Prifysgol Abertawe
Swansea University

Coleg Gwyddoniaeth
College of Science

Department of Biosciences

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Bottlenose dolphin (*Tursiops truncatus*) abundance in Cardigan Bay, Wales, in relation to shellfish factory discards

Jodie Denton

551406

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Research Report

CONTENTS

ABSTRACT

The aim of the project was to investigate what impact whelk shell discards from the Quay Fresh and Frozen Foods Ltd factory, had on the abundance of bottlenose dolphins (*Tursiops truncatus*) in New Quay, Wales. The hypothesis was that there was a positive relationship between bottlenose dolphin abundance and the whelk shell discards from the factory. Whelk shell discards would attract prey species to the area, which in turn would attract bottlenose dolphins. This was tested by conducting two land-based surveys: one from the New Quay harbour wall for 5 months, and one from the shellfish factory for 5 weeks. A positive relationship was found between bottlenose dolphin numbers and the discards from the factory. A higher abundance of bottlenose dolphins was also found when the factory had been open for a prolonged period of time. This supported the initial hypothesis of the project as more bottlenose dolphins were found on days when the factory was open compared to days when the factory was closed. However more abundance data is needed from the shellfish factory to more accurately assess the relationship between bottlenose dolphin numbers and whelk shell discards. There also needs to be more abundance data when the factory has been closed for longer periods of time so a more accurate comparison can be made between the abundance of bottlenose dolphins seen when the factory is open and closed. This would show if the factory truly does cause an increase in bottlenose dolphin abundance in New Quay.

INTRODUCTION

Bottlenose dolphins (*Tursiops truncatus*) have a worldwide distribution in tropical and temperate seas in both hemispheres, and occupy a wide variety of marine habitats including deep oceans, shallow coastal regions, inshore lagoons and estuaries (Leatherwood & Reeves, 1990; Berrow *et al*., 1996; Gnone *et al*., 2011). They usually favour headlands, estuaries and sandbanks due to the uneven seabeds, strong tidal currents and an abundance of benthic and demersal fish (Evans *et al*., 2000; Evans *et al*., 2003; Gnone *et al.,* 2005). In Europe they are commonly found near shore, off the coasts of Spain, Portugal, West Ireland, North-East Scotland, North-West France, and in the Irish Sea and English Channel (Evans *et* al., 2000; Evans *et al*., 2003).

Cardigan Bay is one of two sites in the United Kingdom to have resident populations of bottlenose dolphins throughout the whole year, the other site being the Moray Firth in North East Scotland. Bottlenose dolphin abundance is relatively low around the UK coast; Cardigan Bay supports greater numbers than any other region (Pierpoint *et al*., 2009).

Cardigan Bay is the largest bay in the British Isles with a shallow basin (20m-40m depth) which contains a mixture of sediments from gravel and cobbles offshore, to fine sand and silt near shore with patches of cobble and boulders appearing all along the coast (Evans *et al*., 2000; Gregory & Rowden, 2001). It covers an area of around 5500km² (Gregory & Rowden, 2001) and opens up to the Irish Sea. The tides are semi-diurnal and the tidal range is fairly uniform (Gregory & Rowden, 2001). The site of the project is in New Quay, a small tourist town along the coast of Cardigan Bay. It is a semi enclosed bay with a depth range of around 1-12m (Gregory & Rowden, 2001). New Quay is known to support a regular concentration of semi – resident bottlenose dolphins; and has previously been identified as a nursery area for bottlenose dolphins due to the high proportion of mother and calf pairs (Bristow *et al*., 2001; Simon *et al.,* 2010).

Bottlenose dolphins in Cardigan Bay are protected by appendix II of the EU Habitats Directive 1992, which prohibits the deliberate capture, killing or disturbance of bottlenose dolphins, and bans the keeping, sale or exchange of the species (Evans *et al*., 2003; Bristow *et al*., 2001; Lyons *et al*., 2006; Simon *et al*., 2010). In 1996, around 1000km² of Cardigan Bay was designated as a candidate SAC (Special Area of Conservation) under the European Union "Habitat Directive". It was implemented mainly for the protection of bottlenose dolphins in Cardigan Bay (Pierpoint *et al*., 2009; Simon *et al*., 2010. In 2004 the area was formally designated as a SAC (Simon *et al*., 2010).

The Cardigan Bay Forum was established in 1991 with the intention of allowing organisations to exchange and develop information about bottlenose dolphins and other animals (Scott, 1997). This has resulted in the increase of sustainable initiatives and new research programmes (Scott, 1997).

Bottlenose dolphins are attracted to Cardigan Bay for a variety of reasons, including the rich and abundant marine fauna. They are known to eat a wide variety of benthic and pelagic fish, cephalopods and shellfish (Evans *et al.,* 2000). Some of which are attracted by the high abundance of invertebrates in Cardigan Bay, with polychaetes being the most abundant, followed by crustaceans and molluscs (Evans *et al*., 2000).

The availability and abundance of suitable prey species is an important factor in the distribution of bottlenose dolphins (Evans *et al.,* 2000). Prey of bottlenose dolphins in Cardigan Bay includes: flatfish (Pleuronectidae), dragonet (*Callionymus spp*.), sand eel (Ammodytidae), pollock (*Pollachius polachius*), wrasse (Labridae) and blennies (Blenniidae) (Evans *et al*., 2000; Dunn & Pawson, 2002; Pierpoint *et al*., 2009). Harbours and bays such as the one in New Quay attract mullet (Mullidae), white salmonids and pelagic shoaling species such as mackerel (*Scomber scombrus*) and bass (*Dicentrarchus labrax*) which are most widespread in the summer and are known to be eaten by bottlenose dolphins in the area (Evans *et al*., 2002; Pierpoint *et al*., 2009).

A shellfish processing factory is located at the edge of the New Quay headland. This factory removes the shells from shellfish so that the meat can be used in food products. The main shellfish that is processed is the common whelk, *Buccinum undatum*. The factory is locally licensed to dispose of the shell discharge using a chute from the factory that deposits the shells onto the rocky ledges and sea below. In 1997 and 1999, around 1000 tonnes of shells were discarded by the factory (Bristow *et al*., 2001). This increased in 2000 with over 1000 tonnes of shell discarded between February and July of 2000 (Bristow *et al*., 2001). This has altered the sea bed characteristics of the area including the formation of a beach that consists entirely of whelk shells.

The aim of the project is to find out how the whelk discards from the shellfish factory affects the abundance of bottlenose dolphins in New Quay. The hypothesis is that whelk shell discards attract bottlenose dolphins to the area. The processing of whelk shells could potentially not remove all of the whelk meat from the shells, which in turn would attract smaller bait fish to the local area. This in turn could attract cetaceans to the area due to the increase in prey abundance. Hastie *et al*., (2004) found that bottlenose dolphin distribution was also linked to foraging behaviour, so were likely to spend more time in areas where more food is available. Therefore it is expected that if the bottlenose dolphins are attracted to the factory, they are likely to spend the majority of their time foraging in the area.

To date, no studies have investigated the effect of shellfish discards on bottlenose dolphin abundance, although the factory is mentioned by Bristow *et al*., (2001). They found that there was a negative relationship between the average group size of bottlenose dolphins and the increasing shell waste from the factory discharge, possibly due to the increase in shell discharge changing the composition of the local seabed.

The effects of fish farming on bottlenose dolphins on the North Eastern coast of Sardinia, Italy, have been studied previously by Diaz Lopez and Shirai (2007). Coastal marine fish farms attract large numbers of species including bottlenose dolphins (Beveridge, 1996; Diaz Lopez & Shirai, 2007). The fish farms in these studies are floating marine fin-fish farms. Bottlenose dolphins were present close to the fish farms all year round with peaks during the winter period (Diaz Lopez & Shirai, 2007). Floating fish farms also attracted other wild fish, increasing the prey availability for bottlenose dolphins in the area and decreasing the time spent by the dolphins looking for prey (Diaz Lopez, 2005, 2006; Diaz Lopez *et al*., 2008). This shows that the presence of the fish farms increased the abundance of dolphins that use the area. Diaz Lopez and Shirai (2008) also found the group sizes of bottlenose dolphins to decrease when the availability of prey is high. This is because the benefits from co-operation between bottlenose dolphins decrease when it is easier to catch prey, whilst the costs of co-operation could increase due to an increased chance of competition (Diaz Lopez & Shirai, 2008). Hunting techniques, rather than group size becomes important when such techniques are able to concentrate the target species (Diaz Lopez, 2009). This could explain the small group sizes of bottlenose dolphins found in Cardigan Bay. Diaz Lopez *et al.*, (2005) also noted a change in the temporal and spatial distribution of bottlenose dolphins which was caused by the presence of the fish farms.

