REPORT

Distribution, activity patterns and genetic relations of Eurasian otter (*Lutra lutra*) in Roaring Water Bay, Ireland

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National Parks & Wildlife Service

Hogeschool VHL
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Abstract

In many countries the Eurasian otter (*Lutra lutra*) is extinct or numbers are declining; resulting in a classification as “near threatened” on the IUCN’s Red List. In one-third of the European countries, however, conservation efforts, enabled the return of the species or the improvement of weakened populations. A lot of conservation measures are based on inland populations, living in river systems, lakes and other bodies of freshwater. Ireland is a stronghold for the species, with Roaring Water Bay (which opens up to the Atlantic Ocean) being a core area. Little is known about differences between inland populations (which are the base of conservation measures) and such coastal populations, which may be of great importance. The goal of this study is to find out more about distribution, population makeup (density and diversity) and activity of the animals in relation to humans. Surveys were conducted every eight days, for the duration of eight weeks – to map distribution based on spraint sites and to monitor sprainting activity on 176 such sites. Freshwater (known to be a vital resource in coastal populations) was also mapped. Fresh spraints were collected for DNA analysis and camera traps were deployed to determine activity patterns and estimate population densities. Attempts to GPS tag otters were unsuccessful during this study, but a number of animals was tagged in 2010 by De Jongh *et al.*; providing data on home ranges. Individual ranges measured an average of 6,5km. Population estimates range from 175-219. The population was found to be distributed throughout the bay, with a preference for pools that contain freshwater. The spraint sites that were most active were also the sites that had most activity on camera, which is in line with the findings of Guter *et al.* (2008) who found the sprainting activity to be an indicator for visiting frequency. Individual animals were shown to move throughout the bay over great distances, as indicated by an individual that was tagged showing up on Baltimore and Sherkin Island (250m-1.9km). Another two related animals were found on Sherkin Island and Ringarogy, indicating individual movement and geneflow in the area to cover multiple islands – even if freshwater is available on either. Over 19 succesfully genotyped samples 13 individuals were found with an average observed heterozygosity of 0,585 (moderate to good). The animals are mainly active during the night, thereby mostly avoiding (not a proven causal relation, and contrary to what was found on the Shetlands) human activity in a temporal sense. Human activity is encountered by the otters in a spatial sense, with fishery and aquaculture activities, it is therefore recommended that: creels are only allowed at depths greater than 9 meters; tangle netting and trammel nets are not allowed within 250 meters of the shore (all in line with current practice); thereby safeguarding foraging grounds around the islands as well as movement corridors between them.

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1 – Introduction

1.1. Background and problem description

The Eurasian otter (*Lutra lutra*) has the widest distribution of all otter species around the globe, ranging from Ireland to Japan and from Egypt to northern Finland (IUCN, 2014). Once, the species thrived throughout Europe and parts of Asia and northern Africa, though persecution, habitat loss, habitat fragmentation, and water pollution caused a dramatic decline during the second half of the 20th century. (Grogan *et al.* 2001; Macdonald and Mason, 1994; Strachan and Jeffries, 1999). In many countries the species is extinct or has been reduced to small (and often isolated) populations (European Centre for Nature Conservation, 2014; IUCN, 2014). Nowadays the species remains declining in many areas of its range and is classified as 'near-threatened' under the IUCN Red list (IUCN, 2014). In one-third of the European countries, however, conservation efforts, focused on improving the environment, enabled the return of the species or the improvement of weakened populations (Conroy and Chanin, 2001; De Jongh, 2014). Conservation of the species, where it occurs in Europe, is amongst others organized in the European Union's Natura2000 network. Under this program's Habitat Directive, Special Areas of Conservation (SAC) are designated to maintain ecosystems and biodiversity in Europe. (European Commission, 2014[1]).

The Republic of Ireland is a stronghold for the Eurasian otter and, compared to most other European countries, otters are abundant and densities are generally high (Wickens, 1990; Chapman and Chapman, 1981; Lunnon and Reynolds, 1991; Bailey and Rochford, 2006). In 75% of the total area of Ireland the species was recently found to be present. Although the otter range showed no decrease between 1980 and 2005, the population trend decreased with 23,7%. The area of Roaring Water Bay (RWB), a bay along the southwest Atlantic coast and designated as a SAC, is one of the countries' core areas for the otter. (Marnell *et al*. 2011; National Park and Wildlife Service, 2008[1]).

Other than the, somewhat comparable, coast of Scotland (Kruuk, 2006) – little is known about coastal populations of Eurasian otter like the one in RWB (Marnell *et al.* 2011; Britton *et al.* 2006; Liles, 2003; De Jongh, personal communication).
As such the relevance of marine environments to Eurasian otters is poorly understood – this in times where marine habitats may become increasingly important when fragmentation of wetlands and declining freshwater fish populations occur (Parry *et al.* 2010). The distribution of otters along the Irish coastline has, in recent surveys, also been under-represented (Marnell *et al.* 2011).
The otter was designated "qualifying feature" for the RWB SAC by the Republic of Ireland, aiming to "restore the favourable conservation condition of Otter in Roaringwater Bay and Islands" by preventing the significant decline in the extent of terrestrial habitat, distribution, extent of marine habitat, extent of freshwater habitat, couching sites and holts or fish biomass available. Furthermore there is to be no significant increase in barriers to connectivity. (Appendix I). (NPWS, 2013; Department of Arts, Heritage and Gealtacht, 2011). The NPWS needs to keep informed about the otter's distribution and abundance to validate the species' status.

1.2. Eurasian otter conservation needs

Knowledge of the spatio-temporal organization – in this study described in terms of *home range*, *activity patterns* and *kinship within the population* – of an animal is integral to conservation and management of its species (Kernohan *et al.* 2001; Jones *et al.* 2004). Understanding the spatial structure and range of a population is important for establishing the scale and subunits for conservation management (Moritz, 1999). Information like this, , has led to recommendations for protection of the species for freshwater otter populations, but little is known about the coastal populations (Marnell *et al.* 2011).
Average home range sizes (mentioned above) and social structure influence the carrying capacity of an area and thus determine maximum population size. This aides in conservation as it may paint a picture of a population's ability to cope with environmental changes. (Frankham *et al.* 2004).

Furthermore knowledge on a population's social organisation can help determine the effective population size (Creel and Creel, 1998; Kruuk, 2006).
Activity of otters may conflict with human activity in coastal areas. Direct threats to otters that are reported in general consist of oil spills (Heggberget and Moseid, 1995); fish traps (Jeffries *et al.* 1984); and road mortalities (Philcox *et al.* 1999).

1.3. Study species

Coastal living otters utilise only a narrow strip of both land and water along the coast. These otters can forage as far as 100 meters offshore, in water of over ten meters deep. Most foraging activity, however, takes place closer to shore in water less than three meters deep. (Nolet *et al.* 1993). Observations of diving activity recorded in Shetland showed over 60% of dives occurring within twenty meters of the shore. Home ranges of otters in marine environments are smaller than those in river environments, at a linear length of several kilometers (Kruuk, 1995; Kruuk and Moorhouse, 1991; Erlinge, 1967, 1968) versus twenty to forty kilometers long (Green *et al.* 1984). Movement and distribution of otters in marine environments is dependent on freshwater availability, which is a resource they need to rinse their fur after spending time in salt water (Kruuk and Balhary, 1990; and Moorehouse, 1988).

Activity patterns of most animals are related to circadian rhythms and seasonal changes in environmental conditions (Aschoff, 1966). A combination of prey activity and foraging tactics (hunting based on sight, smell or touch) makes most carnivores use daily cycles (exhibiting bouts of activity during day or night) (Gerell, 1969; Zielinski, 1988; Lode, 1995). Likewise (individual) otters may benefit from varying activity patterns based on seasonal prey availability and avoidance of intraspecific competition (Melquist and Hornocker, 1983; Kruuk, 2006; Garcia de Leaniz *et al.* 2006; Ralls and Siniff, 1990). A pilot study by the Dutch Otterstation Foundation and NPWS, in RWB, gave indications of potential time-sharing of resources in the area by the otters (personal communication De Jongh and NPWS). The concept of time-sharing (when co-existence of two species of predators or a relative high density of one species is enabled by relatively high biomass of prey) is new to otter ecology, but is described in different mammalian predators (Seidensticker, 1976; Bethge *et al*. 2009).

1.4. Research objectives

A study into a coastal living population can bring to light differences with inland living populations, the ecology of which forms the basis for conservation measures to date. Conditions of a marine environment may necessitate more site specific conservation.
The objective of this study is t*o give insight into the ecology of the Eurasian otter (Lutra lutra) in coastal zone areas – in order to aid conservation.*

1.5. Research questions

The research questions that are to be answered for meeting this objective are:

1) *What is the population size and distribution of the Eurasian otter population in Roaring Water Bay?*
- **1B)** What is the average home range size per sex?
- **1C)** What areas on land and/or in the water are important for otter movement?

2) *To what extent are individual Eurasian otters in RWB related to each other?*

3) *What implications may the activity patterns of Eurasian otters inhabiting Roaring Water Bay have for conservation?*
- **3B)** When and for how long do otters exhibit bouts of activity?
- **3C)** When and where does human activity occur?
- **3D)** What areas are most frequently visited by the otters?

2 – Material and methods

2.1. Study area

The otters inhabiting Roaring Water Bay and its islands, in West Cork, Ireland were the focus of this study. Roaring Water Bay is situated at Ireland's southernmost point where it opens up to the Atlantic Ocean. The bay contains numerous small islands and a small number of larger islands, inhabited by people – one of the most notable being Sherkin Island, at coordinates +51° 27' 59.86", -9° 25' 0.58", with about 100 inhabitants. See Figure 1 for a map of the Bay and its islands, as well as its location in Ireland, as shown in the inset. (Wickens, 1990; Harrington *et al.* 2013).

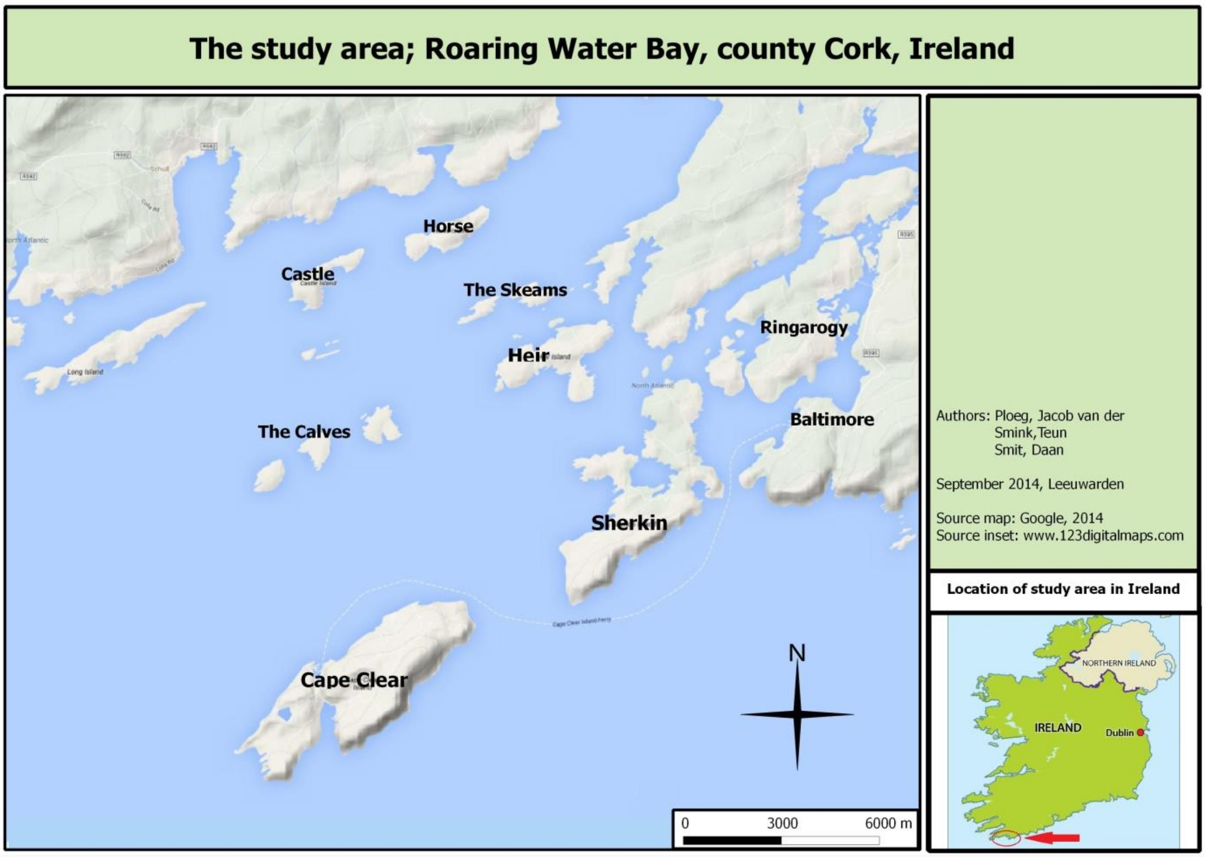

Figure 1: Roaring Water Bay, its islands and its location in Ireland, as shown in the inset

Most of the areas' bedrock is built up of Old Red Sandstone reefs, which emerges to form the islands. Of the great variety of reef habitats, three have been listed as qualifying for the RWB SAC under the EU Habitat Directive (Council Directive 92/43/ EEC): Large shallow inlets and bays (QI1160, 12,809ha), marine caves (QI8330) and reefs (QI1170) (≈3497ha). Here examples of kelp forest communities can be found, grazed by Sea urchin (*Echinus esculentus)* (an inverse relationship between these two exists and is known to be managed by otters (Estes *et al.* 1974) – whereas the caves house the rare Ilamentous red alga (*Pterosiphonia pennata).* (NPWS[A], 2011) (NPWS[B], 2001). A further two occurring habitats are also found in the directive, in dry heath (spatial extend unmapped) and sea cliffs (linear features, measured at around 22km in different surveys) – represented by species like Autumn gorse (*Ulex gallii*), Heather (*Calluna vulgaris*), Bell heather (*Erica cinerea*) and Hairy birdsfoot trefoil (*Lotus subbiflorus*), Spotted rockrose (*Tuberaria guttata*) and Pale heath violet (*Viola occurri*). (NPWS, 2011; NPWS, 2001).

The shores extend from rocky on South Sherkin Island (in Figure 1), to sheltered rock, sand and mud habitats in the Inner Bay – to eventually estuarine communities, where numerous rivers end in the bay (NPWS, 2013). As such it is recognized for its (inter)national importance to the species, as indicated by the SAC designation. Among the so-called "features of interest" for this site are the habitat types, but also three species of mammal; the Harbour porpoise (*Phocoena phocoena*), the Grey seal (*Halichoerus grypus*) and the Eurasian otter (*Lutra lutra*). For each feature of interest conservation objectives are designed based on current knowledge on the status of the species in the area. (NPWS[3], 2014).The otter is listed on Annex II of the EU Habitats Directive. (Harrington, 2013) (NPWS[B], 2001). The current habitat encompasses 171ha of terrestrial habitat (above high water mark), 3ha around river banks, 1562ha of marine habitat and 0.74km of freshwater (river) habitat. (NPWS[A], 2011) (NPWS[C], 2011) (NPWS[D], 2011)

2.2. Sampling methods

2.2.1. Spatial characteristics and demographics

The coastline of Sherkin Island and that of the mainland – starting at the Baltimore Beacon up to and including Ringarogy Island – was surveyed for spraints every eight days (see table 1) in the months of May, June and July. The stretches that were inaccessible because of the terrain can be seen in figure 2. Sherkin Island and Baltimore/Ringarogy were surveyed 9 times, with the last survey only covering not previously visited areas for the sake of distribution (see appendix II for the relation between number of visits per site and average total new spraints found there). A survey consisted of three people moving along the coast, looking for spraint sites at every potential location: a lot of spraint sites are very conspicuous along an otter run, or on patches of grass that will show a different colour than the surrounding grass because of regular sprainting activity. Other signs, such as holts; footprints; runs; sightings and prey remains were also recorded for the mapping distribution of the population. A spraint site was defined as the spraint plus a circular are of 10 meters around it, all spraints within that buffer were considered part of that site. All points found on Sherkin Island and the mainland were revisited in each of the following surveys, with the exception being those points that were too time consuming to get to as well as those only accessible at low tide: as such a total of 176 sites was revisited and used for spraint frequency analysis . A number of other islands as well as outlying points on the mainland was surveyed once or twice for the distribution aspect of the study (see table 2).

