The Response of Commercially Exploited Crustaceans to Protection in Scotland's First No Take Zone – Lamlash Bay, Isle of Arran

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Abstract

Protected areas often promote biomass increases in exploited species and have the potential to maintain and enhance the fisheries surrounding them through spillover and larval export. Three temperate species of crustacean, European lobster (*Homarus gammarus*), Edible crab (*Cancer pagurus*) and Velvet crab (*Necora puber*), were surveyed to assess their population responses to four years of protection from fishing within the Lamlash Bay No Take Zone (NTZ) – Isle of Arran, Scotland. These species represent natural resources of considerable economic importance to the UK fishing industry meaning there is great interest in whether closed area protection could offer benefits for surrounding fisheries. A creeling survey was undertaken to gather data on abundance and size structure of these three species. A tag and release method was used for future analysis of growth and movement. *H. gammarus* were found to be 2 % more abundant within the NTZ. Individuals of an exploitable size were 12 % more abundant and were significantly larger by an average of 6 mm. *C. pagurus* were 11 % more abundant inside the NTZ and exploitable sized individuals were 8 % more abundant. *N. puber* were more prolific on the northern shore of the NTZ but this was believed to be down to habitat suitability rather than a result of protection. There were no significant differences in catch per unit effort (CPUE) between fished and protected areas for *H. gammarus and C. pagurus.* This study has provided a baseline for monitoring the recovery of three species of commercially fished crustaceans within the Firth of Clyde, a heavily fished ecosystem.

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1 Introduction

The world's oceans have been fished for thousands of years. Human endeavour to access diminishing protein stocks added to the pressures of increasingly consumption-focused lifestyles have driven many marine species to near extinction (Myers and Worm, 2003). Technological improvements have enabled fishing to occur both deeper and more intensely than ever before. Very few habitats remain untouched (Roberts, 2012) and protected areas are needed now more than ever. Such havens, generally referred to as Marine Protected Areas (MPAs) are few and far between and protect less than 3 % of global oceans (Greenpeace, 2012; Harrabin, 2012; Marine Reserve Coalition, 2013) with the level of protection varying significantly (Allison *et al.,* 1998).

Mankind's relationship with nature has changed from healthy, primordial, hunter-gathering to meet basic needs to one focused on economic returns and growth. On land, the effects of this transition have been clearly visible and growing awareness of the adverse changes led to the creation of the first nature reserves in the 1870s (Sobel and Dahlgren, 2004). In the marine world their creation lacked the same urgency as disturbances were very much 'out of sight and out of mind' (MWH, 2013). The first MPA was created in 1935 (CGER, 2001) with the number now standing at about 5880 (Toropova *et al.,* 2010). Only a small portion of these are fully protected No Take Zones (NTZs) and they protect less than 1% of global oceans (Marine Reserve Coalition, 2013). Some optimism is justified because of the growing number of plans to protect further and larger areas of marine ecosystems (Toropova *et al.,* 2010) but current levels offer little protection. Roberts and Hawkins (2000) characterized the global nature of the problem as being *"in countries rich and poor, in waters warm and cold"* (Roberts and Hawkins, 2000). The current level of protection falls well short of the 10-30% recommended (World Parks Congress, 2003; Balmford *et al.,* 2004; Toropova *et al.,* 2010).

No Take Zone designations ban all forms of extractive use (Lubchenco *et al.,* 2003; Sobel & Dahlgren, 2004). They provide a safe-haven for marine life, allowing them freedom to spawn, mate, and feed without the pressures of capture or habitat loss (Claudet, 2011). The implementation of MPAs can be highly beneficial in improving the management of fisheries as they can increase the abundance of targeted organisms and restore natural, extended age-structures (Halpern, 2003; Berkeley et al. 2004; Roberts, Hawkins & Gell., 2005; Kelleher and Kenchington, 1992). This may directly benefit fisheries in adjacent waters by offering higher and less variable catches through larval dispersal and spillover (Bradshaw *et al*., 2001; Roberts *et al*.. 2001; Kay *et al*., 2012). MPAs are an efficient and inexpensive, ecosystem fisheries management tool that simultaneously helps preserve biodiversity by limiting habitat loss (Lauck *et al*., 1998).

Top down protection of marine ecosystems through NTZ designations allows for the recovery of all organisms, encourages their natural interactions (presuming the reserve is of an adequate size), and

permits the establishment of more complete and complex ecosystem structures which can translate into benefits for commercially important species (Jennings & Kaiser, 1998).

This study focuses on Lamlash Bay which is situated on the east coast of Arran, the largest island in the Firth of Clyde. It is a tranquil setting, bounded on its western shores by the beautiful Holy Island (home to a Buddhist retreat centre), with openings to the north and south. The Lamlash Bay NTZ is located at the north entrance to the bay. Here, Buddhist culture and a close-knit island community have mingled to present a unique experience. The Lamlash Bay NTZ is unusual in developed countries as its establishment was community-led, following the culmination of a long campaign by The Community of Arran Seabed Trust's (COAST) – a bottom-up process rather than the usual top-down control. Protected since 2008 it offers a 2.67 km^2 haven for marine life, which contrasts strongly with the exploitation in the Firth of Clyde – a stark example of the effect mankind has had on the sea (Thurston & Roberts, 2010).

The Firth of Clyde is Scotland's most southerly fjord and penetrates approximately 100 km inland. The literature describes it as an ecosystem formerly brimming with shellfish, cetaceans and whales, and consisting of more fish than water during the annual herring runs (Thurston and Roberts 2010; Roberts 2012). Due to extensive overfishing this picture of an ecosystem in its prime has been completely overturned, with some considering it to be in a state of 'ecological meltdown' (Thurston & Roberts 2010).

Overfishing has greatly increased our reliance on shellfish as they are relatively more resilient to fishing and have come to dominate intensively fished areas such as the Clyde although critics believe this is only part of the reason. Reductions in primary target species has resulted in fisheries switching to shellfish as the fish ran out, and as a result, shellfish numbers may be proliferating as their predators have been so reduced (Miller, 2012; Roberts, 2012. Howarth *et al*., in press). Finally, climate change appears to be benefiting scallops around the UK (Shephard *et al*., 2010). However, The Firth of Clyde's seabed demonstrates more the effects of intensive fishing – now only supporting a small scallop, *Nephrops* (Langoustine) and crustacean fishery (Thurston & Roberts 2010).

Shellfish are of significant economic importance to UK fisheries particularly in Scotland which has a much higher proportion of fishermen compared to the rest of the UK (MMO, 2011a). Lobsters, accounting for only 2 % in weight of UK shellfish landings in 2011, form 11 % of their total value, fetching £10.19 per kilogram in the same year (MMO, 2011b). Landings of all shellfish in 2009 were worth in the region of £250 million, making up almost 50 % the value of total UK landings (Defra, 2013).

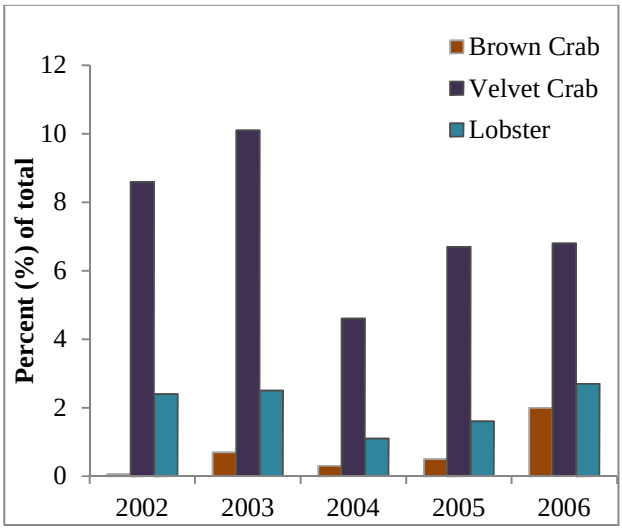

Figure 1: Clyde percentage of total landings into Scotland of brown crab, lobster and velvet crab 2002-2006. (put together from data in Mill et al., 2009)

The importance of MPAs is becoming increasingly evident. Landings of all species by Scottish vessels fell from 488,000 tonnes in 2001 to 359,000 tonnes in 2011 (MMO, 2011a). MPAs could help regenerate these fisheries. Despite the shellfish fishery being better off than most it also is considered to be over exploited (DEFRA, 2013) and because of this overfishing and rising fuel costs fishermen are having to work harder to make ends meet (COAST, 2011). Figure 1 shows the percentage of all Scottish crab and lobster fisheries caught within the Clyde. Most of these are captured using traditional fishing methods such as creeling – the main form of large crustacean capture. This type of fishing has been promoted as being less destructive as it causes minimum habitat disturbance and has a notably low proportion of bycatch (Alverson *et al.*, 1996).

1.2 Marine Reserves in the UK

To date there are only three marine reserves in UK waters with full NTZ protection status. These are at Lundy Island in the Bristol Channel, Flamborough Head on the Yorkshire Coast and in Lamlash Bay on the Isle of Arran. Together they cover just 0.01 % of UK waters (Monbiot, 2012) – which is considerably short of the recommended 30 % (RCEP, 2004).

Under EU law, the British Government was obliged to allocate areas of sea so as to create an 'ecological coherent' network of marine conservation zones (MCZs) around the UK by 2012 (OSPAR, 2013). Marine conservation zones were introduced under the UK Marine and Coastal Access Act (2009). The Government is now in breach of this promise (Monbiot, 2012). The 2011 consultation by the Joint Nature Conservation Committee (JNCC) and Natural England recommended 127 MCZs which would cover only one sixtieth of the area proposed by the Royal Commission on Environmental Pollution (RCEP) in 2004 (Monbiot, 2012; Defra, 2013b). Unsurprisingly the coalition government [which was intended to be the 'greenest government ever' (Randerson, 2010)] was quick to shut down the RCEP (Vaughan, 2010), part of the government's sustainability watchdog that often voiced "inconvenient truths" (Monbiot, 2012). Currently Defra is proposing 31 sites for MCZ designation by the end of 2013 (MCZ Mapping, 2013) with no timeframe given for the rest (Guardian, 2013).

1.3 Aim

This research explores the basic ecological principles and the reasoning behind marine protected areas (MPAs). It focuses on whether the Lamlash Bay NTZ is benefitting commercially exploited crustaceans within the Firth of Clyde, namely: European Lobster (*Homarus gammarus*), Brown Crab (*Cancer pagurus*) and Velvet Swimming Crab (*Necora puber*). It aims to investigate their abundance, movement patterns, spillover rates and population structure. This survey was undertaken as part of joint efforts between the University of York and COAST to assess the overall rate of recovery of the Lamlash Bay NTZ since its first closure to fishing in 2008, and along with further research will contribute to the work of PhD student Leigh Howarth.

The objective of this research was to test the following hypotheses:

1. Crustaceans will be larger within the NTZ.
2. Crustaceans will be more abundant within the NTZ, resulting in higher catch per unit effort (CPUE).
3. CPUE will decline with increased distance from the NTZ as the effects from spillover become less pronounced.
4. Crustacean population structure will continue to recover and improve over time inside the NTZ. (to be verified through further monitoring).
5. Growth will be faster inside the NTZ and mortality will be lower (to be verified through further monitoring).
6. The NTZ has potential to be beneficial to local fisheries.