There are two main methods for assessing the abundance of cetaceans in the sea: the mark-recapture method and land-based observation surveys (Dawson *et al.*, 2008; Sutaria & Marsh, 2011). For this project the land-based observation method was used, because it is useful in recording habitat use and temporal variation in occurrence at different habitats (Pierpoint *et al*., 2009). The method is also less likely to affect cetacean abundance as the requirement of a boat is not necessary, causing less stress on the cetacean and making the data collection relatively cheap (Pierpoint *et al.,* 2009).

The overall population of bottlenose dolphins in Cardigan Bay is unknown but studies indicate the resident population to be around 213 (Evans *et al*., 2000; Evans *et al*., 2002), although numbers fluctuate due to seasonal migrations of dolphins (Evans *et al*., 2000; Evans *et al*., 2003). Within the Cardigan Bay SAC area the mean population was estimated around 121 to 210 bottlenose dolphins between 2001 - 2007 (Evans *et al*., 2002; Pesante *et al*., 2008a, b), with the population either stable or increasing slightly since 2001 (Pesante *et al*., 2008a, b). This could be due to factors such as a change in prey availability or pressure from boat traffic (Pierpoint *et al*., 2009). Bottlenose dolphin abundance in the local area of New Quay has declined since the mid to late 1990's, however it is unknown whether this is due to changes in distribution or changes in abundance (Pierpoint *et al.,* 2009).

Pierpoint *et al*., (2009) showed that bottlenose dolphins in New Quay tend to use flatter areas of the sea bed, in waters less than 5m deep inshore and 5-10m deep in the outer bay between the harbour mouth, New Quay headland and Llanina Reef. The most predominant behaviour recorded was for dolphins to be found diving repeatedly in the same location (Pierpoint *et al*., 2009), most likely foraging. High proportions of dolphins were spotted individually rather than in a group, possibly due to the low risk of predation leading to cooperative foraging being unfavourable inshore (Pierpoint *et al*., 2009). Small groups of bottlenose dolphins tend to hunt for individual prey close to shore, whereas larger groups of bottlenose dolphins tend to hunt for shoals of fish in deeper waters (Wells *et al.,* 1980; Scott & Chivers, 1990). The largest groups of bottlenose dolphins recorded at New Quay were 18 in May 1999 (Bristow *et al*., 2001).

The rates of bottlenose dolphin sightings increased during the summer months with peaks between July and August (92% of sightings occurred between April and November with 48% of sightings occurring between June and August) (Evans *et al*., 2003; Simon *et al*., 2010). The lowest numbers of sightings are between October and April (Evans *et al*., 2003) with March having the lowest sightings rate and July having the highest sightings rate (Bristow & Rees, 2001). In New Quay, bottlenose dolphins were present 60% of the time in the summer of 2007 with them residing in the same habitat for up to 34% of the time (Pierpoint *et al*., 2009). This indicates a seasonal change in the bottlenose dolphin population as they use the inshore waters during the summer but they are relatively uncommon in the winter (Bristow, 2004; Pesante *et al*., 2008a).

Seasonal fluctuations of bottlenose dolphins have also been seen at other sites such as the Moray Firth in Scotland, where bottlenose dolphins were seen all months of the year, with higher numbers seen in summer and autumn and lower numbers seen in winter and spring (Wilson *et al.,* 1997). Atlantic bottlenose dolphins were also found concentrated in different areas near Sarasota in Florida depending on the season, probably in response to the changes in distribution of their prey (Irvine *et al*., 1981).

A topic that has received attention in the published literature is the effects of boat traffic on the bottlenose dolphin population. New Quay has the highest levels of boat traffic in Cardigan Bay (Pierpoint *et al.,* 2009) due to the importance of tourism in the area, especially in the summer. Pierpoint *et al.,* (2009) found that the sightings rates of bottlenose dolphins were significantly lower when there were more boats present; an example of this is that in 2007, due to bad weather conditions the number of boats in the sea decreased, and the number of female dolphins with calves increased. Lamb (2004) also found that bottlenose dolphin occurrence was higher at night than during the day in New Quay; and acoustic detection rates of bottlenose dolphins was inversely related to the number of boats present. Studies from other locations such as the coast of the Mediterranean Sea have also recorded a low abundance of bottlenose dolphins in areas of high human presence (Gnone *et al*., 2011).

In contrast, Gregory and Rowden (2001) found that generally bottlenose dolphins displayed a neutral response to the presence of boats in Cardigan Bay. They showed no apparent change in the directional movement prior to and after the presence of a boat, as they had habituated to the presence of the boats. They did find that bottlenose dolphins displayed a negative response to kayaks, which could be due to the "startle" response as kayaks do not have an engine and so are quiet when they approach.

A code of conduct was developed in Cardigan Bay to decrease the disturbance caused by boat traffic to bottlenose dolphins and other marine mammals in the area. The rules of the code of conduct state that recreational and commercial boat users: must not travel directly towards or approach dolphins, seals or porpoises within 100m; should not change speed or course in an erratic manner; must not feed, touch or swim towards the animals; must not discard litter and fishing tackle into the sea; and avoid unnecessary noise around the animals (http://www.cardiganbaysac.org.uk/?s=code+of+conduct&submit.x=0&submit.y=0). These rules are monitored by the Ceredigion District Council using shore based observers (Pierpoint *et al.,* 2009); however there is no organisation in New Quay to enforce these rules constantly.

Collecting abundance data is very important as it is the scientific basis of conservation planning and finding out the conservation status of a species (Dawson *et al.*, 2008; Sutaria & Marsh, 2011). Abundance data for cetaceans living in coastal environments is especially needed as coasts and rivers suffer from anthropogenic activities more than any other marine mammal habitat (Dawson *et al*., 2008). Aquaculture (both finfish and shellfish) is one of the fastest growing industries in the world food economy, growing by 11% from 1995-2005 (Newton, 2000; Diaz Lopez, 2005), increasing the need for knowledge on how these factories affect the environment around them. Aquaculture can also affect the marine ecosystem by changing the food webs and their potential productivity (Diaz Lopez *et al.,* 2008). It is therefore important to find out how the discard of whelk shells is affecting the fauna in the New Quay area, and how it may affect the bottlenose dolphin population if the factory were to ever stop discarding whelk shells into the sea.

METHOD

Data Collection

Land based data was collected from the harbour wall in New Quay from 11th April 2011 to 16th September 2011. The New Quay harbour wall is an embankment that is adjacent to the headland, with an observer height of 8m and a surveying area of 4.9km² (Pierpoint *et al*., 2009). Data were collected by volunteers from the Cardigan Bay Marine Wildlife Centre for 8hr each day from 9:00am to 5:00pm. Volunteers took it in turns to survey the area using the naked eye and low powered binoculars, each doing a 2hr survey. Volunteers from the Cardigan Bay Marine Wildlife Centre have been used to collect data on cetacean distribution and abundance previously to research their reaction to boat traffic (Pierpoint *et al.*, 2009). Training was given to all volunteers at the centre on how to fill out the data sheets and maps; and how spot the cetaceans in the bay. The same training was given to all volunteers at the centre so that the same method of collecting data was used to reduce bias in the results.

Each 2hr survey was split into 15min intervals during which the time, date, weather conditions, wind direction and sea state were recorded. When a cetacean or group of cetaceans were spotted, their position was noted down on a map of the survey area. The map (Figure 1) included some features of the survey area, making it easier to plot the position of the cetaceans on the map. A map was provided for each 15min interval and any cetaceans found in the survey area were plotted on the map either at the beginning of each interval or when the cetacean was first seen.

In addition to cetacean location, their behaviour was also recorded on the map using an activity code. Activities were either split into S-coded behaviours (where the cetacean or group of cetaceans are staying in or around the same position) or T-coded behaviours (where the cetacean or group of cetaceans are found to be travelling). S1, S2, S3, T1 and T2 were considered slow behaviours, whilst S4, S5, S6 and T3 were considered fast behaviours. Table 1 contains the details on the codes used to describe each behaviour.

Land based surveys were also conducted at the Quay Fresh and Frozen Foods Ltd. factory for 5 weeks from the 13th August to 16th September, from 5:00am to 9:00am each morning. These surveys were taken so that the number of cetaceans seen before and during the factory discarding times could be compared. It also meant that the exact time that the factory started depositing could be noted down as the chute used to discard the whelk shells was next to the surveying site. A different map was made for this location (Figure 2), however the method of writing down cetacean sightings and plotting them on the map remained the same and the same data sheet was used for both locations.