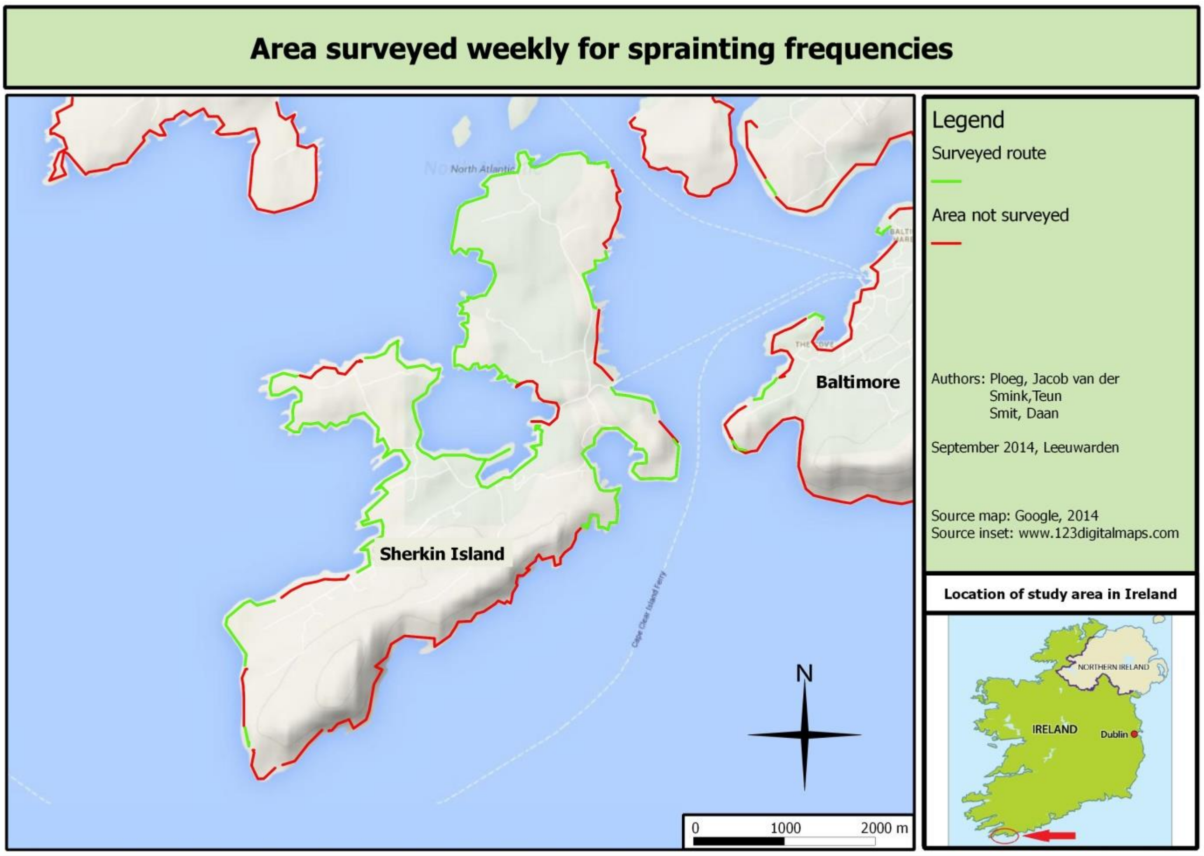

Figure 2: Weekly survey route on Sherkin Island and mainland

During the surveys coordinates of freshwater pools were taken and distance to the sea estimated. A salinity Refractometer RHS 28ATC was used to measure salinity rates of the pools. This measures the salinity of water with an accuracy of 0,20% ppt (part per thousand).

Table 1: Survey schedule, where one week is eight days and Y means that a survey was conducted at that site in the given week

Location	Coastline Length	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9
Sherking Island (SHI)	(25.2km)	Y	Y	Y	Y	Y	Y	Y	Y	Y
Baltimore/Ringarogy (BAL)	(4.8km)	Y	Y	Y	Y	Y	Y	Y	Y	Y
Calf East (CE)	Calf total (9.3km)		Y						Y	
Calf Middle (CM)	Calf total (9.3km)				Y					
Calf West (CW)	Calf total (9.3km)				Y					
Cape Clear (CCI)	Surveyed north side (500m)				Y					
Carrigmore (CAR)	(30m)				Y					
Caste Island (CAI)	n/a		Y							
East Skeam (ESK)	n/a			Y					Y	
West Skeam (WSK)	n/a			Y					Y	
Hare Island (HAI)	(10.5km)		Y				Y			
Horse Island (HOI)	n/a		Y							
Sandy Island (SAI)	(1.0km)			Y			Y			
Spanish Island (SPI)	(4.7km)			Y			Y			
Two Women´s Rock (TWR)	(0.15km)						Y			
Illaungawna (IGA)	n/a			Y						
Illaunkearagh (IKE)	n/a			Y						
Other	n/a			Y						

2.2.1.1. GPS tracking

In 2010 nine otters were trapped, and seven of them tagged with a GPS GSM transmitter (Telitracker, based on the GE863 Telit GPS GSM module running open source python script, Dutch Otterstation Foundation) (License No. 09/2010). Four GPS trackers successfully transmitted their data. A location fix was taken at least every hour and the trackers were active for varying durations, as described below (where the names are those given to the otters for identification):

Ilen: 28th of June – 18th of August; 51 days.

Julie: 1st of July – 8th of July; 7 days.

Mar:* 1st of July – 9th of July; 8 days.

Van Bommel: 8th of July – 15th of August, 38 days.

** Otter Mar was predated, most probably by an orca (de Jongh, personal communication). Large bite scratches of teeth were found on the enclosure of the transmitter after it was retrieved from the field. Later on another otter fell victim to an orca near Clare island (Sleeman, personal communication).*

The successful location fixes and total number of fixes are shown in table 2. The location fixes are used for home range analyses and the total fixes are used for activity analyses.

Table 2: Total and location fixes of GPS GSM transmitters

Otter	Succesful Location fixes	Total fixes
Ilen	124	285
Julie	31	85
Van Bommel	276	401
Average	116	228

2.2.3. Kinship determination

Otter DNA is contained in the intestinal lining cells that are shed with a spraint. The genetic profiles can be detected by *Lutra lutra* specific PCR primers – thereby excluding bacteria and prey species. (Jansman *et al.* 2001). As such, with noninvasive sampling, individuals can be identified and levels of genetic diversity estimated. Analysis yields estimates of individual home ranges and dispersal patterns; it also allows for distinguishing between other species like American mink (*Neovison vison*) and Polecat (*Mustela putorius*). (Hansen and Jacobson, 1999; Jansman *et al.* 2001).

Figure 3: Fresh spraint (left) and dry spraint (right) (Ruairí Ó Conchúir, 2014)

2.2.4. Activity patterns

Activity patterns are described based on camera trapping data. 15 camera-traps were deployed at sites – on Sherkin Island and the mainland – that indicate otter presence: cameras were deployed at active spraint sites, holts and otter runs – at a height of 50-100 centimeters, on wooden posts. In this study Dörr Snapshot *Mini Black 5.0* and *Extra Black 5.0*, Bushnell Trophy HD 2013 and HCO Scoutguard SG570V trail cameras were used (see appendix III for specifications). The cameras were positioned at active spraint sites and holts to increase the chances of recording otter activity. The cameras were set to operate 24 hours with minimal intervals between pictures, using date and time stamps at accurate times with a 24 hour clock. The first cameras were deployed in the week of May 13, with 10 of them not being moved after first instalment (see figure 4 for a map of the camera locations and table 3 for deployment spans of the cameras). Four cameras were redeployed later on in the study for lack of otter activity. The cameras were retrieved on July 6. As such a total of 596 recording days was achieved. The 15 cameras were placed at 19 different sites. Two of these 19 camera sites, camera TC15 and TC16, were used to monitor live traps, the others were used for measuring activity and populations estimations. The cameras were serviced every eight days, to store the data of the memory cards and replace the batteries. Where permitted

Table 3: Camera trap deployment spans

Camera	Installment date	Retrieval date	Recording days
TC1A	13-5-2014	16-6-2014	35
TC1B	17-6-2014	6-7-2014	20
TC2A	13-5-2014	21-6-2014	36
TC2B	26-6-2014	6-7-2014	10
TC3	14-5-2014	6-7-2014	48
TC4	14-5-2014	29-6-2014	39
TC5	14-5-2014	6-7-2014	54
TC6	16-5-2014	6-7-2014	41
TC7	16-5-2014	6-7-2014	47
TC8	18-5-2014	6-7-2014	39
TC9	18-5-2014	6-7-2014	43
TC10	28-5-2014	6-7-2014	26
TC11	28-5-2014	6-7-2014	39
TC12	30-5-2014	6-7-2014	38
TC13	1-6-2014	6-7-2014	33
TC14	10-6-2014	6-7-2014	26
TC15	10-6-2014	24-6-2014	2
TC16	11-6-2014	24-6-2014	4
TC17	14-6-2014	6-7-2014	22
		TOTAL	596 + 4(tc16) + 2(tc15)

by data usage (as determined by previous servicing) some cameras were set to record videos to show activity around freshwater pools.

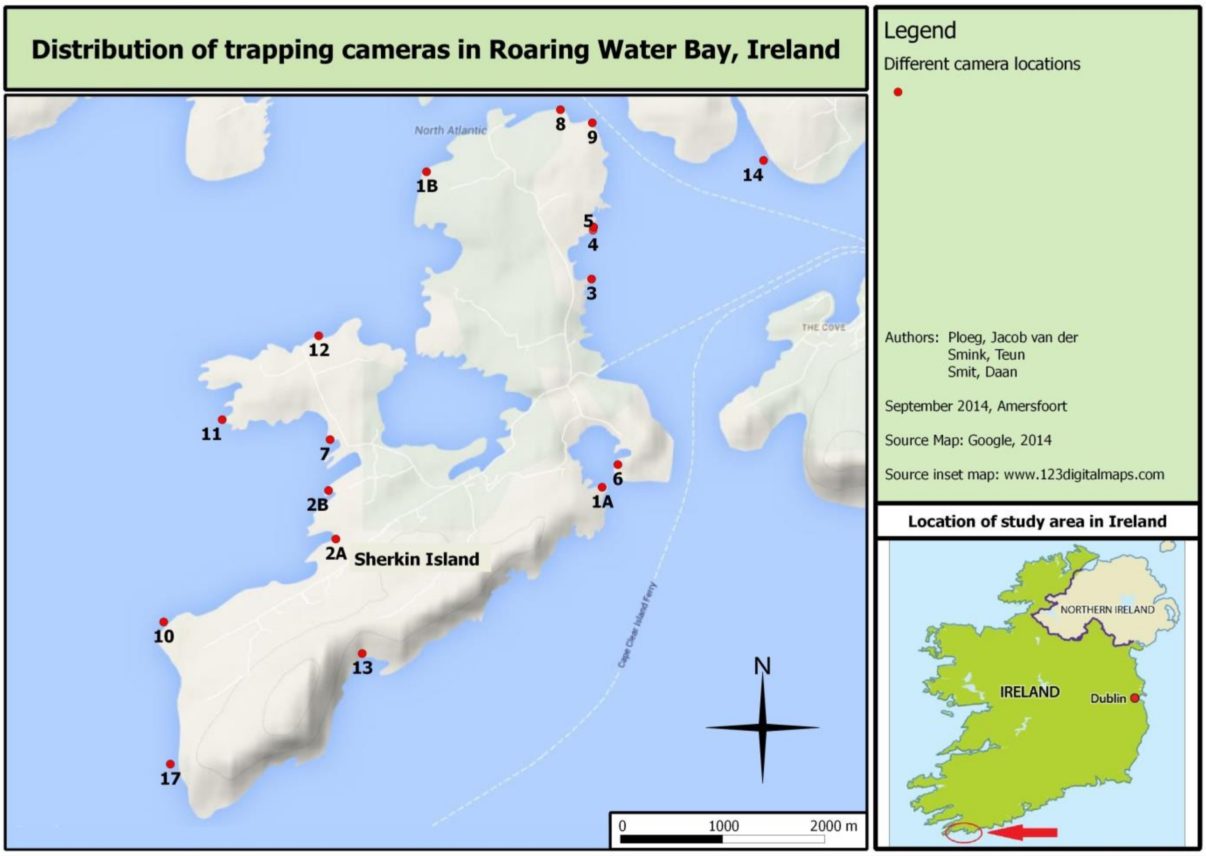

Figure 4: Camera trap locations on Sherkin Island and the mainland

2.3. Data collection

2.3.1. Spatial characteristics and demographics

Every spraint site was individually recorded and coordinates were taken for mapping of distribution. The total number of spraints was counted and pictures were taken for monitoring purposes. On a revisit the total number of spraints was recounted and the number of new spraints established by means of the site pictures, thereby recording the spraint frequency per eight days – for activity patterns and visiting frequency.

2.3.2. Kinship determination

Spraints, for the analysis, were collected – during the surveys – when they were found to be fresh (<24h – as recognized by dimensions, colour, general appearance and odour through field experience of the collectors (Wickens, 1990), (see Figure 3). The collected spraints were stored in Stool Transport And Recovery (STAR) Buffer and frozen. A number of spraints was stored in sealable plastic bags without STAR, but also frozen.

Collected spraints were given a collection ID which were linked to their collection locations. For every collection the weather of the last 12 hours was noted. Any fresh spraint was collected, regardless of site or previous samples. This allows for identification of individual spraints on sites as it is very well possible to find spraints of one to three different females close to that of one male (intrasexual territoriality) (Quaglietta *et al.* 2014)

2.3.3. Activity patterns

In order to measure activity; all camera photos were analyzed. As such for every photo with an otter present, the time of observation; number of otters and location was noted. The bouts of activity of the otter were described by time of day and duration of activity in a 24h span. The differences between time of otter activity and nearest sunset and sunrise as well as nearest low and high tide were plotted in a graph.

2.4. Data preparation and analysis

2.4.1. Spatial characteristics and demographics

All spraint sites were plotted on a map, using QuantumGIS 1.8 Lisboa, to show overall population distribution. The distribution per sex was shown by plotting the locations of all successfully sex-tested animals; producing a map with distribution per male and female.

The 2010 GPS data were plotted, per animal, in a GIS and a minimum convex polygon (MCP) drawn around each of the coordinate sets, after which the area of these polygons was calculated in square kilometers. All outlying location fixes (locations deemed inaccurate because of distance and frequency) were removed. Using the gb.mapometer.com the length of the coastlines in the MCP's was measured. The shore length measurements include the stream from River Ilen to Lough Marsh. This Loch was not included in the MCP's as it would include too much land. Efforts to tag otters during the 2014 study were unsuccessful; resulting in 1 trapped otter over 12 trap nights, but this individual was deemed too small to be able to carry the GPS tag (of 150 grams).

2.4.1.1. Density estimates

PRESENCE

In this study fifteen different sites were non-randomly chosen and used for the population estimation with Programme Presence. Camera traps were used, amongst other things in order to collect absence and presence data on otters. Kruuk (2006) stated that on Shetland on average there is 1 otter per kilometre of coast length. In order to calculate the total population size, only the data from cameras which are at least 1 km shoreline away from each other, were taken into account for this estimation. Therefore 14 camera trap sites (TC1A, TC1B, TC2A, TC2B, TC4, TC5, TC6, TC7, TC8, TC10, TC11, TC13, TC14, TC17) were used for the population estimation. The programme Presence calculated the occupancy rate, psi. The psi was calculated by dividing the number of sites which have at least one otter present by the total number of camera trap sites. The total coastline length times the psi will give the population estimation for the species. A population estimation for the entire bay and only for Sherkin Island is calculated. Roaring Water Bay exists of 307 kilometres shoreline and Sherkin Island has a coastline length of 25,2 kilometres.

Home ranges

In 2010 four otters inhabiting RWB were tagged with a GPS-GSM Tag. From this data a shoreline length for these otters was calculated. RWB contains 307km of shoreline. These two numbers will be used in order to calculate a total otter population size. Besides these numbers other ecological factors will be taken into account in order to calculate a population estimate for the otter in Roaring Water Bay. It was stated by Kruuk (2006) that adult female Eurasian otters can share home ranges but have their own core area. Several females share their group territories with one other male, group ranges were found with at least 2 females, but also higher numbers of females were found, for example 4 or 5 females sharing the same coastline (Kruuk, 2006). In a study conducted in the Shetlands, Kruuk (1989) also calculated that the number of females can be multiplied by 1,83 to calculate the total otter population size. To calculate a population size out of the average home range coastline length estimated by the GPS data from 2010 and the ecological factors the following formula can be used:

N = ((CL/HR)*(ST))*R

N = Otter population size
CL = Total coastline length of area (km)
HR = Home range coastline length (km)
ST = Minimum amount of females sharing territory
R = Female/male ratio factor

2.4.2. Kinship – real time PCR
Using real time PCR the amount of target sequence or gene present in a sample is determined. The C_t (threshold cycle) is the relative measure of concentration of target in the PCR reaction. The C_t value is defined as the number of cycles required for the fluorescent signal (a dye is used to show the targets) to cross the threshold. Since this is an inverse reaction the lower the C_t level the greater the amount of target NA in the sample. This means that samples with a low C_t value have greater chance of being from an otter, greater chance of being sex-typed and greater chance of being genotyped. Samples with a C_t of 34 or less were listed for genotyping.

A total of 353 fecal samples was collected. Where needed (the spraints that were stored without STAR buffer) approximately 0.2mg of scat material was transferred to a vial to which approximately 1 mL of STAR buffer was added (the samples that were put in STAR upon collection were already in vials). All samples were then vortexed and allowed to stand at room temperature for about 30 minutes (enough to defrost). After this the samples were centrifuged at 1000g for 60 seconds. 150 µL of supernatant was removed for DNA isolation. To this 600 µL of genomic lysis buffer was added and the sample was vortexed and allowed to stand for five minutes. The solution was then transferred to a spin column with membrane and spun at 10000g for one minute. This step was repeated with 200 µL of DNA pre-wash buffer and 500 µL of g-DNA wash buffer respectively. Finally the DNA was eluted in 150 µL of H_2O and stored at -20 °C. Species identification was conducted at the Waterford Institute of Technology in Ireland, by targeting mtDNA with PM3F and LLR primers as well as a TaqMan VIC-labelled probe LLP – as described by O'Neill *et al*. 2013. Following the species identification the sex-typing of the spraints was conducted based on fragments of the ZFX and ZFY genes, using chromosome-specific primers described by O´Neill *et al*. 2013. All samples were tested in duplicate and only those which gave duplicated ZFX results were considered female and those which gave duplicated ZFX and ZFY results were considered male.

2.4.3. Activity patterns
For all the camera trap images with an otter present (n=270), all the corresponding hours have been listed, in order to avoid double counts. That means, when for example one otter has been observed at 23:45 and another photo has been taken at 23:46 with an otter present, this hour (23) has been used once.
For each observation the difference in time (minutes) between time of observation and the time of the sunset, sunrise, low-tide and high-tide (the independent variables) was defined using Microsoft Excel 2013. In order to analyze how activity is influenced, IBM SPSS Software is used. The non-parametric One-Sample Kolmogorov Smirnov (K-test) was first used to test on uniformity of distribution of observations during high-tide, low-tide, sunset and sunrise. And afterwards, if the independent variables were not uniformly distributed they were tested on normality of distribution. The One-Sample Binomial Test was used in order to know if significantly more observations were recorded before or after sunrise, sunset, low-tide and high-tide. The One Sample Chi-Square test was used in order to determine if more observations were closer to high-tide or low-tide.

