Stock Annex: Norway lobster (*Nephrops norvegicus*) in Division 6.a, Functional Unit 11 (West of Scotland, North Minch)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Norway lobster
Working Group:	Working Group for the Celtic Seas Ecoregion (WGCSE)
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A. General

A.1. Stock definition

The North Minch Functional Unit (FU 11) is located off the northwest coast of Scotland. The northern boundary of the FU is the 59°N line and the boundary with the South Minch FU is at 57°30′N. The North Minch FU is characterised by numerous islands of varying size and sea lochs occur along the mainland coast and exhibits the most patchy ground amongst west coast FUs. Throughout its distribution, *Nephrops* is limited to muddy habitat, and requires sediment with a silt & clay content of between 10–100% to excavate its burrows. This means that the distribution of suitable sediment defines the species distribution. The sediment data from the British Geological survey is considered incomplete in this FU, therefore the area of the ground is given by the VMS distribution of fishing effort (vessels >15 meters). Results from recent work on mapping the spatial extent of *Nephrops* habitat in the North Minch sea lochs indicate that the muddy habitat is only a very small proportion of the total *Nephrops* grounds. The total area of the ground is estimated to be 2908 km² (Figure B1-4). The North Minch is part of Division 6.a and the fishery data for this Functional Unit includes the following statistical rectangles: 44–46 E3-E4 (Figure B1-3).A.2. Fishery

The North Minch *Nephrops* fishery is predominantly exploited by *Nephrops* trawlers using twin rig gear with an 80 mm mesh, with approximatley 20% of landings made by creel vessels. Landings for this FU are typically only reported from Scotland although Ireland has occasionally reported nominal amounts (2 tonnes) in recent years.

The largest part of the North Minch fleet is based at Stornoway and made up of mostly 15 m length vessels. The Barra vessels are generally bigger than the Stornoway fleet, and are all over 15 m in length. The Barra fleet is more nomadic as the fishing grounds are exposed, which forces the fleet to find shelter on the east side of the North Minch. The majority of vessels are now twin rigging, using 80 mm mesh. In Barra, most trawlers land daily or every second day. Local fleets, mainly formed by smaller trawlers, also operate from ports of Lochinver, Ullapool and Gairloch and typically work 1–4 day trips.

The minimum landing size for *Nephrops* in the North Minch is 20 mm CL, and less than 1% of the animals are landed under size. Discarding takes place at sea, and landings are made by category for whole animals (small, medium and large) and tails. The main

bycatch species is haddock, although whiting and Norway pout also feature significantly in discards. The fishery is exploited throughout the year, with the highest landings usually made in the spring and summer. Vessels usually have a trip duration of one day in the winter, but up to six days in the summer.

The current legislation governing *Nephrops* trawl fisheries on the west coast of Scotland was laid down by the North Sea and West of Scotland cod recovery plan (EC 2056/2001), which established additional measures to EC 850/98. This regulation was amended in 2003 by Annex XVII of EC 2341/2002, which establishes fishing effort and additional conditions for monitoring, inspection and surveillance for the recovery of certain cod stocks. Additional Scottish legislation (SSI No 2000/226) applies to twin trawlers operating North of 56°N. A mesh size of 100 mm or above must be used without a lifting bag and with not more than 100 meshes round the circumference but with up to 5 mm double twine. By comparison, vessels using a single trawl may use 80–89 mm mesh with a lifting bag and 120 meshes round the codend but with 4 mm single twine. Since 2009, vessels have been required to fit 120 mm square meshed panels, in accordance with the west coast emergency measures (Council Reg. (EU) 43/2009). Large SMPs (200 mm) are also widely used in the North Minch and are mandatory for all TR2 vessels with power >112 kW fishing under the Scottish Conservation Credits scheme, which in addition requires vessels fishing with gear <100 mm within ICES Area 4.a (within the CRZ) to fish exclusively with any of the highly selective fishing gears specified in Annex C of the scheme rules.

A.3. Ecosystem aspects

The North Minch (FU 11) is located at the northern end of the west coast of Scotland. The area is characterised by numerous islands of varying size and sea lochs occur along the mainland coast. These topographical features create a diverse habitat with complex hydrography and a patchy distribution of soft sediments.