Table 1: List of cetacean behaviours and their activity codes

Activity Code	Behaviour
S1	Staying in same area - motionless on surface of water
S2	Staying in same area - mingling at surface or slow circling
S3	Staying in same area - long dives, most likely foraging
S4	Staying in same area - chasing prey at surface with fish seen
S5	Staying in same area - playing or tossing objects e.g. jellyfish or seaweed
S6	Staying in same area - fast circling at surface, tail slaps, leaps or lunges
T1	Travelling - regular surfacing with all cetaceans making determined progress in the same direction
T2	Travelling - long dives with cetaceans surfacing at irregular intervals, searching for prey on the move
T3	Travelling - rapid progress with forward leaps or splashy surfacing

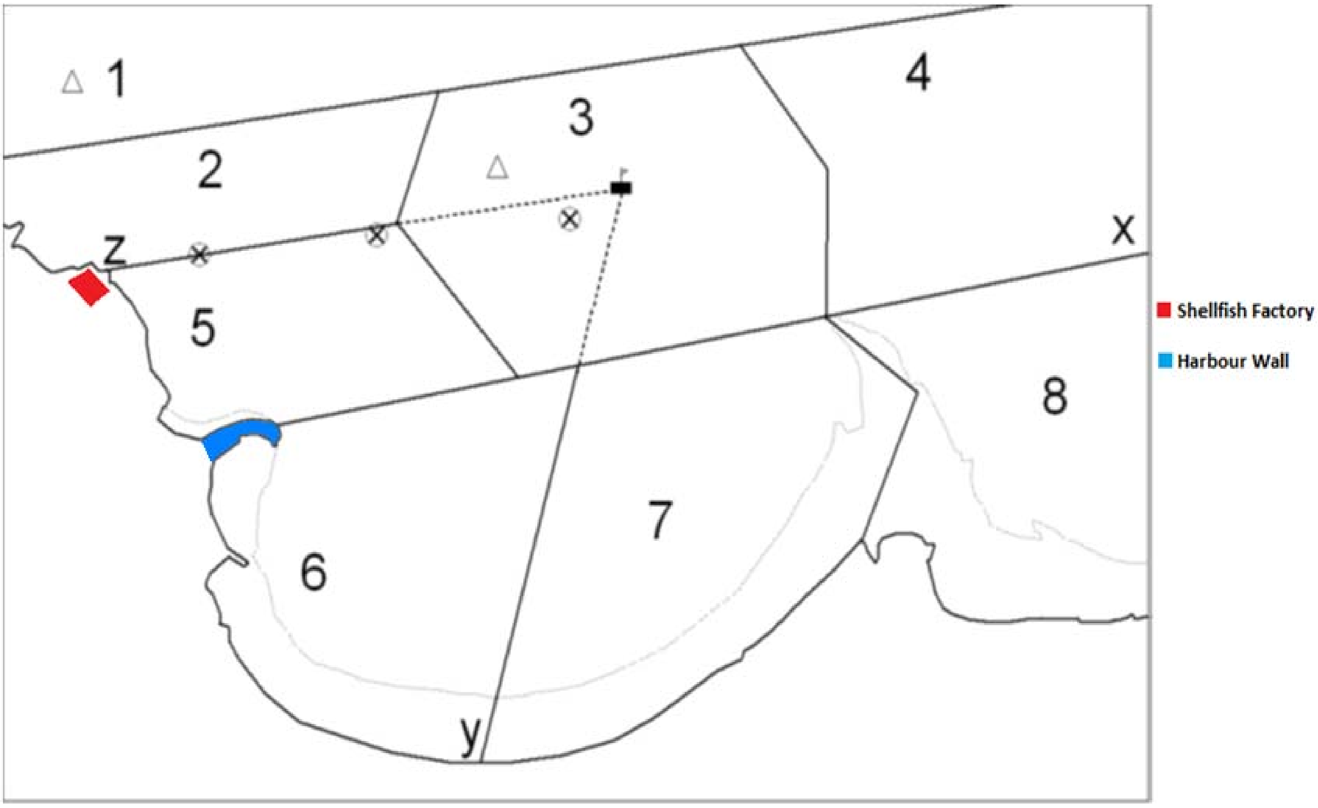

Figure 1: Map of survey area from the New Quay harbour wall. The black rectangle in zone 3 represents the black and yellow cardinal buoy which is around 900m from the harbour wall. The distance from the harbour wall to the shellfish factory is around 500m, and from the cardinal buoy to the shellfish factory is around 900m.

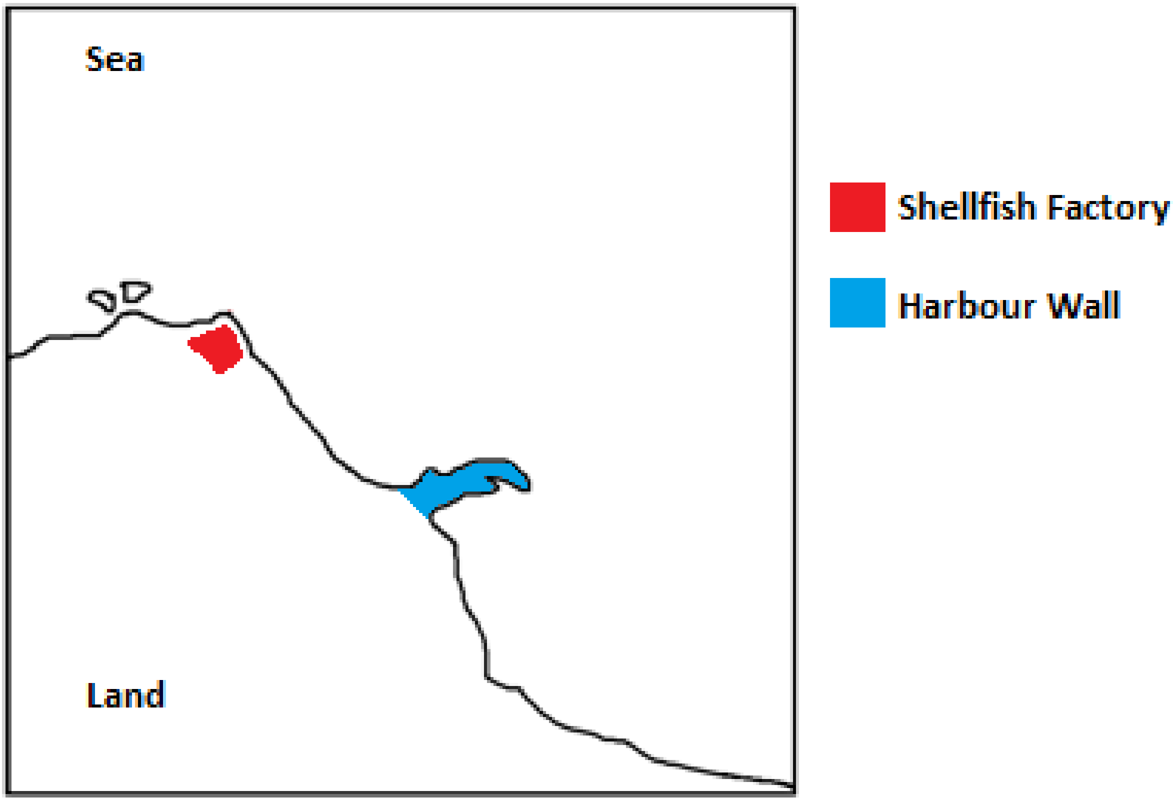

Figure 2: Map used for land – based observations taken from the Quay Fresh and Frozen Foods Ltd. The positions of the harbour wall and factory are shown colour coded on the map.

Data Analysis

Data were analysed using SPSS and graphs were constructed using Microsoft Excel. One sample Kolmogorov – Smirnov test showed the distribution of the harbour wall data was significantly different from normal ($p < 0.05$). This meant a Mann – Whitney U test was used to compare the median number of bottlenose dolphins seen on days when the factory was open, and days when the factory was closed. A Kruskal – Wallis test was then used to compare the median number of bottlenose dolphins seen when the factory was closed and each consecutive day when the factory is open. One-way ANOVA (analysis of variance) was then used to compare the mean bottlenose dolphin numbers found in three different weeks of the surveying period; each week with a varying amount of factory activity. The week between the 4th and 10th September had a low factory activity week with only two days when the factory was open; the week between the 9th and 15th May had a medium factory activity week with four days when the factory was open; and the week between 27th June and 3rd July had a high factory activity week with the factory open all week. One-way ANOVA was used because a Kolmogorov – Smirnov test showed the mean distribution of data was not significantly different from a normal distribution ($p > 0.05$).

The Kolmogorov – Smirnov test also showed the data from the shellfish factory to be normally distributed ($p > 0.05$). Two paired T-tests were undertaken with the data to compare the number of dolphins seen before the factory started discarding whelk shells and during the discarding of whelk shells. One paired T-test was taken with data from days when the factory was discarding and a second paired T-test was taken with data from days when the factory was not discarding to see if there was a statistical difference between the two.