Although the Lamlash Bay NTZ is small compared to others around the world, rapid increases in lobster abundance and size at Lundy Island in southern UK suggest that even small NTZs can benefit crustaceans (Hoskin *et al*., 2010).

2 Methods

2.1 Study Area

Located on the south-eastern shore of the Isle of Arran, Lamlash Bay is semi-enclosed, sheltered on its eastern side by the Holy Island (Fig 2a & 2b). The seabed composition is generally soft sediments with some scattered patches of sublittoral rocks and kelp communities, and, most importantly in northern parts of the bay seagrass (*Zosteras* sp.) and maerl (*Corallinaceae* sp.) beds have been

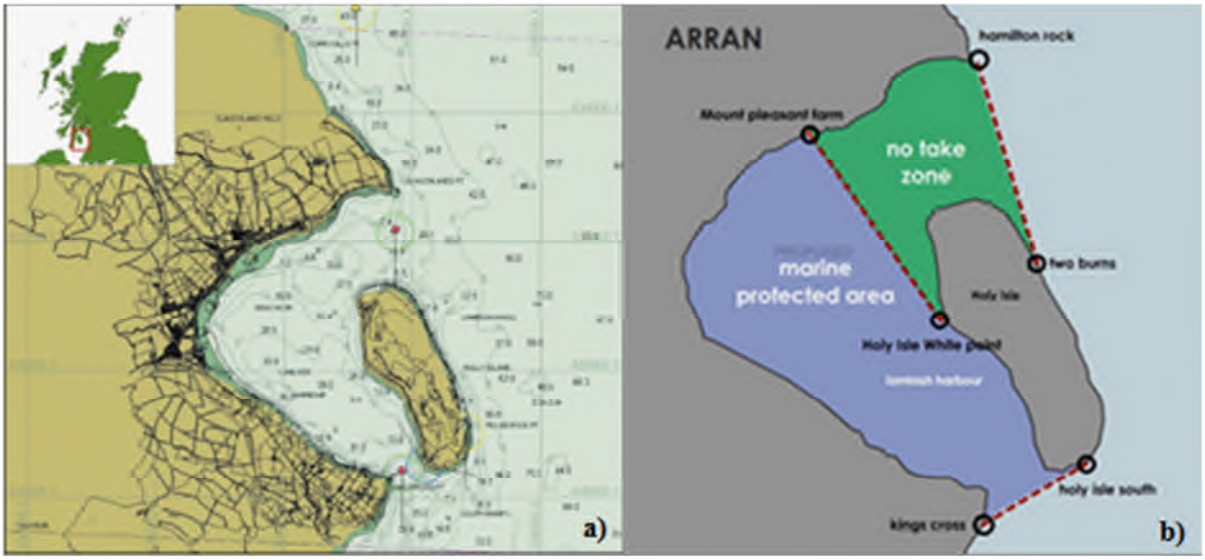

Figure 2: a) Lamlash Bay and (inset) location of the Isle of Arran, Scotland (source: Axelsson et al., 2010); b) The NTZ in Lamlash Bay (source: COAST, 2013).

reported (Duncan, 2003; Kamenos *et al*., 2004). These are priority habitats under the UK Biodiversity Action Plan (JNCC, 1999). The northern channel is strewn with boulders and dominated by mixed sediments [sand, mud, broken shell and gravel (Axelsson *et al*., 2010)]. The majority of the bay is deeper than 20 m with the maximum depth being 43 m below chart datum (Axelsson *et al*., 2010). Lamlash Bay is home to a salmon and mussel farm and a small boat mooring area.

The Lamlash Bay No Take Zone was designated in September 2008 to protect maerl beds and to promote the regeneration of the marine ecosystem (COAST, 2013; Scottish Gov., 2008). Its protection encompasses an area of 2.67 km^2 (Roberts and Thurston, 2010) at the northern end of the bay (Fig. 2b & Table 1). Early studies indicate that benefits are beginning to be seen in particular due to a greater benthic species richness inside the NTZ (Cross, 2011) and the provision of a greater abundance of macroalgae within the NTZ which in the case of scallops (*Pecten maximus* and *Aequipecten opercularis*) appears to encourage sprat settlement (Howarth, 2010; Howarth *et al*., 2011).

Table 1: Coordinates of the Lamlash Bay No Take Zone Boundary (Scottish Gov., 2008)

Location	Latitude	Longitude
Mount Pleasant Farm	55˚ 32.603' N	005˚ 06.512' W
Holy Isle West	55˚ 31.556' N	005˚ 05.216' W
Holy Isle East	55˚ 31.876' N	005˚ 04.304' W
Hamilton Rock	55˚ 33.000' N	005˚ 04.823' W
Clauchlands Point	55˚ 33.002' N	005˚ 04.957' W

2.2 Species:

Species response to protection in the Lamlash Bay NTZ was assessed for three species of commercially-fished crustaceans. These were (*i*) lobster (*Homarus gammarus* L.); (*ii*) brown crab (*Cancer pagurus* L.) and (*iii*) velvet crab (*Necora puber* L.).

2.2,1 European lobster (*Homarus gammarus)* – Linnaeus, 1758

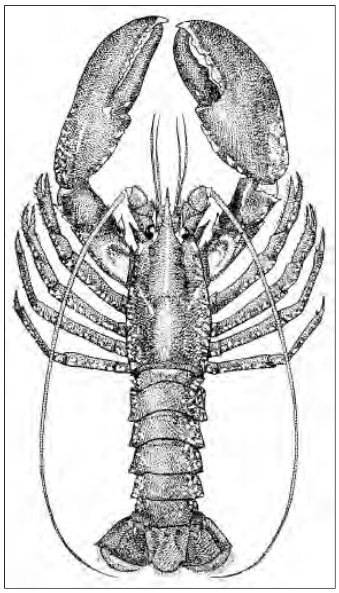

Figure 3: *H. gammarus* (Holthius, 1991)

The European lobster (*Homarus gammarus*) generally occurs in habitats with an abundance of rocks, gullies and reefs that provide crevices, holes and voids for shelter (Clark, 2008; Holthius, 1991). They are found at depths of 0-150 m but generally occur at ≤ 50 m. They have a fairly extensive range extending to north of the Arctic Circle and south of Morocco, and are found in the Mediterranean and eastern Black Sea (Ingle & Christiansen, 2004). They are bluish-brownish-greenish black to almost black. Lobsters are opportunistic feeders relying on filter feeding, scavenging and predation (Ingle & Christiansen, 2004). Their diet consists of seabed invertebrates such as crabs, molluscs, sea urchins, polychaete worms, starfish, fish and plants (Marine Scotland, 2012). They can also be cannibalistic; hence claws are generally banded upon capture (Clarke, 2008).

Homarus gammarus are nocturnal, territorial and solitary. Ovigerous (egg bearing) minimum carapace length is approximately 77 mm (Simpson, 1961) with sexual maturity being reached at 4-12 years (Clarke, 2008; Davis, 2007; Scottish Gov., 2013). Growth rate is highly variable and females mature at different sizes depending on location (Scottish Gov., 2012). They grow throughout life, living to > 50 years, sometimes to 100 (Clarke, 2008). Large individuals have been found weighing > 4 kg (Hayward & Ryland, 1995; Marine Scotland, 2012) and in sizes as large as 591 mm total maximum length (Wolf, 1978). Females spawn around July and carry eggs for ten to eleven months.

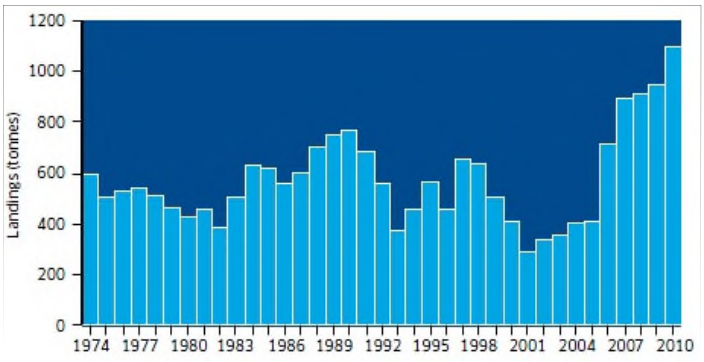

Figure 4: Landings (tonnes) of lobsters into Scotland by Scottish vessels, 1974-2010. (Marine Scotland, 2012 p. 51)

They hatch as free swimming larvae and begin life as planktonic zoeal. Whilst growing in size following several moults they acquire additional somites, setae, limbs or limb buds. Zoea then moult to a megalopa which usually bear resemblance to the juvenile form (Holthius, 1991).

Lobster is one of the most highly esteemed seafood delicacies and is fished throughout its range fetching very high prices. France and Spain have also experimented with the possibilities of aquaculture production (Holthius, 1991). In Scotland catches have been on the rise, especially in recent years (Figure 4). The Scottish lobster fishery is not subject to EU Total Allowable Catches (TAC) or national quotas. The main regulatory mechanism is a minimum landing size of 87 mm carapace length (CL) and a maximum landing size of 166 mm CL for females (Marine Scotland, 2012). Approximately 5 tonnes were landed within the Clyde in 2010 (Marine Scoltand, 2012). Within the Clyde, particularly males are growth overfished and fishing mortality is estimated to be significantly above F_{MAX} [the level of fishing mortality (rate of removal by fishing) that produces the greatest yield from the fishery] for both males and females.

2.2,2 Edible crab (*Cancer pagurus*) - Linnaeus, 1758

Figure 5: *P. pagurus* (courtesy of Angus Robson).

Cancer pagurus inhabits a range of habitats from rocky reefs to soft sediments (Scottish Gov., 2012b) and ranges from Scandinavian to Portuguese (CEFAS, 2011) coasts, from shallow sub-littoral waters to offshore and to depths exceeding 100 m (Scottish Gov., 2013). They occur mostly in depths of 6-40 m (FAO, 2013). Their diet consists mainly of benthic invertebrates, bivalves, small decapods and barnacles (Marine Scotland, 2012).

In Scottish waters, female brown crab typically mature at a carapace width between 120-150 mm (Pickerell, 2008; Scottish Gov., 2012) at which time they are 4-7 years of age (BlueOcean, 2013). Eggs are carried under the tail for up to 9 months during which females can undertake extensive seasonal migrations. On hatching the pelagic larvae drift in the water column until they settle at about 2.5 mm in size. Juveniles are more commonly found in shallow inshore waters, but the structure of Scottish populations is poorly understood (Scottish Gov., 2012).