The GPS tracking data also shows activity versus inactivity. All fixes with time and coordinates were considered active, and those with only time but no coordinates inactive. As tests in the area showed coverage to be good everywhere, it is assumed that when no coordinate fix could be obtained – this is due to the otter being in a holt and under cover; which is interpreted as “inactive”.

3 – Results

3.1. Spatial characteristics and demographics

Ten weeks of surveying Roaring Water Bay for indicators of otter presence, resulted in an array of maps aimed at visualising the findings. Figure 5 shows the distribution of otters in the study area, based on all possible tracks. A total of 468 spraint sites was found throughout the bay. On Sherkin Island and Baltimore/Ringarogy alone the total was 319 (the majority of which was used for spraint frequency analysis). A total of 36 other features indicating otter presence was also recorded (these include holts, footprints, runs, sightings and prey-remains). The otter is present in the entire study area, not a single island or mainland shoreline excluded. Higher densities of points are visible on Sherkin Island and Baltimore coast (the areas that were most frequently visited, as these were used for spraint frequency as well).

Sprainting frequency on Sherkin Island and Baltimore/Ringarogy was mapped weekly to show areas of interest (as indicated by visiting frequency based on this sprainting frequency). These maps are included in appendix V. (Further described in paragraph 3.3 on otter activity).
No relation was found between our number of visits and the average total of new spraints (figure 6).

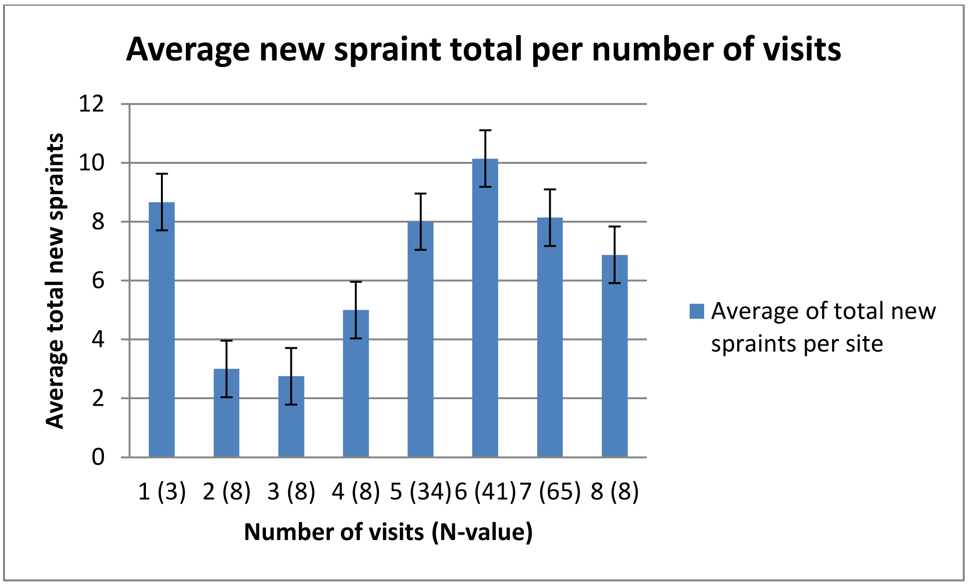

Figure 6: Average new spraint total per number of visits

3.1.1. Limiting factors for otter distribution

Freshwater pools that have a spraint site within a 10 meter radius are defined as pools utilized by otters. A 10 meter radius is set because spraints were found right next to the pool or close by the pool within 10 meter distance. Overall, the pools' salinity ranges varied between 0,0% ppt (freshwater) and 4,9% ppt (saltwater) (Steward, 2008). The pools which are used by otters have an average salinity of 1,02% ppt (Standard deviation = 1,35), with a median of 0,3% ppt, and a 95% confidence interval of 0,38 (N = 47).

Pools which are utilized by otters have average distance between the pool and the shore of 9,7 meters (N = 56) and these pools have a size of 5,5 m2 (N = 82). The average size of all the pools is 5,5m^2 (N = 133), and the average distance from pool to shore is; 8,71 meters (N=99).

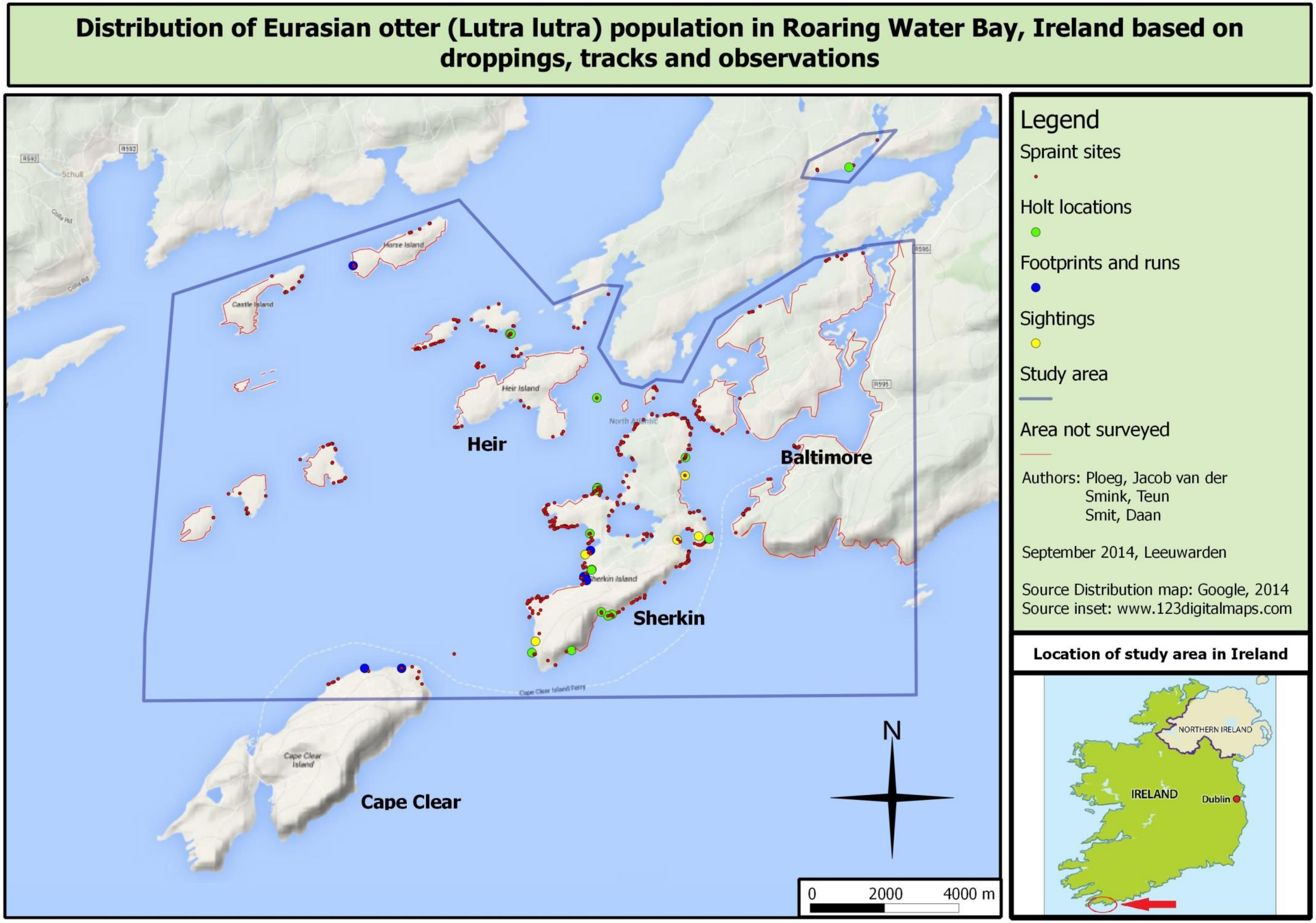

Figure 5: Distribution of Eurasian otter spraint sites and sightings in Roaring Water Bay, Ireland, based on spraints; tracks; holts and

3.1.2. Home ranges

GPS GSM 2010 data

Four out of seven otters trapped and tagged in 2010 successfully transmitted GPS GSM tracking data – three female and one male. No data points were used for one otter (Mar) that died, and therefore only provided limited data (her range is plotted in the map to show its location). The home range locations are shown in figure 7. The ranges of the two females were 1,7km^2 and 1,6km^2 and 7,6km and 6,4km in shore length. The male home range was estimated, by MCP, to be 2,0km^2 encompassing a shore length of 5,6km. The overall average home range was 1,8km^2 and 6,5km. See table 4 for overview. The otter with its home range actually in coastal RWB (Van Bommel) commuted regularly between the mainland and Sherkin Island, covering distances ranging from 250m to 1,9km. The otters in the bay are shown to be using multiple islands.

Table 4: Individual MCP area size of GPS tracking data (2010)

Otter	Unique location fixes	MCP area size (km²)	Shore length (km²)
Ilen	124	1,7	7,6
Julie	31	1,6	6,4
Van Bommel	276	2,0	5,6
Average	116	1,9	6,5

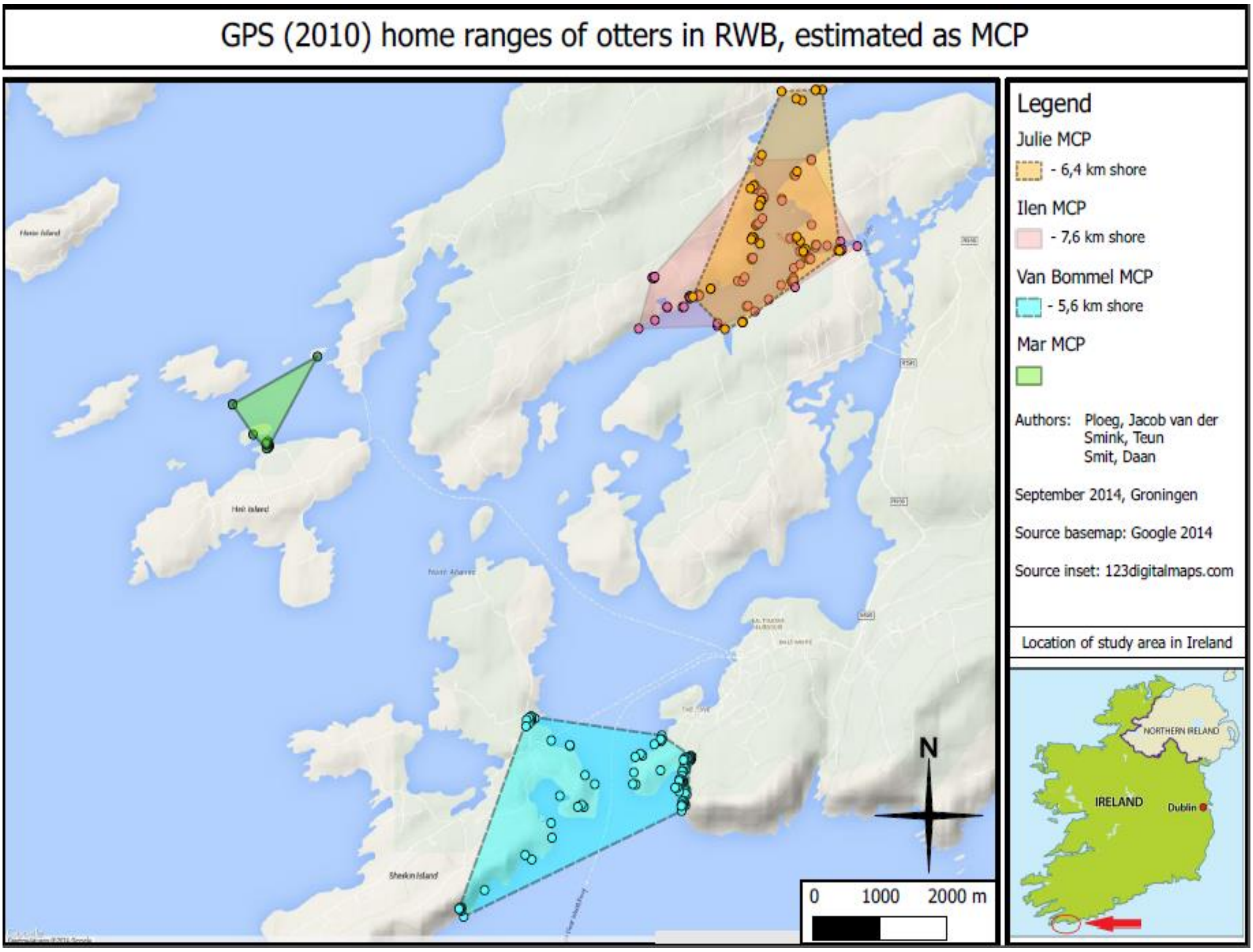

Figure 7: GPS (2010) home ranges of otters in RWB, estimated as MCP

3.1.3. Population estimates

PRESENCE

On ten of fourteen camera trap sites an otter was recorded. In table 5, the total number of days a camera recorded and the total number of days on which an otter was recorded are given, per camera trap site the average otter visits per day and the number of otter visits can also be seen (see also figure 8, for exact locations).

Table 5: Days of observation and otter presence for each camera

Camera trap site	*Total days of observation*	*Days with otter presence*	*% of otters presence per day*	*Number of otter visits*	*Average otter visit per day*
TC1A	35	0	0	0	0,0
TC1B	19	9	47,4	16	0,8
TC2A	36	0	0	0	0,0
TC2B	10	8	80	10	1,0
TC3	47	2	4,3	3	0,1
TC4	39	17	43,6	30	0,8
TC5	53	11	20,8	16	0,3
TC6	40	0	0	0	0,0
TC7	46	1	2,2	1	0,0
TC8	39	28	71,8	46	1,2
TC9	43	24	55,8	32	0,7
TC10	26	12	46,2	17	0,7
TC11	39	11	28,2	18	0,5
TC12	37	0	0	0	0,0
TC13	32	7	21,9	10	0,3
TC14	26	9	34,6	11	0,4
TC17	22	0	0	0	0,0
	Total: 589 days (24h)	***Total: 139 days***	***Average: 26,9%***	***Average: 12,4 visits per trap cam***	***Average: 0,40 otters per day***

The psi, calculated with Programme Presence, for the Roaring Water Bay is 0,7143. (More information about the output of Programme PRESENCE can be found in Appendix VI).

Site		estimate	Std.err	95% conf. interval
psi	site	0.7143	0.1207	0.4395 - 0.8885

The psi value times the coastline length of Sherkin Island, will give the population estimation for only Sherkin Island. The psi value times the total coastline length of RWB, will give the population estimation for Roaring Water Bay.

25,2 kilometres * 0,7143 = 18 otters

307 kilometres * 0,7143 = 219 otters

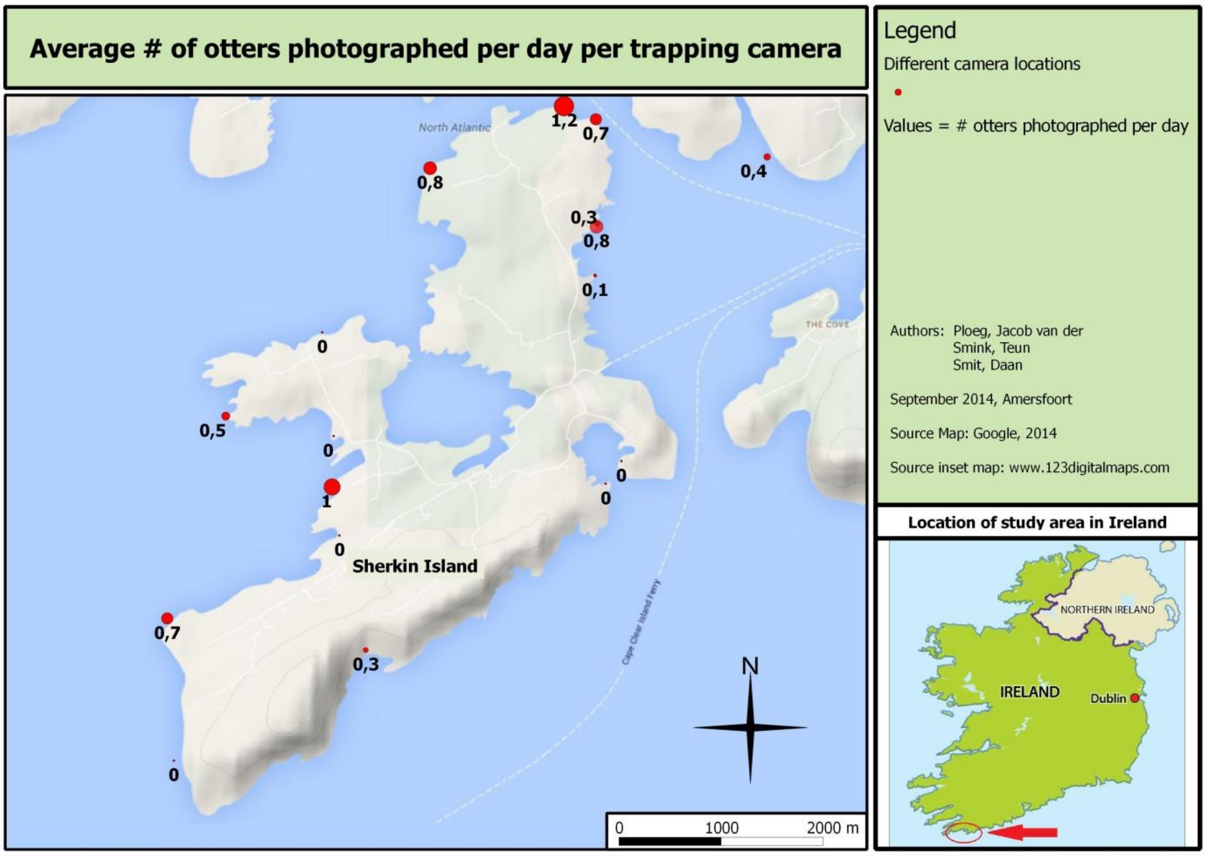

Figure 8: Average number of otters recorded per day on each camera trap site

GPS home ranges

The otters which were tagged in 2010 on average used a 6,5km shoreline (see paragraph 3.1.2.). Roaring Water Bay contains 307km shoreline. These numbers and the numbers concerning the ecological factors of the otter inhabiting a coastal zone (minimum amount of females sharing territory; 2, female/male ratio factor; 1,83) will be used in the following formula.