RESULTS

Figure 3 records the position of bottlenose dolphins between 9:00am and 5:00pm everyday from the 11^{th} April 2011 to the 16^{th} September 2011. Figure 4 records the position of bottlenose dolphins between 5:00am and 9:00am everyday from 14^{th} August 2011 to the 16^{th} September 2011. Both figures show bottlenose dolphins are not randomly distributed with most dolphins seen around the shellfish factory, harbour wall and Llanina reef.

A Kolmogorov – Smirnov (K-S) test showed the land survey data from the harbour wall was significantly different from a normal distribution ($p < 0.05$). Therefore a Mann Whitney U test was employed to compare the bottlenose dolphin abundances between days of shellfish factory activity and inactivity. The Mann – Whitney U test showed a significant difference between the number of bottlenose dolphins seen on days when the factory was discarding whelk shells and days when the factory was closed ($U = 2318$, $p < 0.05$, $N = 159$). Therefore the null hypothesis that the abundance of bottlenose dolphins seen on days when the factory was open and closed had the same median value is rejected. This supported the hypothesis that the factory has a positive effect on bottlenose dolphin abundance in the area. Figure 5 supported this data as more bottlenose dolphins were seen when the factory had periods of high factory activity.

Kruskal – Wallis test showed no significant difference between the abundance of bottlenose dolphins seen when the factory was closed, and the abundance of bottlenose dolphins seen the first day the factory was open, up to the seventh day the factory was open ($N =137$, $p > 0.05$, $df = 7$). Therefore the null hypothesis that the abundance of bottlenose dolphins seen when the factory was closed and when the factory was open for consecutive days had the same median value is accepted. This does not support the hypothesis that the factory has a positive effect on bottlenose dolphin abundance in the area.

To investigate this further, a three week subsample of data taken from the harbour wall were compared using one-way ANOVA to find out if there was a difference in the abundance of bottlenose dolphins seen in these different weeks (figures 6a-c). One – way ANOVA was used as a Kolmogorov – Smirnov test proved the data to be normally distributed ($p > 0.05$). One-way ANOVA showed a significant difference between the abundance of bottlenose dolphins seen each week ($F = 34.323$, $p < 0.05$, $df = 2$). Therefore the null hypothesis that the abundance of bottlenose dolphins seen in the three different weeks of varying factory activity had the same mean value is rejected. This shows that the factory had more influence on the abundance of bottlenose dolphins when the factory had been open over a longer period of time which supported the hypothesis.

The immediate effect of the whelk discards on bottlenose dolphin abundance was then tested by comparing the number of bottlenose dolphins seen before and during whelk discarding times, on days when the factory was open and closed. Figure 7 shows more bottlenose dolphins were found after the factory had opened and when the factory had been open for a longer period of time. Kolmogorov – Smirnov test showed the data to be normally distributed ($p > 0.05$). Therefore paired T-tests were used which showed no significant difference between the abundance of bottlenose dolphins seen before and after 6:30am (the time when the factory usually began discarding the whelk shells) on days when the factory was closed ($T = -2.094$, $p > 0.05$, $df = 13$). Therefore the null hypothesis that the abundance of dolphins seen before and after 6:30am on days when the factory was closed came from the same data set is accepted. However the paired T – test showed a significant difference between the abundance bottlenose dolphins found before and after 6:30am on days when the factory was open ($T = -3.547$, $p < 0.05$, $df = 14$). Therefore the null hypothesis that the abundance of bottlenose dolphins seen before and after 6:30am on days when the factory was open came from the same data set is rejected. This supported the hypothesis that the factory had a positive effect on the number of bottlenose dolphins in the New Quay area, as more dolphins were seen after 6:30am on days when the factory was open and had began to discard the whelk shells into the sea.

During the analysis of the data from the shellfish factory, five days (27th and 28th August and 5th, 6th and 7th September) were removed from the data set during statistical analysis. This was due to the bad weather conditions on these days making it too hard to locate bottlenose dolphins accurately, which would have caused anomalies within the results.

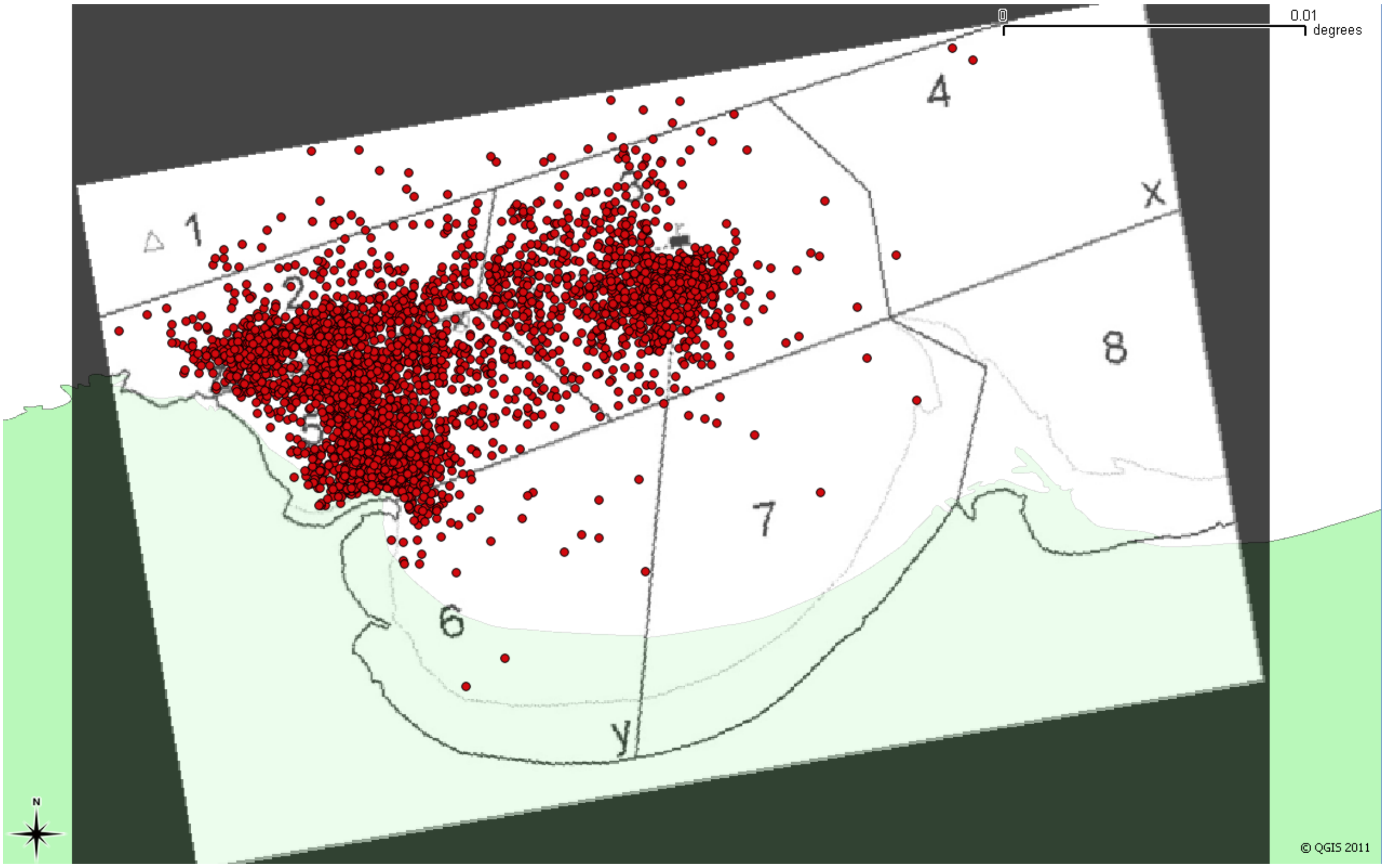

Figure 3: Map of New Quay bay with the position of every bottlenose dolphin seen from New Quay harbour wall between 11th April – 16th September 2011. The red circles indicate the presence of a single bottlenose dolphin or a group of bottlenose dolphins.