Within the North Minch functional unit suitable *Nephrops* substrates (mud, sandy mud and muddy sand) are distributed according to prevailing hydrographic and bathymetric conditions. The North Minch exhibits the most patchy ground amongst west coast FUs. Very soft sediments are found in the southeast of the FU while coarser sandy mud prevails to the north and west. Results from recent work on mapping the spatial extent of *Nephrops* habitat in the North Minch sea lochs indicate that the muddy habitat is only a very small proportion of the total *Nephrops* grounds.

B. Data

B.1. Commercial catch

Landings by gear category for FU11 provided through national laboratories are presented in Table B1-1. Landings from this fishery are usually only reported from Scotland but in 2012–2014, 2 tonnes of *Nephrops* were reported by Ireland. There were concerns over the accuracy of historical landings and effort data prior to 2006 when Buyers and Sellers legislation was introduced and the reliability began to improve. Because of this the final assessment adopted is independent of official statistics.

In 2015 WGCSE agreed that effort should be reported in Kw days (previously reported as days absent) as this is likely to be more informative about changes in the actual fleet effort. Reported effort by all Scottish trawlers has shown a decreasing trend since 2000 (Figure B1-1) but in 2012 the effort increased by 20% due to the influx of vessels from the North Sea during the first quarter of the year. Effort was lower in 2013 and

remained at a similar level in 2014 but fell in 2015. Note that the effort time-series (2000–2015) does not match with the more extensive year range available for landings, due to a lack of reliable effort data in the MSS in-house database.

Length compositions of Scottish landings and discards are obtained during monthly market sampling and quarterly on-board observer sampling respectively. Length compositions for the creel fishery are available for landings only as the small numbers of discards survive well and are not considered to be removed from the population. Sampling for this FU is considered to be adequate. Although assessments based on detailed catch analysis are not presently possible, examination of length compositions can provide a preliminary indication of exploitation effects.

In general, males make the largest contribution to the landings (Figure B1-2). This is likely to be due to the varying seasonal pattern in the fishery and associated relative catchability (due to different burrow emergence behaviour) of male and female *Nephrops*. This occurs because males are available throughout the year and the fishery is also prosecuted in all quarters. Females on the other hand are mainly taken in the summer when they emerge after egg hatching.

B.2. Biological

Biological parameters for this stock are outlined in the summary table below. Mean weights-at-age for this stock are estimated from fixed Scottish weight–length relationships (unpublished data). The size-at-maturity was estimated by Queirós *et al*. (2013). Relevant biological parameters are as follows: natural mortality was assumed to be 0.3 for males (Morizur, 1982) of all ages and in all years. Natural mortality was assumed to be 0.3 for immature females, and 0.2 for mature females.

A discard survival of 25% is assumed for the trawl fleet (Charuau *et al*., 1982; Sangster *et al*., 1997; Wileman *et al*., 1999). The discard survival rate for creel caught *Nephrops* have been shown to be high and a value of 100% is used.

Summary of biological parameters

Parameter	Value	Source
Discard Survival (trawl)	25%	Charuau *et al*., 1982; Sangster *et al*., 1997; Wileman *et al*., 1999
Discard Survival (creel)	100%	Wileman *et al*., 1999; Harris and Ulmestrand (2004); Chapman,1981
MALES		
Growth – K	0.16	Adapted from Bailey and Chapman (1983)
Growth - L(inf)	70 mm	Adapted from Bailey and Chapman (1983)
Natural mortality - M	0.3	Morizur, 1982
Length/weight - a	0.00028	Howard and Hall (1983)
Length/weight - b	3.24	Howard and Hall (1983)
Size at maturity	27 mm	Adapted from Bailey and Chapman (1983)
FEMALES		
Immature Growth		
Growth – K	0.16	Adapted from Bailey and Chapman (1983)
Growth - L(inf)	70 mm	Adapted from Bailey and Chapman (1983)
Natural mortality - M	0.3	As for males
Size at maturity	22 mm	Queirós *et al*., (2013)
Mature Growth		
Growth – K	0.06	Adapted from Bailey and Chapman (1983)
Growth - L(inf)	60 mm	Adapted from Bailey and Chapman (1983)

Natural mortality - M	0.2	
Length/weight - a	0.00074	Howard and Hall (1983)
Length/weight - b	2.91	Howard and Hall (1983)

B.3. Surveys

Underwater television surveys of *Nephrops* burrow number and distribution, reduce the problems associated with traditional trawl surveys that arise from variability in burrow emergence of *Nephrops*. TV surveys are available for this FU from 1994 to present (missing suvreys in 1995 and 1997) with the survey usually taking place in May/June. On average, approximately 40 stations have been considered valid each year.