N = ((307/6,5)*2*1,83 = 175 otters inhabiting RWB

3.2. Kinship and geneflow

Out of the 353 fecal samples, 330 were positively identified as Eurasian otter. 120 were suitable for sex-typing, from these 59 tested positive for female and 66 for male (see figure 7 for distribution). Unusable samples came from a total of 23 samples that went undetected in the species test (due to low quantity of DNA). In the sex-typing 76 samples failed to duplicate either the ZFX or ZFY target and 111 samples failed sex-typing because both targets went undetected.

19 samples were successfully genotyped (3 of which were blood samples). Table 6 shows the relatedness estimates for these samples.

Table 6: Relatedness Estimates 0.5 = identical, 0.25 = parent/offspring or siblings 0.1 -2.5 = relatives, negative values = non relatives

JP160714.21	JP170714.:	ES120814.	TS160714.	ES120814.	JP170714.:	TS170714.	JP170714.:	JP170714.:	JP150714.:	DS150714	TS140714.	JP150714.:	JP140714.!	TS150714.	ES180714.	TS160714.	DS150714	JP170714.8	
0																			JP160714.21
-0,12562038	0																		JP170714.16
-0,077114634	-0,16293	0																	ES120814.2
-0,12562038	0,5	-0,16293	0																TS160714.14
-0,077114634	-0,16293	0,5	-0,16293	0															ES120814.1
-0,134679481	-0,09703	-0,0366	-0,09703	-0,0366	0														JP170714.3
-0,12562038	0,5	-0,16293	0,5	-0,16293	-0,09703	0													TS170714.13
0,090503126	-0,12739	-0,10467	-0,12739	-0,10467	0,26772	-0,12739	0												JP170714.22
-0,039811548	0,00979	-0,15784	0,00979	-0,15784	-0,10185	0,00979	-0,09585	0											JP170714.29
0,077096097	-0,14961	0,092852	-0,14961	0,092852	-0,07787	-0,14961	-0,00187	-0,01158	0										JP150714.2
0,035318781	-0,14008	0,188614	-0,14008	0,188614	-0,07521	-0,14008	-0,10355	-0,13389	-0,08124	0									DS150714.18
0,002381355	-0,1373	-0,06966	-0,1373	-0,06966	0,121667	-0,1373	0,053018	0,118197	0,052698	-0,16141	0								TS140714.3
0,017893335	-0,02763	-0,09248	-0,02763	-0,09248	-0,05882	-0,02763	0,000431	0,073031	0,024443	-0,16838	0,023203	0							JP150714.24
-0,037363485	-0,07783	-0,12262	-0,07783	-0,12262	-0,01329	-0,07783	-0,08894	-0,03545	-0,00327	-0,02075	-0,1274	-0,07348	0						JP140714.5
-0,073298819	-0,02025	-0,19362	-0,02025	-0,19362	-0,11529	-0,02025	-0,17767	0,383133	-0,135	-0,07894	0,113349	-0,00301	0,070612	0					TS150714.15
-0,140172035	-0,18086	0,064993	-0,18086	0,064993	-0,00811	-0,18086	-0,09482	-0,04093	0,063771	-0,0232	-0,03828	-0,00933	0,109312	0,267204	0				ES180714.2
-0,12562038	0,5	-0,16293	0,5	-0,16293	-0,09703	0,5	-0,12739	0,00979	-0,14961	-0,14008	-0,1373	-0,02763	-0,07783	-0,02025	-0,18086	0			TS160714.51
0,097556248	-0,05284	-0,25294	-0,05284	-0,25294	-0,08091	-0,05284	0,08245	0,013187	-0,07568	-0,00271	0,024723	0,131043	0,069067	-0,02187	-0,02221	-0,05284	0		DS150714.8
-0,088442735	-0,19706	0,5	-0,19706	0,5	-0,04369	-0,19706	-0,06963	-0,17815	0,100819	0,208257	-0,08076	-0,10714	-0,09844	-0,19362	0,069509	-0,19706	-0,23467	0	JP170714.8

13 individual otters were found in these samples. Their locations are shown in figure 9. The related animals and their relations are also shown in this figure. The direct distance between *Edel* and *Fiona* is 6,5km. Table 7 gives the genetic overview of the population: an average observed heterozygosity of 0,585 was detected.

Table 7: Genetic overview of genotyped samples (calculated using Genalex v6.5 (Peakall and Smouse 2006, 2012). N number of individuals; Na number of alleles; He expected heterozygosity; Ho observed heterozygosity; HW probability values of Hardy-Weinberg expectations, where ns=non-significant P<0.05

	Locus1	Locus2	Locus3	Locus4	Locus5	Locus6	Locus7	Locus8	
	Lut435	**Lut833**	**04OT17**	**04OT05**	**Lut457**	**04OT14**	**04OT22**	**Lut701**	**Average**
N	14	14	14	14	14	14	13	13	13,85714286
Na	5	4	3	5	4	2	5	4	4
He	0,717	0,625	0,554	0,663	0,559	0,459	0,731	0,689	0,625
Ho	0,643	0,500	0,571	0,714	0,429	0,286	0,692	0,846	0,585
HW	ns	ns	ns	ns	ns	ns	ns	ns	

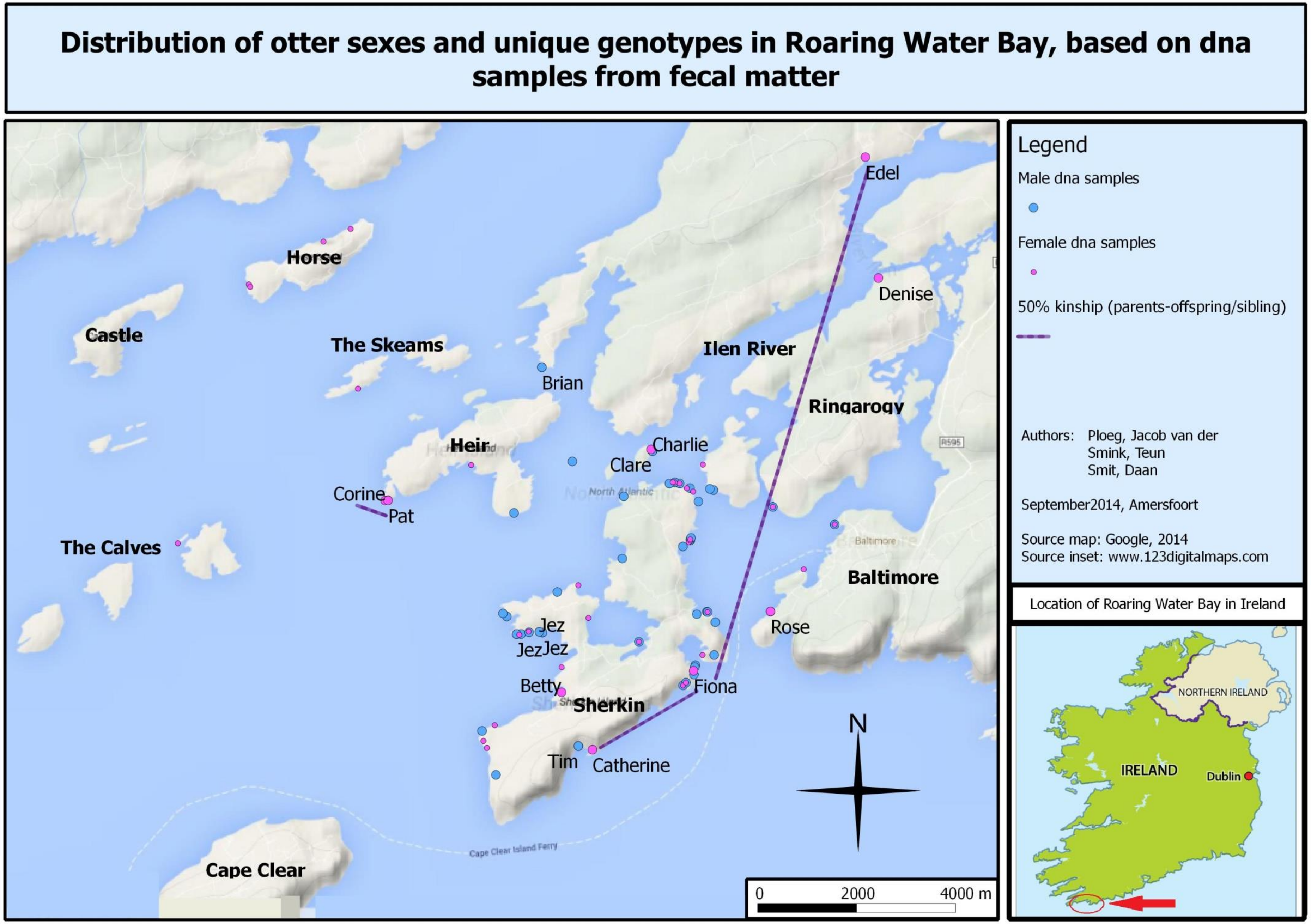

Figure 9: Distribution of sexes in RWB otter population and locations of individually identified animals

3.3. Otter activity patterns

3.3.1. Natural factors

Otters were observed on 12 of 17 camera locations. During a 7-week period, on 139 of the 679 successful camera days (23%) at least one otter has been observed. 210 unique otter visits were recorded, 83 observations were nearest to sunrise (in time) and 127 observation were nearest to sunset (see figure 11 for overview of all observations and figure 12 for observations per day).

The One-Sample Kolmogorov Smirnov Test showed observations over low-tide to be uniformly distributed (Z = 0,728; N = 210; P = 0,664), high-tide to be uniformly distributed (Z = 0,410; N = 210; P = 0,996), sunrise to be not uniformly distributed (Z = 4,031; N = 83; P = 0,000) and sunset not to be uniformly distributed (Z = 6,499; N = 127; P = 0.000). The One-Sample Kolmogorov Smirnov Test showed sunrise not to be normally distributed (Z = 0,177; N = 83; P = 0,000) and sunset to be normally distributed (Z = 0,065; N = 127; P = 0,200).

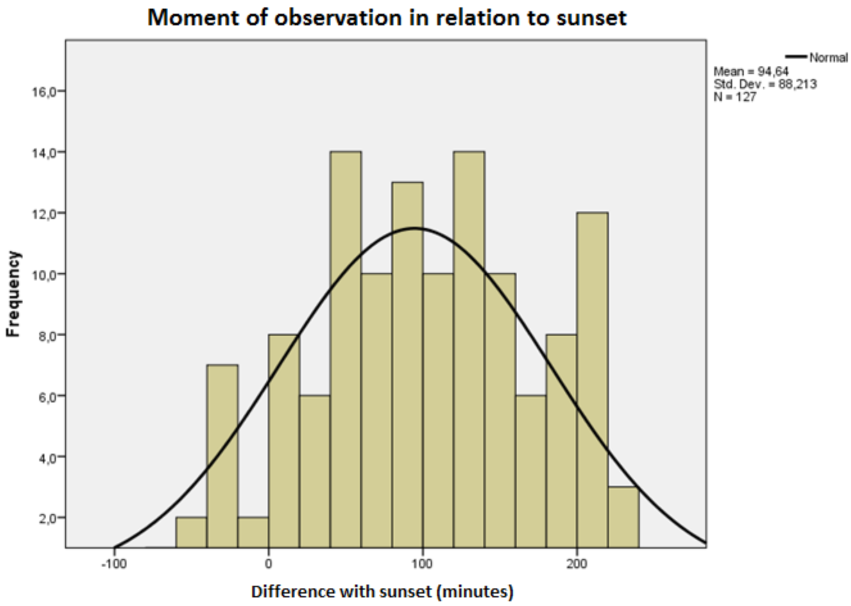

Figure 10: Histogram showing how the observation frequencies are normally distributed compared to the difference between time of sunset and time of observation in minutes (Z = 0,065; N = 127; P = 0,200).

Otters exhibited, on average, most activity 95 minutes after sunset. With a mean of 95 minutes and a standard deviation of 88 minutes, this normal distribution is shown in a histogram in figure 10.

The One-Sample Binomial Test showed observations closest to moment of sunrise not to be equally distributed between before and after sunrise (Z = 5,488; N = 83; P = 0,000) and observations closest to moment of sunset not to be equally distributed (Z = -8,874; N = 127; P = 0,000). 90% of the observations closest to sunset are after sunset and 10% is before sunset. 81% of the observations closest to sunrise are before sunrise and 21% of the observations after sunrise. Otters showed more activity between sunset and sunrise, 87,1%, than between sunrise and sunset, 12,7%.

The One-Sample Binomial Test showed: observations over low-tide to be equally distributed between before and after moment of low-tide (Z = -0,621; N = 210; P = 0,535), and observations over high-tide showed to be equally distributed (Z = 0,207; N = 210; P = 0,836). 48% of the observations are before low-tide and 52% of the observations after low-tide, and 51% of the observations are before high-tide and 49% of the observations after high-tide.

There are not significantly more observations closer to low-tide than high-tide: N = 210; P = 0,890. There are not significantly more observations closer to high-tide than low-tide: N = 210; P = 0,890. The tidal movement showed not to be a significant influence on the moment otters exhibited activity.

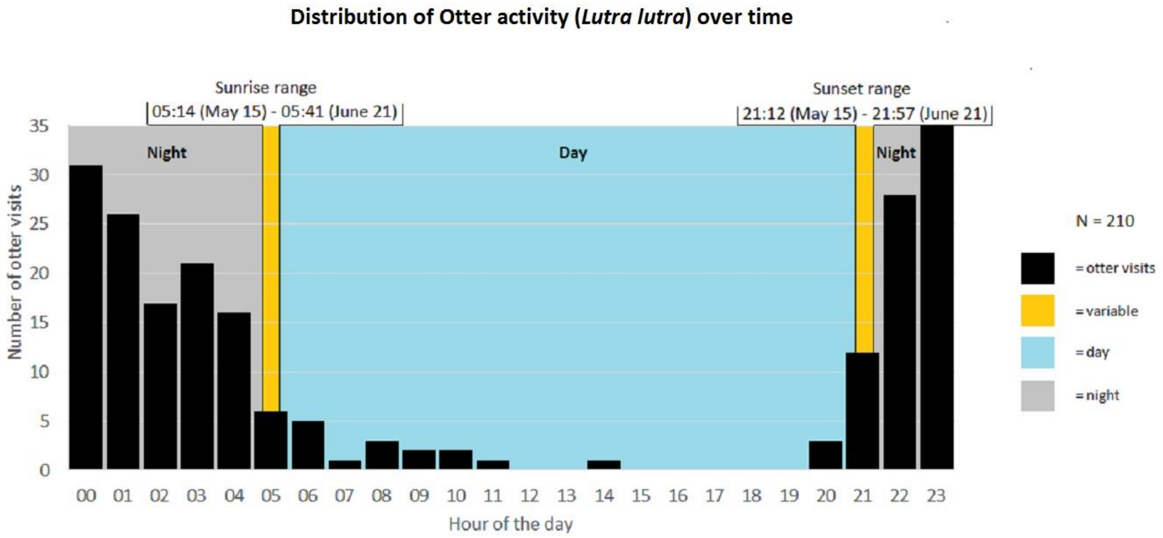

Figure 11: Distribution of otter activity over time

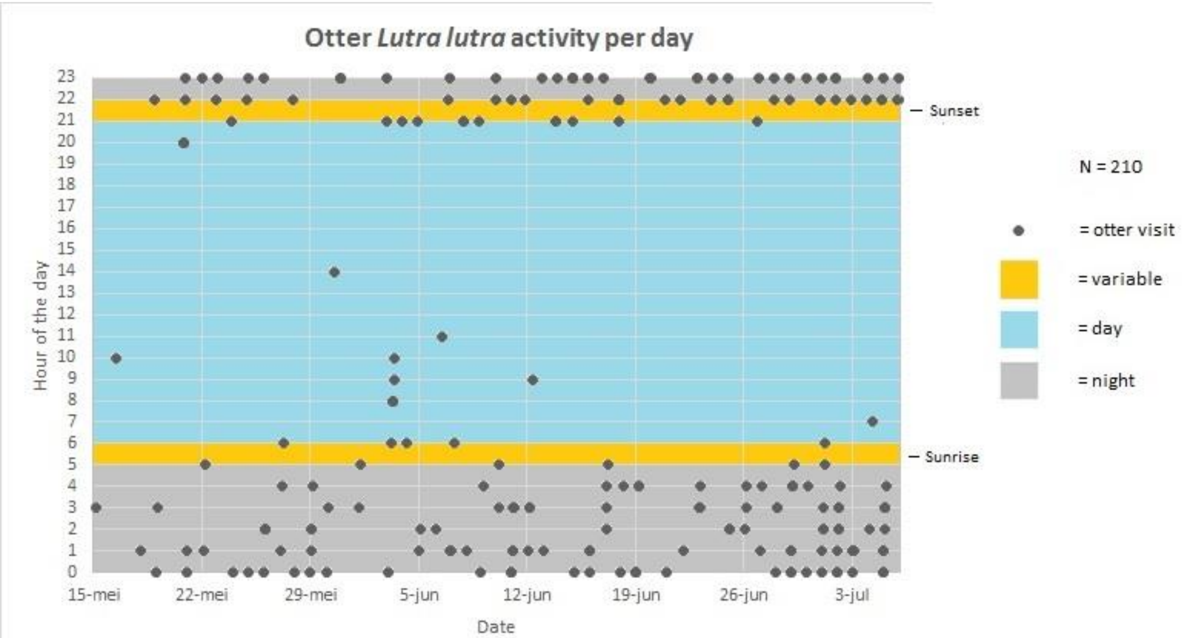

Figure 12: Distribution of otter activity per day

3.3.1.1. Daily and nightly activity GPS data

Figure 13 shows the activity of the individual GPS tracked otters per day and night. Out of 402 nightly recordings 239 (59,5%) are active and 163 (40,5%) are inactive. Of 242 daily recordings 117 (48,3%) are active and 125 inactive (51,7%).