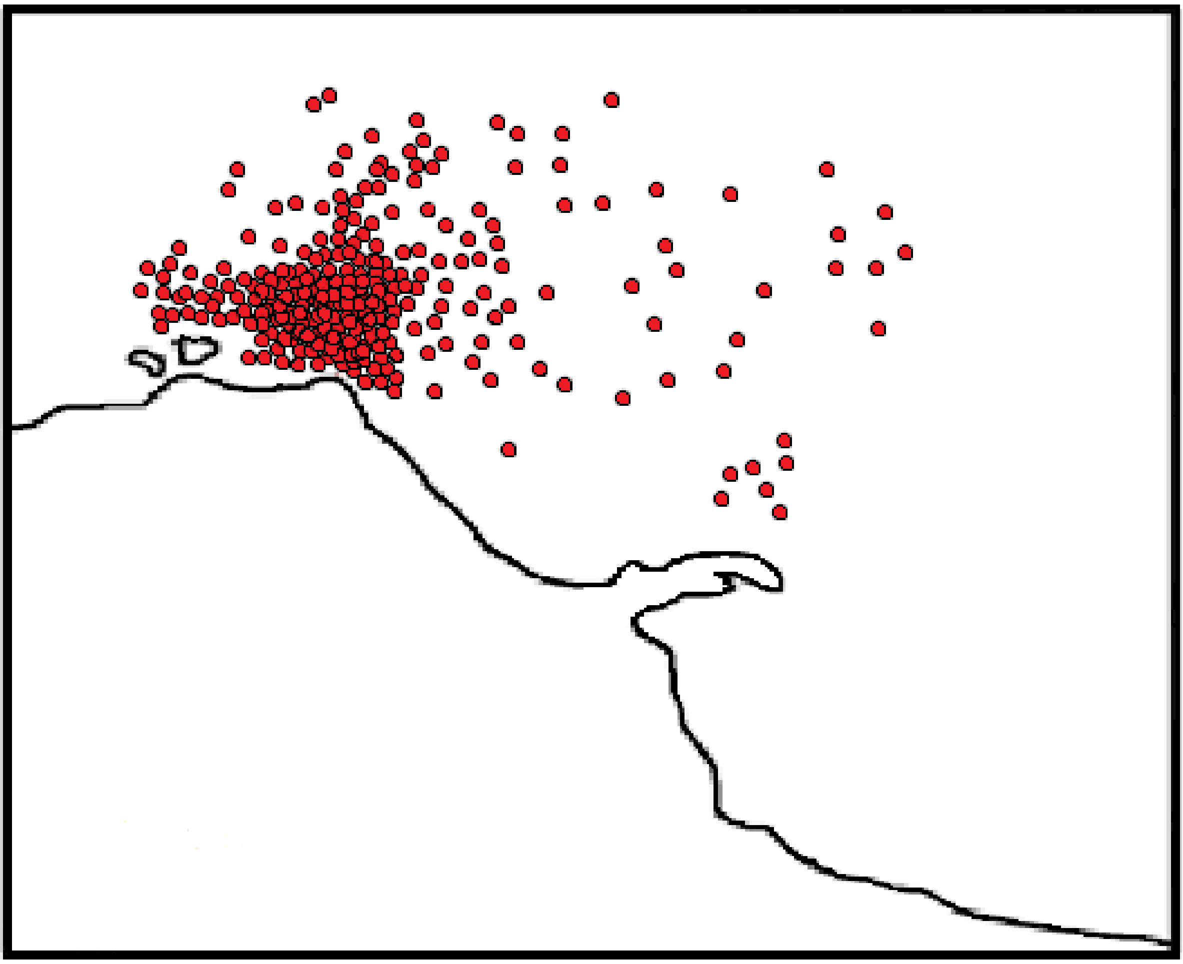

Figure 4: Map of New Quay bay with the position of every bottlenose dolphin seen from the shellfish factory between the 14th August-16th September 2011. The red circles indicate the presence of a single bottlenose dolphin or a group of bottlenose dolphins.

Figure 5: The abundance of bottlenose dolphins seen each day relative to the days when the factory is discarding whelk shells, from 9:00am to 5:00pm.

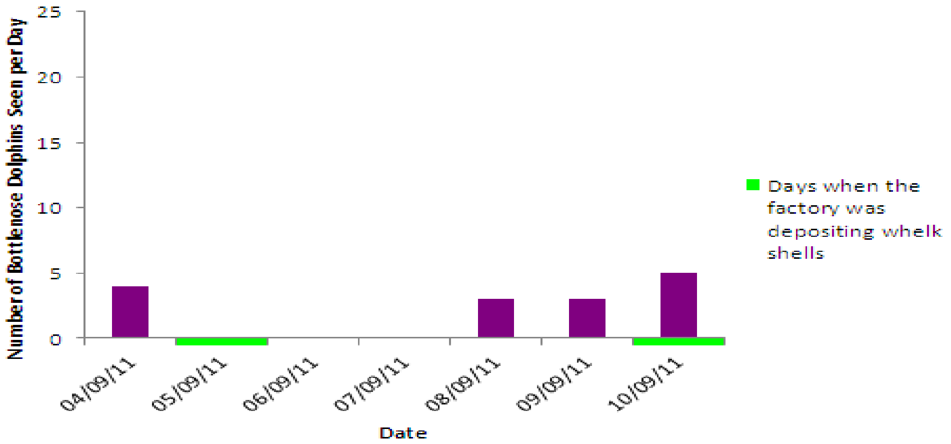

Figure 6a: Abundance of bottlenose dolphins seen each day in relation to a week of low factory activity

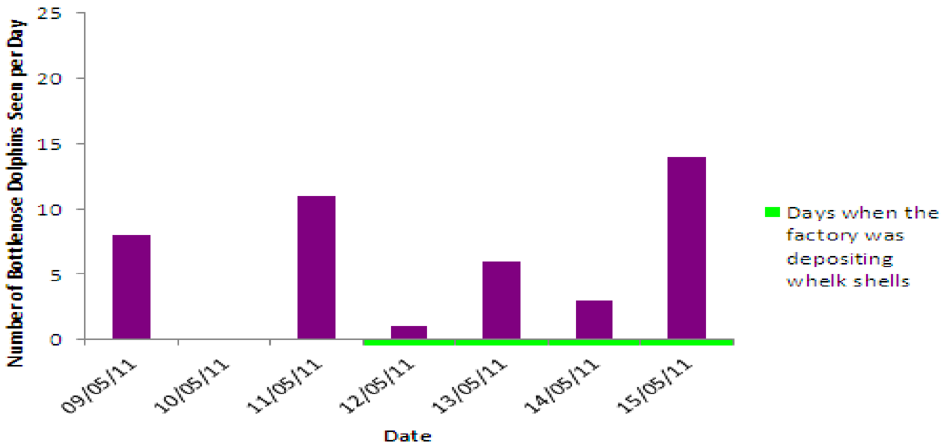

Figure 6b: Abundance of bottlenose dolphins seen each day in relation to a week of medium factory activity

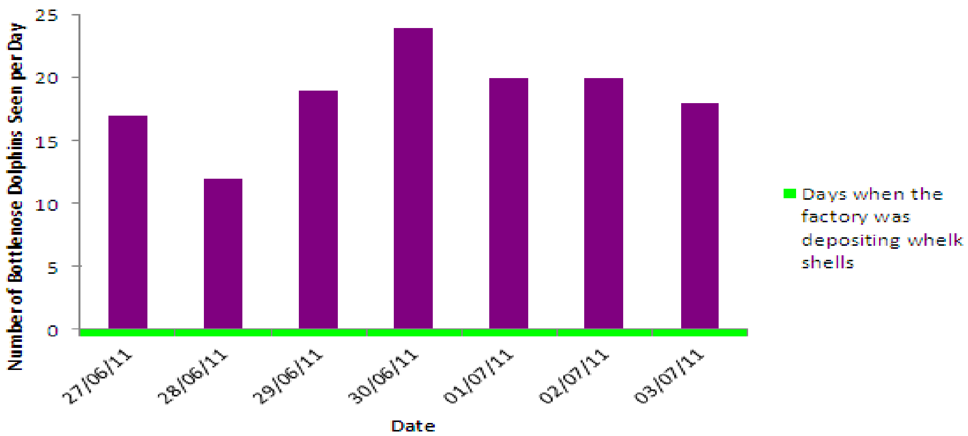

Figure 6c: Abundance of bottlenose dolphins seen each day in relation to a week of high factory activity

Figure 6a – c: Abundance of bottlenose dolphins seen in three different weeks in relation to different levels of factory activity.