The methods used in the survey were similar to those employed for UWTV surveys of *Nephrops* stocks around Scotland and are documented by WKNEPHTV (ICES, 2007) and SGNEPS (ICES, 2010; ICES, 2012). In the assessment, burrow densities are raised to the total estimated area. The survey provides a total abundance estimate, and is not age or length structured. Samples are distributed randomly over the area of suitable sediment. The area calculation was based on the alpha convex-hull method to define and characterize the overall shape of a set of points and is described in ICES (2010). A number of annual polygons based on the VMS distribution of effort (2007–2011) was generated and the union of these used to define the area of *Nephrops* ground in the North Minch. The VMS area was updated in 2013 at the WKNEPH2013 and estimated to be 2908 km^2.

A number of factors are suspected to influence the ability of the surveys to map directly to absolute abundance. In order to use the survey abundance estimate as an absolute it is necessary to correct for these potential biases. The history of bias estimates are given in the following table and are based on simulation models, preliminary experimentation and expert opinion (ICES, 2009). The biases associated with the estimates of *Nephrops* abundance in the North Minch are:

	Time period	Edge effect	detection rate	species identification	occupancy	Cumulative absolute conversion factor
FU 11: North Minch	2009–2012	1.38	0.85	1.1	1	1.33

B.4. Commercial cpue

Landings, discards and effort data for Scottish *Nephrops* trawl gears are used to generate a cpue index. Cpue is estimated using officially recorded effort (KW days) although the recording of effort is not mandatory. Effort data are available for the trawl fleet from 2000. There is no account taken of any technological creep in the fleet. Effort data for the creel fleet are not available.

B.5. Other relevant data

InterCatch

Uploaded catch sampling data are worked up in InterCatch to generate raised international length–frequency distributions. Data exploration in InterCatch has previously shown that outputs of raised data were very close to those generated by the

previous method applied internally with differences being <0.1%. As such, InterCatch length–frequency outputs have been used in the stock assessment since 2012. Allocation schemes for any unsampled fleets are described are based on matching fleet (using both TR1 & TR2) for respective quarter weighted by CATON. If data for a given quarter are unavailable the following rule is applied: Q1-Q4 and Q2-Q3.

C. Assessment: data and method

Model used: UWTV Based Approach to generate catch options

Software used: Age-Structured Simulation model per recruit analysis in R

In 2009 WKNEPH debated the use of the surveys as either an absolute measure of abundance or a relative index (ICES, 2009). Ultimately this led to a consensus that bias corrected survey abundance estimates could be used directly in the formulation of catch advice. Two modelling approaches were used to estimate sustainable stock-specific Harvest Ratio reference points; SCA (a separable LCA model Bell) & Age-Structured Simulation model (Dobby) (ICES, 2009).

1) Survey indices are worked up annually resulting in the TV index.

2) Apply the Absolute Conversion Factor. The combined effect of these biases is to be applied to the new survey index.

3) Generate mean weight in landings. Check the time-series of mean landing weights for evidence of a trend in the most recent period. If there is no firm evidence of a recent trend in mean weight use an average taken over an appropriate time scale. If, however, there is strong evidence of a recent trend then apply most recent value (don't attempt to extrapolate the trend further in the future).

4) The catch option table will include the harvest ratios associated with fishing at $F_{0.1}$, $F_{35\%SpR}$ and F_{MAX}. These values are estimated by benchmark workshops but may be revised if there are indications of changes to fisheries or biological factors.

5) Create catch option table on the basis of a range of harvest ratios ranging from 0 to the maximum observed ratio or the ratio equating to F_{MAX}, whichever is the larger. Insert the harvest ratios from step 4 and also the current harvest ratio.