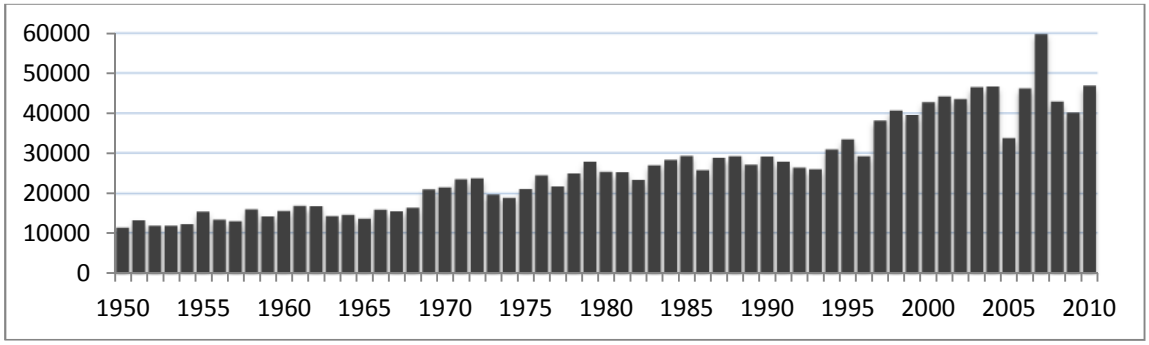

Figure 6: Global Capture Production of Cancer pagarus (tonnes). Edited from FAO Fishery Statisic (FAO, 2012).

Juveniles generally spend up to 3 years in intertidal areas, following first settlement (Clark, 2008). It typically takes 4-6 years for juveniles to grow to commercially exploitable sizes (CEFAS 2011; Scottish Gov., 2012).

Brown crab is economically very important for the Scottish fishery. Around 10,600 tonnes were landed in 2010 valued at £13.3 million, with UK-wide landings of 26,000 tonnes in 2006 valued at £34 million (Pickerel, 2008). Landings have increased significantly over the past 30 years [Figure 7, Scotland (and Figure 6 for worldwide catch)] with technological advances allowing the fishery to expand offshore. A large proportion of the catch is exported live to southern European markets. The fishery is not subject to EU total allowable catch (TAC) or national quotas with the main regulatory mechanism being the minimum landing size of 140 mm carapace width (Scottish Gov., 2012). Within the Clyde where approximately 5 tonnes were landed in 2010 (Scottish Gov., 2012) fishing mortality is estimated to be significantly above F_{MAX}.

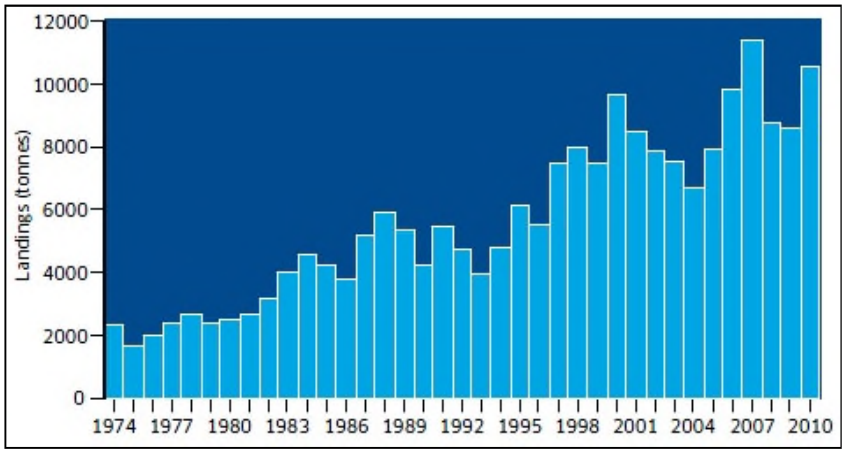

Figure 7: Landings (tonnes) of brown crabs into Scotland by Scottish vessels, 1974-2010 (Marine Scotland, 2012).

2.2,3 Velvet Swimming Crab (*Necora puber*) - Linnaeus, 1767

Figure 8: *N. puber* (courtesy of Angus Robson)

The velvet crab is the largest swimming crab found in British coastal waters. It has a fairly homogenous range from northern Norway to the Saharan coast of West Africa and occurs in the Western Mediterranean (WorRMS, 2013).

The species lives in the shallows of rocky shores below the low water mark to depths of about 25 m and under rocks in rock pools (Hayward, Nelson-Smith & Sheilds, 1996). It is aggressive in nature, attacking and consuming what it can (EOL, 2013).

Males grow quicker and larger than females with the largest individuals having a carapace width (CW) of about 80 mm (BBC, 2013). Velvet crabs reach maturity at CW of about 40 mm (with variations depending on water temperature, population density, genetics and fishing pressure) and recruit to the fishery at about 3 years old typically living 4-6 years (Scottish Gov., 2013). Their movement is thought to be fairly minimal.

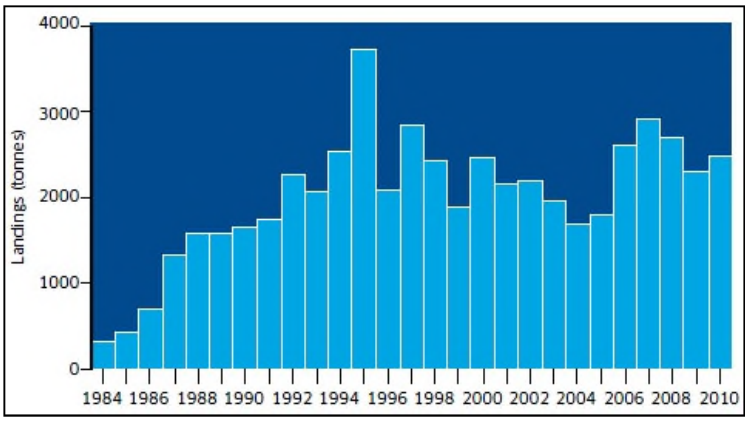

Figure 9: Landings (tonnes) of velvet crabs into Scotland by Scottish vessels, 1974-2010 (Marine Scotland, 2012).

The collapse of the Spanish fishery in the 1980s spurred the development of this fishery in Scotland (Henderson & Leslie, 2006; Scottish Gov., 2012) with 2,500 tonnes landed in 2010 valued at £6.4 million, making it the largest supplier in Europe (Scottish Gov., 2012). The majority are landed between July and November in mixed creel fisheries along with lobster and other crab. Velvet crabs are not subject to EU TACs or national quotas. The main regulatory mechanism is the minimum landing size of 65 mm CW. In the Clyde both males and females are fished significantly above F_{MAX} with approximately 5 tonnes landed in 2010 (Scottish Gov., 2012).

2.3 Sampling

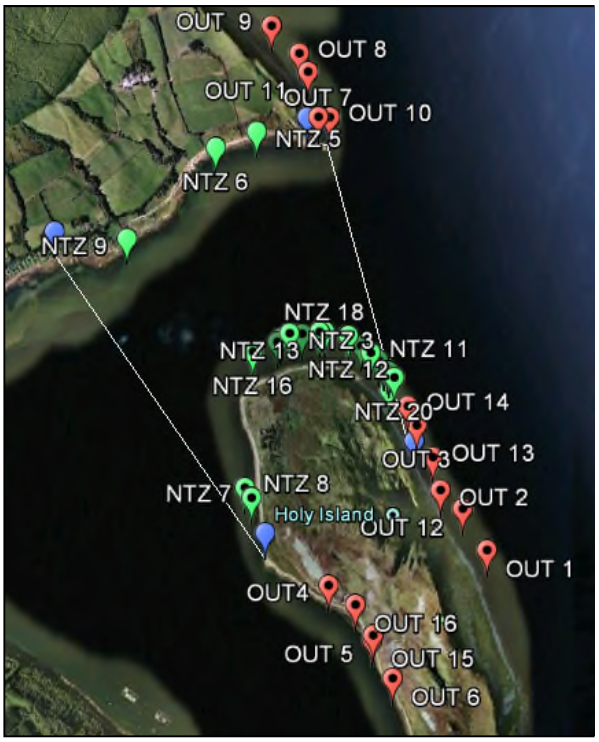

Figure 10: Sampling site locations (GoogleEarth). Green points are within the NTZ, red points outside

Lobsters and crabs were sampled using standard specification commercial shellfish pots (2 side eye entrance design with 65 mm meshsize) baited with a mix of mackerel (*Scomber scombrus* L.) and 'redfish bait'. Pots were deployed in 'strings' of 5 with approximately 20 metres between each pot from The Kimberely (registration number: OB345), a licensed creeling vessel. The pots were heavy enough to act as their own anchor. Marker-buoys were attached to the pots at either end of the string.

A total of 32 strings were deployed during two weeks, one in mid July and one in mid August 2012. These were distributed between the NTZ and bordering waters, parallel to the shoreline. Strings were left to soak for periods of 48 hours. Sites were spatially distributed in suitable habitats, as recommended from past experience by local fishermen (Figure 10).

2.4 Measurement of variables and other methodological details

The measure of abundance of each species was the number of individuals per pot. Catch per unit effort (CPUE) was calculated as the mean number of a species per string of pots – one unit effort being one pot. As pots were hauled, lobster and crabs were separated in boxes according to their species and the pots were immediately re-baited (if needed).

On capture, carapace size (width or length to nearest mm as appropriate using Vernier callipers), sex, and position of capture was recorded. Lobster and brown crab were tagged with unique alphanumerical and colour coded tags to enable later identification should they be recaptured. Orange tags were used for those caught outside the NTZ and green ones for those caught inside (Figure 11a-d).

External, plastic Burnham double T-bar-type tags (Hallprint Pty) were used as extensive lobster tagging programmes reported these to have the best tag retention rate and caused the least harm to the specimens during insertion. The procedure caused no 'allergic' reactions as well as appearing to

Figure 11: a) tagging gun (photo Dubois, 2012); b) Burnham tags used (Dubois, 2012); c) H.gammarus showing location of tag (photo courtesy of Howarth, 2012); d) the largest H. gammarus captured within the NTZ at 130 mm carapace length (Howarth, 2012).

not hinder locomotion (Bennett and Lovewell, 1983). These were inserted dorso-laterally between the cephalothorax and the first abdominal segment of lobster and to one side of the mid-line to avoid the dorsal abdominal artery and gut, and between the carapace and hind leg of brown crab using a tagging gun (Figure 11a). The 'T'-portion of the tag was anchored in muscle to persist through moulting. Specimens were promptly returned to their capture location following processing to limit stress.

Lobster sizes were taken from their carapace lengths from the inner edge of the eye socket to the rear edge of the carapace (Figure 12); brown crab and velvet crab sizes were measured at the point of widest carapace width (Figure 13).

On a specimens recapture, tag identification number and colour was recorded together with date and position of capture. Local fisherman Charlie Weir, who was thought to be the most likely captor of tagged specimens, was issued with data collection sheets. The tags also had a phone number to enable individuals to notify us of any captures. This will allow for subsequent tag-recapture studies to obtain a picture of movement and emigration patterns and rates from sites inside the reserve to fished areas or vice versa.

Figure 12: Measuring a lobster (photo: Pascal Dubois, 2012).