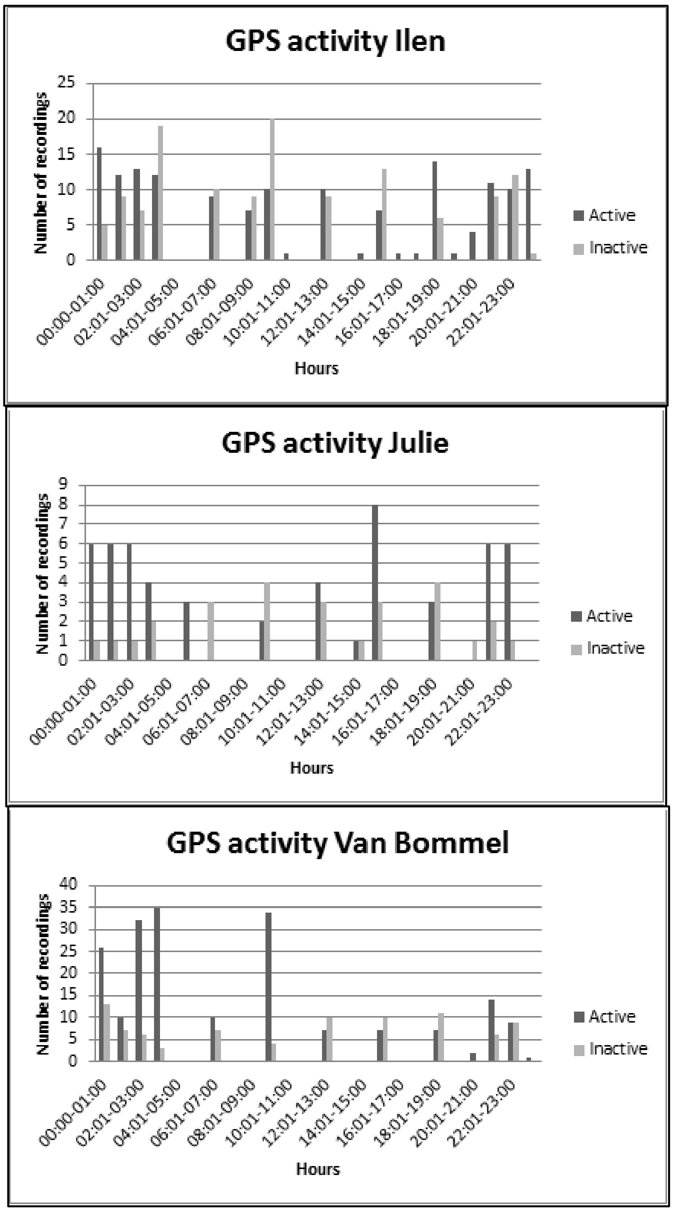

Figure 13: Individual hourly activity and inactivity of GPS tagged otters in 2010

3.3.2. Sprainting frequency

Sprainting frequency was mapped weekly to show areas of interest (as indicated by visiting frequency based on this sprainting frequency. These maps are included in appendix V. Figure 14 shows the average weekly new spraints per site. All spraintsites that were located during the study are shown in this figure. The spraintsites are – except for a cluster on the Southwest-corner of Sherkin Island – located within 100 meters along the shoreline. The high cliffs that face the Atlantic Ocean on the Southwest corner of Sherkin Island show a lack of spraintsites, as does “Kinnish harbour”, the circular-shaped inlet in the centre of Sherkin. As mentioned previously in the methods chapter a fixed group of spraintsites was visited a successive number of eight rounds (of eight days) and the number of new spraints was counted to identify the areas preferred by otters. The maps in appendices IV show that the frequencies of new spraints per site per week are relatively similar, with three stretches of shoreline with relative higher quantities. These are the North-West and North-East corners of Sherkin Island and the location West of Sherkin Island at Baltimore Harbour. All three mentioned locations are less accessible and distanced further away from human settlements and paved roads.

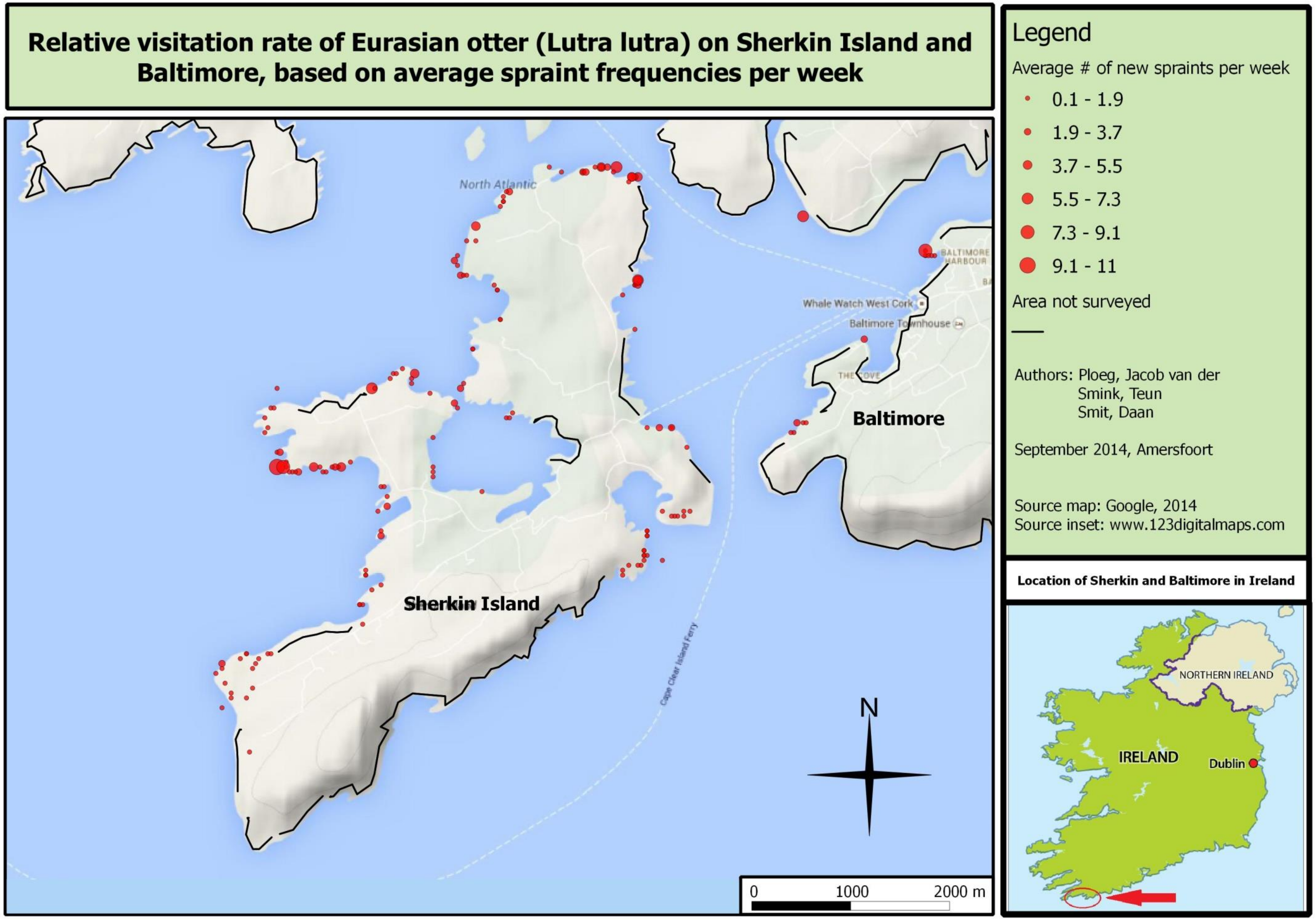

Figure 14: Relative visitation rate based on average new spraints per week per site

4 – Discussion

4.1. Spatial characteristics and demographics

Otters were recorded throughout Roaring Water Bay, on all the islands that were visited. Individual otters are shown to be using multiple islands; crossing great distances, even if freshwater is readily available on both sides (Van Bommel on Sherkin Island and Baltimore in figure 7).

Sprainting frequency was recorded as a means of determining visitation rate at spraint sites (discussed in paragraph 5.3.2.). It, however, also gives an indication of areas that are important to the animals. The average weekly new spraints show a high visitation rate at northern and western points on Sherkin Island (the Docks and Sherkin Point respectively).

4.1.1. Limiting factors in distribution

Previous studies showed the availability of freshwater pools in a coastal zone to be the single most important factor in determining the distribution of the Eurasian otter (Beja 1992). Not only the number of freshwater pools available is considered important but also their physical characteristics like: rock substratum of a pool, depth of a pool and grass coverage around the pool (Lovett *et al.* 1997). If there is an abundance of freshwater along the coast, like in the case of the River Ilen in Roaring water Bay, Eurasian otters show a preference for deep pools, with flat rocks and short grass for rolling. Size of the pool was irrelevant to the Eurasian otter (Lovett *et al.* 1997). It is assumed that the presence of the otter spraints beside a pool relates to utilization of that pool by otters. This study was conducted in May and June whilst otters sprainting activity appears to be more frequent during the winter period (Conroy & French, 1987; Kruuk, 1993).

Data of this study shows the otter to be active near pools that have a salinity in the lower end of the spectrum (mostly 0) – again indicating the importance of freshwater in saltwater habitats (an observation further strengthened by the lack of spraint sites on West and Middle Calf Islands where no freshwater is available).
In this study most of the pools present in the study area are located near the seashore, because of small distance between seashore and pool, the pool may differ in salinity a lot. In this study the pools have been measured only once. Salinity fluctuations for pools over time have not been noticed. The pools differ in salinity frequently, because of different weather conditions and wave action (Jeffrey *et al.* 2001). This means that the deposition of salt particles may change the salinity rate. Another reason for high salinity rates for pools, could be that some pools were rather small and may have been frequently used by the otter to wash its fur. The washing of an otter may increase the salinity rate, and this has a higher effect on smaller pools than on larger pools. Also solar heating and evaporation may cause a higher salinity rate (personal observation) (Steward, 2008).

In this study a salinity average of 1,02 ppt (std dev. 1,13 % ppt) was found for pools which are being used by otters. No previous studies were found showing salinity rates of pools used by otters inhabiting coastal zones. Pools with 1,02 % ppt may be considered as fresh water pools. The Atlantic Ocean has an salinity rate of 3,5 – 4,5% ppt, but salinity rates of Irish coastal waters decreases when water is closer to an estuary or other river inlet (Anninou 2009). This may be the case as well with the River Ilen in Roaring Water Bay.

4.1.2. Home ranges GPS data

Otters use one-dimensional home ranges, usually measured in shore length. As such the use of MCP's may overestimate the actual home range. (Blundell *et al.* 2001; Kruuk, 2006). MCP's depict the overall spatial range, useful in a habitat with multiple shorelines (the otters use both shores of the river Ilen and the habitat contains numerous islands) (Gerht *et al.* 2009). The inland MCP's mainly cover the River Ilen and the surrounding banks; on each of which numerous location fixes were recorded. There is not a lot of land included in these MCP's. Still the length of shoreline is a better indication. The length of shoreline measured in each of the MCP's shows the two females to have a longer range than the male, which is contrary to previous findings that show males to have larger ranges; overlapping up to three females (Kruuk, 1995). Home ranges in freshwater were previously found to be longer than those along the coast – due to the differences in food availability; which is often higher in seawater (Kruuk, 1995); which explains the difference between the females that solely occupy the River Ilen and the male that lives along the coast.

4.1.3. Population size estimates

PRESENCE

Estimation of occupancy rates and associated dynamics (i.e. extinction and colonization) from presence-absence data is fundamental to many habitat models (Cabeza et al. 2004), metapopulation studies (Hanski & Gilpin 1997) and monitoring efforts. The population size estimate by presence was conducted with non-random camera traps sites. Programme Presence does not provide analyses for non-randomized data. In this study, the presence and absence data collected by camera traps were used as if the sites were randomly chosen. In other studies, non-randomized data is used to estimate population size (Bailey and Adams, 2005).

Kruuk stated that there is on average about one adult otter for each kilometre of coast, but each otter uses a stretch of shore several kilometres long (Kruuk 2006). Otter ranges are expressed in terms of length of coast, not size of area, this is why in this study kilometres are used rather than square kilometres – the same method was also used in other studies (e.g. Erlinge, 1967; Mequist and Hornocker, 1983). With this information a population size of 219 otters was estimated. In other studies, concerning comparable habitat features, different numbers arise. Using radio tracking a study done in Norway concluded 0,4 – 0,6 otters per 1km shoreline (Heggberget, 1995). Based on holt density two studies were conducted in the coastal zone of Scotland, one study estimated 0,4 otters per km shoreline (Yoxon, 1999), another holt-based estimation concluded 0,4 otters per km shoreline (Kruuk *et al.* 1989), in 1988 and 0,5 otters per km shoreline (Conroy and Kruuk, 1995). In this study 0,7 otters per km shoreline was estimated, this higher density may be explained because the data was collected in a non-randomized way, overestimating otter presence over absence – or indeed may be an indication of more suitable habitat.

Home range

Spatial data shows Ilen and Julie shared the same home range, and it was stated by Kruuk (2006) that adult female Eurasian otters can share home ranges but have their own core area. That means a coastal group territory exists. This study was conducted in an area comparable to RWB – on the Shetland Islands. Several females share their group territories with one other male (Kruuk, 2006). To get a more reliable estimation of the population size a formula that incorporates home range sizes from 2010 GPS data, shared female ranges and female/male ratio was used: N = ((307/6,5)*2*1,83 = 175 otters inhabiting RWB.

While the two population estimates are a little apart, they suggest that the shorter home ranges we found allow for higher densities of otters in coastal zones. This suggests that coastal zones can have a high importance for overall otter populations, and can be prioritized in management actions aimed at conservation.

4.2. Kinship and geneflow

13 individuals were found in 19 samples collected from locations shown in figure 7. The levels of genetic diversity are moderate to good (personal communication David O'Neill), and slightly higher than that recorded in Cork City (White *et al.* 2013). Suggesting interaction between individuals from different parts of the bay. This idea is strengthened when looking at related animals (0,5), who live in Ringarogy and south Sherkin: a direct distance of roughly 6,5 kilometers .

4.3. Activity patterns

4.3.1. Natural factors

It is expected that the Eurasian otter is more active during high-tide than low-tide and during day time in a coastal zone area. Where Eurasian otters inhabit coastal zone areas they are active during daytime whereas in fresh water areas most otters are active at night time (Kruuk 2006). Animal life appears to be geared to the state of the tide (Kruuk 2006). Melquist and Hornocker (1983) and Kruuk *et al.* (1993) concluded that prey availability was the main factor determining abundance and distribution of otters in North American studies.

If the presence of otters depends on the availability of prey species, maybe the activity of otters depends on their prey's activity as well. If the activity of otters depends on the availability of fish, and fish activity depends on tidal rhythms then this might affect the activity pattern of the otter as well. Interactions between tidal currents and topographic features are known to influence the foraging behaviour of vertebrate predators from several taxa, including reef fishes (e.g. Noda et al., 1994), seabirds (see review by Hunt et al., 1999) and baleen whales (e.g. Brown et al.,1979; Brown and Gaskin, 1989). It is found some fish species showed a pattern of activity that was related primarily to the tidal cycle and secondarily to the diel cycle. Most movements of fish species occurred during flood tide (Ralston and Michael, 1986). Bottom living fishes and crabs are most active at high tide (Kruuk *et al.* 1988). If fish activity is related to the tidal cycle, this could influence other coastal predators inhabiting Roaring Water Bay as well. No significant differences were recorded by Anderson (2008) between day and night activity levels of Grey seals (Halichoerus grypus), nor was there any relationship between activity and tide state (Anderson 2008). The published information (Cameron, 1970) on diurnal rhythms in Grey seals; at the Basque Islands, Nova Scotia, was concerned with movements of animals between land and sea. It was concluded that movements of bulls showed no correlation with time of day or tide, but that cows had a cycle of swimming and suckling which was related to tides. Looking at activity of harbour seal, during 1995–97, seal abundance in the water during flooding tides was significantly greater than median daily abundance. Large-fish captures were episodic and occurred more often on the incoming tide near constricted water flow. Tidal differences in capture rates are predicted to have a significant impact on both the hunting strategy and energy intake of individuals. Results support the idea that interactions among tidal currents, topographic features, and fish play a role in structuring marine predator–prey dynamics (Zamon, 2001). Because the habitat and foraging area of the otters in RWB is subject to tidal motions too, and most sightings were made during low-tide, the hypothesis was that there was a correlation between the two.

In this study a total opposite result was found, a significant number of otters were recorded during night time and no significance in otter activity is found between low tide and high tide. The observations of otters are equally distributed over time difference with low-tide and high-tide. What this difference means for the prey species of the otter in Roaring Water Bay cannot be stated after this study. Whether the activity is different from other coastal zone areas, because the otter feeds on other prey species has not been researched in this study.

In this study camera traps on land were used to record activity on land. Whether otters have a different activity pattern for being active on land and being active in water has not been studied before. If these patterns differ from each other, which is not likely, this could be an explanation for the high activity during the night. However this is probably not the case, because otter activity is related to latrine visits, also in other studies the same method is used to measure activity (Leuhtenberger *et al.* 2014).