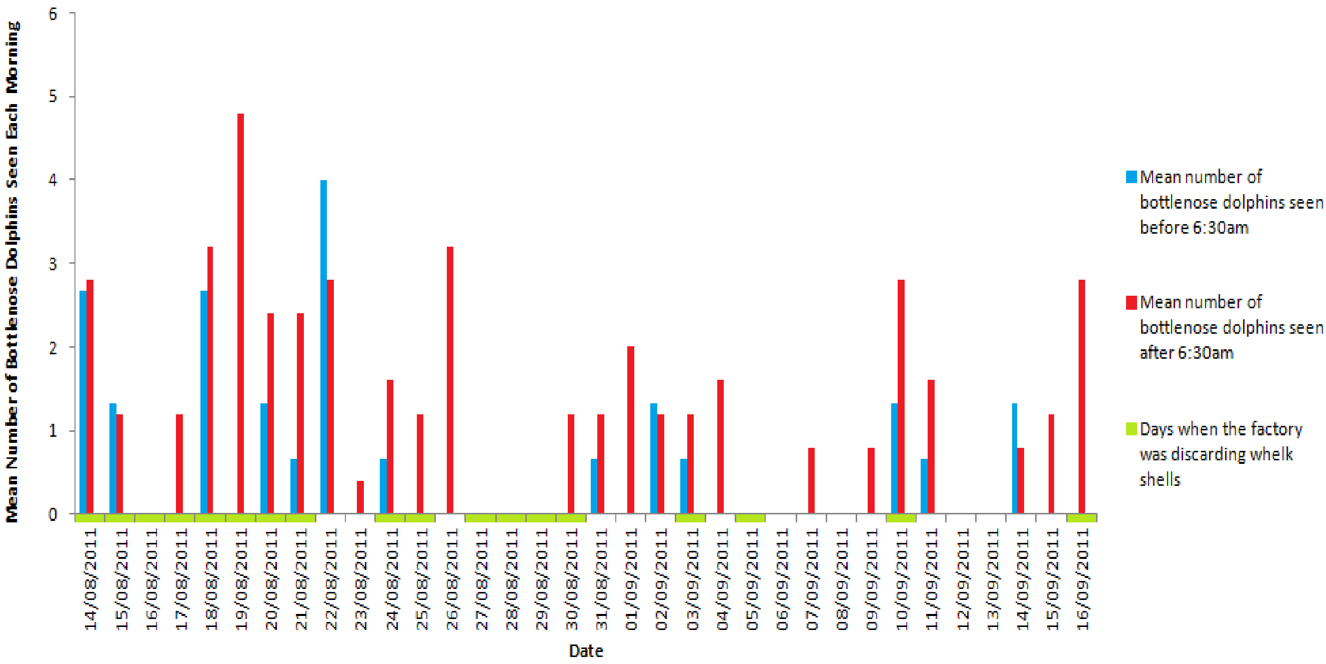

Figure 7: Abundance of bottlenose dolphins seen each day, relative to the days when the factory is discarding whelk shells; and the comparison between the mean abundance of bottlenose dolphins seen before and after 6:30am when the factory began to deposit the whelk shells.

DISCUSSION

The results supported the initial hypothesis that the shellfish factory had a positive influence on bottlenose dolphin abundance in New Quay. Figure 5 shows a higher abundance of bottlenose dolphins seen on days when the factory was open and discarding whelk shells, than on days when the factory was closed. The statistical analysis supported figure 5, however the significant difference between the abundance of dolphins seen on days when the factory was open and closed was small as the p value was close to 0.05. Therefore the difference in number of bottlenose dolphins seen when the factory was active and inactive was small. For more accurate data, a larger data set would be needed. If the project was extended over a few years it would then show if the factory has a constant influence on bottlenose dolphin abundance.

Figure 6a-c show a larger abundance of bottlenose dolphins in the New Quay area when the shellfish factory had been open for a longer period of time. The statistical analysis also showed a larger significant difference between the number of bottlenose dolphins seen between three weeks of varying factory activity levels, compared to the significant difference seen between the number of bottlenose dolphins found on days when the factory was opened and closed. This showed that more bottlenose dolphins were attracted to the area when the factory was open more frequently. This could be because the longer the factory was open, a greater amount of discarded whelk shells built up, which in turn attracted more fish into the area. Greater abundance of prey fish would, in theory, attract more bottlenose dolphins and other marine mammals into the area. Therefore the shellfish factory would have to be closed for a longer period of time in order for the whelk meat to be used up and no longer attract fauna to the area.

It was expected that the longer the factory was open, the more bottlenose dolphins would be found. This was not supported by comparing the abundance of bottlenose dolphins each day the factory was continuously open and days when the factory was closed, as there was no statistical difference seen in the numbers of bottlenose dolphins seen each day. However there was not enough data to fully prove or disprove this, as the factory was usually only open for four days at a time before it was closed again. Therefore there was not enough data for an accurate mean abundance of bottlenose dolphins to be calculated after the factory had been open more than four days. The observation period of the bottlenose dolphins would have to be extended over a longer period of time in order to obtain enough data. The factory would also have to be closed for a longer period of time to produce an accurate control to compare the results with.

The bottlenose dolphins in New Quay may have also experienced a change in behaviour. If the dolphins were used to travelling to the factory for food, then they would still travel to the area to forage even on the days when the factory was closed, as fish stocks may still be in the area. Whelk shells were still present in the sea due to the previous days of the factory being open, causing their presence to still affect the fauna in the area whether the factory was open or not. This could explain the high abundances of bottlenose dolphins found on days of no factory activity.

Diaz Lopez and Shirai (2008) discovered that feeding opportunities created by humans, such as the discarding of fish into the sea, had become part of the bottlenose dolphins habitat requirements in the Mediterranean. The study showed that human activities influenced the distribution of food resources and so had changed the behaviour of bottlenose dolphins in the area (Diaz Lopez & Shirai, 2008). These behavioural changes may have occurred in New Quay with some bottlenose dolphins relying on the shellfish factory to attract fish stocks to the area, therefore altering their foraging behaviour in response to plentiful food abundance. Bottlenose dolphins have a preference for opportunistic feeding, which causes a reduction in the numbers of bottlenose dolphins found in a group. This could have caused the decrease in bottlenose dolphin group number mentioned in papers by Pierpoint *et al.,* (2009) and Bristow *et al.,* (2001).

Whilst collecting data, it was found that foraging seemed to be the most used behaviour by bottlenose dolphins. This suggested that bottlenose dolphins used the area predominately for feeding, indicating that the dolphins were attracted to the area by the abundant prey species found around the shellfish factory. It confirms the findings by Hastie *et al*., (2004) that dolphin distribution is linked to foraging behaviour. It also supports Pierpoint e*t al.,* (2009) findings that bottlenose dolphins were mostly recorded foraging between the harbour wall and Llanina reef.

Figures 3 and 4 demonstrate that bottlenose dolphins were not randomly distributed because they were mostly seen clustered around the harbour wall, and in close proximity to the shellfish factory. This is another indication that the shellfish factory does have an impact on bottlenose dolphin abundance and distribution in the area. It also supports Pierpoint e*t al*., (2009) findings that bottlenose dolphins were mostly found in the area between the harbour mouth, New Quay headland and Llanina Reef. Figure 3 shows clusters of bottlenose dolphins found around the cardinal buoy which indicates the edge of Llanina reef. This could be due to the difference in topography and sea depth which has been shown to attract fish and therefore dolphins to the area (Gregory & Rowden 2001). Bottlenose dolphins in the Moray Firth showed a preference for several areas where the topography has sudden changes in depth as there is a higher abundance of migratory fish in the area, increasing the foraging opportunities (Wilson *et al.*, 1997; Hastie *et al*., 2004).

Figure 7 demonstrates a bigger difference in the abundance of bottlenose dolphins seen before and after 6:30am when the factory was open, compared to when the factory was closed. The statistics show that more bottlenose dolphins are seen after 6:30am on days when the factory was open. This proves that there is a positive relationship between the abundance of bottlenose dolphins and the timing of whelk discards from the shellfish factory. However the amount of light available before 6:30am limited the ability to locate bottlenose dolphins, especially as it was still dark later in the morning towards the middle of September. This resulted in fewer data being collected and so could be a reason why there was significantly less dolphins seen before 6:30am.

The results of the project may have been affected by the limitations of the method. For example most of the time there was only one person conducting each land survey, which increased the difficulty of tracking the positions of the dolphins when there was more than one group present in the survey area. By having at least two people survey the area it would increase the accuracy of the data collected.

It was not possible for an individual recorder to see the whole of the survey area from the shellfish factory, as part of the sea was covered by protruding rocks. Having another person collecting data from the other side of the headland would increase the survey area and produce more accurate data. However communication between the surveyors would be needed so that the same dolphin or groups of dolphins were not counted more than once.

The use of volunteers to collect the data may have also altered the reliability of the data. Even though all the volunteers were trained the same, there would still have been variation in detection skill of each volunteer. Pierpoint *et al.,* (2009) mentioned that variation in detection skill may introduce bias in the comparisons of sightings between sites and time.

Pierpoint *et al*., (2009) also noted that results from shore based observations were limited by the height of observation position and the available field of view. This could be why dolphins were not seen in areas further out in the survey map, as the harbour wall was only around 8m above sea level limiting the field of range seen by the naked eye and binoculars. The number of bottlenose dolphins might have been low in section one of the survey map (Figure 3), because the New Quay headland blocked the view of the sea on the left side of the factory from the harbour wall.

The majority of the data from the harbour wall was provided by the Cardigan Bay Marine Wildlife Centre. Therefore some of the data might have been unreliable as the weather conditions and sea state were not recorded during the transfer of information. This could influence the results because when the weather is rough and there is a sea state of 4 or over, it becomes increasingly difficult to locate bottlenose dolphins in the sea (Sutaria & Marsh, 2011) as the shadows from the waves can be mistaken for the back of a dolphin; and the lack of sunlight makes surveying difficult.