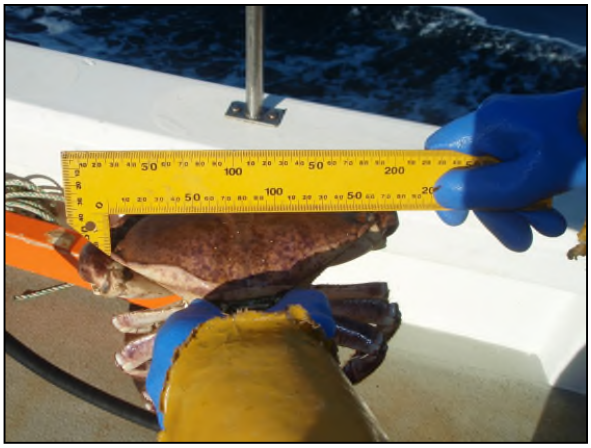

Figure 13: Measuring a brown crab (courtesy of A. Senechal)

2.5 Statistical Approach

All statistical tests were done at a significance level of $p < 0.05$.

2.5,1 Analysis of size and abundance (hypotheses 1 and 2)

Size structures of the species inside the closed area and in the fished area were compared using Kolmogorov-Smirnov (K-S) analysis. The first and second objective was to compare the abundance, sizes and catch per unit effort (CPUE) of lobster, brown crab and velvet crab caught inside versus those caught outside the NTZ. These univariate hypotheses about the potential effects of the Lamlash Bay NTZ on mean abundance and size were tested using parametric T-tests for the ease this gave in comparing two variables in normally distributed data (Dytham, 2007). Tests were carried out in order to be able to compare all sampled individuals between closed and fished areas, as well for data on abundance and size of individuals both larger than minimum landing size (lobster CL ≥ 87 mm; brown crab CW ≥ 140 mm; velvet crab ≥ 65 mm) and smaller (referred to subsequently as 'legal' and 'sublegal' sized respectively). The mean number of a species per creel was used to represent a 'unit of effort' using the following equation:

$$CPUE = \frac{\Sigma\, Species\ x\ in\ string}{number\ of\ pots\ on\ string}$$

2.5,2 Regression Analysis of Potential for Spillover (hypothesis 3)

The third objective was to test the relationship between CPUE of species and distance from the NTZ boundary. The effect of distance from the NTZ border on mean size per string of pots was also studied. This analysis was completed for lobsters only as they have the highest market value, hence they are considered to be of most interest to local fishermen.

Lobsters were divided into legal and sublegal size groups. The distance (metres) between the trapping locations and the NTZ boundary was measured using the GoogleEarth distance tool. For the strings inside the NTZ, measurements were made from the recorded GPS locations at 90 ˚ to the nearest NTZ border across open water.

Table 2: String and associated distance from nearest NTZ border, average lobster size and legal individuals' CPUE.

	INSIDE NTZ			OUTISDE NTZ		
String	Distance from Border	Average Size (mm)	Legal Sized CPUE	Distance from Border	Average Size (mm)	Legal Sized CPUE
1	42	94	1.8	-843	86	1
2	276	94	1.6	-357	95	0.4
3	591	94	1.6	-47	92	1
4				-522	89	1.4
5				-967	87	0.6
6				-1256	87	1
7				-6	82	0.2
8	55	69	0	-436	72	0
9				-697	77	0
10	58	95	0.4	-18	87	1
11	124	92	1.2	-300	97	2.8
12	236	95	1.4	-538	87	0.2
13	410	87	0.8	-159	77	0.2
14	522	87	0.8	-16	82	0.2
15	590	91	1.2	-979	88	0.8
16	660	77	0.2	-737	85	0.8
17	658	92	0.2			
18	373	86	0.4			
19	81	95	1.2			
20	19	89	0.4			

For the sampling locations outside the NTZ this was not possible, so measurements were made to the nearest NTZ corner. The NTZ boundaries were assigned a value of 0 m, with negative distance values being attributed to the locations outside the NTZ and positive values to those inside (Table 2). The mean size of lobster per string was calculated and a linear regression analysis was undertaken on SPSS. The same was done for CPUE.

2.5,3 Size Fecundity Analysis of Lobsters

Using Lizarraga-Cubedo *et al*.'s (2003) data on fecundity estimates of European lobster in Southwest Scotland in relation to their carapace length, estimates were made for the female lobsters in this study. Lizarraga-Cubedo *et al*.'s (2003) data (summarized in Agnalt, 2007) was used to produce a linear trend line on Excel and the resulting equation (y = 155.4x-10286) was applied to the Lamlash data. Some authors (Lizarraga-Cubedo *et al.*, 2003; O'Tully *et al.*, 2001) prefer a power fit model to demonstrate this relationship. For simplicity this study used a linear model favoured by Agnalt, (2007).

3 Results

3.1 Abundance and Catch Per Unit Effort (CPUE)

3.1, 1 European Lobster (*H.gammarus*)

One hundred and eight lobsters were captured and tagged within the NTZ, whilst 104 were captured and tagged outside. The creels located on the northern NTZ shore (Mountpleasant Farm to Hamilton Rock) were not included as the habitat was deemed to be unsuitable for lobster as only two were captured in the four strings of creels placed here. Hence four further strings of pots were distributed at suitable sites within the NTZ. Legal sized individuals were 12 % more abundant within the closed area.

There were no significant differences in CPUE for lobsters between the NTZ and fished areas (Table 4) indicating that density was not greater. Likewise, there were no significant differences in CPUE for legal sized lobsters (p = 0.67) and sublegal sized lobsters (p = 0.54) between the NTZ and fished areas.

3.1,2 Brown Crab (*C. pagurus*)

Fifty five brown crabs were captured and tagged with males being 283 % and 125 % more abundant than females within the closed area and fished area respectively. Overall, brown crabs were 11 % more abundant in the NTZ, although it is important to note that this is only a difference of three individuals (Table 3). Legal sized brown crab were 8 % more abundant in the closed area [a difference of only 1 individual (see Table 3)].

There was no significant difference in CPUE of brown crab between the locations (p = 0.806) and this was the case for legal (p = 0.806) and sublegal (p = 0.87) sized brown crab also.

3.1, 3 Velvet Swimming Crab (*N. puber*)

Two hundred and seventy one velvet crabs were captured in total. They were 461 % more abundant within the NTZ, although this is thought to be largely down to habitat suitability not due to protection. Legal sized individuals were 28 % more abundant within the closed area. A summary of abundance data is given in Table 3.

Catch per unit effort for *N. puber* was substantially higher within the NTZ (Table 4). CPUE of legal sized individuals was significantly higher within the NTZ (M = 1.85) than outside (M = 0.4) which was also the case for sublegal sized ones.

Table 3: Abundance data of all sampled species (genders are combined for abundance of legal/sublegal individuals).

	Closed Area					**Fished Area**				
	n	Male	Female	Legal	Sublegal	n	Male	Female	Legal	Sublegal
Homarus gammarus	106	75	31	65	41	104	62	42	58	46
Cancer pugurus	29	23	6	13	16	26	18	8	12	14
Necora puber	230	212	18	41	189	41	33	8	32	9

Table 4 : End statistics for comparison of CPUE (all sizes) between the closed area and fished area.

	Closed Area		**Fished Area**		*T-test statistics*			
CPUE	*Mean* (mm)	*SE*	*Mean* (mm)	*SE*	*T-stat*	*df*	*r*	*p*
Homarus gammarus	1.33	0.19	1.3	0.16	0.099	30	0.018	0.922
Cancer pugurus	0.29	0.09	0.33	0.09	-0.248	34	-	0.806
Necora puber	2.3	0.48	0.51	0.12	3.265	34	0.489	0.003

3.2 Mean Sizes and Size Structure

All sizes have been rounded to closest millimetre.

3.2,1 *H. gammarus*

On average, the lobsters within the NTZ were significantly larger than those outside (Figure 5). There were no significant statistical size differences between male (p = 0.054) or female (p = 0.119) lobster populations either inside or outside the NTZ despite a difference in mean sizes of 5 mm and 4 mm respectively. Although the larger individuals of both genders originated from the NTZ, there was no significant difference between male (p = 0.84) and female (p = 0.441) sizes both within and outside the NTZ.

Table 5: H. gammarus: Kolmogorov-Smirnov (K-S) 2 sample tests

	Closed Area (n)	Fished Area (n)	K-S Z	p
All	106	104	1.351	> 0.05 (0.052)
Legal	65	58	1.580	< 0.05 (0.014)
Sublegal	41	46	0.879	> 0.05 (0.423)

3.2,2 Legal Sized *H. gammarus*

Exploitable individuals were 12 % more abundant inside the NTZ. Their size was significantly larger within the NTZ than those outside and this was the case for both males (p = 0.017) and females (p = 0.013). Legal sized individuals within the NTZ (genders combined) were on average 6 mm larger than those from outside of the NTZ. Legal sized females from outside the NTZ were significantly larger (p = 0.019) than their respective males by an average of 8 mm. This was not found to be the case for those from inside the NTZ.

3.2,3 Sublegal Sized *H. gammarus*

The 89 sublegal sized lobsters captured, displayed no significant size differences between those in the NTZ and those in the fished area. Sub-legal sized females were significantly larger than males, both within the NTZ (p= 0.025) and outside (p = 0.001) of it.

3.2,4 *C. pagurus*

There were no significant differences in sizes between those from the NTZ and those from the fished area. Legal sized brown crab, those ≥ 140 mm, showed no significant difference in size between those from the NTZ and those from the fished area despite those from the NTZ being an average of

4 mm larger. Sublegal sized lobsters showed no significant size difference between protected and unprotected areas.

3.2,5 *N. puber*

Observed sizes of individuals were significantly larger within the NTZ compared to those from outside. One-way ANOVA with added Post Hoc test (Tukey HSD) showed there to be a significant difference (p = 0.006) between male and female sizes within the NTZ individuals, with males being on average 4 mm larger than females which is common for the species and not related to protection. However male individuals inside the NTZ were significantly larger (T-test: p = 0.05) than their counterparts outside. This was not the case for females (p = 0.75).

No Take Zone protection had no significant effect on the sizes of legal-sized individuals, although, males were significantly larger within the NTZ (T-test: N = 117, M =70.53, SE = 0.319) than females (N = 12, M = 68, SE = 0.461, $t(187)$ = 2.045, p = 0.042, r = 0.15). This was not the case for those from the unprotected areas.

Sublegal sized velvet crabs were significantly larger within the NTZ. NTZ males were an average of 4 mm larger than those from outside whilst females showed no significant difference.

Table 6: End statistics for size comparison of all individuals between the closed area (NTZ) and the fished area.

	Closed Area		**Fished Area**		*T-test statistics*			
ALL	*Mean* (mm)	*SE*	*Mean* (mm)	*SE*	*T-stat*	*df*	*r*	*p*
Homarus gammarus	91.17	1.51	86.67	1.11	2.4	208	0.164	0.017
Cancer pugurus	126.1	5.37	128.81	6.27	-0.329	53	-	0.743
Necora puber	68.91	0.33	66.9	0.95	2.289	269	0.138	0.023

Table 7: End statistics for size comparison of legal sized individuals only between the closed area (NTZ) and the fished area.

