Summary of MSc Thesis on the Ecology and Economics of the Common Skate in the Oban Area

James Thorburn

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Introduction

The Common Skate *Dipturus batis* (formerly *Raja batis* Linnaeus 1758) is the largest of the European Batoids (IUCN, 2007). Batoids are members of the elasmobranch (shark) family and are characterised by their flattened bodies, with ventral gills and mouths. Batoids include skates, rays and guitar fish. Female common skate can reach a length of 285cm (approx 120kg) and males 205cm (approx 75kg) (Ellis and Walker, 2005). They can be found in the northeast region of the Atlantic, ranging from the Mediterranean near Madeira and northern Morocco up to the Barents Sea and across the Atlantic to Iceland (MarLIN, 2008) (Figure 1).

Figure 1: The known range of common skate throughout Europe. Image adapted from ZeeInZicht

They are found at varying depths throughout their range but are most commonly found in water around 200m deep on the edge of continental shelves (IUCN, 2007). Growth rates for common skate have been shown to be 1-9kg per year for males and 4-13kg per year for females (Little, 1998) and they are generally thought to live to 50 years of age (IUCN). In common with many other species of elasmobranchs, common skate are slow growing and late to mature (Brander, 1981) with both sexes thought to reach maturity at approximately 11 years old, with males being 125cm long (Ellis and Walker, 2005) and females 180cm (Walker & Hislop, 1998). The number of eggs laid per female is dependent on her size but is estimated to be approximately 40 eggs (Brander 1981) which get deposited on the sea bed once every two years (Little 1995). The young of common skate hatch from the eggs at approximately 22cm long with a wingspan of 13-15cm (Brander 1981).

Common skate were once common around the coast of the British Isles (Brander, 1981 and Ellis and Walker, 2005) but increased fishing effort has led to a rapid decrease in its numbers. The number of common skate caught in commercial trawls began to decline in the 1920s and, after a brief recovery period during World War II, they had all but disappeared from North Sea trawls by the early 1980's (Walker & Hislop, 1998). Elasmobranchs are well known for their vulnerability to commercial fisheries, and of these, skates and rays are arguably the most sensitive (Dulvy et al, 2000). For the same level of mortality among Batoid species, it is expected that the longer the maturation period (Jennings et al, 1998) and the larger the body size (Dulvy and Reynolds, 2001) the greater the population decline. This places common skate as one of the most sensitive species of batoid as it is a strong K-strategist (Stevens et al, 2000). Characteristics of K-strategists include large body size, long life expectancy, and the production of fewer offspring that require extensive parental care until they mature, in the case of skates, this is the formation of a sturdy egg case, protecting embryo until it develops to a larger size. Common skate have the longest maturation period for any species of batoid and is the largest species in Europe. Even the hatchlings of common skate are vulnerable to commercial fishing due to their size and morphology (Brander 1981). As mentioned previously, common skate were once common around the coasts of the UK, however, even at the beginning of the 1900s it was clear that the population levels were rapidly declining. In a study by Rogers and Ellis (2000) survey trawl data from the Irish and North Seas (in which specimens were identified by species) from 1901-1907 and 1989-1997 was compared. Even in the 1901-1907 common skate were absent from the North Sea and were only present in low numbers in the Irish Sea (maximum 1 per hour trawl time (Roger and Ellis, 2000) showing the reaction of the population to early commercial pressure. In the trawls conducted between 1989 and 1997, common skate were absent from all trawls. This has led to common skate being declared extinct from the Irish Sea (Brander, 1981). The species is currently on the IUCN red list as an endangered species throughout its range (IUCN, 2007) and is the subject of a UK Species Action Plan (Anon, 1999) although neither of these offers it any protection in terms prevention of landing and killing.

Despite the falling population of common skate around the UK, the waters around the Isle of Mull and the Firth of Lorn have retained a seemingly strong population and appear to be one of the last remaining strongholds for the species. As common skate is a favoured sport fish and has been pursued by anglers for many years, the comparatively large population attracts a lot of angling interest, which created a good opportunity to involve the anglers in a tagging study to monitor the West Coast population. Glasgow Museum initiated a tagging programme in 1975 to gather tag and recapture information on the population.

Aims

The aim of this project was to gain more insight into the life history characteristics and behaviour for the species as well as assessing the population around the Isle of Mull and Firth of Lorn, using the data set provided by Richard Sutcliffe from the Museum of Glasgow and collected by local anglers. Growth rate, annual depth migration, maturation, annual geographical movement, population composition, fishing mortality and economic importance were all assessed and the major findings are presented in this report.

As well as looking at the ecological features of the population of Common skate around the Isle of Mull, the study also focused on the economic value of the charter boat industry based in Oban that are running skate angling trips. It looked at the value of the industry and also the amount of money the industry brings to other businesses in the area.

Results

Angling areas

Tagging has occurred throughout the region, mainly in the Sound of Mull (area A), the Passage of Coll (area B) and the Firth of Lorn (area C) (in order of analysis). The tagging effort has been shaped by angling effort, as most of the data was collected by a few key anglers with a preference for particular areas and geographical grouping of the data has occurred. There was no evidence to suggest that this geographical grouping was in anyway caused by population segregation. Areas A, B and C are referred to throughout the results section. In some incidences it was important to analyse the data from each area separately as geographical differences between the areas may have influenced the results, the most importance of these was depth. The three areas have different depth profiles, with area A being typically between 75-145 m deep, area B (the shallowest) typically less than 45 m deep and area C typically 75-145m deep, but with some areas greater than 145m.