6) Multiply the survey index by the harvest ratios to give the number of total removals.

7) Create a landings number by applying the discard ratio (dead discard rate).

8) Produce landings biomass by applying mean weight.

D. Short-term projections

Catch options are now provided for a range harvest ratios associated with potential F_{MSY} proxies which are obtained from per-recruit analysis (see below for details on reference points).

Create catch option table on the basis of a range of harvest ratios ranging from 0 to the maximum observed ratio or the ratio equating to F_{MAX}, whichever is the larger.

Multiply the survey index by the harvest ratios to give the number of total removals.

Create a landings number by applying a discard factor (three year mean value).

Produce landings biomass by applying mean weight.

E. Medium-term projections

F. Long-term projections

G. Biological reference points

Under the new ICES MSY framework, exploitation rates which are likely to generate high long-term yield (and low probability of stock overfishing) have been explored and proposed for each functional unit. Owing to the way *Nephrops* are assessed, it is not possible to estimate F_{MSY} directly and hence proxies for F_{MSY} are determined. Three candidates for F_{MSY} are $F_{0.1}$, $F_{35\%SpR}$ and F_{MAX}. Owing to the strong difference in relative exploitation rates between the sexes, values for each of the candidates are determined for males, females and the two sexes combined. The appropriate F_{MSY} candidate has been determined for each Functional Unit independently according to the perception of stock resilience, factors affecting recruitment, population density and the nature of the fishery (relative exploitation of the sexes and historical Harvest Rate vs stock status).

In the North Minch the absolute density observed on the UWTV survey is medium (~0.59 burrow/m^2). Historical harvest ratios in this FU have been above that equivalent to fishing at F_{MAX} and landings have been relatively stable in the last thirty years. $F_{35\%SpR}$ (combined between sexes) is expected to deliver high long-term yield with a low probability of recruitment overfishing and therefore is chosen as a proxy for F_{MSY}. These calculations assume that the TV survey has a knife-edge selectivity at 17 mm and that the supplied length frequencies represented the population in equilibrium.

New reference points were derived for this stock at WKMSYREF4 (ICES, 2015). These are updated on the basis of an average of estimated F_{MSY} proxy harvest rates over a period of years, this corresponds more closely to the methodology for finfish. In cases where there is a clear trend in the values a five year average was chosen. Similarly, the five year average of the F at 95% of the YPR obtained at the F_{MSY} proxy reference point was proposed as the F_{MSY} lower bound and the five year average of the F above F_{MAX} that leads to YPR of 95% of the maximum as the upper bound. Using an average value also has the advantage of reducing the effect of any unusually high or low estimates of the F_{MSY} proxy which occasionally appear. For this stock the F_{MSY} proxy has been revised from 10.9% to 10.8%.

For *Nephrops* stocks MSY $B_{trigger}$ has been defined as the lowest stock size from which the abundance has increased. The $B_{trigger}$ point for this FU (bias adjusted lowest observed UWTV abundance) is calculated as 541 million individuals.

These should remain under review and may be revised should improved data become available.

			F_{bar}(20–40 mm)		HR (%)	SPR (%)		
		Fmult	M	F		M	F	T
$F_{0.1}$	M	0.21	0.134	0.060	6.9	39.9	65.9	49.0
	F	0.46	0.294	0.131	12.8	20.5	47.9	30.1
	T	0.24	0.153	0.068	7.7	36.2	63.0	45.5
F_{max}	M	0.38	0.243	0.108	11.1	24.6	52.4	34.3
	F	1.07	0.684	0.305	23.0	8.2	30.2	15.9
	T	0.48	0.307	0.137	13.2	19.7	46.9	29.2
$F_{35\%SpR}$	M	0.26	0.166	0.074	8.2	34.0	61.2	43.5
	F	0.84	0.537	0.240	19.6	10.8	34.8	19.2
	T	0.37	0.237	0.106	10.9	25.2	53.0	34.9

Harvest ratio reference points

	Type	Value	Technical basis
MSY	MSY $B_{trigger}$	541 million individuals	Bias-adjusted lowest observed UWTV survey estimate of abundance (corrected for the new VMS area estimate)
Approach	F_{MSY}	10.8% harvest rate	Equivalent to $F_{35\%SpR}$ combined sex. F_{MSY} proxy based on length-based Y/R.