	Closed Area		**Fished Area**		*T-test statistics*			
LEGAL	*Mean* (mm)	*SE*	*Mean* (mm)	*SE*	*T-stat*	*df*	*r*	*p*
Homarus gammarus	100.66	1.37	94.98	0.845	3.43	121	0.298	0.001
Cancer pugurus	152.85	2.73	156.92	3.414	-0.938	23	-	0.358
Necora puber	70.37	0.30	69.13	0.619	1.588	219	0.107	0.114

Table 8: End statistics for size comparison of sublegal sized individuals only between the closed area (NTZ) and the fished area.

	Closed Area		**Fished Area**		*T-test statistics*			
SUBLEGAL	*Mean* (mm)	*SE*	*Mean* (mm)	*SE*	*T-stat*	*df*	*r*	*p*
Homarus gammarus	76.12	1.19	76.20	0.87	-0.050	85	-	0.960
Cancer pugurus	104.38	4.54	104.71	5.95	-0.045	28	-	0.964
Necora puber	62.22	0.38	59	2.28	2.451	48	0.33	0.18

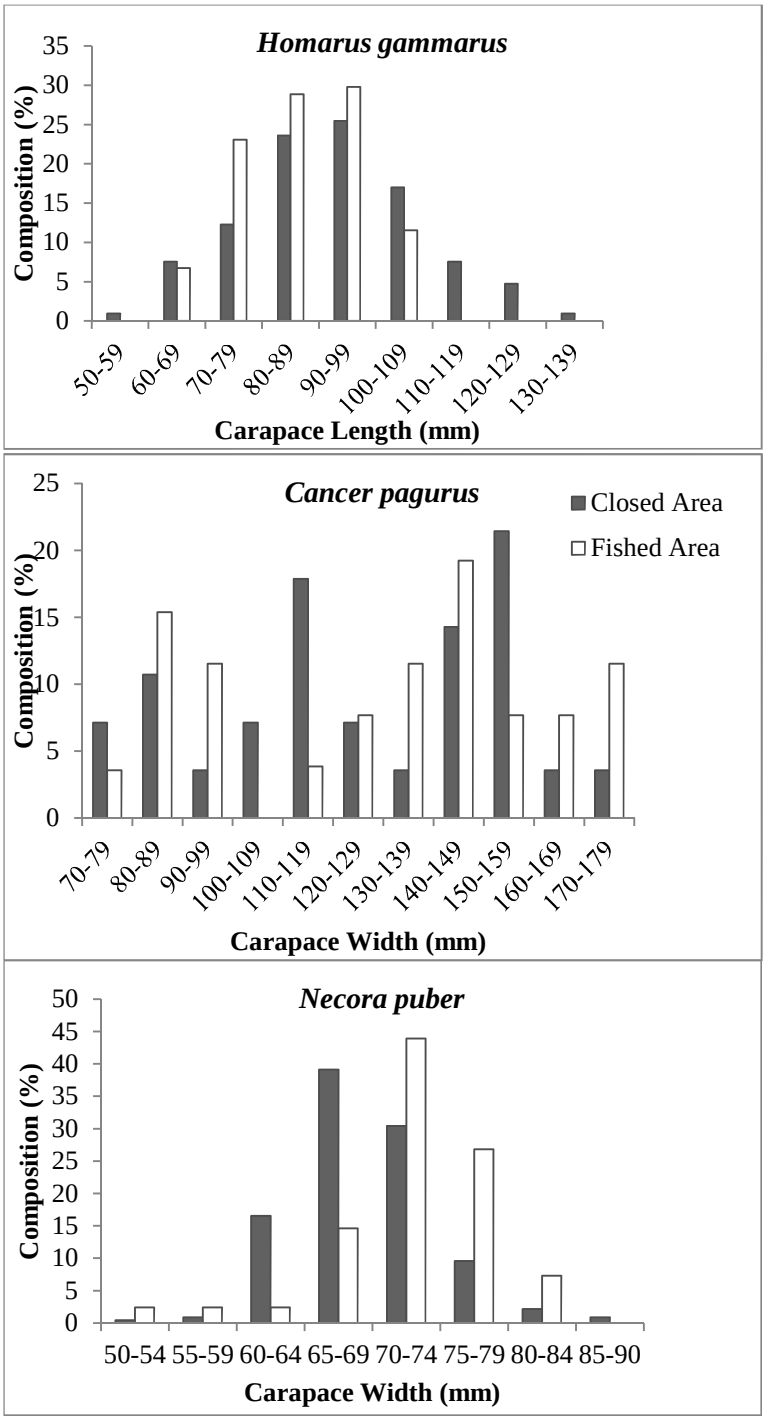

Figure 14: Size composition within the closed area (NTZ) and fished areas (OUT) of *Homarus gammarus* (NTZ n = 106; OUT n = 104), *Cancer pagurus* (NTZ n = 28; OUT n = 26) and *Necora puber* (NTZ n = 230; OUT n = 41).

3.3 Regression analysis of *H. gammarus* spillover (hypothesis 3)

No significant trends were observed. There appeared to be no significant relationship indicating a decline in lobster CPUE (R^2 = 0.001, F = 0.021, p = 0.886) or average size (R^2 = 0.030, F = 0.886, p = 0.0354) with increased distance from the NTZ although the method was not without its caveats. A near/far control method, as used at Lundy, was also attempted but results were not significant.

Although there was no statistically significant reduction in lobster CPUE with increased distance from the NTZ, plotting the relationship for legal sized individuals (Figure 15) shows a very minor trend. Likewise the average size of lobsters per string can be seen to get less variable with increased distance from the NTZ (Figure 16) indicating that there is a more natural population distribution near the NTZ. A preferable method to test this hypothesis would have been to use Geographical Information Systems to plot abundance isobars and make clear density maps as done by Follesa *et al.* (2011).

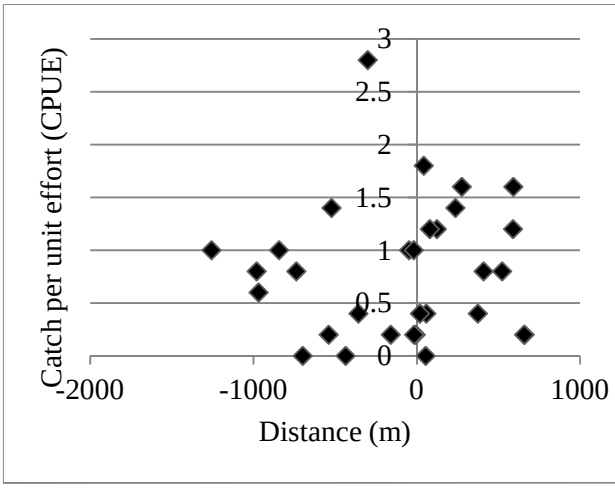

Figure 15: CPUE of legal sized lobsters in relation to distance from the reserve boundary. Positive distance values are inside the reserve, negative ones outside

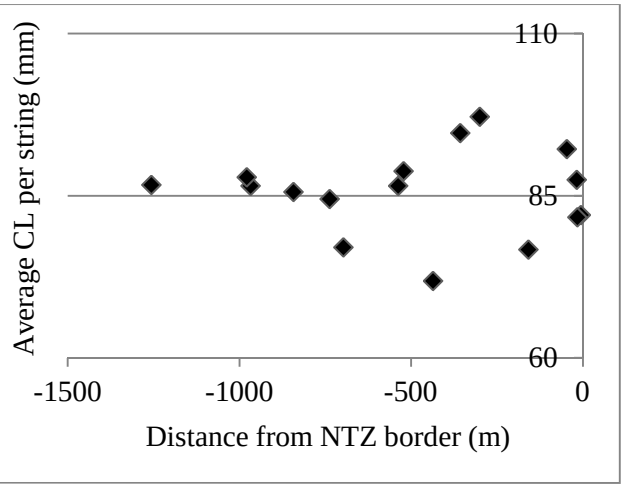

Figure 16: average size of lobster per string in relation to distance from the reserve boundary.

3.4 Recaptures

Two tagged lobsters were recaptured on the northern shore of The Holy Island within the NTZ during the study period at the same location as released. Four recaptures, caught on the south-western side of The Holy Island (fished area), have been reported since by local creel fishers but measurements were not reported. The tags matched those previously sampled at this location.

3.5 Fecundity of *H. gammarus*

The literature shows that the relationship between fecundity and female size is generally a near linear one [y = 155.4x – 10286 (after Lizarraga-Cubedo *et al.*, 2003)]. Female lobsters were an average 3.93 mm larger within the NTZ, hence average egg production was also higher (Mean Difference: 610 eggs per lobster) but this difference was not significant (T-Test: $t(71) = 1.578$, $p = 0.119$). Only eleven ovigerous females were captured within the study period (Figure 19) with a higher number of eggs being contributed by the larger females from the NTZ (estimated using same technique).

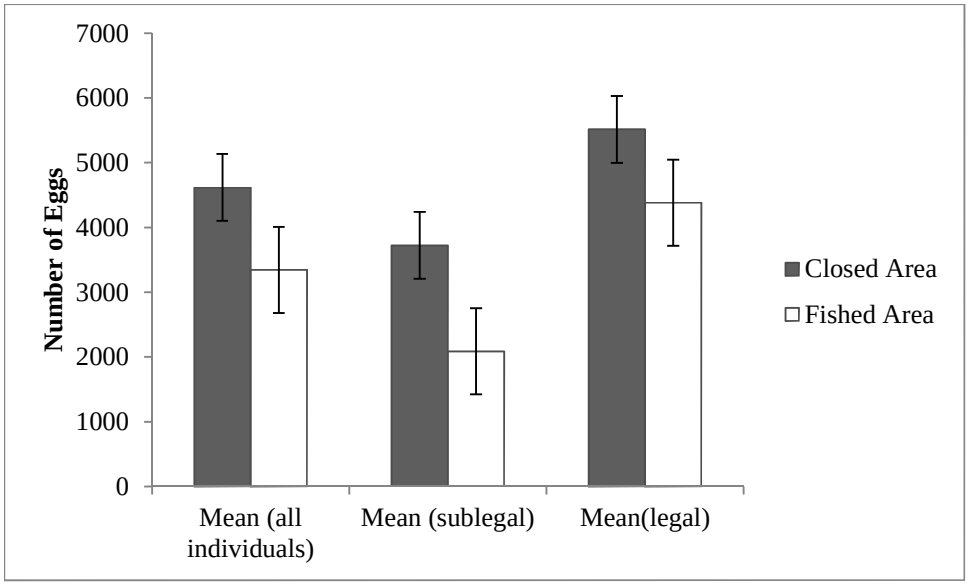

Figure 17: Mean number of eggs per female (showing standard error).