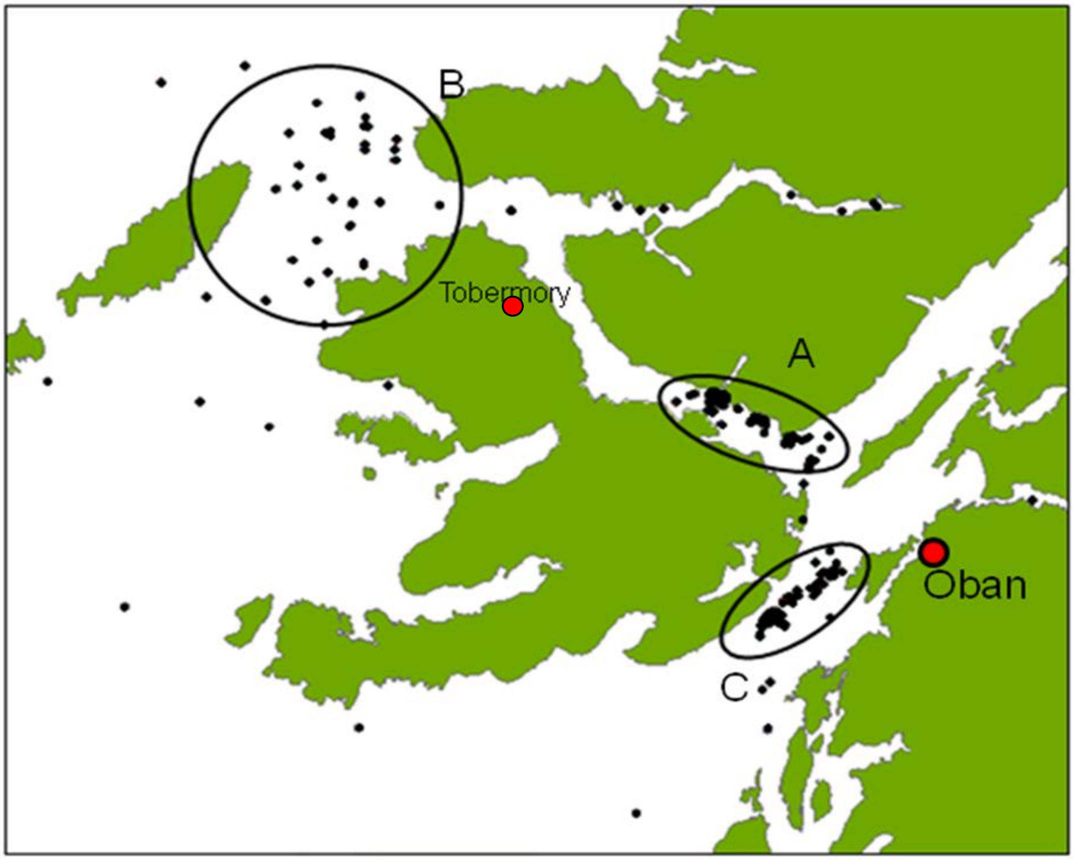

Figure 1: The study area around the Isle of Mull showing the locations of tagging sites. Area A: the Sound of Mull, area B: the Firth of Lorn and area C: the Passage to Coll

Growth Rates

Establishing a growth rate for fish in the area was important as it allows for population division into mature and juvenile individuals based on weight at maturity (11 years old, Ellis and Walker 2005). This is important for identification of possible breeding areas. Figures 2 and 3 show the estimated growth curves for males and females in the area. 'Smoothed' and 'Unsmoothed' data has been plotted on the graph to create a range for the estimated growth rate. As growth rate was taken from the weight change between capture incidences this included weight loss and change due to other factors other than growth such as feeding or spawning. The growth change between each pair of capture incidences for the same fish were recorded and used (the unsmoothed data) as was an average growth rate between the initial and final capture incidence (the smoothed data) this is shown in figure 4.

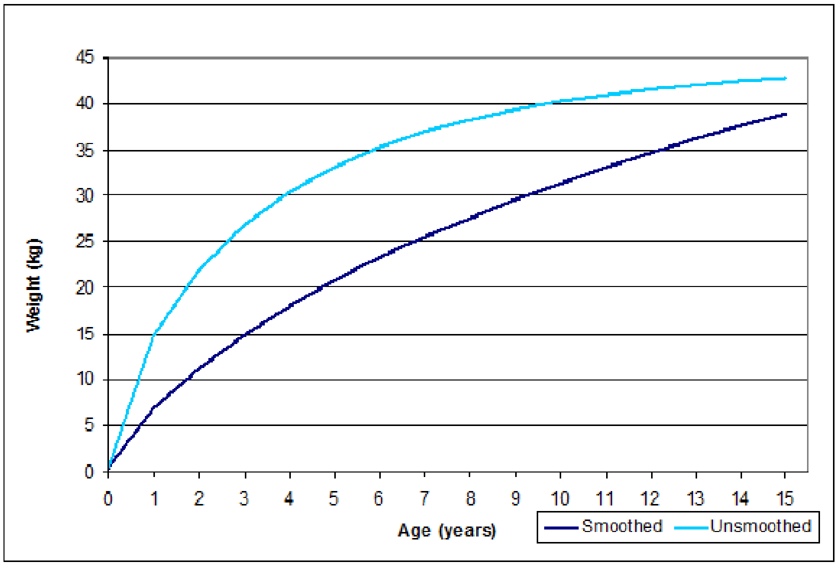

Figure 2: Line graph showing the estimated Growth Curves for Males using Smoothed and Unsmoothed data for the first 15 years of the animal's life.

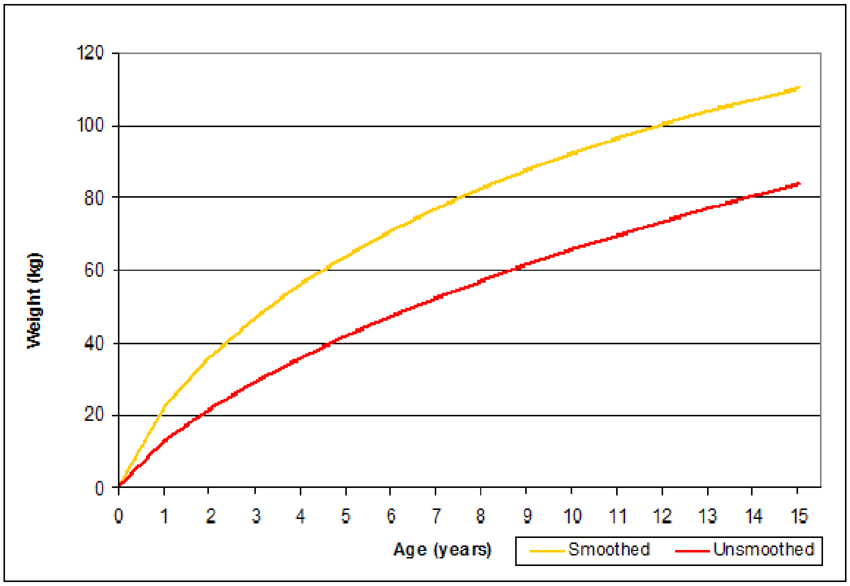

Figure 3: Line graph showing the estimated Growth Curves for Females using Smoothed and Unsmoothed data for the first 15 years of the animal's life