4.3.2. Sprainting frequency

For decades spraints are being used to study different aspects of otter biology and population ecology. Studies into otter diet and nutritional needs focused on the contents of the spraints (M. Brzeziński *et al.* 1993; Clavero *et al.* 2003), inventories aimed at detecting the species in specific areas used spraints as an indicator of its presence (Madsen *et al.* 2003; Romanowski *et al.* 1996; Bailey &

Rochford, 2006), and several studies used the fluctuations in frequency of sprainting to derive information about habitat preferences from (Cho *et al.* 2009; Jenkins & Burrows, 1980). Though the latter method of counting new spraints per unit of time – in this study referred to as ''sprainting frequency'' – is well established in otter research, its value for understanding otter ecology has been a constant input for debate. Whereas studies carried out in the 1980's found no positive correlation between sprainting frequency and true visiting rate of a latrine (Kruuk *et al.* 1986; Mason & Macdonald, 1987), a more recent and very thorough study did detect a strong (P=0,02) positive relationship between the two factors (Guter *et al.* 2008). In the Roaring Water Bay study no count of visits to a certain area could be compared to the amount of spraints, since there was no constant observation of the sites. However, trapping cameras installed throughout Sherkin Island and Baltimore had the highest detection rate in areas where relatively also the highest number of new spraints were found per week. Camera site 8 and 9 located in the North-East corner of Sherkin Island captured otters in 72% and 56% of the nights (39 and 43 respectively) they were active. Camera site 11, located on the mid-Western corner of the island filmed otters in 28% of the nights (39) it was active. These cameras were among those with the highest detection rate and were positioned at the locations that show highest relative visiting frequency by otters, as can be seen in Appendix V. At the very least this emphasizes the power of the data on sprainting frequencies that was collected in this study. It also shows the high value of combining camera trapping and counting spraint frequencies for studies into otter habitat preference. Figure 15 (next page) shows, again, the average visitation rate per week; with water depths and currents added. It seems like the strength of the local current and the depth of water influence the pattern. Frequencies seem to be lower in areas where either the current is strong (lower Western corner of Sherkin Island), or the water is very shallow or deep (less than 1 meter depth, mid-Western inlet and largest inland bay in Sherkin Island, more than 9 meters; lower Western corner of Sherkin Island). Otters do mainly forage on bottom-dwelling species in marine habitats (Herfst, 1984; Kruuk et al. 1987), and on average dive to a maximum-depth of 8 meters (Kruuk et al. 1987), though prefer depths between 0 and 3 meters (Nolet *et al.* 1993). With high densities of piscivorous birds like the Northern gannet (Morus bassanus), Razorbill (Alca torda), Common shags (Phalacrocorax Aristoteles) and different species of gulls (Lari) and terns (Sternidae) constantly 'patrolling' the waters, most prey-species of the otter might avoid very shallow waters. The combined limitation of not being able to forage beyond a certain depth and the lack of prey-items in the shallow waters might lead to an optimum depth-range in which the otter forages. The relatively higher sprainting frequencies might be explained by time spent in the suitable waters nearby, which fall within the aforementioned 'optimum range'. The limited information available on water current strengths in the area raised the theorem of otters avoiding locations with a relatively strong current, as is shown in the sprainting frequencies map along the South-Western corner of the island. A study into niche separation between American Mink (Mustela vison) and the American counterpart of the Eurasian otter, the American or Canadian river otter (Lontra Canadensis) in a marine environment revealed that the otters preferred the areas with the strongest wave action (Ben-David *et al.* 1996).

No relation was found between our number of visits to a site (for our surveys) and the average total of new spraints found (appendix II). This may be explained since we aimed to visit sites as often as possible and consequently visited a lot more sites all of the 8 rounds than just the one.

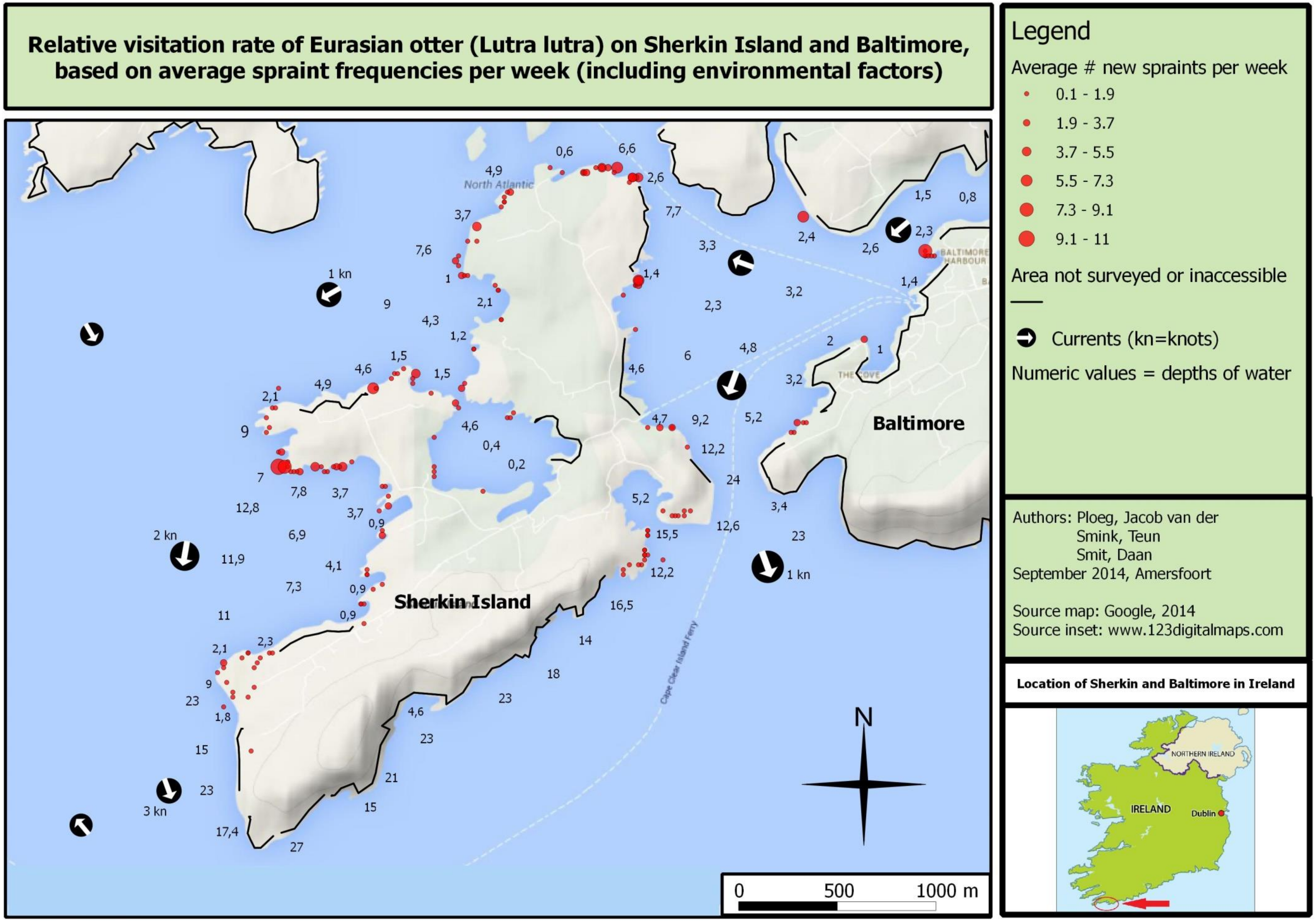

Figure 15: Relative visitation rate based on average new spraints per week per site, with currents and water depth shown

4.3.3. Otters and human activity

In 2013 an assessment of current fisheries and aquaculture in Roaring Water Bay was conducted by the Marine Institute in Rinvile, Ireland. Numerous fishing techniques, with varying equipment were found to be used in Roaring Water Bay – targeting a number of species (see table 6). (Marine Institute, 2013). All of these methods were in active use at the time of the review; at frequencies varying from year-round for creels, otter trawl and trammel nets to only seasonal for all others.

The spatial distribution of these methods can be found in appendix IV. Creels, trammel nets and shrimp pots can be found throughout the bay and surrounding Sherkin Island. Gill nets cover the entire south shore of Sherkin Island. (Marine Institute, 2013).

Tabel 6: Fishing techniques in Roaring Water Bay (Marine Institute, 2013)

Fishery technique	Target Species	Equipment use
Shrimp pots in demersal zone	Shrimp	Static
Creel in demersal zone	Lobster, crab, velvet crab	Static
Tangle net in demersal zone	Crayfish, turbot	Static
Dredge fishing in benthic zone	Scallop	Mobile
mid-water trawl in pelagic zone	Mackerel, herring	Mobile
Hooks and lines in pelagic zone	Mackerel, pollack	Mobile
Gill nets in demersal zone	Pollack	Static
Otter trawl in demersal zone	Pollack, prawn, hake, monkfish, haddock, whiting	Mobile
Hand picking in benthic zone	Periwinkle	Mobile
Trammel nets	Various	Static

Mussel and oyster aquaculture also takes place in the bay. At the end of May to the beginning of June the collector ropes, for mussels, are deployed for collection of larva. After the growing stage (14-18 months) the mussels are usually harvested in winter. 18 sites in RWB are licensed for intertidal aquaculture of Pacific oyster (*Crassostrea gigas*). These are grown in plastic mesh bags, secured to metal frames. After the oysters have grown enough they are harvested in the months of November, December and January. The spatial distribution of these activities can be found in appendix III. Around Sherkin Island, intertidal oyster culture takes place around the northernmost point (the docks) and in Kinish Harbour. Further aquaculture is conducted at specific sites in-between the islands and more extensively in the River Ilen estuary (mussels). (Marine Institute, 2013).

Further human activity consists of irregular recreational boating (from, among others, Baltimore Saling Club) and the regularly scheduled ferry service from Baltimore to Sherkin Island and Cape Clear - running every half hour during the day (along the ferry routes shown in figure 1, of the study area). In the actual bay, this activity predominantly takes place in-between Baltimore and Sherkin Island. Little such activity is conducted at night time (no organized, regular activities).

Out of the listed fishery and aquaculture techniques the Nature2000 SAC assessment of the Marine Institute recognizes the following potential direct pressures on the otter (a designated species):

- By-catch in tangle netting; midwater (pelagic) trawling nets; gill nets and trammel nets (Marine Institute, 2013).

The other equipment can, in itself, still pose a threat to the otter – if no preventive measures are taken. National Parks and Wildlife Service recognizes marine foraging habitat of the otter in the area as the area within 80 meters of the coast, but a greater area of 250 meters from the coast may be used for commuting between sites of interest (holts, feeding sites, freshwater etc.). Furthermore our study shows that otters swim between the islands. No by-catch limits are calculated for the otter, as there are no population estimates or growth rate figures available.

In reality tangle nets are said to not pose a significant threat as they are set in deeper waters than those used by the otter (>15m, where the otter dives to 9 meters (Kruuk, 1995)). Similarly, it is stated that pelagic (midwater) trawling in this area should not pose a threat to the otters as it occurs in open subsurface water.

Creels pose a risk to otters as they can drown in them (Twelves, 1983). Creels were said to be deployed in waters deeper than those used by otters (>9m; personal communication), and were designed with entrances that do not allow otters to enter (Marine Institute, 2013; personal communication and observation). In 2010 however creels with entrances that are large enough for otters to enter were still seen on Heir Island. It is recommended that the opening of creels be manufactured in such a way that it does not allow otters to enter. Furthermore it is recommended that creels are not placed in waters shallower than 9 meters, or directly at the coastline. For the protection of the otter it is recommended such rules are enforced.
Trammel nets, used to catch bait for the lobster and crab fisheries, pose a threat to otters when they are used in shallow waters. The Marine Institute, in their SAC assessment of 2013, attributed a high risk of otter population depletion because of trammel nets; requiring mitigation measures.

Aquaculture should pose no direct risks to otters as they are unlikely to become entangled in mussel ropes (large diameter). (Marine Institute, 2013). Migration routes, however, could potentially be affected if such equipment is deployed. Mussel frames were seen in narrow strips of water; potentially preventing the otter from swimming there. (De Jongh, 2010; personal observation).

No interaction with recreational boating or ferry services was seen or heard of. Otters were seen swimming in or close to the ferry route, and the GPS data of Van Bommel shows him to cover this area as well when moving between Baltimore and Sherkin Island. This would indicate that otters can cope with such human activity well; as supported by findings of MacDonald *et al.* (1994) who state that otters tolerate significant levels of disturbance, and can be found living in urban areas, as long as safe shelters are readily available.
The predominantly nocturnal activity of the otter and diurnal activity of humans in the area could be another reason why no significant influence was seen or heard off (Madsen *et al.* 2001).

5 – Conclusion and recommendations

The Eurasian otter is found throughout Roaring Water Bay (N=175-219), with a lot of visiting activity being recorded at locations near the Docks and Sherkin Point on Sherkin Island – both of which have ample freshwater nearby, and the former offers the shortest crossing to the mainland. Otters in this coastal region have smaller home ranges than inland populations, making for a higher density.
The animals are mainly active during the night; no relation with high or low tide was found, thereby mostly avoiding (not a proven causal relation, and contrary to what was found on the Shetlands (Kruuk, 1995)) human activity in a temporal sense. Human activity is encountered by the otters in a spatial sense, with fishery and aquaculture activities. While no interaction with aquacultural equipment is recorded, new installations may disturb foraging and or migration routes (as oyster frames were seen to block the waterway between Sherkin Island and Rat Island). Similarly creels should only be used at depths greater than 9 meters. Tangle netting and trammel nets can, by the nature of the equipment, pose a threat to the otter population – it is therefore recommended to not use these techniques within 250 meters of the shore; thereby safeguarding foraging grounds around the islands as well as movement corridors between them. Movement between the islands was shown to take place, in this study, as one of the GPS tracked otters commuted between Baltimore and Sherkin Island and since related animals (parent/offspring or sibling relationship) were found on the southside of Sherkin Island and on Ringarogy. In the tested samples the genetic diversity was moderate to good, which would be diminished if movement through the bay were to be hampered.

Coastal regions can harbor healthy otter populations, with smaller home ranges leading to higher density – suggesting coastal regions to be potentially important for the overall conservation of otter populations. The main limiting factor in distribution is freshwater, and where this is available movement of individuals is recorded over great distances. There is a potential for specific threats through aquaculture and fishery.

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Daan Smit

References

Anderson S. (2008) Day and night activity of Grey seal bulls. Mammal Rev. 1978, Great Britain, Vol. 8 43-46.

Anninou P. (2009). How conservative is arsenic coastal marine environments? A study in Irish coastal waters. Elsevier, Estuarine, Coastal and Science 82, 515 – 524

Aschoff J. (1966). *Circadian activity pattern with two peaks*. Ecology 47: 657–662.

Bailey, M., Rochford, J. (2006).*Otter Survey of Ireland 2004/2005*. Irish Wildlife Manuals No. 23. National Parks and Wildlife Service, Department of Environment, Heritage and Local Government, Dublin, Ireland.

Beja PR (1992). *Effects of freshwater availibility on the summer distribution of otters Lutra lutra on the southwest Coast of Portugal.* Ecography 15: 273-278, Copenhagen.

Ben-David M., Bowyer R.T., Faro J.B. (1996). Niche Separation by Mink and River Otters: Coexistence in a Marine Environment. *Oikos*. Vol. 75, Fasc. 1, pp. 41-48

Bethge, P., Munke, S., Otley, H., Nicol, S. (2009). *Activity patterns and sharing of time and space of platypuses, ornithorhynchus anatinus, in a subalpine Tasmanian lake.* Journal of Mammalogy, 90 (6): 1350-1356

Blundell, G.M.; Maier, J.A.K.; Debevec, E.M. (2001) Linear home ranges: effects of smoothing, sample size, and autocorrelation on kernel estimates. Ecological Monographs 7:469–489.

Britton R.J., Pegg J., Shepherd J.S., Toms S. (2006) Revealing the prey items of the otter Lutra lutra in South West England using stomach contents analysis. Folia Zool 55:167–174

Brown, R.G., Barker, S.P., Gaskin, D.E. (1979) Daytime surface swarming by Meganyctiphanes norvegica (M. Sars) (Crustacea, Euphausiacea) off Brier Island, Bay of Fundy. Can J. Zool. 57 : 2285–2291.

Brown, R.G. & Gaskin, D.E. (1989) Summer zooplankton distributions at the surface of the outer Bay of Fundy, eastern Canada. Can J. Zool. 67 : 2725–2730.

Brzeziński†, Jęldrzejewski W. and Jędrzejewska B. (1993*). Diet of otters (Lutra lutra) inhabiting small rivers in the Bialowieża National Park, eastern Poland*. Journal of Zoology. Volume 230, Issue 3, pp 495–501

Cabeza M., Araujo M.B., Wilson R.J., Thomas C.D., Cowley M.J.R. & Moilanen A. (2004) Combining probabilities of occurrence with spatial reserve design. J Appl Ecology, 41, 252-262

Cameron, A. W. (1970) Seasonal movements and diurnal activity rhythms of the Grey seal (Halichoerus grypus). Journal of Zoology, London, 161, 15-23.

Chapman, P. J., Chapman, L.L. (1982).*Otter survey of Ireland*. Vincent Wildlife Trust.

Cho H-S., Choi K-H., Lee S-D., Park Y-S. (2009). Characterizing habitat preference of Eurasian river *otter (Lutra lutra) in streams using a self-organizing* map. Limnology, Volume 10, Issue 3, pp 203-213

Clavero M., Prenda J. and Delibes M. (2003). *Trophic diversity of the otter (Lutra lutra L.) in temperate and Mediterranean freshwater habitats*. Journal of Biogeography. Volume 30, Issue 5, pp 761–769.