It was also hard to distinguish different groups of bottlenose dolphins at times because dolphins can continuously travel around the survey area with groups splitting and joining other groups. This made it difficult to keep track of the total number of bottlenose dolphins in the area. The varying length of dolphin dives made it difficult to count the total number of bottlenose dolphins, because they could disappear for minutes at a time before returning to the surface.

Without the ability to identify the individual bottlenose dolphins, it was unknown whether it was different groups of dolphins that foraged in the bay or the same group of dolphins' continuously travelling back to New Quay. This meant that some dolphins may have been counted more than once, producing a false representation of the numbers of bottlenose dolphins found in New Quay bay.

One way to overcome this would have been to use the photo-identification mark-recapture method. Photographs are taken to identify each dolphin, using their naturally marked dorsal fin, to accurately calculate the abundance of different dolphins travelling in the area, and lessen the chance of counting the same dolphin more than once (Dawson *et al*., 2008; Gnone *et al.*, 2011). It can also be used to calculate reproduction and survival rates as well as movements of the population and associations (Williams *et al*., 1993). However this is not possible from land surveys as the dolphins would be too far away to capture accurate photos of the dorsal fin, as the best angle is for the photo to be perpendicular to the fin (Sutaria & Marsh, 2011). Therefore a boat would be needed, but this was unsuitable as it would have caused disturbance to the dolphins affecting the results. It would also increase the expense of the project as a boat would need to be hired and a suitable camera would be required with volunteers trained in its correct use.

Other factors found to directly affect the abundance and distribution of bottlenose dolphins in the area, should also be taken into account when attempting to identify the influence of factory discards on bottlenose dolphin abundance in the future. For example, Pierpoint *et al*., (2009) noted that high levels of boat traffic affected the abundance of bottlenose dolphins; high levels of boat traffic found in New Quay bay may affect the number of dolphins present whether the fish factory is discarding whelk shells or not. However, Gregory and Rowden (2001) found the bottlenose dolphins to show no response to the presence of boats in the area.

Boat traffic can disturb bottlenose dolphins by causing physical injuries and increasing the time it takes to look for prey causing a net energetic cost to the dolphins (Lusseau, 2003; Stockin *et al*., 2008; Pierpoint *et al*., 2009). The motors of boats could also damage the dolphins hearing ability which would affect the dolphins' ability to passively locate soniferous prey (Berens McCabe *et al.,* 2010).

Further research into the effect the shellfish factory has on the abundance of bottlenose dolphins in the New Quay area could include a comparison between the abundance of bottlenose dolphin sightings found at the factory with the levels of boat traffic in the area. One way to compare the timing of factory discards with the boat traffic would be to see if the bottlenose dolphins still show a positive relationship with the whelk shell discards in the winter time when boat traffic is at its lowest. However, dolphin numbers are already known to be lower in New Quay bay during the winter (Bristow *et al*., 2001; Pesante *et al*., 2008a). Also the weather conditions, sea state and daylight hours worsen and shorten during winter making monitoring bottlenose dolphins in winter very difficult (Bristow *et al.,* 2001).

Tidal state is another factor that affects the behaviour and abundance of bottlenose dolphins. Most resident groups of bottlenose dolphins show systematic patterns in their behaviour which changes from area to area in relation to environmental cues such as tidal state, time-of-day and depth (Irvine *et al*., 1981; Wilson *et al.*, 1997; Gregory & Rowden, 2001). Gregory and Rowden (2001) found that whilst no relationship was found between the number of bottlenose dolphins seen in relation to the tidal cycle or time of day, movements of bottlenose dolphins did correlate with tidal state at New Quay. They also found that foraging behaviour correlated with tidal state, with bottlenose dolphins foraging mostly between the flood and ebb tide of high water (Gregory & Rowden, 2001). A reason for this could be that dolphins used the tides to improve foraging time by travelling with the tidal flow or when the tidal flow was at its weakest around slack water. This would reduce the energetic cost of moving. Bottlenose dolphins could also be using the tide as a response to their prey's movements as many fish species follow the tides to search for food (Gregory & Rowden, 2001). In the Shannon Estuary in Ireland, bottlenose dolphins were frequently recorded during the mid ebb tide when the tidal current was strongest (Berrow *et al*., 1996). Irvine *et al.,* (1981) also found that bottlenose dolphins in Sarasota Bay in Florida mainly swam with the tidal currents. Land-based surveys from the shellfish factory could be undertaken at different times of the day depending on the tidal state. This would show if bottlenose dolphins are travelling to the factory due to the whelk shell discards or because they are travelling with the tide.

Other further research could include looking at how the shellfish factory affects other marine mammals in the area, and the relationships between the different species. For example, harbour porpoise (*Phocoena phocoena*) are also found in New Quay bay all year round. They have similar prey species to the bottlenose dolphin and so would likely be attracted the fish found around the factory. Unlike the bottlenose dolphins however, their numbers peak between the months October and March whilst bottlenose dolphins numbers peak between April and October (Evans *et al*., 2003; Simon *et al*., 2010). There is also an indication of temporal habitat partitioning between the two species in some parts of the Cardigan Bay SAC (Simon *et al*., 2010). Where the habitats overlap there is interspecific competition between the two species as they both have similar prey species, which is often fatal for the porpoises as shown by the incidence of porpoise strandings where both bottlenose dolphins and harbour porpoise forage for food (Simon *et al*., 2010). Post mortem reports from these strandings show that the most common cause of harbour porpoise death is from bottlenose dolphin attack (Simon *et al*., 2001; Penrose, 2006). Therefore when there bottlenose dolphins are present in the area, it is very unlikely to find a harbour porpoise. This was observed during the experiment as very few harbour porpoise were seen in comparison to the bottlenose dolphins. Atlantic grey seals (*Halichoerus grypus*) were also found along the coast of Cardigan Bay and were seen frequently around the shellfish factory early in the mornings.

CONCLUSION

The Quay Fresh and Frozen Foods Ltd factory does have a positive effect on the bottlenose dolphin population in New Quay. There was a higher abundance of bottlenose dolphins on days when the factory was open than when the factory was closed. Weeks of higher factory activity attracted a higher abundance of bottlenose dolphins than weeks with lower factory activity. This showed that the factory was an important factor in bottlenose dolphin abundance and foraging techniques.

This project is a basis for more research to be conducted on the shellfish factory's influence on the abundance of bottlenose dolphins in New Quay. The factory was not closed for more than a few days at a time, which did not give sufficient time to accurately compare the abundance of bottlenose dolphins seen between the days when the factory was open and closed. Closing the factory or stopping the whelk shells from being discarded into the sea would, in theory, reduce the numbers of fish attracted to the area. This would show if bottlenose dolphin abundance increased as a result of the increase in fish attracted to the area, thereby showing the factory of having a positive effect on the bottlenose dolphin abundance. Or it would show no change in the numbers of bottlenose dolphins in the area and so would show that the factory has no effect on bottlenose dolphin abundance in New Quay. More data from over a period of years would also increase the accuracy of the data by showing if the factory continuously attracts bottlenose dolphins to the area or if it only occurred in 2011. Research could also be done to show how much the factory contributes to the abundance of bottlenose dolphins to the area in relation to other factors, such as tidal state and boat traffic.

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APPENDIX I

Table 2: The mean number of bottlenose dolphins (*T. truncatus*) seen each day when the factory was closed and open.

Index no. of *T. Truncatus* seen when factory is open	Index no. of *T.truncatus* seen when factory is closed
0.375	0
0.875	0
1	0.625
0.25	0.875
0.75	3.625
0	1
0	0.625
0	0.875
0.875	0.125
0	0.75
0	0
0.5	0
0	0.75
0.125	0.625
0.75	3.75
0.375	1
1.75	0
2.125	1.375
1.125	8
0	0
0.5	0
0.375	0.375
0.25	0.125
0.875	0
1.875	0.375
2.25	1.375
0.375	2
0.625	0
0.75	3.625
0	1.25
2.25	3.375
1.375	2
1.25	3.75
0.125	1.375
2.5	3.5
3.375	2.625
2.75	2.375
1.125	0.75
3.75	1.125

1.75	0
0.375	0.5
1.875	2.5
2.125	0.625
1.5	0.5
2.375	1.5
3	0.75
2.5	0
2.5	0.375
2.25	0.5
1.125	0
2	0
2	0.375
2.75	0.375
2.5	0.5
0.75	0
0.125	0
1.375	0
1	1.5
1.25	
2.875	
1.25	
1.25	
0.375	
0.375	
2	
1.625	
0.25	
0.25	
0	
0	
0.75	
0	
3.375	
2.125	
0.375	
1.5	
1.125	
1.25	
1.875	
0.75	
0.625	
1.5	
2.75	
1.25	
2	

3.375
1.75
1.375
1.5
2.125
1
3.25
2.5
1.625
1.375
0
1.5
0.875
0
0.625
0.75

Table 3: One sample Kolmogorov – Smirnov Test showing the mean distribution of bottlenose dolphin (*T. truncatus*) abundance seen from the harbour each day is significantly different from normal.