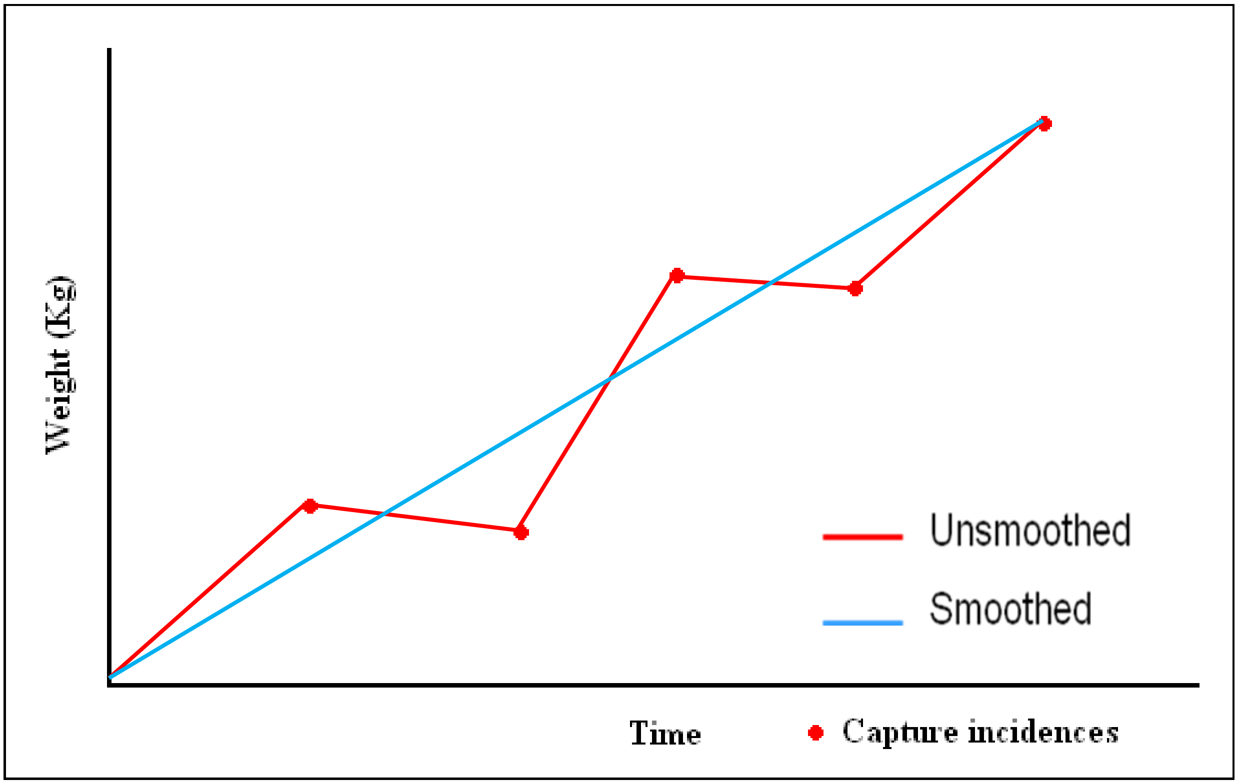

Figure 4: Showing the difference between smoothed and unsmoothed data for 1 individual fish.

The growth curves show that the lowest estimated weight of maturity for male is 33kg and for females is 69kg. Care must be taken with the estimated growth curves as in most cases the weights are taken from weight charts and are not 100% accurate, although they are however accurate enough for estimating approximate weights at maturity.

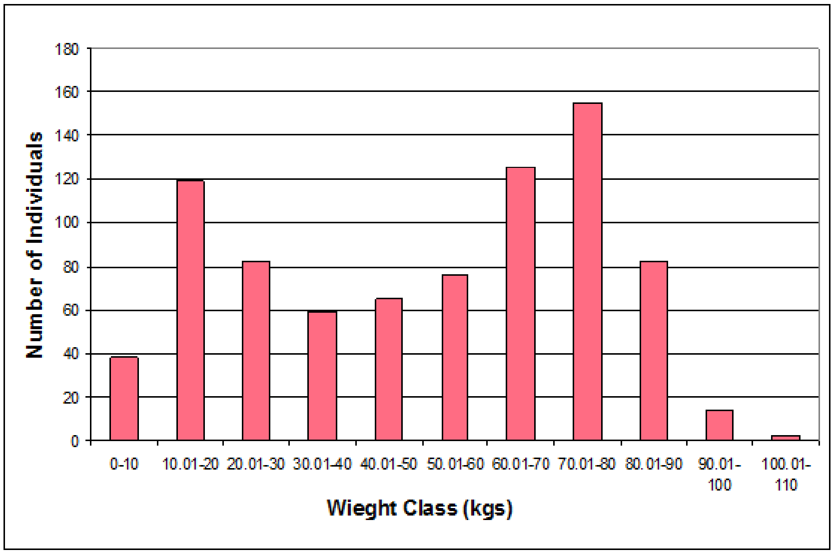

Figure 5: Histogram showing the number of female specimens caught in the study area for each weight class between 1975-2008. Each weight class has a 10kg interval and the maximum weight for adult female specimens of common skate in the area was 102.06kg

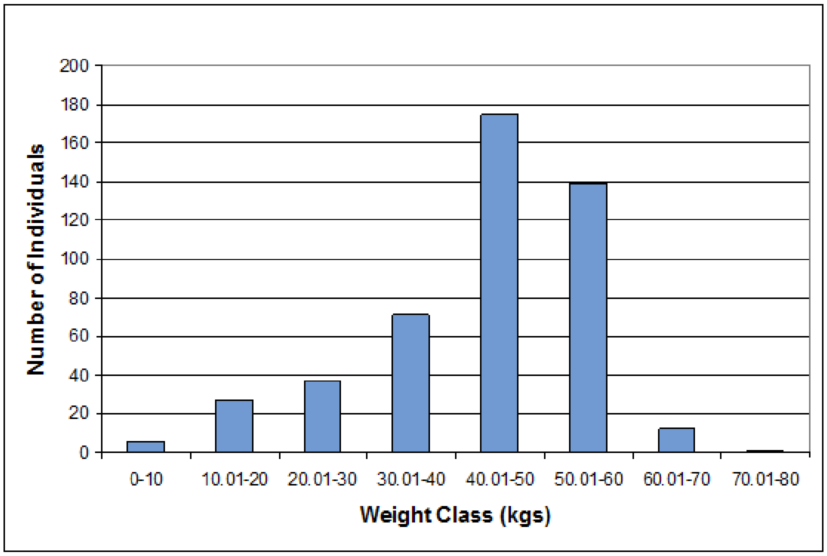

Figure 6: Histogram showing the number of male specimens caught in the study area for each weight class between 1975 and 2008. Each weight class has a 10kg interval and the maximum weight for adult male specimens of common skate in the area was 74kg.

Maturation

By splitting the weight classes into 10kg classes, we can see the number of fish caught in each weight class which is important to identify the number of immature and mature fish in the area. Looking at the number of female fish in each weight class, we can see that there is a large number of fish in the 10-20kg and 60-70kg classes (figure 5). This was surprising as it was expected there would be a higher number of larger fish due to anglers using fishing gear to target large skate. This suggests that there are a high number of young females in the area, approximately 1 year old (there may be similar numbers of younger fish, but these may be too small to be caught by the gear anglers are using to target skate). The second peak in numbers in the 60-70kg class represent mature females (from estimated weights from growth curves). This pattern is not seen for the male fish (figure 6) as there is only one peak within the 40-50kg weight class which suggests mature fish. Male fish of a comparative age to the female fish weighing between 10-20kg would weigh considerably less (approximately 5kg) so are unlikely to be caught by skate anglers so it is not possible to say they are not present only that they were not caught. There is a possibility that young fish remain in the area to feed before they grow and have to compete with the local dogfish population, prolific in the area. When competition becomes too fierce, the skate may head to deeper offshore waters to make feeding easier, returning to breed when mature.

Breeding Congregation

The high number of mature fish of each sex could suggest that they congregate in the area for breeding purposes; other species of batoid have been shown to display this behavior, most notably thornback rays in the southern North Sea (Hunter et al 2005). It is reasonable to expect common skate to have similar life history behavior. Further evidence for this can be found by comparing the depths fish were caught in for each season compared to weight. As each geographical area is fished at different times of the year and are different in depth the data for each area (A, B and C) were looked at separately to remove these influences (see depth differences from 'Angling Areas' previously). The catches for each area were split into four seasons, Winter (Nov-Jan), Spring (Feb-Apr), Summer (May-Jul) and Autumn (Aug-Oct). Figures 7 and 8 show the depth female fish were caught in for each season in areas A and B (some seasonal data is lacking for area B), while Figures 9 and 10 show the depth male fish were caught in for areas A and B for each season (again, some seasonal data is lacking for area B). Depths for area C were also plotted but not enough data entries existed for this area to show any distinct patterns.

What can be seen for female fish in areas A and B is that individuals weighing more than 50 kg were caught in shallower water during summer and autumn months. The same is true for male fish, with individuals over 35kg being caught in shallower water during the summer and autumn. For both sexes, we would expect these fish to be mature, using the estimated growth curves (figures 2 and 3). The increase in mature fish being caught in shallow water during the summer and the autumn supports the idea of annual migration to shallower water for the purposes of breeding, suggesting that breeding and/or spawning does occur within areas A and B.

