Biology, exploitation and conservation. Chapman & Hall, London

Prat F, Zanuy S, Bromage N, Carrillo M (1999) Effects of constant short and long photoperiod regimes on the spawning performance and sex steroid levels of female and male sea bass. J Fish Biol 54:125–137

Quayle VA, Righton D (2007) Preliminary observations of the behaviour of sea bass (*Dicentrarchus labrax*). CEFAS:2007

R Core Team (2014) R: A language and environment for statistical computing.

Richardson E, Kaiser MJ, Edwards-Jones G, Ramsay K (2006) Trends in sea anglers' catches of trophy fish in relation to stock size. Fish Res 82:253–262

Rodrıguez L, Zanuy S, Carrillo M (2001) Influence of daylength on the age at first maturity and somatic growth in male sea bass. Aquaculture 196:159–175

Saillant E, Chatain B, Menu B, Fauvel C, Vidal MO, Fostier A (2003) Sexual differentiation and juvenile intersexuality in the European sea bass *(Dicentrarchus labrax*). J Zool 260:53–63

Sant FI (1978) The bass *(Dicentrarchus labrax*) in Cardigan Bay. Nat Wales Q J West Wales F Soc 16:123–126

SeaFish (2011) Responsible Sourcing Guide: Sea Bass.

Vandeputte M, Quillet E, Chatain B (2012) Are sex ratios in wild European sea bass *(Dicentrarchus labrax)* populations biased? Aquat Living Resour 25:77–81

Vinagre C, Ferreira T, Matos L, Costa MJ, Cabral HN (2009) Latitudinal gradients in growth and spawning of sea bass, *Dicentrarchus labrax*, and their relationship with temperature and photoperiod. Estuar Coast Shelf Sci 81:375–380

Vinagre C, Madeira D, Narciso L, Cabral H, Diniz M (2012) Impact of climate change on coastal versus estuarine nursery areas: cellular and whole-animal indicators in juvenile seabass *Dicentrarchus labrax*. Mar Ecol Prog Ser 464:237–243

Walmsley S, Pawson M (2006) Length distribution of bass discards in the UK trawl fishery. CEFAS

Ward D (2008) The biology and ecology of bass (*Dicentrarchus labrax*) in the Menai Strait, and an assessment of the applicability of otolith microchemistry and body-shape morphometric analyses as methods of discriminating between juvenile bass from disparate nursery are. Bangor University

Wilson K, Hardy IC. (2002) Statistical analysis of sex ratios: an introduction. In: Sex Ratios; concepts and research methods.

Wootton RJ (1998) Ecology of Teleost Fishes, 2nd edn. Chapman and Hall

URLS

CEFAS (2014) Sea temperature and salinity trends. http://www.cefas.defra.gov.uk/our-science/observing-and-modelling/monitoring-programmes

MET (2012) The record breaking heat and sunshine of July 2006. http://www.metoffice.gov.uk/climate/uk/interesting/july2006

www.totalseamagazine.com

7.0 APPENDICES

Appendix 1. Fishers per location and number of fish provided for the study.

Fisher Name		**Fisher Type & Number of Fish Provided**		
	Location	**Recreational**	**Commercial**	**Processor**
Dave Kendall	Mid		46	
Gill's Plaice (Tywyn)	Mid			7
Berwyn Robert	North	56		
Brett Garner	North		38	
Mark	North		4	
Mermaid Seafoods (Llandudno)	North			512
Peter Jackson	North		2	
"Fish Plaice" (Milford Haven)	South			643
Berwyn Dennis	South		237	
Channel Fish (Burry Port)	South			136
Coakley Green (Swansea)	South			3
Dai Bulley	South		20	
Dean Gifford	South	16		
Dorian Harris	South		42	
Gerald Banfield	South		20	
Sean Evans	South	2		
Simon Frobisher	South	5		
Stuart Denman	South		93	
Swansea Fish (Swansea)	South			92
Tucker's Fish (Swansea)	South			5
Total		**79**	**502**	**1398**

Appendix 2. Area and coordinates used for the creation of figure 7. Latitude and longitude arbitrarily derived for illustrative purposes only. The name of capture location was given in most cases, but it was rare to have coordinates. The 8 areas are used in the map in Figure 7 and are made up of capture locations.