One-Sample Kolmogorov-Smirnov Test

		Dolphin_No
N		159
Normal Parametersa,b	Mean	1.2036
	Std. Deviation	1.17122
Most Extreme Differences	Absolute	.152
	Positive	.122
	Negative	-.152
Kolmogorov-Smirnov Z		1.917
Asymp. Sig. (2-tailed)		.001

Table 4: Mann – Whitney U Test comparing the medians between the mean numbers of bottlenose dolphins (*T.* truncatus) seen on days when the factory was open and days when the factory was closed.

Ranks

	Factory_Activity	N	Mean Rank	Sum of Ranks
Dolphin_No	Factory Open	101	85.83	8668.50
	Factory Closed	58	69.85	4051.50
	Total	159		

Test Statisticsa

	Dolphin_No
Mann-Whitney U	2340.500
Wilcoxon W	4051.500
Z	-2.114
Asymp. Sig. (2-tailed)	.035

Table 5: Number of bottlenose dolphins (*T. truncatus)* seen on days with no whelk shell release and the number of bottlenose dolphins (*T. truncatus)* seen on consecutive days after whelk shell release.

Number of *T. Truncatus* seen when the factory is closed	**Number *T. Truncatus seen on* consecutive days when the factory was discarding whelk shells**						
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**
0	3	2	6	0	20	20	18
0	7	0	3	14	8	10	23
5	8	0	0	5	16	13	2
7	0	6	3	9	14	11	12
29	7	9	18	24			
8	0	3	1	11			
5	4	18	22	3			
7	1	0	19	27			
6	17	10	1	12			
0	4	27	3				
0	2	14	16				
6	7	15	0				
5	15	12					
30	6	6					
8	11	10					
0	20	12					
11	16	10					
16	3	20					
0	17	11					

0	20						
3	10						
1	5						
0	22						
3	26						
11	13						
16	7						
0	0						
29	5						
10	6						
27							
30							
11							
28							
21							
19							
6							
9							
0							
4							
20							
5							
4							
12							
6							
0							
3							
4							
0							
0							
3							
3							
4							
0							
0							
0							
12							
447	262	185	92	105	58	54	55
7.982142857	9.034482759	10.57894737	8.75	10.6	14.5	13.5	13.75

Table 6: One sample Kolmogorov – Smirnov Test showing the abundance of bottlenose dolphins (*T. truncatus)* seen on days when the factory was closed and consecutive days of factory discarding was significantly different from the normal distribution.

One-Sample Kolmogorov-Smirnov Test

		VAR00001
N		137
Normal Parametersa,b	Mean	9.1825
	Std. Deviation	8.24373
Most Extreme Differences	Absolute	.133
	Positive	.132
	Negative	-.133
Kolmogorov-Smirnov Z		1.553
Asymp. Sig. (2-tailed)		.016

Table 7: Kruskal – Wallis Test comparing the median abundance of bottlenose dolphins (*T. truncatus*) seen of days when the factory was closed and consecutive days of the factory being open.

Ranks

	Factory_Activity	N	Mean Rank
Dolphin_No	Factory Closed	56	60.21
	1st Day Factory Open	29	70.90
	2nd Day Factory Open	19	74.21
	3rd Day Factory Open	12	60.21
	4th Day Factory Open	9	81.00
	5th Day Factory Open	4	101.25
	6th Day Factory Open	4	97.88
	7th Day Factory Open	4	91.88
	Total	137	

Test Statisticsa,b

	Dolphin_No
Chi-Square	10.724
df	7
Asymp. Sig.	.151

Table 8: Mean number of bottlenose dolphins (*T. truncatus)* seen each day in three different weeks of varying factory activity.

Mean number of *T. truncatus* seen in different weeks of vaying factory activity		
Low Factory Activity	**Medium Factory Activity**	**High Factory Activity**
0.5	1	2.125
0	0	1.5
0	1.375	2.375
0	0.125	3
0.375	0.75	2.5
0.375	0.375	2.5
0.625	1.75	2.25

Table 9: One sample Kolmogorov – Smirnov Test showing the mean number of bottlenose dolphins (*T. truncatus)* seen each day in three different weeks of varying factory activity is normally distributed.

One-Sample Kolmogorov-Smirnov Test

		Mean_Dolphin_No
N		21
Normal Parametersa,b	Mean	1.1190
	Std. Deviation	1.00660
Most Extreme Differences	Absolute	.167
	Positive	.167
	Negative	-.133
Kolmogorov-Smirnov Z		.765
Asymp. Sig. (2-tailed)		.603

Table 10: One-way ANOVA comparing the mean number of bottlenose dolphins (*T. truncatus)* seen each day in three different weeks of varying factory activity.

ANOVA

BND_No

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16.055	2	8.028	34.323	.000
Within Groups	4.210	18	.234		
Total	20.265	20			

Table 11: Abundance of bottlenose dolphins (*T. truncatus*) seen before and after 6:30am on days when the factory was open and closed.

Date	Start Discard	Finish Discard	Number of *T. truncatus* seen before 6:30am	Number of *T. truncatus* seen after 6:30am	Index number of *T. truncatus* seen before 6:30am	Index number of *T. truncatus* seen after 6:30am
14/08/2011	06.30am	09.00am	4	7	2.666666667	2.8
15/08/2011	06.30am	11.00am	2	3	1.333333333	1.2
16/08/2011	06.30am	10.00am	0	0	0	0
17/08/2011	06.30am	09.30am	0	3	0	1.2
18/08/2011	06.30am	12.30pm	4	8	2.666666667	3.2
19/08/2011	06.30am	13.30pm	0	12	0	4.8
20/08/2011	06.30am	11.50am	2	6	1.333333333	2.4
21/08/2011	06.30am	11.00am	1	6	0.666666667	2.4
22/08/2011			6	7	4	2.8
23/08/2011			0	1	0	0.4
24/08/2011	06.30am	16.30pm	1	4	0.666666667	1.6
25/08/2011	06.30am	10.30am	0	3	0	1.2
26/08/2011			0	8	0	3.2
27/08/2011	06.30am	15.00pm	0	0	0	0
28/08/2011	06.30am	8.30am	0	0	0	0
29/08/2011	06.30am	10.00am	0	0	0	0
30/08/2011	06.30am	9.00am	0	3	0	1.2
31/08/2011			1	3	0.666666667	1.2
01/09/2011			0	5	0	2
02/09/2011			2	3	1.333333333	1.2
03/09/2011	06.30am	10.00am	1	3	0.666666667	1.2
04/09/2011			0	4	0	1.6
05/09/2011	06.30am	10.00am	0	0	0	0
06/09/2011			0	0	0	0
07/09/2011			0	2	0	0.8
08/09/2011			0	0	0	0
09/09/2011			0	2	0	0.8
10/09/2011	06.30am	9.00am	2	7	1.333333333	2.8
11/09/2011			1	4	0.666666667	1.6
12/09/2011			0	0	0	0
13/09/2011			0	0	0	0
14/09/2011			2	2	1.333333333	0.8
15/09/2011			0	3	0	1.2
16/09/2011	06.30am	10.10am	0	7	0	2.8

The highlighted red areas indicate the dates not included in the statistical test due to bad weather.

Table 12: One sample Kolmogorov – Smirnov Test showing the mean distribution of bottlenose dolphin (*T. truncatus)* abundance seen from the shellfish factory each day is normally distributed.

One-Sample Kolmogorov-Smirnov Test

		Dolphin_No
N		34
Normal Parametersa,b	Mean	.9118
	Std. Deviation	.82545
Most Extreme Differences	Absolute	.195
	Positive	.195
	Negative	-.135
Kolmogorov-Smirnov Z		1.139
Asymp. Sig. (2-tailed)		.149

Table 13: Paired T-test comparing the mean number of bottlenose dolphins (*T. truncatus)* seen before and after 6:30 on days when the factory was open.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Before	.7556	15	.93831	.24227
	After	1.9200	15	1.27571	.32939

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Before & After	15	.372	.172

Paired Samples Test

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Before - After	-1.16444	1.27139	.32827	-1.86851	-.46037	-3.547	14	.003

Table 14: Paired T-test comparing the mean number of bottlenose dolphins (*T. truncatus)* seen before and after 6:30 on days when the factory was closed.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Before	.5714	14	1.10499	.29532
	After	1.2000	14	.99228	.26520

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Before & After	14	.430	.125

Paired Samples Test

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Before - After	-.62857	1.12340	.30024	-1.27720	.02006	-2.094	13	.056