H. Other issues

H.1. Historical overview of previous assessment methods

A re-working of the UWTV survey abundances for Division 6.a was presented to the *Nephrops* benchmark workshop (WKNEPH) in 2009 (ICES, 2009) and further details of the technical changes to the camera can be found in the report of that workshop. The revised abundance estimates for FU 11 from 1999 onwards were presented for the first time at WGCSE 2009 and are slightly higher than the previous values due to the field of view being smaller than previously calculated.

Up to 2010 the ground area for the North Minch was based on the British Geological Survey (BGS) and estimated as 1775 km^2. Marine Scotland Science recent access to Vessel Monitoring System data (VMS) has shown that fishing effort for trawlers (length >15 m) clearly extends outside of the BGS area for FU 11, which would imply an underestimate of the stock area. In the 2011 and 2012 assessments, a preliminary VMS based area estimated as 2506 km^2 was used for raising abundances. A correction ratio calculated as 1.41 (VMS area / Sediment area) was applied to the previous sediment abundances estimates to get a rough measure of the abundance raised to the VMS area. As more VMS data became available since 2010, in 2013 at the WKNEPH2013 the sediment area of North Minch was updated to 2908 km^2. This was based on the union of annual polygons produced from the VMS data which was shown to the best method to define the ground area in FU 11 as it includes the main fishing areas while it excludes some low intensity areas. The correction ratios to be applied to the previous abundance estimates are now 1.64 (new VMS area / Sediment area) for years 1994–2010 and 1.16 (new VMS area / preliminary VMS area,) for years 2011–2012.

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Table B1-1. *Nephrops*, North Minch (FU11). Nominal Landings of *Nephrops*, 1981–2015.

	UK SCOTLAND				OTHER UK & IRELAND	TOTAL
year	*Nephrops* trawl	other trawls	creel	Subtotal		
1981	2320	171	370	2861	0	2861
1982	2323	105	371	2799	0	2799
1983	2784	96	317	3197	0	3197
1984	3449	160	534	4143	0	4143
1985	3235	117	708	4060	0	4060
1986	2641	203	537	3381	0	3381
1987	3459	143	482	4084	0	4084
1988	3450	148	437	4035	0	4035
1989	2603	112	490	3205	0	3205
1990	1941	134	471	2546	0	2546
1991	2229	126	438	2793	0	2793
1992	2978	149	432	3559	0	3559
1993	2699	86	408	3193	0	3193
1994	2916	246	453	3614	0	3614
1995	2940	183	532	3655	0	3655
1996	2354	148	370	2872	0	2872
1997	2553	102	391	3046	0	3046
1998	2023	68	350	2441	0	2441
1999	2792	56	409	3257	0	3257
2000	2695	28	524	3247	0	3247
2001	2649	42	568	3259	0	3259
2002	2775	79	586	3440	0	3440
2003	2606	45	618	3269	0	3269
2004	2391	30	661	3082	0	3082
2005	2270	23	656	2949	0	2949
2006	3446	23	697	4166	0	4166
2007	3361	26	591	3978	0	3978
2008	3229	13	557	3799	0	3799
2009	2849	34	613	3496	0	3496
2010	1783	9	621	2413	0	2413
2011	2109	17	571	2697	0	2697
2012	2963	12	565	3540	2	3542
2013	2356	480	575	3411	2	3413
2014	2177	586	490	3253	2	3255
2015*	1858	720	417	2995	0	2995