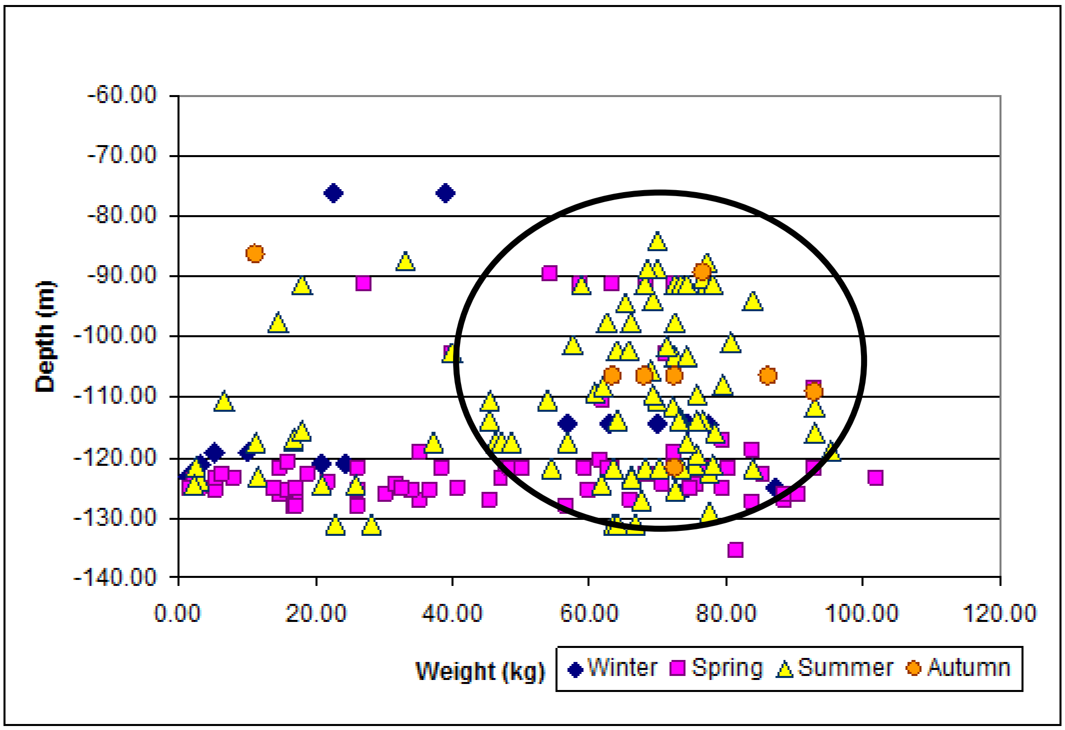

Figure 7: Showing the depth female fish were caught in compared to weight for each season within area A

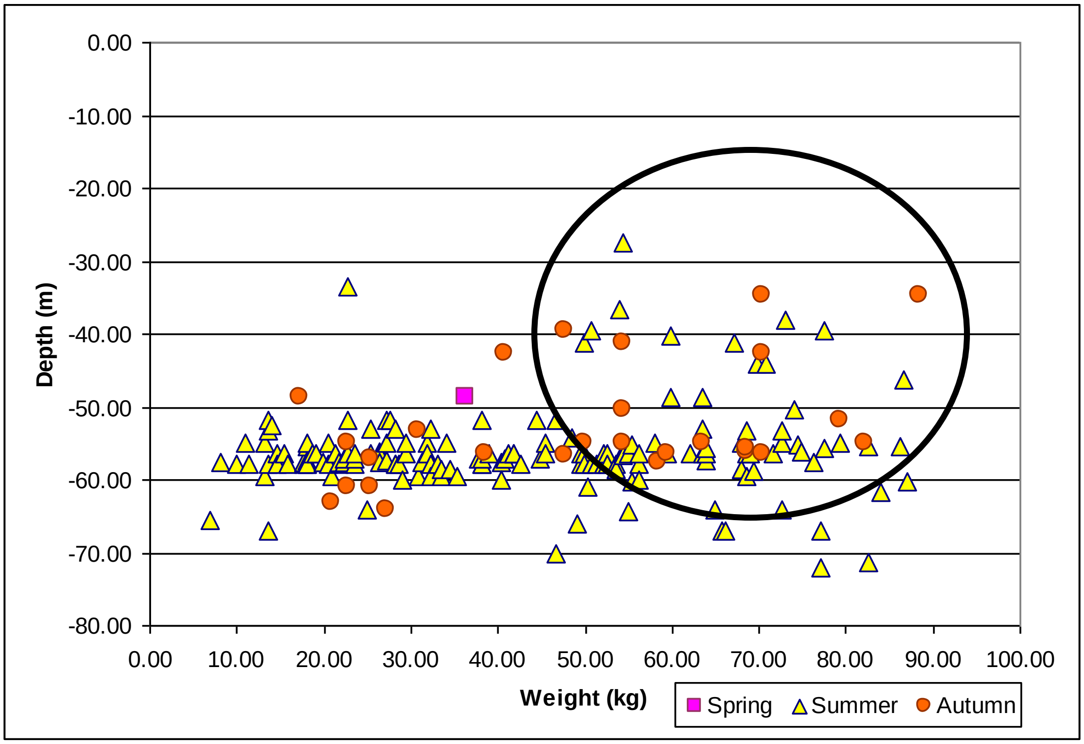

Figure 8: Showing the depth female fish were caught in compared to weight for each season within area B

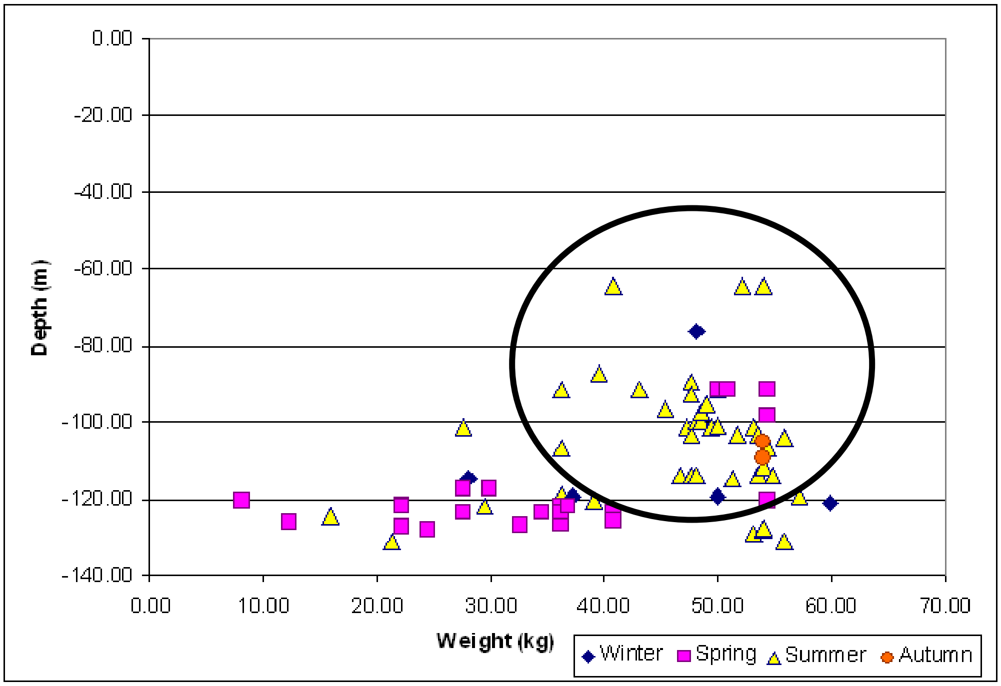

Figure 9: Showing the depth male fish were caught in compared to weight for each season within area A