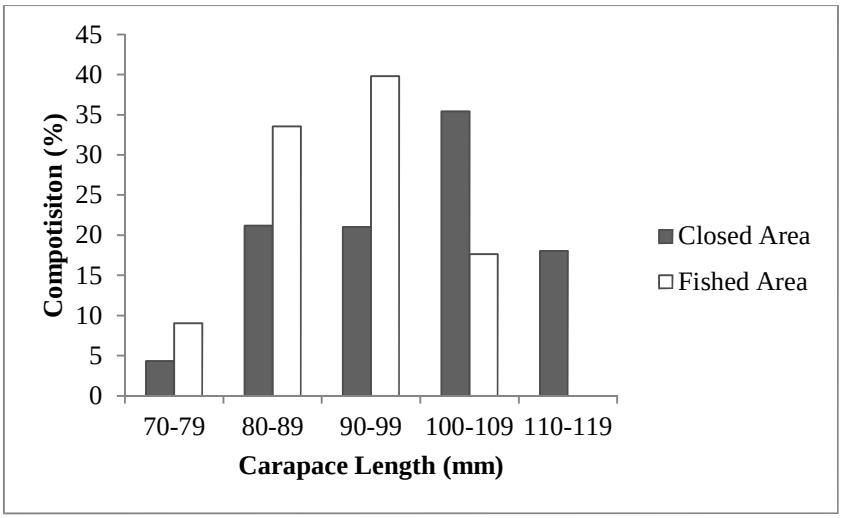

Figure 18: Composition of lobster size groups potential for contribution to egg production.

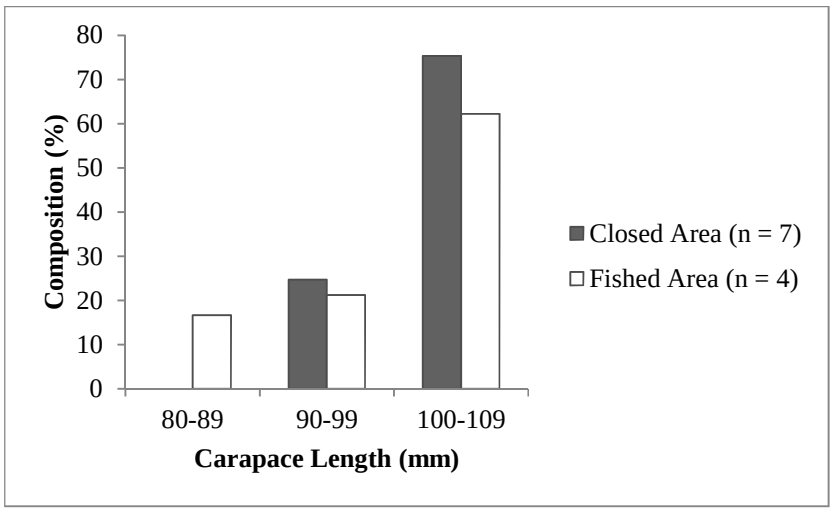

Figure 19: composition of contribution to egg production of actual berried females caught

4 Discussion

Four years after the Lamlash Bay NTZ was implemented, several small but significant benefits were detected from this baseline assessment of commercially fished crustaceans. Two of the studied species (lobster and velvet crabs) showed signs of population change, although the great abundance of velvet crabs within the NTZ is considered to be more down to habitat suitability and not fishing pressure.

4.1 European Lobster (*H. gammarus*)

The results for lobster in particular are a classic portrayal of the effects of protection from fishing. The upwards shift in size-frequency composition is not unlike that found for scallops in areas closed to fishing (Beukers-Stewart *et al*., 2005) and larger crustaceans have been found within the Lundy NTZ (Hoskin *et al.*, 2010) as well as in other reserves around the world (Babcock *et al*., 2010; Follesa *et al*., 2011; Diaz *et al*., 2011; Freeman *et al*., 2012; Kay *et al*., 2012). The size-frequency composition clearly shows that larger individuals are absent outside the NTZ. This greater abundance of legal sized lobsters within the NTZ is consistent with the increased survivorship of resident individuals due to the removal of fishing disruption (Hoskin, *et al.*, 2010). The reduction in fishing mortality of any species within an NTZ is proportional to the time spent by these individuals within that reserve (Roberts & Sargant, 2002). Therefore, to ensure full protection, reserves must be as large as the annual movement of the species (Pawson *et al*., 2007). Given the size of the Lamlash Bay NTZ this is unlikely to be the case for large decapods which can undertake migrations (Haakonsen & Anoruo, 1994) although the clear lack of large lobsters outside the NTZ suggests that

the Lamlash population is generally territorial. Future re-captures of tagged lobsters will further investigate this question.

It is possible that other ecological (e.g., competition) and environmental factors (e.g., terrestrial run off, habitat quality, oceanographic processes and productivity) may influence the distribution and size of lobster (Wootton *et al.,* 2012). However, the distinct presence of larger individuals within the NTZ would seem to indicate that fishing is the main factor affecting their population dynamics. An additional mechanism suggested for explaining this response is the fact that protection also increases habitat quality and presence of prey species, hence mobile species are attracted and retained (Rodwell *et al*., 2003).

Whilst there was no significant difference in lobster CPUE between the NTZ and fished areas, larger individuals were more abundant within the NTZ. These have the potential to recruit to the surrounding fishery through spillover due to intraspecific competition (Rowley, 1992). These larger NTZ individuals are also able to have a greater impact on the spawning stock, as larger lobsters have a higher reproductive potential (Lizarraga-Cubedo *et al.,* 2003; O'Tully *et al.,* 2001). During pelagic dispersal, NTZ juveniles may recruit to surrounding areas and benefit their fisheries (Roberts & Polunin, 1991). If lobster catch rates were to decline in the Clyde as they have done in Ireland (Tully *et al.,* 2001), our research on size and fecundity shows that protected areas, such as the Lamlash Bay NTZ, have the potential to be a key management tool for supporting their numbers.

4.2 Brown Crab (*C. pagurus)*

It is possible that brown crabs showed little response to protection due to the fairly heterogeneous habitats found within and outside the NTZ, meaning that habitat was not a limiting factor. Large decapod crustaceans such as these, exhibit various forms of habitat use ranging from territoriality, central-place foraging through to nomadism and migration (Smith *et al*., 2001). Brown crabs also undertake seasonal migrations (ScottishGov, 2012). As a result the NTZ would only protect them for part of the year. Furthermore, it is possible that the naturally occurring low abundance of brown crab in this area may mean that they are not heavily targeted, so changes in abundance would be difficult to detect. Either way our results are in line with those from Lundy where no apparent differences in abundance were found between closed and fished areas (Hoskin *et al*., 2010). The Lundy study suggests that NTZ brown crab may have failed to increase in number due to competition and (or) predation of small individuals by large lobster (Hoskin *et al*., 2011). The fact that larger lobsters were found only inside the NTZ indicates that they are a fairly territorial population (as excursions outside the NTZ would make them vulnerable to fishing) and that they may limit the abundance of juvenile brown crabs. As well as this, crustaceans are a moderately long lived species that mature slowly (Moore *et al.,* 2013) and further effects of protection on different size-classes may only materialise in due course (Follesa *et al*., 2011). As with lobsters, a clearer picture of the movement

patterns at Lamlash will only be developed through further monitoring work along with industry compliance in reporting the re-capture of tagged individuals.

4.3 Velvet Swimming Crab (*N. puber*)

The northern shore of the NTZ, where velvet crabs were particularly prolific raised the question of whether these species are fulfilling the role of dominant predator here and perhaps reducing the chances of both brown crab and lobster establishing. Hoskin *et al*., (2011) suggest that low numbers of velvet crabs may be due to predation from abundant legal sized lobsters. Although this hypothesis is untested it is possible that the opposite is true here, after all velvet crabs are notoriously aggressive scavengers. Using Hoskin *et al's.* (2010) argument, the more likely reason for the abundance of velvets is the absence of other scavenger competitors such as brown crab and lobster which may have been absent on this side of the bay due to a lack of suitable habitat. Large boulders were observed from deck but finer habitat details were not included at the time of sampling.

4.4 Further work:

This study did not account for the role currents and tides play in affecting catch rates of crustaceans, and therefore the hypotheses. In the interest of designing a more rigorous and effective monitoring program to assess the average abundance and density of crustaceans in relation to NTZ protection, bait plume modelling could be used to gauge the impact these factors have on attracting our target species. As currents affect the dispersion of the bait plume, individuals may be attracted from various distances and jeopardise the analysis of differences between inside and outside the protected area. Bait plume modelling would address the effect of using bait on crustacean behaviour by adding an 'area' variable. This would aid the analysis of densities including the distance over which they were attracted. A more accurate CPUE could then be calculated by analysing whether bait plumes from adjacent string/pots overlapped or not to develop a probability of catch dependent on this. Priede & Merret (1996) made some attempt at modelling bait plume behaviour in relation to fish swimming speeds, and similar methods could be applied here, however caution must be applied as these models currently rely on some unverified assumptions (Moore *et al*., 2013).

Importantly, in relation to our hypotheses on assessing the effects of protection on mortality, a better understanding of habitat characteristics present at creeling locations is key to understanding species distribution. In the absence of a robust model on factors affecting attraction to bait, habitat considerations are particularly crucial in defining the patchy distribution of these species (Moore *et al*., 2013). The contribution habitat makes should be clearly separated from the effects of protection (García-Charton *et al*., 2004; Kay *et al*., 2012) as short-range movements appear to be largely influenced by the spatial distribution of suitable habitat (Smith *et al*., 2001).

To assess whether the Lamlash Bay populations are representative of the average populations within the Clyde, 'far controls' could be included at other sites to establish whether the abundance and size-structure is similar (Hoskin *et al*., 2011). This would enable a better quantitative analysis of whether or not spillover is occurring by comparing whether there are more sublegal sized individuals adjacent to the NTZ – in theory they should be 'pushed out' when space becomes limiting as they grow and increase in density (Hoskin *et al*., 2011). Past spillover models of exploited species predict gradients in relative abundance that peak near reserve centres, reaching an asymptotic low value as you move farther into fished areas (Kaundara-Arara & Rose, 2004).

During the first three years of protection, the Lamlash Bay NTZ is reported to have suffered from several compliance breaches (COAST, 2011b). During the course of this study some creels were noted near the NTZ border suggesting that 'fishing the line' does occur. Whilst not illegal, reporting of these catches would be useful in gauging the effects of protection on crustacean mortality and size. Both locals and tourists should be encouraged to do so by increasing signage at key locations (mooring spots/slipways, ferries, Scottish fishing news/associations). This approach would be beneficial to our study as fishing effort is the main determinant of the probability of recapture.

4.5 General

Landings by Scottish vessels have increased substantially in recent years and have given rise to anxieties about the possible introduction of Gaffkemia or red-tail disease - an extremely virulent infectious disease caused by the bacterium *Aerococcus viridians*. Fear of a spread of the disease from North America raises concerns over the future of the fisheries (Scottish Gov., 2012). Although NTZ protection does not stop the spread of such diseases, they can serve as centres of productivity in raising the rate of successful, healthy offspring survival due to the larger average size of individuals (Roberts, 2008). Although a higher density of individuals isn't always favourable in light of limiting the spread of disease (Tarwater, & Martin, 2001), healthier NTZ offspring should have better chances of developing resistance. The fact that juvenile lobsters generally spend up to 3 years in intertidal areas following first settlement (Clark, 2008), is just one reason for critical shoreline protection as offered by the Lamlash Bay NTZ and to ensure the longevity of both the species and dependent fisheries.