*** Provisional.**

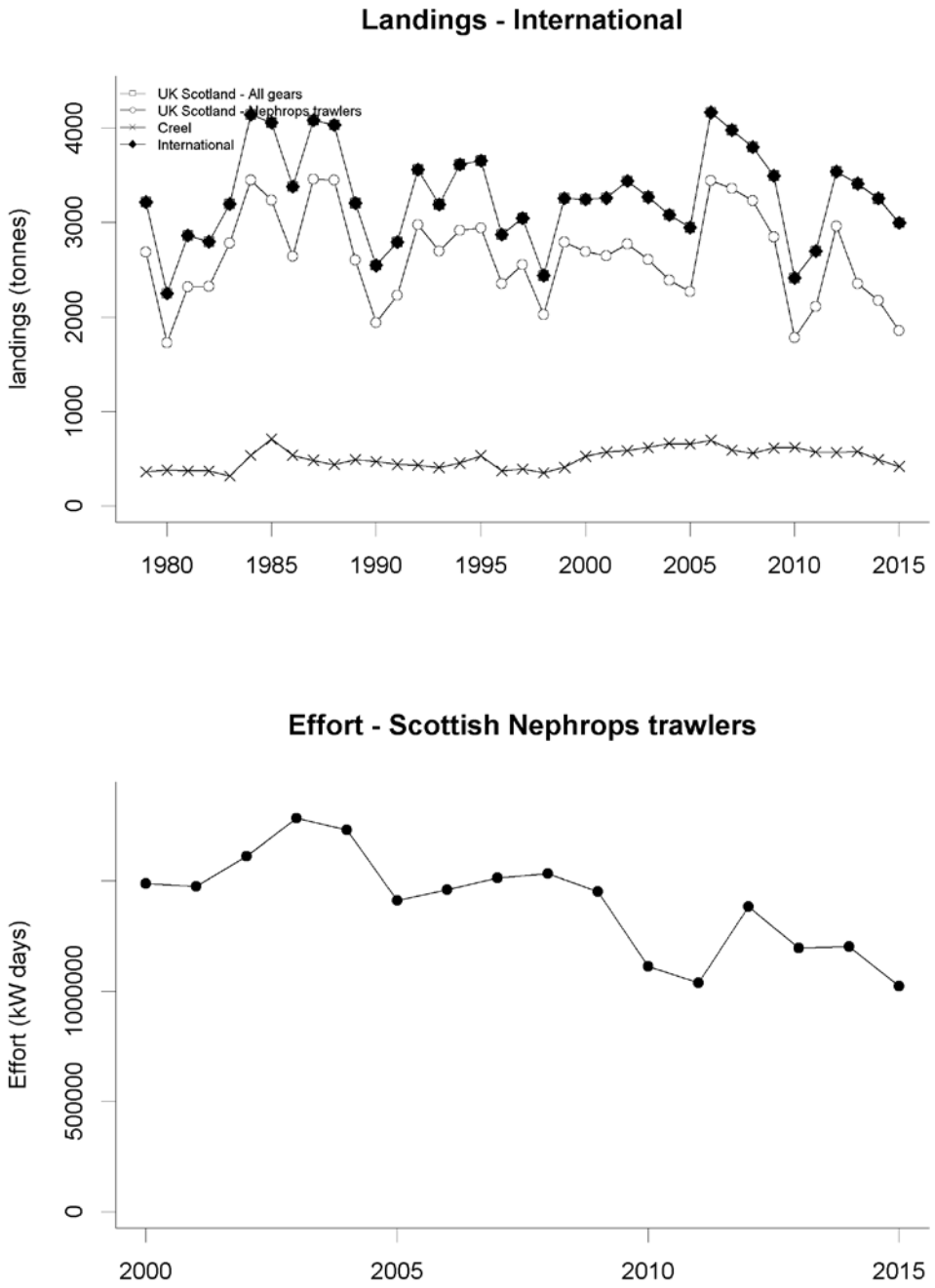

Figure B1-1. ***Nephrops,*** **North Minch (FU 11). Long-term landings andeffort. The interpretation of the lpue series is likely to be affected by the introduction of the "buyers and sellers" regulations in 2006.**