Area (Locations)	**Latitude**	**Longitude**	**N**
Swansea (Bristol Channel, Swansea Bay, Mumbles, Port Talbot, Gower, Oxwich, Worms Head, Rhosilli)	51.562083	-4.332474	258
Loughor (Loughor, Burry Port, Whitford Point)	51.647667	-4.231028	225
Tenby (Tenby, Drify Rock, Caldey Island, Kidney Rock, Carmarthen Bay)	51.649	-4.640724	617
Milford Haven (Milford Harbour, St Anns Head, Skomer Island)	51.740139	-5.317833	208
Llyn Peninsular (Llyn, Pwllheli, Aberdaron, Abersoch, Aberdesach)	52.875472	-4.417972	235
Anglesey (Newborough, Penmon, Caenarfon, Wylfa Power Station)	53.138778	-4.300167	100
North Wales Coast (Llandudno, Conwy, Colwyn Bay, Llanfairfechan, Dee Estuary)	53.306	-3.718611	277
Mid Wales (Cardigan Bay)	52.367528	-4.412516	53

*Appendix 3. Summary of the age - sex structure of bass caught in Wales for 2014. Number of males, females, percentage males and females (of total number of fish) and χ^2. The * denotes significance between males and females (χ^2) at the $p < 0.001$ level. NA = sample size too small to compute χ^2 test*

2014						
Age (years)	Male	% Male	Female	% Female	χ^2	Total
3	1	0.438596	0	0	NA	1
4	1	0.438596	2	0.877193	NA	3
5	5	2.192982	5	2.192982	0.1	10
6	40	17.54386	85	37.2807	15.488 *****	125
7	20	8.77193	28	12.2807	1.020833	48
8	14	6.140351	10	4.385965	0.375	24
9	4	1.754386	3	1.315789	0	7
10	3	1.315789	3	1.315789	0.166667	6
11	0	0	1	0.438596	NA	1
12	1	0.438596	1	0.438596	NA	2
13	1	0.438596	0	0	NA	1
Total	90	39.5	138	60.5	-	228

*Appendix 4. Summary of the age - sex structure of bass caught in Wales for 2013. Number of males, females, percentage males and females (of total number of fish) and χ^2. The * denotes significance between males and females (χ^2) at the $p < 0.001$ level. NA = sample size too small to compute χ^2 test*

2013						
Age (years)	**Male N**	**Male %**	**Female N**	**Female %**	**χ^2**	**Total**
4	4	0.925926	9	2.083333	1.230769	13
5	18	4.166667	25	5.787037	0.837209	43
6	99	22.91667	136	31.48148	5.52*	235
7	43	9.953704	50	11.57407	0.387097	93
8	7	1.62037	14	3.240741	1.714286	21
9	6	1.388889	8	1.851852	0.071429	14
10	2	0.462963	4	0.925926	0.166667	6
11	1	0.231481	0	0	NA	1
12	0	0	2	0.462963	0.5	2
13	0	0	1	0.231481	NA	1
14	0	0	1	0.231481	NA	1
15	0	0	1	0.231481	NA	1
16	0	0	1	0.231481	NA	1
Total	**180**	**41.7**	**252**	**58.3**	**-**	**432**

Appendix 5. Packages installed in R for statistical analysis.

R package	Citation
FSA	Ogle, D. H. (no date) FSA: Fishereies Stock Analysis. R Package Version 0.4.25. http://www.rforge.net/FSA/InstallFSA.R
nlstools	Baty, F., Ritz, C., Charles, S., Brutsch, M, Flandrois, J.P. & Delingnette-Muller, M.L. (2014). A toolbox for nolinear regression in R: The package nsltools. Under revision at Journal of Statistical Software.
Hmisc	Harrell, F.R, and many with contributions from Dupont. C. others (2014). Harrell Miscellaneous. R Packafe version 3.14-4. http//CRAN.R-project.or/package=Hmisc
car	Fox, J & Weisberg S., (2011) An R companion to apllied regression, 2nd Edition. Thousand Oaks CA: Sage. http//socserv.socsci.mcmaster.ca/jfox/Books/Companion

Appendix 6. Catch at age matrix for 2013. Length (cm), age (years), total (N). No fish age 0-3 or 17years. Excludes undersized fish.

2013															
Length/Age	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**18**	**Total**
35	3	3	1												**7**
36	3	10	6	1											**20**
37	4	12	17	4											**37**
38	5	10	35	12											**62**
39	2	13	57	7											**79**
40	1	7	55	12											**75**
41		7	45	24	2										**78**
42		8	48	15	6										**77**
43		3	35	23	4	1									**66**
44		1	22	28	5										**56**
45		1	25	11	2	1									**40**
46			11	17	7	2									**37**
47		1	6	6	10	3	1								**27**
48			1	8	6	3	1								**19**
49			1	5	7	7	2								**22**
50				6	6	5	2	2							**21**
51			1	2	10	7	2		1	1					**24**
52				1	9	4	5	1	2	1					**23**
53						4	4	2	2	1					**13**
54					2	5	4								**11**
55					1	5	4	1	2						**13**
56					1	2	3	1			1				**8**
57					1		2	1	1		1				**6**
58						2	1	2	1						**6**
59						1	1	1	1						**4**
60							2		2	2					**6**
61							1		1			1			**3**
62									1	1					**2**
63								2							**2**
64									1						**1**
65						1				2	1				**4**
66								1	1						**2**
67										1					**1**
68												1			**1**
69														1	**1**
70											1		1		**2**
72										1					**1**
75											1				**1**
77													1		**1**
Total	**18**	**76**	**366**	**182**	**79**	**53**	**35**	**14**	**16**	**10**	**5**	**2**	**2**	**1**	**859**