Fisheries policies generally assume that a long term increase in yield and biomass per recruit will occur by reducing the level of fishing mortality (effort) (Marine Scotland, 2012). Although certainly being a step in the right direction, worldwide fisheries trends suggest that current measures are not enough to limit the decline in catches (FAO, 1995; Pauly *et al*., 2002; Jackson, 2013). Marine reserves, such as the Lamlash Bay NTZ have been identified as offering key benefits to biodiversity and fisheries enhancement (Halpern, 2003; Berkeley et al. 2004; Roberts, Hawkins & Gell, 2005;

Kelleher and Kenchington, 1992). For the health of our planet, regenerating and maintaining marine productivity and keeping fishermen in business, I believe NTZs are fundamental for fisheries management.

Whilst no data were collected on crustacean populations prior to the NTZ's implementation, this research has provided baseline data on the targeted crustaceans which are of commercial importance. This is a first step, and only with further monitoring will a full understanding of the Clyde's crustacean population's recovery rates as a result of NTZ status protection become apparent, along with any benefits such protection may provide to surrounding fisheries.

The timeframe for a protected area to become effective is one of the key questions managers want answered. This study, which is in line with findings worldwide, indicates that even several years protection can have positive outcomes. Given the lack of data on crustaceans prior to the Lamlash Bay NTZ's establishment the exact level of recovery cannot be fully assessed. With Marine Conservation Zones (MCZs) due to become the norm in UK waters under the Marine Act , extensive baseline studies should be undertaken prior to their implementation to fully gauge their possible benefits to the UK – an island nation with a heavy reliance on fishing. PhD student Leigh Howarth's on-going research on the recovery of the Lamlash Bay NTZ has already demonstrated benefits to scallop and biodiversity from protection (Howarth, 2010) and due to the interconnectedness of ecological processes these will no doubt be of further benefit to those commercially exploited crustaceans in this study.

No Take Zone designations are argued to be a crucial step in achieving a better management system for marine ecosystems (WWF (Roberts & Hawkins), 2000; Greenpeace, 2012b; MCS, 2013). Results from the 2012 Lamlash Bay NTZ potting survey found large lobsters to be more abundant within the NTZ following only four years' of protection. Given the decline in catches of many species in the Clyde (Thurston & Roberts, 2010), these findings support the expansion of marine reserves within the Clyde to sustain and rejuvenate species that have borne the brunt of fishing through history.

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7 Appendices

Figure 9: GPS coordinates of sites sampled.

Sampling Sites	Latitude	Longitude	Sampling Site	Latitude	Longitude
NTZ 1	55° 32.118'N	5° 4.455'W	OUT 1	55° 31.496'N	5° 3.852'W
NTZ 2	55° 32.207'N	5° 4.628'W	OUT 2	55° 31.705'N	5° 4.141'W
NTZ 3	55° 32.250'N	5° 5.066'W	OUT 3	55° 31.930'N	5° 4.284'W
NTZ 4	55° 32.964'N	5° 4.992'W	OUT 4	55° 31.374'N	5° 4.828'W
NTZ 5	55° 32.951'N	5° 5.268'W	OUT 5	55° 31.200'N	5° 4.553'W
NTZ 6	55° 32.895'N	5° 5.520'W	OUT 6	55° 31.050'N	5° 4.433'W
NTZ 7	55° 31.678'N	5° 5.300'W	OUT 7	55° 33.003'N	5° 4.888'W
NTZ 8	55° 31.713'N	5° 5.341'W	OUT 8	55° 33.224'N	5° 5.006'W
NTZ 9	55° 32.579'N	5° 6.066'W	OUT 9	55° 33.318'N	5° 5.178'W
NTZ 10	55° 32.143'N	5° 4.486'W	OUT 10	55° 33.002'N	5° 4.818'W
NTZ 11	55° 32.182'N	5° 4.567'W	OUT 11	55° 33.160'N	5° 4.952'W
NTZ 12	55° 32.242'N	5° 4.704'W	OUT 12	55° 31.640'N	5° 4.002'W
NTZ 13	55° 32.255'N	5° 4.883'W	OUT 13	55° 31.819'N	5° 4.185'W
NTZ 14	55° 32.248'N	5° 4.990'W	OUT 14	55° 31.997'N	5° 4.340'W
NTZ 15	55° 32.220'N	5° 5.141'W	OUT 15	55° 31.184'N	5° 4.558'W
NTZ 16	55° 32.186'N	5° 5.292'W	OUT 16	55° 31.307'N	5° 4.664'W
NTZ 17	55° 32.234'N	5° 5.120'W			
NTZ 18	55° 32.256'N	5° 4.850'W			
NTZ 19	55° 32.157'N	5° 4.519'W			
NTZ 20	55° 32.143'N	5° 4.486'W			

Tracking of lobsters in Lamlash Bay

As part of on-going research into the impact of the No Take Zone (NTZ) in Lamlash Bay, York University in conjunction with local creeler Charlie *Weir and COAST will be* assessing lobster and crab sizes within the NTZ between July 19 and 27.

Charlie, who assisted COAST last year on a similar survey outside the NTZ will be skippering his boat the Kimberley, which will be used in the study.

A second survey will be carried out in August. All lobsters caught will be released after measurement.

Andrew Binnie, marine project office for COAST, said: 'The research, which is being done under licence from Marine Scotland, will improve understanding of how marine life is recovering within the NTZ and will include tagging the lobsters to track their movements.

'In this way it will be possible to get an idea of how far they travel and to where, if they are caught again outside the zone.'

Leigh Howarth, York's PhD researcher will also be carrying out year three of his NTZ scallops and biodiversity study with the assistance of York students Lowri Evans and Pascal Dubois who are on Arran for the summer.

This programme of research is yielding some interesting results with increased biodiversity recorded within the zone compared to areas outside.

The York students and COAST will be keeping Arran residents and summer visitors up to date with progress over the next couple of months.

Former Arra found dead i

A former Arran resident and one of the UK's richest women has been found dead in west London.

The body of US national Eva Rausing, 48, a member of the family behind the Tetra-Pak cartons empire, was found at Cadogan Place, Belgravia.

She and her husband Hans Kristian Rausing sold their second home in Corrie two years ago after spending many holidays on the island.

The couple's home was easily identified by the helicop-

Figure 20: excerpt from The Arran Banner: Saturday 14th July 2012, p.3

6 THE ARRAN BANNER, Saturday, 21 July, 2012

C.O.A.S.T.
NTZ RESEARCH

KIMBERLY

University of York researcher Pascal Dubois and local fisherman Charlie Weir aboard his licensed creeling vessel The Kimberley. b29coa01

Positive impact on marine life in Lamlash Bay

In last week's Banner we reported on the on-going research into the positive impact of the No Take Zone (NTZ) within Lamlash Bay.

This is being carried out by York University PhD researcher Leigh Howarth, assisted by students Pascal Dubois and Lowri Evans.

For their studies, they are being aided by local creeler Charlie Weir, and community group COAST is assessing lobster and crab sizes between 19 and 27 July.

A second such survey i planned for August.

This research will improv understanding of how marin life is recovering within th NTZ and will include tag ging the lobsters to track the movements.

Figure 121: excerpt from The Arran Banner: Saturday 21st July 2012, p. 6

7.1

RISK ASSESSMENT

- Research & diving to be conducted in UK waters by Pascal Dubois - Environment Department, University of York, BSc Environmental Science 2nd Year Undergraduate

Description of the work to be carried out, including location:

Fieldwork will take place around the Isle of Arran, Scotland from beginning of July till September of 2012. Dive surveys will be carried out to provide quantitative and qualitative information on the present condition of the seabed. This may involve a number of techniques including photo quadrats and 50m transects. The water temperature will vary little from 14^{o}C throughout the sampling period, visibility around the island is relatively good for UK waters (between 1-8m depending on conditions), and surveys will be conducted in waters deeper than 5m and will not exceed 30m.

Diver safety and procedures

I (Pascal Dubois) will be covered by University of York insurance as a 'diver at work'.

Divers will always be in buddy pairs or trios, and boat cover will always be provided by an experienced helmsman. All divers will be 2* qualified (I myself am PADI Open Water/Enriched Air certified) and competent to dive in UK cold waters, and will have received training in emergency oxygen administration and CPR. All divers will be requested to provide contact details of next of kin, who will be contacted in the event of an emergency. The University Health and Safety Officer (Tel: 01904 324057) will also be contacted if any accidents do occur. All individuals will be included in the dive logs.

All divers will be equipped with:

- Exposure suits appropriate to the water temperature (i.e. drysuits, hood and gloves)
- Reel and Surface Marker Buoys (SMB) in case of drifting out to sea and need to signal the boat as the diver surfaces
- Dive computers to ensure the diver remains within no decompression limits.
- All divers will be equipped with BCDs and octopus rigs.

All dives will follow recognised procedures, in particular:

- Normally, dives will be conducted in depths of 5-25m.
- No dive will be deeper than 30m.
- At least a 3 minute safety stop at 5m will be conducted on every dive.
- Divers shall never extend their bottom time outside of no-decompression limits.
- Diver shall never be allowed access to Nitrox air unless they are a qualified Nitrox diver, and both divers within a buddy pair shall breathe the same type of air.
- A shot line and buoy will be deployed at each site. This will be used wherever possible for ascents/descents by divers, and as a visual reference for boat cover in monitoring likely diver location.
- All divers will stay in buddy pairs or trios, throughout their time in the water.

- All diving equipment will be checked for condition and operation before use. Divers take individual responsibility for this.
- All divers will carry out a buddy check before each dive, in which they check that their buddy's equipment is correctly assembled and fitted and check the location and operation of their buddy's alternate air supply and harness quick releases.
- If separated, divers will follow standard separation procedures, and each deploys their own SMB to mark their ascent.
- A suitably qualified supervisor will remain on the surface in the boat (i.e .first aid and emergency oxygen trained).
- Water currents and weather will be analysed before setting off each day. Dives will be terminated if deemed unsafe to go out on the boat and/or dive that day.

Boat safety and procedures

Due to the nature of this work, divers will spend at least 25 hours a week at sea in Rigid Inflatable Boats (RIBs), with weather permitting. Each RIB will be skippered by an experienced helmsman, and there will always be at least one person left in the boat when divers are in the water. All RIBS will be equipped with:

- A spare tank of diesel in case fuel runs out, or the RIB experiences a fuel leak etc.
- Oars and an anchor in case the engine stops working.
- Tough gloves for handling the anchor and ropes, protecting the diver from cuts and jellyfish stings.
- VHF radio, which will be set to channel 16 (coastguard) at all times, and a fully charged mobile phone.
- Lifejackets, flares, first aid kit and emergency oxygen (for use in diving-related incidents).
- Dive flag to indicate when divers are underwater.
- An emergency assistance plan, outlining the actions to be taken in case of an emergency (see below).