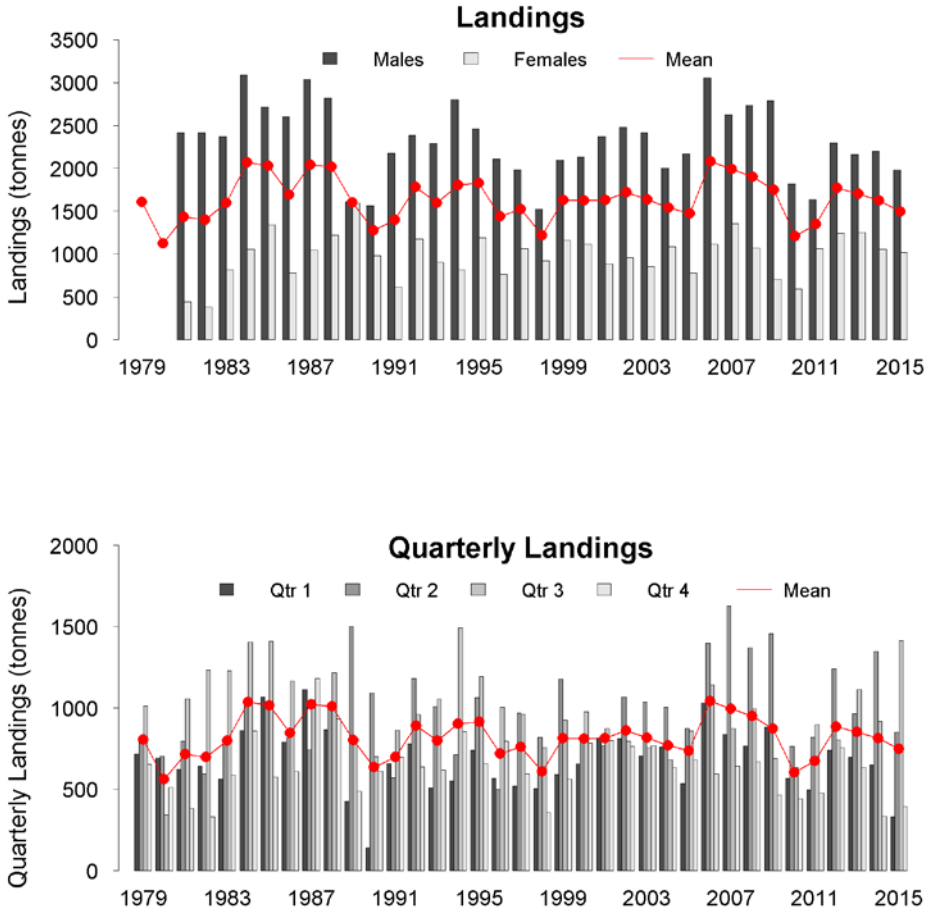

Figure B1-2. ***Nephrops,*** **North Minch (FU 11). Landings by quarter and sex from Scottish trawlers.**