Conroy JWH and Kruuk H (1995). Changes in otter number in Shetland between 1988 and 1993. Oryx, 29, 179-204.

Conroy, J. W. H. & French, D. D. (1987), *The use of spraints to monitor populations of otter (Lutru lutra L.)*. *Symp. zool.* Sot.. *Lond.* No. *58:* 247-262.

Conroy,J. W.H., Yoxon,P., Gutleb,A. C. (2000). *Proceedings of the First Otter Toxicology Conference.*

Creel, S. and Creel. N.M. (1998). *Six ecological factors that may limit African wild dogs Lycaon pictus.* Animal Conservation, 1, 1-9.

Department of arts, heritage and the gealtacht. (2011). National Parks and Wildlife Services, Roaring Water Bay and islands SAC 000101, conservation objectives. Accessed on 03-04-2014, at www.npws.ie

Erlinge, S. (1967). *Home range of the otter Lutra lutra in Southern Sweden.* Oikos, 18, 186-209.

Erlinge, S. (1968). *Territoriality of the otter Lutra lutra L.*Oikos, 19, 81-98.

Estes, J.A., and Palmsian, J.F. (1974) *Kelp Forests* Science 185 (1974): 1058-1060

European Centre for Nature Conservation. (2014). Eurasian-otter. Accessed on 04-06-2014, at www.lhnet.org

European Commission[1]. (2014). Natura2000. Accessed on 03-04-2014, at www.ec.europa.eu

European Commission[2]. (2014). Nature legislation: Habitat Directive. Accessed on 03-04-2014, at www.ec.europa.eu

Frankham, R., Ballou, J.D., Briscoe, D.A. (2004). *A Primer of Conservation Genetics.* Cambridge: Cambridge University Press.
Garcia de Leaniz C., Forman D.W., Davies S. and Thomson A. (2006). *Non-intrusive monitoring.*

Gerell R. (1969). *Activity patterns of the mink Mustela vison Schreber in southern Sweden*. Oikos 20: 451–460.

Green,J., Green, R., and Jefferies, D.J. (1984). A radio-tracking survey of otters *Lutra lutra* on a Perthshire river system. Lutra, 27, 85-145.

Hanski I.A. & Gilpin M.E. (1997) Metapopulation biology - ecology, genetics and evolution. Academic Press, San Diego.

Harrington, A; O'Meara, D; O'Neill, D; Coffey, L; Guest, B; Sheerin, E; Turner, P; O'Reilly, C (2013) *A preliminary report from the Roaringwater Bay otter survey, Co. Cork, 27th - 28th of April, 2013.* MISE Project

Heggberget TM (1995). Food resources and feeding ecology of marine feeding otters (Lutra lutra). In Skjoldal, Hopkins, Erikstad and Leinas (eds), Ecology of fjords and coastal waters pp. 609-618. Elsevier Science, London, UK.

Heggberget, T.M. and Moseid, K.-E. (1995). Coastal otter habitats and exposure of otters to offshore oil spills. Proceedings VI International Otter Colloquium Pietermaritzburg 1993 (eds. C. Reuther and D. Rowe-Rowe).

Herfst, M. S. (1984). Habitat and food of the otter Lutra lutra in Shetland. Lutra 27: 57-70

Hunt, G.L., Mehlum, F., Russell, R.W., Irons, D., Decker, M.B., Becker, P.H. (1999) Physical processes, prey abundance, and the foraging ecology of seabirds. In: Proceedings of the 22nd International Ornithological Congress, 16–22 August 1998, Durban. N.J. Adams, and R.H. Slotow (eds). Johannesburg: Birdlife South Africa, pp. 2040–2056.

IUCN Otter Specialist Group 2014. Lutralutra. Accessed on 04-04-2014, at ww.otterspecialistgroup.org

Jansman, J., Chanin, P.R.F. and Dallas, J.F. (2001) *Monitoring otter populations by DNA typing of spraints.* IUCN Otter Spec. Group Bull. 18(1): 12 – 19

Jeffrey S. Reid (2001). *Evolution of the vertical profile and flux of large sea-salt particles in a coastal zone.* Journal of geaphysical research, 106, 12,039 – 12,053.

Jeffries, D., Green, J., and Green, R. (1984). Commercial fish and crustacean traps: a serious cause of otter (*Lutra lutra*) mortality in Britain and Europe. Vincent Wildlife Trust, London.

Jenkins D. & Burrows G. O. (1980). *Ecology of Otters in Northern Scotland. III. The Use of Faeces as Indicators of Otter (Lutra lutra) Density and Distribution*. Journal of animal ecology, Vol. 49, No. 3, pp 755.

Jones, M.A., Paetkau, D., Geffen, E. and Moritz, C., (2004). *Genetic diversity and population structure of Tasmanian devils, the largest marsupial carnivore.*
Journal of the International Otter Survival Fund No 1

Jongh de, A.W.J.J., Ó Néill, L.,de Jong, Tj. (2011). *Coastal otters (Lutra lutra) in Roaringwater bay, Ireland, A pilot study on coastal otters tagged with GPS GSM transmitters.* Report National Parks and Wildlife Service and Dutch Otterstation Foundation, 26 pp.

Jongh de, 2014 De Otter in Claassen, T.H.L., 2014. Een duistere geschiedenis opgehelderd. Waterkwaliteit en waterkwaliteitsonderzoek in Friesland, een historisch literatuuroverzicht

Jongh de, A.W.J.J. (1995). In het Spoor van de Otter, Interboek.

Johnston R. B., Bettany S. M., Ogle R. M., Aikman H. A., Taylow G. A., Imber M. J., (2003). *Breeding and fledging behaviour of the Chatman taiko (Magenta petrel) Pterodromamegentae and predator activity at burrows*. Marine Ornithology 31: 193-197

Kernohan, B.J., Gitzen, R.A., Millspaugh, J.J., (2001). *Analysis of animal space use and movements*. In:

Millspaugh, J.J., Marzluff, J.M. (Eds.), Radio Tracking and Animal Populations.

Kruuk, H. and Balhary, D. (1990). Effects of water on thermal insulation of the otter *Lutra lutra*. J. Zool. London 220: 405-415

Kruuk, H. (2006). *Otters: ecology, behavior and conservation*. New York: Oxford University Press.

Kruuk H., Conroy J.W.H., Glimmerveen U., Ouwerkerk E.J. (1986). *The use of spraints to survey populations of otters Lutra lutra.* Biological Conservation, Volume 35, Issue 2, 1986, pp 187–194.

Kruuk, H., Moorhouse, A., Conroy, J. W. H., Durbin, L., Frear, S., (1989). *An estimate of numbers and habitat preference of otters Lutra lutra in Shetland, UK*. Biol. Conserv. 49, 241-254

Kruuk H. (1993). *Scent marking by otters (Lurru lutru): signalling the use of resources*. *Behav. Ecol.* **3:** 133-140.

Kruuk H, Nolet B and French D (1988). *Fluctuations in numbers and activity of inshore demersal fishes in Shetland.* Journal of Marine Biological Association of the United Kindom, 68, 601-617

Kruuk,H. (1995) Wild Otters. Predation and Populations. Oxford University Press, Oxford.

Leuchtenberger, C.A. Zucco, C. Ribas, W. Magnusson & G. Mourão (2014) Activity patterns of giant otters recorded by telemetry and camera traps, Ethology Ecology & Evolution, 26:1, 19-28, DOI: 10.1080/03949370.2013.821673

Liles, G. (2009). Otter (Lutra lutra) activity on the open coast and islands within the Pembrokeshire Marine Special Area of Conservation. A report to the Pembrokeshire Marine SAC Relevant Authorities Group

Lode T. (1995). *Activity pattern of polecats Mustela putorius L. in relation to food habits and prey activity*. Ethology 100: 295–308.

Lovett L, Kruuk H and Lambin X (1997). *Factors influencing use of freshwater pools by otters, Lutra lutra in a marine environment.* Journal of Zoology, London, 243, 825-831

Lunnon, R.M., Reynolds, J.D. (1991).*Distribution of the otter (Lutra lutra) in Ireland and its value as an indicator of habitat quality*. In: Jeffrey D.W., Madden, B.(eds.). *Bio-indicators and environmental management*, 435-443. London, Academic Press.

Macdonald and Mason. (1994). *Status and conservation needs of the otter in the western Palearctic.* Council of Europe. Nature and environment, no. 67

Madsen A.B., Prang, A. (2001). *Habitat factors and the presence or absence of otters Lutra lutra in Denmark.* Acta Theriologica, June 2001, Volume 46, Issue 2, pp 171-179

Marine Institute (2013). *Article 6 Assessment of Aquaculture and Fisheries in Roaringwater Bay.* Rinvile Oranmore, Co. Galway.

Marnell, F., Ó Néill, L., Lynn, D. (2011). *How to calculate range and population size for the otter? The Irish approach as a case study.* IUCN Otter Spec. Group Bull. 28(B)

Mason C.F., Macdonald S.M. (1987). *The use of spraints for surveying otter Lutra lutra populations: An evaluation*. Volume 41, Issue 3, 1987, pp 167–177.

Melquist W.E. and Hornocker M.G. (1983). *Ecology of river otters in west Central Idaho*. Wildlife Monographs 83: 1–60.

Miller, S. 0. & Everett, D. D. (1987). *Interactions between Felidae and their prey species: a review*. Cats of the world: ecology, conservation and management. National Wildlife Federation, Washington, pp. 353-374

Moritz C (1999) *Conservation units and translocations: strategies for conserving evolutionary processes*. Hereditas, 130, 217–228.
National Parks And Wildlife Service (2001). *Roaringwater Bay Site Synopsis*. Accessed on December 28, 2013 at www.npws.ie

National Parks And Wildlife Service (2011). *Roaringwater Bay and Islands Conservation Objectives*. Accessed on December 28, 2013 at www.npws.ie

National Parks And Wildlife Service (2011). *Roaringwater Bay Conservation Objectives Supporting Document – Coastal Habitats*. Accessed on December 28, 2013 at www.npws.ie

National Parks And Wildlife Service (2011). *Roaringwater Bay Conservation Objectives Supporting Document – Marine Habitats*. Accessed on December 28, 2013 at www.npws.ie

Noda, M., Gushima, K., Kakuda, S. (1994) Local prey search based on spatial memory and expectation in the planktivorous reef fish,Chromis chrysurus (Pomacentridae). Anim. Behav. 47 : 1413–1422.

Nolet, B.A., Dennis, E.H., Wansink, and Kruuk, H. (1993). Diving of otters (*Lutra lutra*) in a marine habitat: use of depths by a single-prey loader. Journal of Animal Ecology 62, 22-32.

NPWS. (2008). *Conservation Status in Ireland of Habitats and Species listed in the European Council Directive on the Conservation of Habitats, Flora and Fauna 92/43/EEC.*

NPWS. (2014). About NPWS. Accessed on 02-04-2014, at www.npws.ie

NPWS. (2014). Special Areas of Conservation. Accessed on 03-04-2014, at www.npws.ie
of otters (Lutra lutra) using infrared technology. Journal of Zoology 270: 577–584.

O'Neill, D., Turner, P.D., O'Meara, D.B, Chadwick, E.A., Coffey, L., O'Reilly, C. (2013) Development of novel real-time TaqMan® PCR assays for the species and sex identification of otter (Lutra lutra) and their application to noninvasive genetic monitoring. Molecular Ecology Resources (2013) 13, 877–883

Philcox, C.K., Grogan, A.L. and Macdonald, D.W. (1999). Patterns of otter (Lutra lutra) road mortality in Britain. Journal of Applied Ecology, 36, 748-762.

Quaglietta, L., Fonseca, V.C., Mira ,A. and Boitani, L. (2014)*Socio spatial organization of a solitary carnivore, the Eurasian otter (Lutra lutra)*. Journal of Mammalogy, 95(1):140-150.

Ralls K. and Siniff D.B. (1990). *Time budget and activity patterns in California sea otters.* The Journal of Wildlife Management 54: 251–259.

Ralston and Michael (1986). High tide movements of the temperate-zone herbivorous fish Cebidichthys violaceus (Girard) as determined by ultrasonic telemetry. Journal of Experimental Marine Biology and Ecology, 98, 35 – 50.

Scottish Natural Heritage (2014). Otters: Biology. Accessed on 14-04-2014, at www.snh.org.uk

Seidensticker, J. (1976). *On the ecological seperation between tiger and leopard.* Biotropica. Vol. 8, No. 4, Dec

Steward R.H. (2008). *Introduction To Physical Oceanography*. Department of Oceanography Texas A & M University.

White S, O'Neill D, O'Meara DB, Shores C, Harrington AP, O'Reilly C, Weyman G and Sleeman DP (2013). A non-invasive genetic survey of otters (*Lutra lutra*) in an urban environment: a pilot study with citizen scientists *IUCN Otter Specialist Group Bulletin*

Twelves, J., 1983 - Otter (Lutra lutra) mortalities in lobster creels. J. Zool, Lond. 201, 585-588

Wickens, J.D. (1990). *Otter Survey of Roaringwater Bay, South West Cork, Ireland.* Sherkin Island Marine Station Issue 12. Cork, Ireland.

Wilson, S.P. (2012). River otter (Lontra canadensis) home range, habitat use, overnight movement, and survival in the Platte river of Nebraska. University of Nebraska.

Yoxon P (1999). Geology and otter distribution on Skye. PhD Thesis, Open University, Milton Keynes, UK.

Zamon J. (2001). Seal predation on salmon and forage fish school as a function of tidal currents in theSan Juan Islands, Washington, USA. Fisheries Oceanography10:4, 353 – 366.

ZielinskI W.J. (1988). *The influence of daily variation in foraging cost on the activity of small carnivores*. Animal Behaviour 36: 239–249.

Appendices

Appendix I – Conservation objectives for Roaring Water Bay and Islands

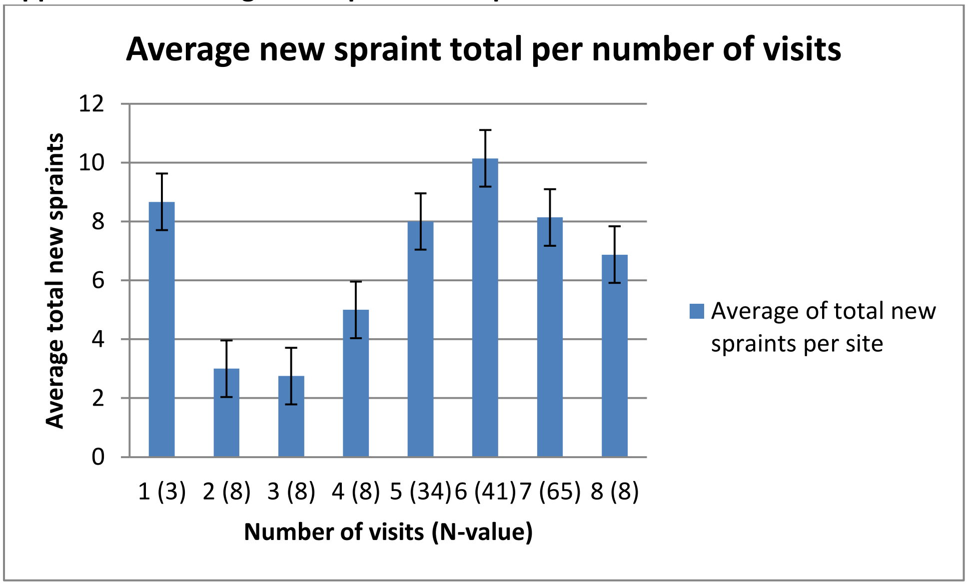
Conservation objectives for: Roaringwater Bay and Islands SAC [000101]

1355 Otter *Lutra lutra*

To restore the favourable conservation condition of Otter in Roaringwater Bay and Islands SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Distribution	Percentage positive survey sites	No significant decline	Measure based on standard otter survey technique. FCS target, based on 1980/81 survey findings, is 88% in SACs. Current range estimated at 75% (Bailey and Rochford, 2006; Rapid assessment results from Roaringwater Bay)
Extent of terrestrial habitat	Hectares	No significant decline. Area mapped and calculated as 171ha above high water mark (HWM); 3ha along river banks/ around ponds	No field survey. Areas mapped to include 10m terrestrial buffer along shoreline (above HWM and along river banks) identified as critical for otters (NPWS, 2007)
Extent of marine habitat	Hectares	No significant decline. Area mapped and calculated as 1562ha	No field survey. Area mapped based on evidence that otters tend to forage within 80m of the shoreline (HWM) (NPWS, 2007; Kruuk, 2006)
Extent of freshwater (river) habitat	Kilometers	No significant decline. Length mapped and calculated as 0.74km	No field survey. River length calculated on the basis that otters will utilise freshwater habitats from estuary to headwaters (Chapman and Chapman, 1982)
Couching sites and holts	Number	No significant decline	Otters need lying up areas throughout their territory where they are secure from disturbance (Kruuk, 2006; Kruuk and Moorhouse, 1991)
Fish biomass available	Kilograms	No significant decline	Broad diet that varies locally and seasonally, but dominated by fish, in particular salmonids, eels and sticklebacks in freshwater (Bailey and Rochford, 2006) and wrasse and rockling in coastal waters (Kingston et al., 1999).
Barriers to connectivity	Number	No significant increase. For guidance, see map 7	Otters will regularly commute across stretches of open water up to 500m. e.g. between the mainland and an island; between two islands; across an estuary (De Jongh and O'Neill, 2010). It is important that such commuting routes are not obstructed

Appendix II – Average new spraint total per number of visits



Appendix III – Trap cam specifications

Product	7 x Dörr SnapShot mini black 5.0	3 x Dörr SnapShot Extra Black 5.0	1 x Bushnell Trophy Cam HD Black flash 2013	2 x HCO ScoutGuard SG570V Green Trail Camera SG570V-GRN
Flash distance	8 metres	20 metres	15 metres	12 metres
Black flash	Yes infra-red	Yes infra-red	Yes infra-red	Yes infra-red
	5 MP	5 MP	8 MP	5 MP
Video	1-60 seconds	1-60 seconds	1-60 seconds	1-60 seconds
Reaction time	1,3	1,2 seconds	0,9 seconds	1,3 seconds
Video resolution	640x480	640x480	1280x720p HD-video	640x480
Hybrid function	No	No	Yes	No