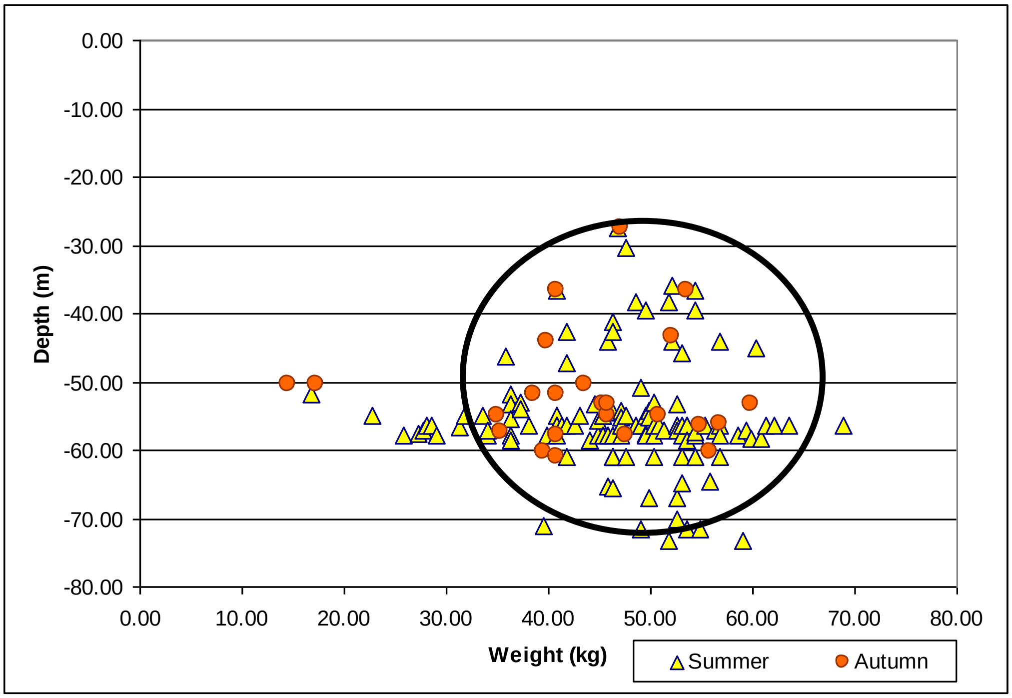

Figure 9: Showing the depth male fish were caught in compared to weight for each season within area B

Migration

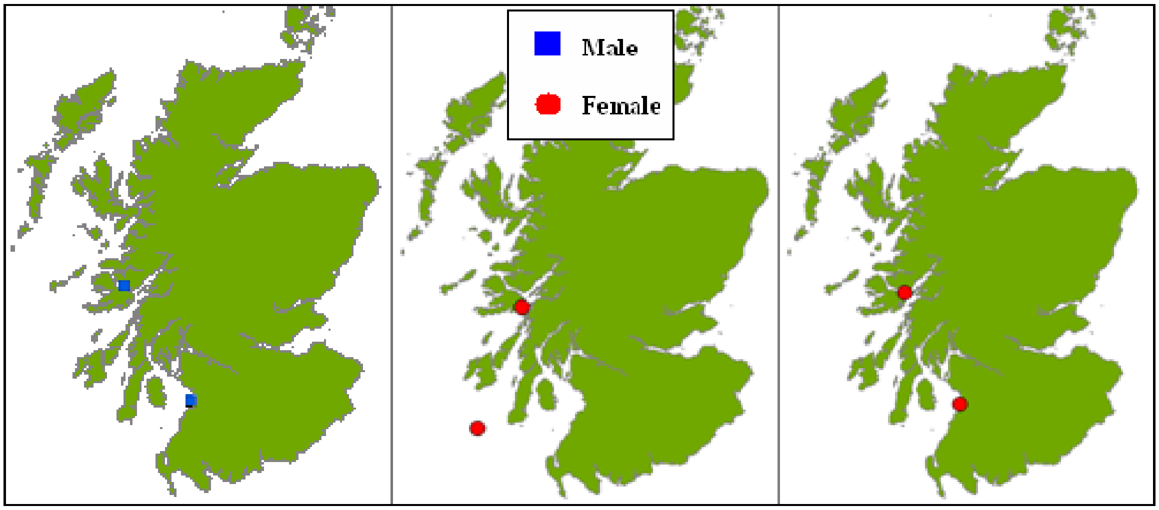

Figure 10: Showing the three longest recorded movements between captures made by male and female common skate.

Two females and one male made journeys of over 200km between capture sites. Two of these, shown in the first and last map of figure 10, were initially tagged in the waters around the Isle of Mull and were then recaptured in the Firth of Clyde while one female (middle map of figure 10), was tagged off the coast of Ireland, and re-caught in the Firth of Lorn. This is important as this is confirms that the population in the waters around the Isle of Mull and Firth of Lorn are not isolated and that some individuals move around the coast of Scotland. All three recorded fish are mature so they could be travelling these distances to breed.

Most fish were re-caught in the same area and displayed similar patterns of capture sites. The capture sites are not in a straight line, but rather suggest that the skate is remaining within the same area. This is true of both males and females and is shown in figures 11 and 12. This is also important as the movement patterns strongly suggest residency within the area. Fish that remain in the area are more susceptible to local pressures and the management of a resident population is very different to the management of a migrational population.

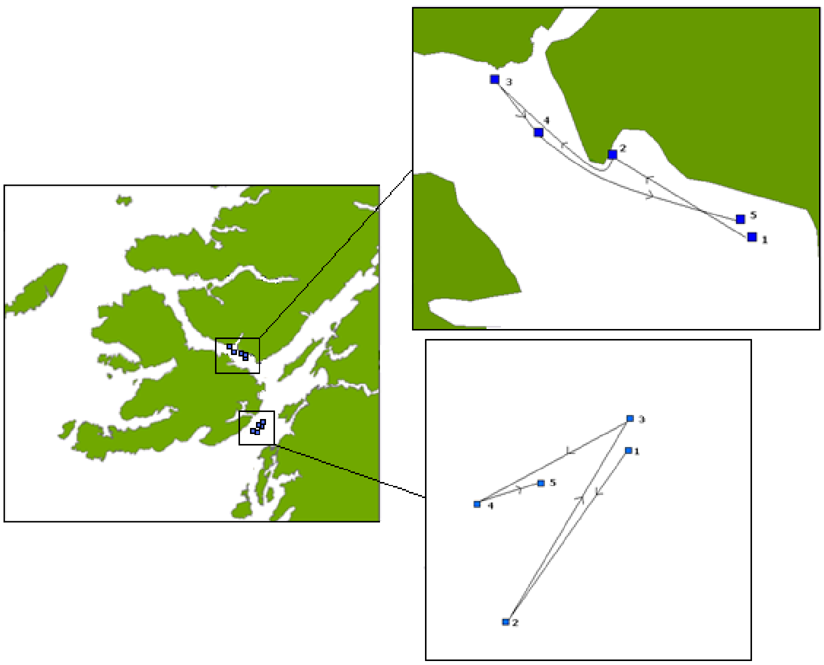

Figure 11: Showing the capture sites of a male Common skate within the region. Note, the lines and direction arrows are not actual paths of movement, but represent the movement between capture points