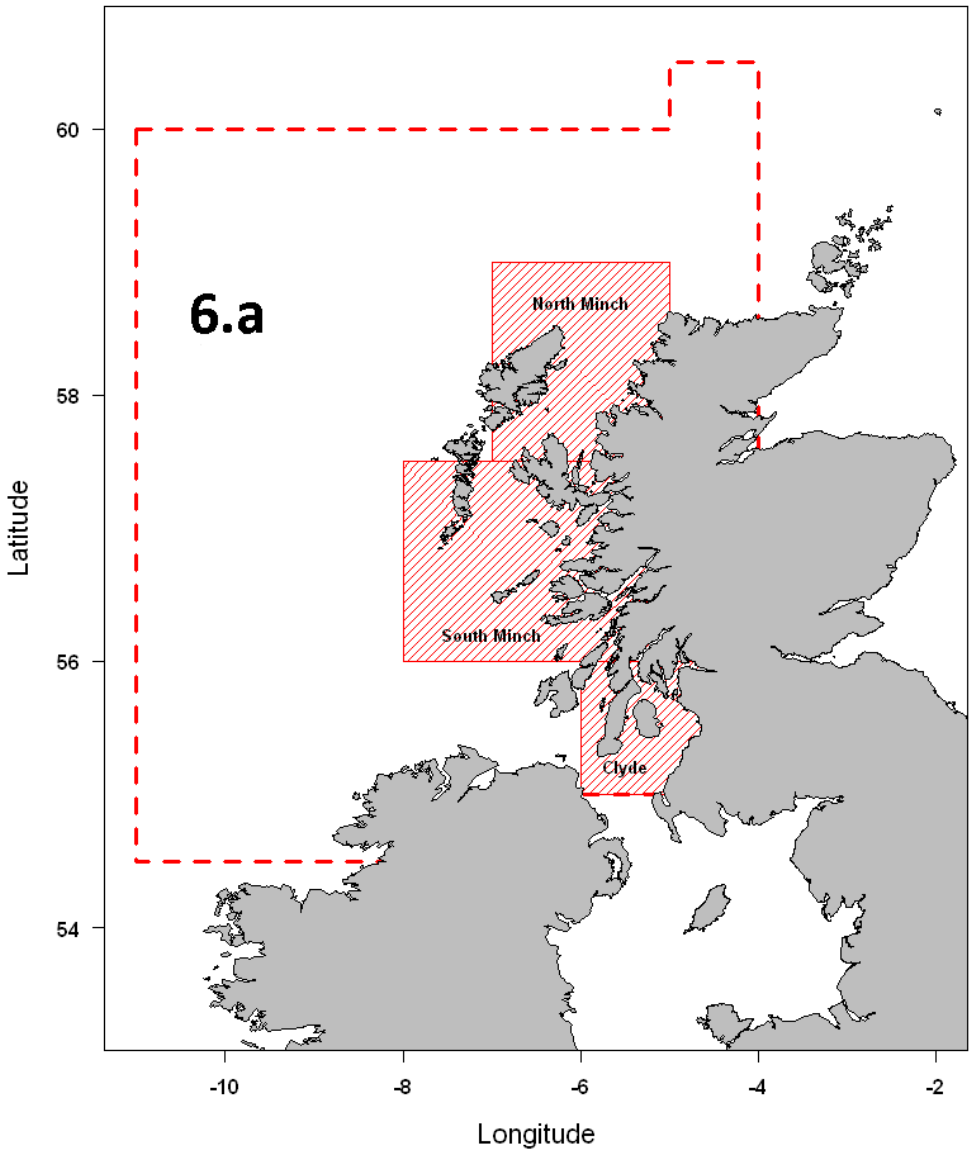

Figure B1-3. ***Nephrops*** **Functional Units in 6.a. North Minch (FU 11), South Minch (FU 12), Clyde (FU 13).**

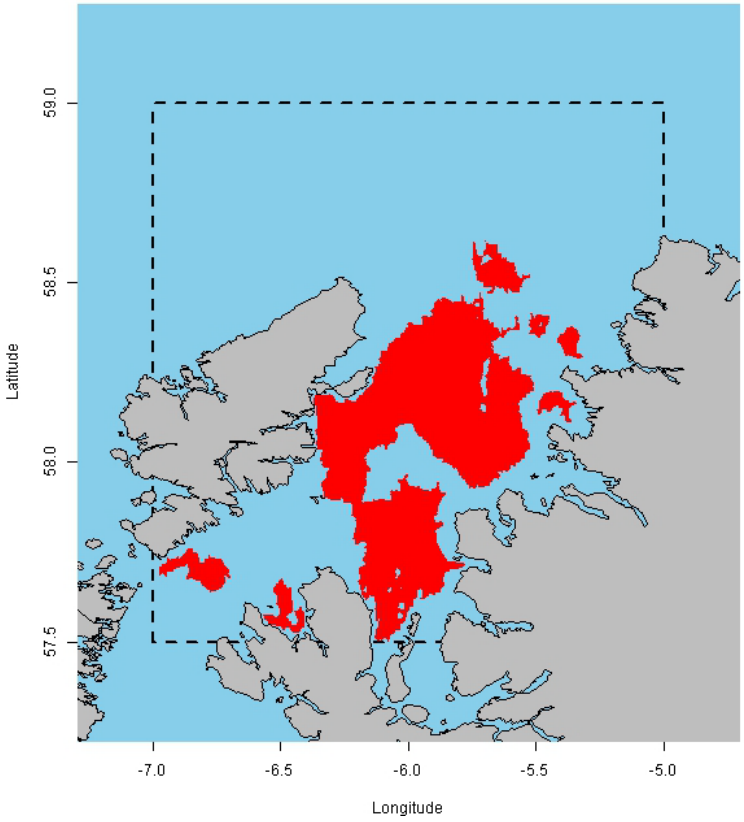

Figure B1-4. ***Nephrops,*** **North Minch (FU 11).** ***Nephrops*** **ground area (shown in red) estimated using VMS data (2908 km²).**