Appendix IV – Distribution of fisheries in Roaring Water Bay

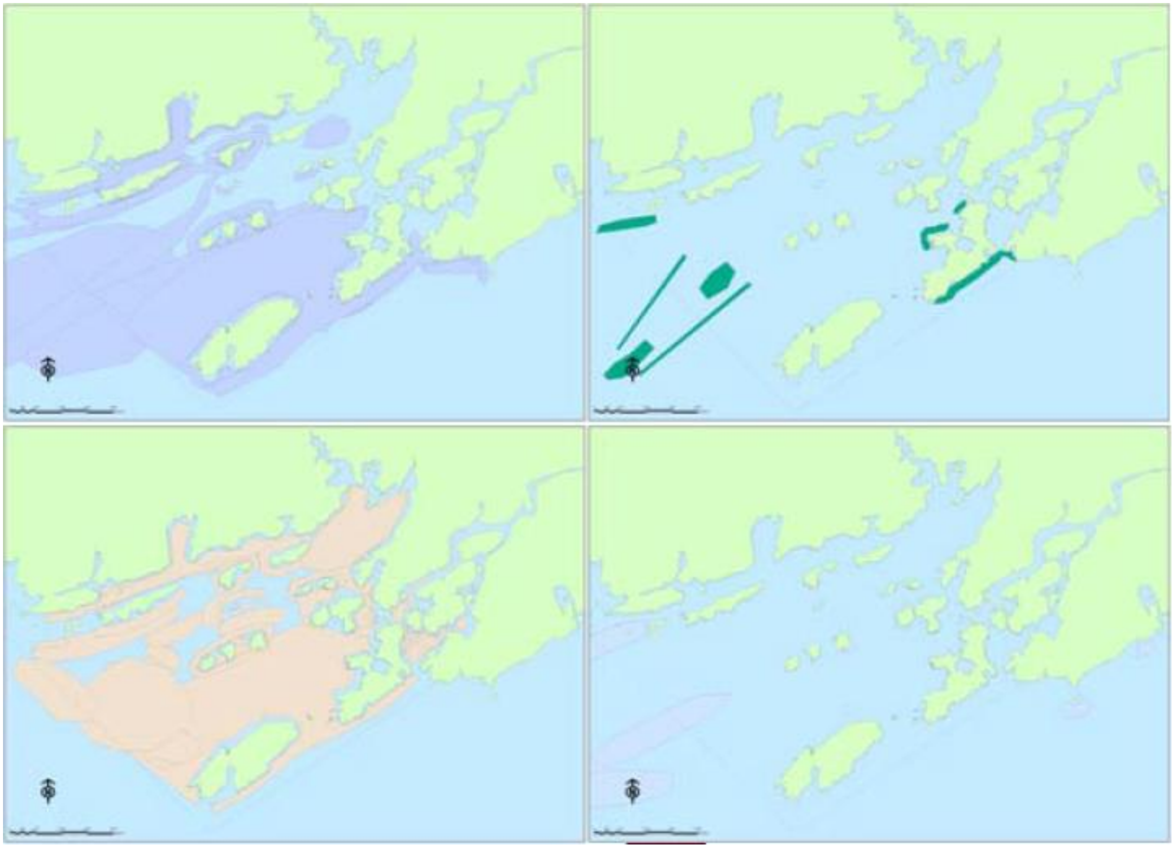


Figure III.A: Distribution of static fishing gear in Roaring Water Bay. From left to right: Creel fisheries, Gill nets, Shrimp pots, Tangle nets. Trammel nets are a subset of creel fisheries (Marine Institute, 2013)

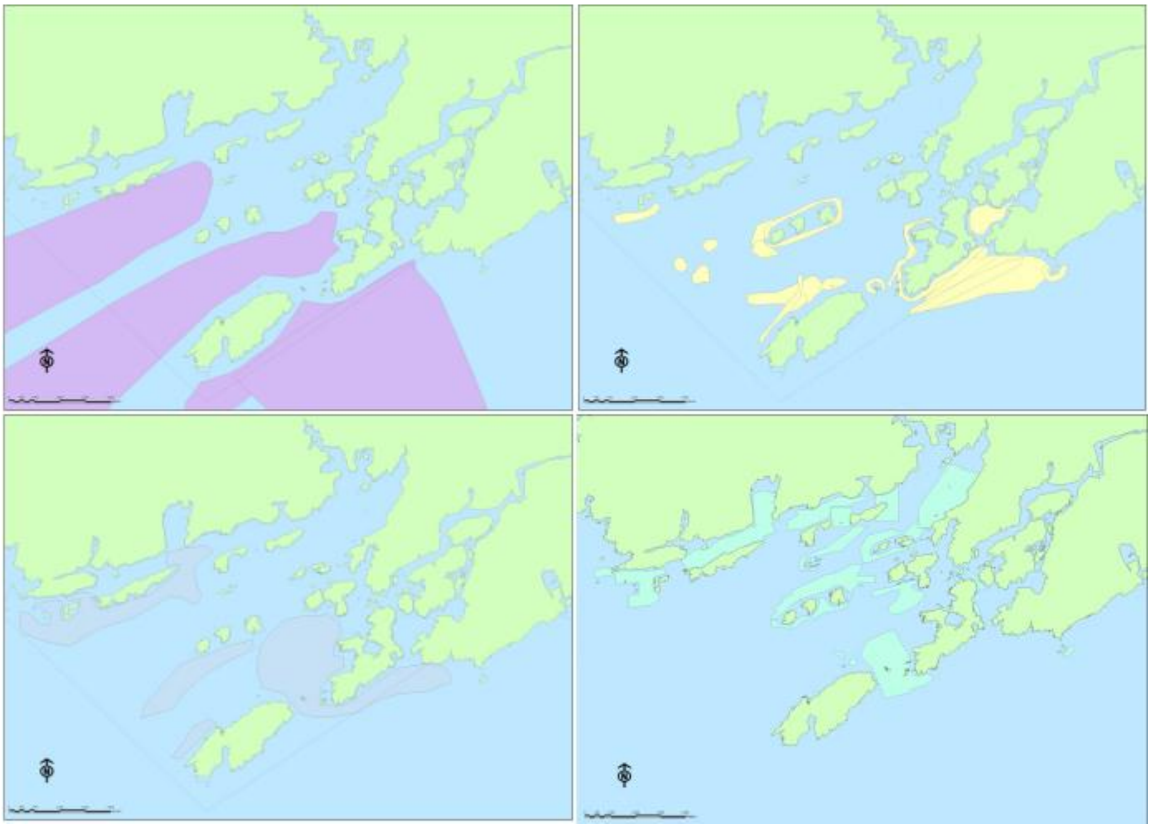


Figure III.B: Distribution of mobile fisheries in Roaring Water Bay. From left to right: Demersal fisheries, Hook and Line fisheries, Pelagic nets, Scallop fisheries (Marine Institute, 2013)

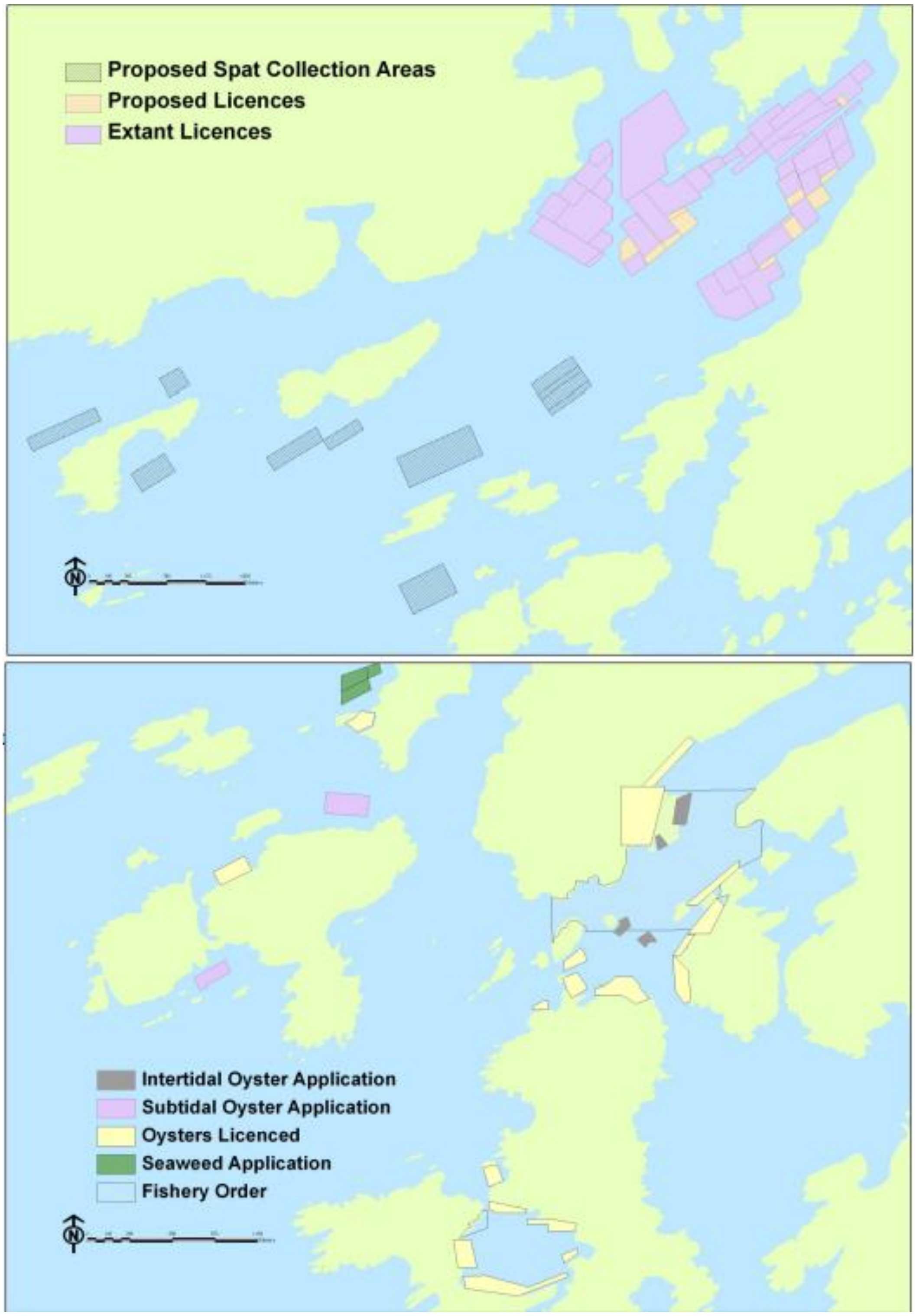


Figure III.C: Distribution of aquaculture (mussels above and oysters below) in Roaring Water Bay. The Fishery Orders on Sherkin Island consist of oyster culture with bags and metal frames as described in the text. (Marine Institute, 2013)

Appendix V – PRESENCE input and output

```
PRESENCE - Presence/Absence-Site Occupancy data analysis
Tue Sep 30 16:06:18 2014,       Version 6.9_140829
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
==>i=otter_pop_30-09-14.pao
==>l=pres_1_group__Constant_P.out
==>name=1 group, Constant P
==>model=100
==>j=c:\users\daan\documents\afstuderen\analyse\lutra_presence_test_project\otter_pop_30-09-14_project\otter_pop_30-
09-14.dm
==>lmt=200
varcov: nsig=6 eps=1.000000e-002
model=100 N,T-->14,55




********* Input Data summary *******
Number of sites              = 14
Number of sampling occasions   = 55
Number of missing observations = 305
Data checksum = 26710

NSiteCovs-->0
NSampCovs-->0
Primary periods=1 Secondary periods: 55
Naive occupancy estimate       = 0.7143

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Otter_pop_3-09-14
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
N=14 T=55 Groups=1 bootstraps=0

-->1-55
Matrix 1: rows=2, cols=2
          -,a1,
psi          1
=======================

Matrix 2: rows=56, cols=2
          -,b1,
P[1]         1
P[2]         1
P[3]         1
P[4]         1
P[5]         1
P[6]         1
P[7]         1
P[8]         1
P[9]         1
P[10]        1
P[11]        1
P[12]        1
P[13]        1
P[14]        1
P[15]        1
P[16]        1
P[17]        1
P[18]        1
P[19]        1
P[20]        1
P[21]        1
P[22]        1
P[23]        1
P[24]        1
P[25]        1
P[26]        1
P[27]        1
P[28]        1
P[29]        1
P[30]        1
P[31]        1
P[32]        1
P[33]        1
P[34]        1
```

```
P[35]        1
P[36]        1
P[37]        1
P[38]        1
P[39]        1
P[40]        1
P[41]        1
P[42]        1
P[43]        1
P[44]        1
P[45]        1
P[46]        1
P[47]        1
P[48]        1
P[49]        1
P[50]        1
P[51]        1
P[52]        1
P[53]        1
P[54]        1
P[55]        1
========================

Matrix 3: rows=0, cols=0
========================

Matrix 4: rows=0, cols=0
========================

Matrix 5: rows=0, cols=0
========================

Matrix 6: rows=0, cols=0
========================

modtype=1

Custom Model:

Number of parameters          = 2
Number of significant digits   =   7.7

Model has been fit using the logistic link.


Number of parameters          = 2
Number of function calls          = 53
-2log(likelihood)            = 457.5330
AIC                          = 461.5330
LikeNRSig=6 eps=0.01 ETA=1e-013

Untransformed Estimates of coefficients for covariates (Beta's)
======================================================================
                              estimate    std.error
A1   psi                    :  0.916315    0.591618
B1   P[1]                   :  -0.491602    0.113100

============================================================

   Individual Site estimates of <psi>
           Site              estimate  Std.err   95% conf. interval
psi           1 site 1        :  0.7143   0.1207     0.4395 -  0.8885

============================================================

   Individual Site estimates of <P[1]>
           Site              estimate  Std.err   95% conf. interval
P[1]          1 site 1        :  0.3795   0.0266     0.3289 -  0.4329
P[2]          1 site 1        :  0.3795   0.0266     0.3289 -  0.4329
P[3]          1 site 1        :  0.3795   0.0266     0.3289 -  0.4329
P[4]          1 site 1        :  0.3795   0.0266     0.3289 -  0.4329
P[5]          1 site 1        :  0.3795   0.0266     0.3289 -  0.4329
P[6]          1 site 1        :  0.3795   0.0266     0.3289 -  0.4329
P[7]          1 site 1        :  0.3795   0.0266     0.3289 -  0.4329
P[8]          1 site 1        :  0.3795   0.0266     0.3289 -  0.4329
P[9]          1 site 1        :  0.3795   0.0266     0.3289 -  0.4329
```

```
P[10]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[11]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[12]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[13]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[14]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[15]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[16]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[17]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[18]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[19]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[20]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[21]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[22]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[23]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[24]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[25]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[26]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[27]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[28]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[29]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[30]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[31]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[32]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[33]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[34]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[35]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[36]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[37]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[38]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[39]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[40]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[41]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[42]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[43]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[44]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[45]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[46]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[47]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[48]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[49]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[50]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[51]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[52]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[53]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[54]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329
P[55]      1 site 1      :  0.3795   0.0266    0.3289 -  0.4329

=================================================================


 DERIVED parameter - Psi-conditional = [Pr(occ | detection history)]

     Site              psi-cond  Std.err     95% conf. interval
    1   site 1            0.0000  0.0000     0.0000 - 0.0000
    2   site 2            1.0000  0.0000     1.0000 - 1.0000
    3   site 3            0.0000  0.0000     0.0000 - 0.0000
    4   site 4            1.0000  0.0000     1.0000 - 1.0000
    5   site 5            1.0000  0.0000     1.0000 - 1.0000
    6   site 6            1.0000  0.0000     1.0000 - 1.0000
    7   site 7            0.0000  0.0000     0.0000 - 0.0000
    8   site 8            1.0000  0.0000     1.0000 - 1.0000
    9   site 9            1.0000  0.0000     1.0000 - 1.0000
   10  site 10            1.0000  0.0000     1.0000 - 1.0000
   11  site 11            1.0000  0.0000     1.0000 - 1.0000
   12  site 12            1.0000  0.0000     1.0000 - 1.0000
   13  site 13            1.0000  0.0000     1.0000 - 1.0000
   14  site 14            0.0001  0.0001     0.0000 - 0.0006

hist      obs     exp
   1 000000000000000000000000000000000000....................     1.00000     3.99993       2.250
   2 ...................................010000011111101001.     1.00000     0.00002    44908.674
   3 000....00000000000000000000000000000000..............     1.00000     3.99993       2.250
   4 .........................................1111010111.     1.00000     0.00166     601.523
   5 .01000011100111011011101010..0111000000......000.......     1.00000     0.00000 51642969043.222
   6 .0000110000001001100011001000110000000000000000100000000.     1.00000     0.00000 2156686048568.752
   7 ...00.....0000....00000000000000..00000000000000000000.     1.00000     3.99993       2.250
```

```
  8 ...10..0000...00000000000000000000000000000000000000.      1.00000      0.00000 559629453.550
  9 .....01001010111000...........0111110111111011111111111      1.00000      0.00000 11521524138124.379
 10 .....0...1110....10111011001111010111100100110000010011      1.00000      0.00000 10878999995533.057
 11 ...............00.....00001101..00111..0010....1110011.      1.00000      0.00000  8933184.282
 12 ...................000101110110100000000000000...00000.      1.00000      0.00000 13400616.356
 13 ............................11000101000001101000011000.      1.00000      0.00000  2044119.642
 14 ................................0000000000000000000000.      1.00000      4.00021        2.250

Total chi-square=24609437204162.434000

CPU time= 0 seconds (0.00 min)
```