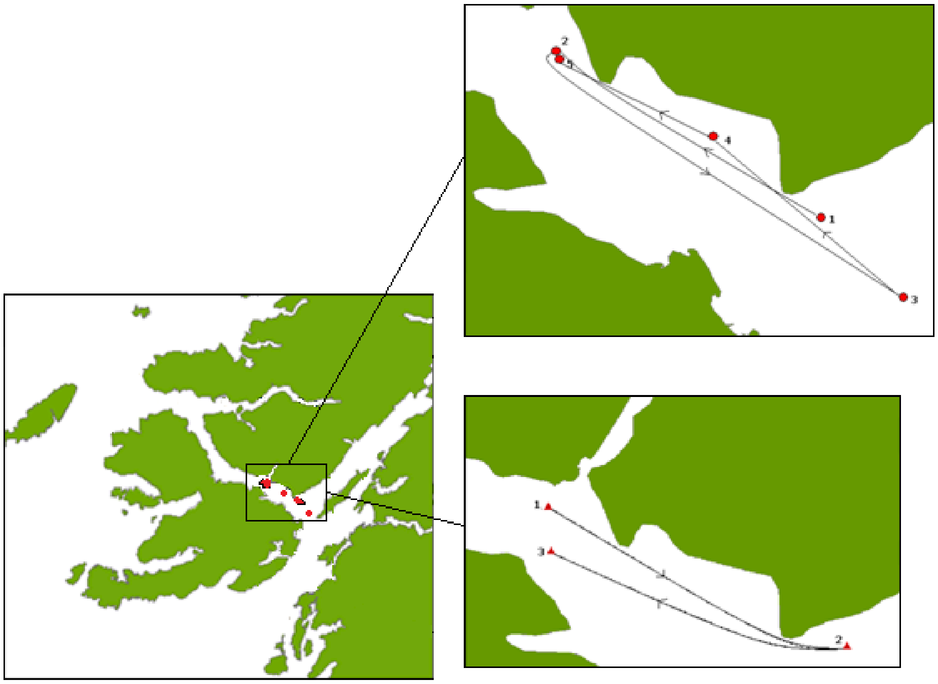

Figure 12: Showing the capture sites of a female Common skate within the region. Note, the lines and direction arrows are not actual paths of movement, but represent the movement between capture points

We can also see that males travel further distances between capture sites (figure 13). This is still within the same area so cannot be classed as migrational but suggest that within the area, males move more than females, possibly because males move between breeding areas within the region.

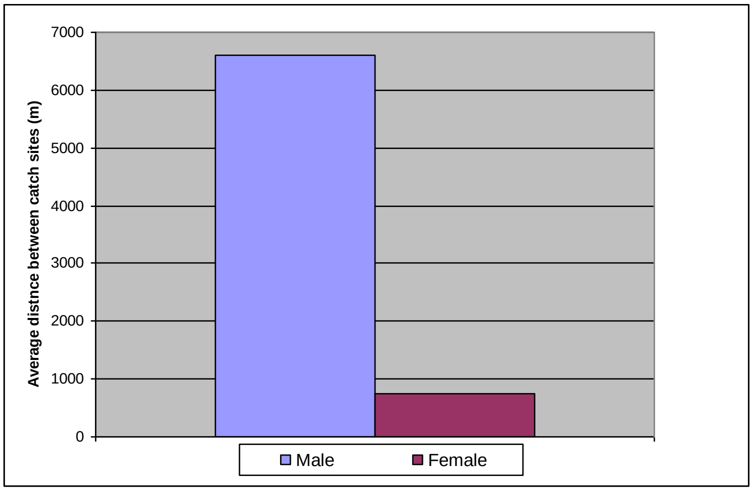

Figure 13: Average distance between capture sites for male and female fish.

Population estimate

The data was used to predict population numbers for the region, using a Schnabel model to predict numbers based on the recapture data.

The Schanbel model: This is a mark/recapture method using multiple sampling episodes to gain a population estimate, the model uses the following parameters:

$$\textbf{Population number} = C_tM_t^2 / R_tM_t$$

Ct = total number of individuals captured in sample *t*

Rt = number of individuals already marked in sample *t*

Ut = number of individuals newly marked and released in sample *t*

Mt = total number of individuals marked in population at sample *t*

t simply refers to the sampling episode number, this number however should not be included in the equation, any number greater than t+1 relies on data from previous sampling episode. (i.e. first sampling episode will have no recaptures).

The population figures are very likely to be overestimates as they do not take into account any form of mortality either natural due to death, outward migration or anthropogenic mortality from commercial capture, dredging operations, angling deaths caused by 'deep hooking' and other deleterious activities. Additionally they are also are heavily influenced by tagging effort, as the more tagging and recapture incidences reported, the larger the population estimate. The data was analysed three times with different mixing periods and the three estimates are displayed on figure 14. A mixing period is used to allow the fish to integrate with the rest of the population. This is important to try and reduce the possibility of 'targeting' one fish as this will increase its recapture rate). Population estimates were estimated for each geographical area, A, B and C then added together for a total population estimate for the region.

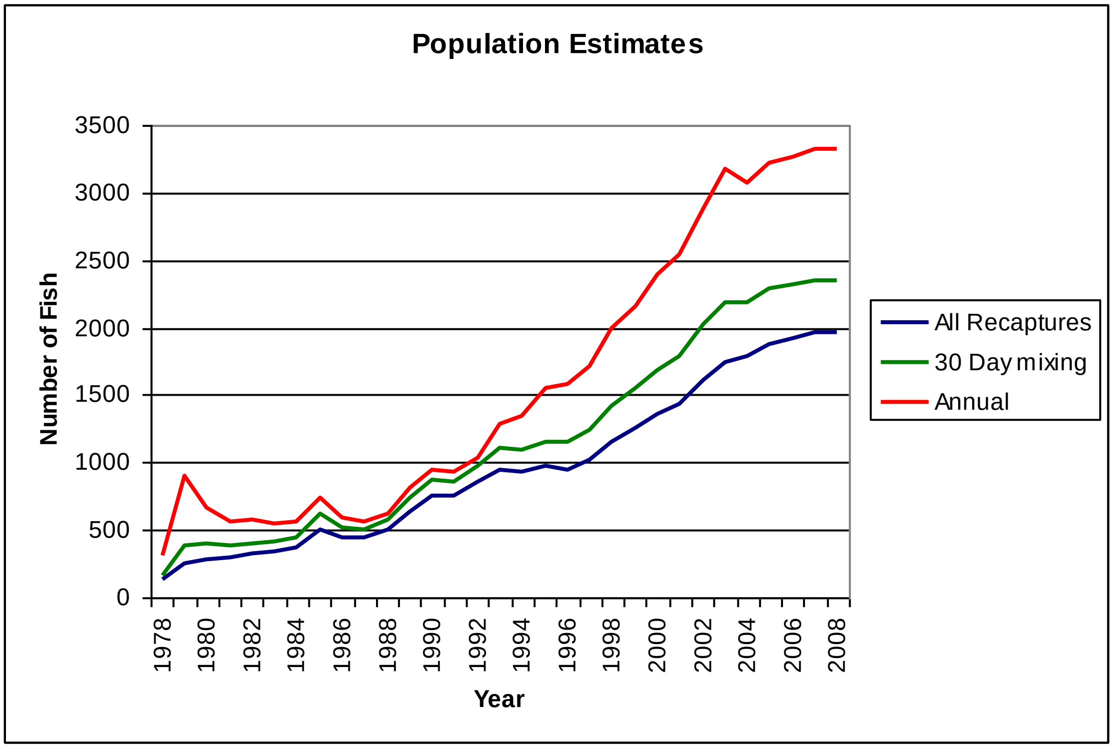

Figure 14: Three estimates for the population number for common skate in the region. Estimates obtained using the Schnabel model.