General illness

Hazard: Divers may be ill for a variety of reasons before a scheduled dive, in which case they should not dive at all. However divers may not make it clear to others that they are unwell, possibly because they do not want to hinder diving operations.

Precaution: All divers will be warned about diving with sinus-related or other illnesses. Divers that are suspected to be unfit on the day will not be allowed to dive. If this brings the team size to below the minimum allowed for scientific diving, activities will be called off until a later date.

Diving-related illnesses

Hazard: Diving with sinus-related problems such as a cold can cause problems with ear-clearing during descending and sometimes ascending.

Precaution: Divers will be warned about diving with sinus-related illnesses. Divers that are suspected to be unfit on the day will not be allowed to dive. During the safety briefing divers will be reminded about clearing their ears upon descent, and to halt descent should they experience problems.

Hazard: Fast ascents or 'sawtooth' profiling e.g. regular ascents and descents during a dive can increase the risk of decompression illness (DCI). Holding breaths during ascents can also cause problems such as pulmonary barotrauma, resulting in lung damage or air embolisms.

Precaution: Members of the team are all experienced divers who are aware of the dangers of fast ascents or buoyancy problems. All divers will be reminded during the safety briefing to be aware of their ascent rates and not to hold their breath at any point throughout a dive. Safety stops also significantly decrease the likelihood of problems as a result of DCI. Decompression dives will not be allowed.

In the event of a diving-related illness, or in a situation where the onset of illness is deemed likely e.g. following a rapid ascent, emergency oxygen will be provided and emergency services informed. All divers will be briefed on what to do in an emergency. A list of emergency contact numbers will be provided, although it is anticipated that the emergency services will deal with this. An emergency diver recall procedure will also be in place. The primary method for contacting emergency services will be via the coastguard using the vessel VHF radio however mobile phones will also be on board the vessel as back-up.

Losing contact underwater

Hazard: UK dive sites often have limited visibility due to high sediment loads following heavy rainfall or long periods of surface swell.

Precaution: Standard separation procedures will be in place should buddy pairs become separated underwater. These are, search for your buddy for 1-2 minutes after noticing the separation, if buddy is not found ascend and search for your buddy at the surface. Conditions will be assessed on the day, and should visibility be bad enough that research work cannot be carried out then it will be postponed until a later date.

Extreme temperatures

Hazard: During the research period, sea temperatures are likely to be around 14^{o}C.

Precaution: All divers will be wearing drysuits to minimise their exposure to cold temperatures.

Hazard: As a result of their exposure protection, divers may become dehydrated and suffer heat exhaustion, or even heat stroke, when at the surface.

Precaution: Water will be readily available on the boat and divers will be encouraged to unzip their dry suits when on the surface on a stationary boat.

Currents/separation from surface vessel

Hazard: Some areas around the UK are subject to strong tidal currents, this may result in divers being swept out to sea or a long way from the surface vessel.

Precaution: Currents are moderate off the majority of dive sites in Arran. In sites where currents are stronger, dives will be conducted during slack water. All work underwater will take place close to either the shot line or to the line transect attached to the shot weight. This will limit the

geographical area in which divers could be reasonably expected to be. All divers will carry an SMB to identify their position during non-shot line ascents and to increase the chances of surface cover spotting them once they have surfaced. Surface cover will keep an active lookout around the shot line/buoy and in the down tide direction of this.

Equipment failure/loss of air supply

Hazard: There is a slight chance of equipment malfunction, the most likely result being loss of air supply. There is also the chance that a diver's air supply will run out because they have failed to monitor their air properly.

Precaution: All volunteers will be using their own diving equipment, including a personal dive computer. All will be wearing appropriate equipment suited to the conditions and all will have a redundant supply which is/can be isolated from their main air supply should this fail. Buddy checks will be done before each dive. Divers will be reminded to monitor their air supply throughout the dive, especially if exerting themselves. All divers will carry a spare octopus in case their buddy's air becomes depleted. Divers will then terminate the dive and surface immediately.

Injury from boats

Hazard: Surfacing divers may be at risk of collision with recreational or commercial boat traffic.

Precaution: Under normal circumstances divers will use the shot line/buoy for all ascents/descents. SMBs will be carried by all divers to be deployed in the case of a free ascent in order to warn boat traffic that divers are just below the surface. The surface cover vessel will also have the dive flag deployed at all times divers are in the water to warn approaching vessels of their activities.

Weather conditions

Hazard: High winds may result in choppy conditions or large swells which make diving conditions dangerous, either because divers cannot get off and on to the vessel safely, or they cannot be seen adequately from the surface vessel whilst in the water. Surface visibility may also deteriorate due to bad weather conditions, making it harder to see surfacing divers from the diving vessel or from other boats in the area.

Precaution: Weather conditions and suitability for diving will have to be assessed in the week leading up to the dive activities. Conditions will also be assessed on the day. If conditions are deemed to be unsafe for diving i.e. strong onshore winds resulting in swell, or unexpected strong currents, then diving will be delayed until another time. If bad weather conditions do not affect other dive sites in different areas, diving may be relocated to such safer sites.

Travel and accommodation

Divers will be staying in local accommodation close to the dive site. Details will be provided to supervisors.

Launching of boat

Hazard: There is a slight risk of collision with people upon launching of the boat into the water.

Precaution: All divers to remain clear of the rear of the boat upon launching with a suitably qualified person coordinating the launch/recovery.

Boat engine failure

Hazard: There is a risk of the boat engine refusing to start whilst at sea, potentially leaving divers stranded and unable to get to land.

Precaution: All RIBs will have at least 2 engines. In the event of failure, oars will be aboard for and a radio can be used to notify the coastguard with mobile phones as back up. The vessel is equipped with a suitable anchor/spare and sufficient rope to prevent drifting and flares are kept onboard to summon attention.

Pot sampling onboard a licensed fishing vessel

This year we intend to fish for lobsters and crabs onboard a licensed fishing vessel. This will involve deploying a number of shellfish pots to the seabed and collecting them after 48 hours.

Hazard: Possible dangers include falling overboard, and getting a limb caught in the fishing gear as it is being deployed and being dragged to the seabed.

Precaution: A full safety briefing will be given to all individuals, life jackets will be worn by all, and the rope of the fishing gear will be pushed neatly to one side of the boat so entanglement is far less likely. The boat will have a VHF radio, flares and a fully stocked first-aid kit.

Unforeseen circumstances

If any unforeseen circumstances arise, I shall assess the situation for additional risk and take the appropriate precautions. If in doubt, I shall contact my supervisor (01904 324789) and/or the University health and safety team.

Emergency Assistance Plan for Diving off Arran

Whiting Bay Slip	**Directions:** Off the A841, opposite the Whiting Bay primary school.
Emergency Contact Details	**Phone:** Dial **999** or **112** and ask the operator for Ambulance and Fire services. Inform the operator that you have an accident involving a diver and give directions as above. If possible send some one to meet the emergency services. **Offshore contact:** When offshore you can use: • VHF radio set to **channel 16** • Medium or high frequency radio on **2182KHz** • Satellite phone dial **112** **Mayday message:** Say slowly and clearly: • "Mayday, Mayday, Mayday" • "This is (**name of vessel**)" [**repeat three times**] • "Mayday" • Your vessel's name, call sign and MMSI number • Your position • The nature of distress **[for example, "diver emergency"]** • Immediate assistance required • How many people are on board • Any other information • "Over" When a distress call is received by HM Coastguard, they will acknowledge it, respond and ask for further information on: • what and where the incident is • how many people are in trouble • how much danger they are in The coastguard will then decide how to respond to the distress alert, which might be sending lifeboats, search and rescue helicopters or coastguard rescue teams. They will also contact any ships or boats near to the incident and ask them to assist if they can. When you receive help from the coastguard, they will guide you through the rescue process. **Using a VHF radio with digital selective calling (DSC):** If you have DSC, send a distress alert by activating the distress button. All DSC-equipped boats and Maritime Rescue Co-ordination Centres (MRCCs) in the area will automatically receive information about:

Emergency Contact Details	• your vessel's identification number • the type of call (distress) • the channel you want to speak on (channel 16 is selected automatically) • your position This alert will be repeated every four minutes until it's acknowledged. All MRCCs in the UK and most European coastguards are equipped with VHF DSC and will respond quickly if called. Follow up the DSC alert with a voice Mayday or Pan-Pan message on **channel 16**. To automatically send a precise position, make sure the DSC is connected to a Global Positioning System (GPS). Otherwise, you'll need to make regular manual position updates. **Firing a flare** In an emergency, you can fire either a: • red rocket • red parachute flare • red hand-held flare Don't rely on flares alone to raise an alert. Someone else has to report that they have seen your flare in order for you to get help. Make sure you don't fire red rocket or parachute flares when there are helicopters or aircraft nearby.
Air Evacuation	The main hazards at the scene of a helicopter landing site are as follows: • Danger to persons from the main rotor and the tail rotor • Danger to persons and property caused by the downwash • Danger to the helicopter due to loose items carried up into the rotors • Danger to the helicopter due to over head cables If DCI is suspected you should inform the helicopter crew that they should fly as low as possible
Hyperbaric Chambers & Divers Network	**DAN:** National Emergencies 0845 0291990 **University Marine Biological Station,** Isle of Cumbrae, Contact available via coastguard only

Hyperbaric Chambers & Divers Network	**Dunstaffnage Marine Laboratory,** Oban**,** Argyll, Scotland, PA37 1QA Tel: 01631 559000 Alternative Tel: 01631 563175 **The Underwater Centre,** Fort William, Scotland, PH33 6FF Tel: 01397 703786
Local Hospital	The nearest accident and emergency hospital is **Ayrshire Central Hospital, Irvine, North Ayrshire KA12 8SS, Tel: 01294 274 191**
Important Information to Accompany Patient	• Name • Age • Emergency Contact Number • Any Known Medical History • Dive Details: Time in, Time out, Max depth and previous dives • Surface intervals

marinescotland

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DELIVERING
A GAMES LEGACY FOR SCOTLAND

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21 June 2012

Dear Leigh

KIMBERLY OB345 – DEROGATION – 01 JULY to 08 SEPTEMBER 2012

I refer to your recent correspondence, regarding the charter of the Kimberly OB345, during the period of 01st July to 08th September 2012 to sample and tag crustaceans (using pot sampling) which will then be returned to the sea.

I can confirm that authority is granted, in accordance with the terms of Section 9 of the Sea Fish Conservation Act 1967 and Article 43 of Council Regulation No. 850/98 to conduct this survey in the area Lamlash Bay No-Take Zone (NTZ), Isle of Arran.

This authority shall be valid in the period 01 July 2012 to 08 September 2012. A copy of this letter should be carried on board the vessel at all times, during these periods.

A copy of this letter goes to my colleagues in the Marine Monitoring Centre for onward transmission to FPVs, all Marine Scotland Fishery Offices, Marine Scotland Science and Eamon Murphy within Fisheries, Marine Scotland.

Yours sincerely

Ingrid Drever
Regulation and Licensing Policy Team

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