Appendix 7. Catch at age matrix for 2014. Length (cm), age (years), total (N). No fish age 0-3 years. Excludes undersized fish. (2014 consists only of 7 months from January-July)

2014											
Length/Age	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Total**
35	1										**1**
36	3	2	3								**8**
37	2	6	8	2							**18**
38			9	3							**12**
39			8	3							**11**
40		4	13	5							**22**
41			20	2							**22**
42		2	28	3							**33**
43		2	21	8	2						**33**
44			19	7	1						**27**
45			14	8	2						**24**
46			12	5	2	1					**20**
47			4	10	1						**15**
48			5	5	6						**16**
49			2	2	6	1					**11**
50				2	3		1				**6**
51				1	1		1				**3**
52				2		2		1			**5**
53						1	2				**3**
54						2					**2**
55					1						**1**
56							1		1		**2**
60							1		1	1	**3**
Total	**6**	**16**	**166**	**68**	**25**	**7**	**6**	**1**	**2**	**1**	**298**

Appendix 8. Catch by weight (kg) of fish per age and length category for 2013. No fish age 0-3 or 17years. Excludes undersized fish.

2013															
Length/Age	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**18**	**Total Weight (kg)**
35	1.4	1.4	0.5												**3.3**
36	1.6	5.1	3.8	0.6											**11.1**
37	2.3	7.1	10.0	2.3											**21.7**
38	3.0	6.0	22.1	6.9											**38.0**
39	1.4	7.9	36.3	4.8											**50.5**
40	0.8	5.0	39.5	8.3											**53.6**
41		5.5	33.7	17.9	1.4										**58.5**
42		6.2	39.4	12.4	4.8										**62.7**
43		2.3	29.8	20.4	2.6	1.0									**56.1**
44		0.9	21.2	24.2	4.6										**50.8**
45		0.9	25.7	11.3	2.0	1.1									**41.1**
46			12.4	18.3	5.2	2.3									**38.3**
47			4.2	5.7	7.8	3.4									**21.2**
48			0.9	5.4	2.2	2.3	1.1								**12.0**
49				6.5	6.0	7.3	2.6								**22.4**
50				6.8	6.2	5.4	2.5	2.5							**23.5**
51			1.6	1.2	9.6	4.0	2.6	0.0	1.4						**20.4**
52				1.1	12.7	2.5	4.4	1.4	1.5	1.7					**25.3**
53						4.6	6.7	3.0	1.6						**15.9**
54					1.0	8.4	4.8								**14.2**
55						7.2			1.7						**8.8**
56					1.8	2.0	5.4	1.8			2.1				**13.2**
57					2.0		3.6	1.9			1.6				**9.0**
58						1.6		4.3	2.1						**8.0**
59						2.2		2.2	2.2						**6.6**
60							4.2		4.0	4.8					**13.1**
61							2.0		2.6			2.7			**7.3**
62									3.0						**3.0**
63								5.0							**5.0**
64									2.3						**2.3**
65						2.4				2.8	2.9				**8.1**
66								2.9	4.0						**6.9**
67										3.1					**3.1**
69														3.1	**3.1**
70											3.6		3.4		**7.0**
72										2.5					**2.5**
75											5.0				**5.0**
77													5.0		**5.0**
Total Weight (kg)	**10.6**	**48.3**	**281.1**	**153.9**	**70.1**	**57.8**	**40.0**	**25.0**	**26.3**	**14.9**	**15.2**	**2.7**	**8.4**	**3.1**	**757.5**

Appendix 9. Catch by weight (kg) of fish per age and length category for 2014. No fish age 0-3. Excludes undersized fish. (2014 consists only of 7 months from January-July).

2014											
Length/Age	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Total Weight (kg)**
35	0.5										**0.5**
36	1.6	1.0	1.7								**4.2**
37	1.1	3.5	4.4	1.1							**10.0**
38			5.2	1.8							**7.0**
39			5.1	1.8							**6.8**
40		2.8	9.0	3.4							**15.1**
41			14.9	1.4							**16.3**
42		1.6	21.8	2.3							**25.6**
43		1.7	18.0	6.5	1.7						**28.0**
44			16.8	6.2	0.9						**23.9**
45			13.0	7.4	1.7						**22.1**
46			12.1	5.1	2.1	1.0					**20.3**
47			4.5	10.7	0.8						**16.0**
48			5.6	5.4	6.7						**17.7**
49			2.5	2.2	7.0	1.3					**13.0**
50				2.5	4.0		1.3				**7.8**
51				1.8	1.5		1.4				**4.7**
52				2.6		3.0		1.4			**7.0**
53						1.4	2.9				**4.4**
54						3.4					**3.4**
55					1.8						**1.8**
56							1.1		1.9		**3.0**
60							2.2		2.1	2.2	**6.5**
Total Weight (kg)	**3.1**	**10.6**	**134.6**	**62.1**	**28.3**	**10.0**	**8.9**	**1.4**	**4.0**	**2.2**	**265.2**