Commercial fishing mortality

Any mortality caused by commercial fisheries is through by-catch as there are no targeted fisheries for the species in the region. Total landings of all skate and ray species for the region are recorded by Fisheries Research Services (FRS) in Aberdeen, as is common for batoids in the UK. This has caused problems assessing the impact of fisheries on common skate as it is unknown the number of individuals landed. This was changed in 2008 and now landings are required to be identified by species, although this itself poses the problem of identifying species. Using common skate catch rates from previous studies, a range of different values for common skate catches as percentages of total catch were applied to the total landing data from the FRS to get fishing mortality from commercial fishing for the species. Figure 15 shows that the estimated number of skate captured by commercial fishing has dramatically declined over the last 25 years from an estimated maximum of 210 individuals taken in 1984 to a maximum of 15 in 2007. These are estimates and obviously, as no previous trawl surveys have been done in the area, the proportion of common skate is unknown. With such a strong population in the area, it is possible that the number of common skate captured by commercial fishermen is actually higher but there was not enough time during this project to collect anecdotal data from the fishermen on this subject. It should be noted that fishermen in the area return caught common skate to the sea as they are of no commercial value and they are aware of the tagging program.

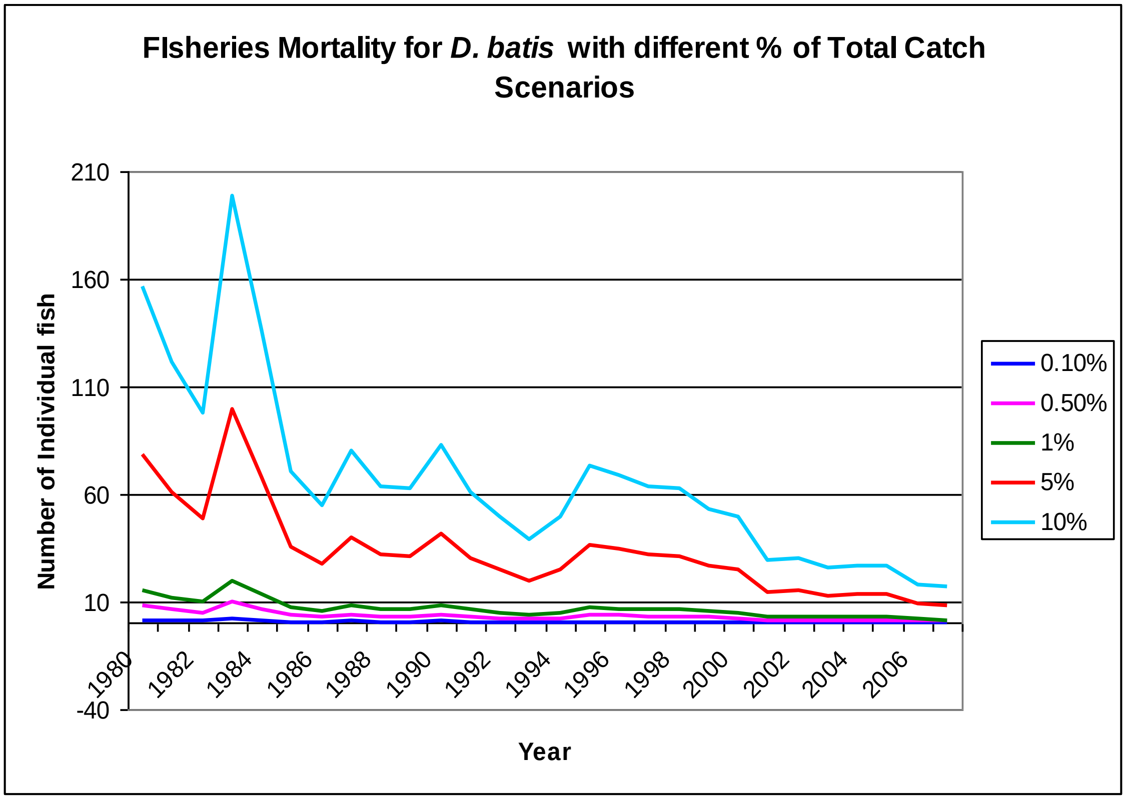

Figure 15: estimated landings of common skate by the commercial fishing industry in the ICES rectangles 42E3, 42E4 and 41E4 assuming different proportions of total landings. Assuming an average weight of 88.495kg for common skate

Economic Importance

During the summer of 2008, anglers on board charter vessels were asked to complete questionnaires aimed to establish the amount of money the anglers had spent in the area. The figures in this report were estimated from the results of these questionnaires.

By looking at the average number of people going on charter trips per day and how much money they spend on average an estimate was made of how much money the charter anglers bring to the Oban area in total (table 1).

Table 1. Showing the total amount of money brought to the area by charter anglers, the amount of money that the charter boat industry earns and the amount of money that goes to the other local businesses.

	Amount in £'s
Total spent annually in area (300 days charter fishing)	292500.00
Contribution to local economy	157500.00
Charter boat industry Gross income	135000.00

An estimated £292,500 is brought to the Oban area every year by charter anglers, £135,000 of this goes to the charter industry while £157,500 goes to the local economy. This shows that the charter boat industry is a valuable asset to the local community, bringing in a substantial amount of money every year. It is also worth mentioning that this figure is liable to be a substantial underestimate as it does not take into account people using the charter boats for other trips such as sightseeing and other angling trips and does not include any income being brought to the area by private anglers either with their own boat or shore fishing.

Using these figures and also the population estimates we can estimate the value of each fish and compare it to commercial market values to see if it is worth more to keep fish alive for angling purposes. The values for common skate are shown in table 2.

Table 2: Showing the value of each fish in the waters around the Isle of Mull and Firth of Lorn, splitting this down into value to the local economy and the charter boat industry.

	Value of individual fish
Value to local economy	£67.25
Value to Charter boat industry	£57.64
Total Value of fish	£124.89

The value of fish in Area C is of particular importance as this is where the majority of charter trips target. Assuming 80% of charter trips target area C (therefore contributing 80% towards the Oban economy), and using a population estimate for area C, the value of fish in area C (table 3) is over ten times the worth of fish in the region in general (figure 16).

Table 3: Showing the value of fish in area C as a total figure, value to the charter boat industry and the value to the local economy.

% of money spent in:	Amount £'s	Minimum Worth of individual fish
Total Spend on Area C	234000	£1384
Contribution to local economy of Area C	126000	£745
Contribution to charter boat of Area C	108000	£639

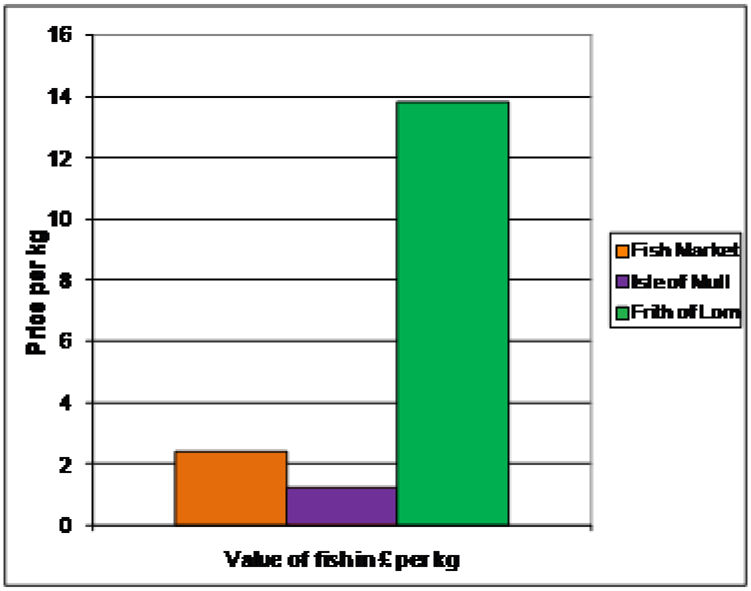

Figure 16: The value of common skate, comparing the fish market price (from Grimsby fishmarket), the estimated value of skate for the study region and within the Firth of Lorn (area C).

Conclusions

In conclusion, this investigation has shown that immature and mature individuals of common skate are present throughout the northern Passage of Coll, the Sound of Mull and the Firth of Lorn. There was no observed geographic preference of either sex throughout the study area, although seasonal preference for one area was not attainable from the results due to the seasonal change in fishing effort in different areas.

Clear trends were identified showing annual movement of mature individuals of common skate of both sexes, from deep water to shallow water in relation to the cited breeding cycle (Ellis and Walker, 2005). Analysis of movement in areas A and B strongly suggested the preference of common skate to breed and lay eggs in shallower water during the summer and autumn. There was no preference to a specific depth displayed by either mature or immature individuals of either sex. There is a strong suggestion that larger animals are found in shallower water and this association was shown to be significant for females in all areas, with the strongest association in area A (Spearmans Rank 2-tailed correlation test, $p=<0.01$) and also for males in area A and the study area as a whole ($p=<0.01$). Careful management of areas A and B might aid the rebuilding of the population around the Isle of Mull and Firth of Lorn, and this in turn, due to proven movements of common skate, might help the population growth along the west coast of Scotland.

It is also clear that the Isle of Mull and Firth of Lorn population is not closed, this can be seen by the long migrations of both sexes shown in figure 3.26. It is unknown to what extent these migrations occur and whether or not they are one way or cyclic but more sophisticated tagging techniques could provide more information on this, some of these are discussed in the 'further research' section.

This study also calls into question previous estimates for length and associated weight at maturity for common skate. Using age at maturity as 11 years old (Brander, 1981, Ellis and Walker, 2005 and Little 1995), weight at maturity was estimated to be between 33-42kg for males and 69-96kg for females. These estimates are substantially higher than those quoted in the literature and suggest, especially for males, that either common skate matures at an earlier age than previously thought, or that the previous estimates for length at maturity from other papers are under estimates.

No clear conclusions can be drawn from the population estimates as the results are dependent on many assumptions and are heavily influenced by the number of tag returns. What is clear is that when a skate is tagged more data is required from the anglers to make this effort worthwhile, for example, a record of time spent fishing for common skate to enable a more in depth study into population levels and to determine the current status of the Isle of Mull population. As we have no official record for the commercial landings of common skate it is unclear what impact the commercial industry has on the Isle of Mull and Firth of Lorn Common skate population. Landing data recording individuals of common skate rather than just "skates and rays" is needed to examine fisheries mortality, this is already in motion but the identification tools are still being developed.

Charter trips for common skate bring a substantial amount of money to the Oban area. This has made individual fish in the area worth more to the angling industry than to the commercial market and due to their ability to survive the process of netting are worth returning to the sea upon capture.

More research into the population is needed before any firm management decisions can be made for the area, the following areas of research would increase our understanding of the population and how best to mange it to ensure its survival and economic benefit to the local economy.

Further Research

- The current tagging study provides some very useful information, with a few extra records taken by anglers, the information may prove to be even more useful. A record of 'fishing effort' i.e. the amount of time spent fishing would provide useful information, making population estimates easier to calculate.

- Genetic study: Looking into the mixing between regional populations of common skate. This would indicate to what level populations mix and whether or not regional populations are closed or not. This is essential as closed populations are more vulnerable to fisheries mortality and are less likely to survive in exploited areas. Possible ways of collecting genetic data would be to train charter skippers and other interested anglers to take either 'fin snips' or 'skin cores' from captured individuals. These would be returned along with tag numbers. Other tagging studies, such as the one in Orkney, could provide useful genetic information into the amount of mixing between populations.

- Study into the annual migration of both sexes of common skate: Using electronic data tags or/and sonar tags to track the movement of individual skate more closely to see how common long migrations are and if they are cyclic by nature or one way. This would also show any annual migrations. Electronic data tags record required data, often depth and temperature and store this information within the tag. These tags automatically detach from the fish and float to the surface from where they can be collected. The data can then be downloaded and analyzed. Very useful for depth movement, this can be used in association with bathymetrical data to try and position the fish. Sonar tags alert a receiver unit when they are within a certain distance. Using several 'base' receivers, position can be estimated. This would be especially useful for monitoring longer migrations between known points, such as the Firth of Clyde and the Sound of Mull.

- Study into the weight classes found in various areas of sea including offshore: This will further our understanding into the movements of young common skate and will substantiate if they do indeed move into deeper water offshore to mature. Due to the new obligations on commercial fishermen to record skate and ray landings by species, this should make it easier to gain data on the size of specimens caught at sea. Trawl or long line sampling could be used to specifically monitor common skate further offshore, but this is expensive and potentially destructive. Collaborating with commercial fishermen would be a more straight forward method for sampling offshore specimens, even if this information is anecdotal, this would still prove useful.

- Sampling for common skate throughout all waters around Mull and the Firth of Lorn: This will lead to better understanding of any geographic congregation areas for common skate and will help in the allocation of breeding and hatchery areas for the species, allowing more effective management. As fishermen are going to fish in areas they prefer, some areas are unfished and therefore un-sampled. Chartering boats to fish un-sampled areas may be an option for sampling these areas. Long line sampling would produce results, but the potential of skate becoming 'deep hooked' is a real threat and this sampling method should be considered carefully with as many measures as possible installed to prevent deep hooking.

- An in depth study into the breeding cycle of common skate most likely aquarium based to confirm the months of breeding and egg laying for the species, again, to allow more effective management, an ethical law against keeping common skate in captivity may complicate this as, although it is not legally binding, it may be frowned upon by many people, and the question of whether breeding behavior in captivity displayed is representative of natural behavior can also be raised. However, if it is possible to keep a breeding pair of common skate then this would provide useful information. Even the incubation of egg cases would prove useful in terms of factors effecting hatching and time spent in the egg case.

- A more in depth study into the economic worth of common skate to the Oban area, examining for the contribution to the local economy. This could be done by further questionnaires, both on the charter boats and at the local businesses (especially residential). Angling clubs can easily reach their members and questionnaires targeting private anglers could be sent through these channels.

- Collection of egg case data via trawl surveys and commercial trawlers: This will help us to understand the egg laying nature of common skate and if females do congregate in a common hatchery, where these areas are.

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