Stock Annex: Norway lobster (*Nephrops norvegicus*) in Division 6.a, Functional Unit 12 (West of Scotland, South Minch)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Norway lobster
Working Group:	Working Group for the Celtic Seas Ecoregion (WGCSE)
Created:	9 March 2009 (WKNEPH2009)
Authors:	
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A. General

A.1. Stock definition

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, and this means that the distribution of suitable sediment defines the species distribution. Adult *Nephrops* only undertake very small scale movements (a few 100 m) but larval transfer may occur between separate mud patches in some areas. In the South Minch area the *Nephrops* stock inhabits a generally continuous area of muddy sediment extending from the south of Skye to the Stanton Bank, to the south of the Outer Hebrides. The South Minch functional unit (FU12) is located off the west coast of Scotland, and is bounded to the north and south by the 56°00′ and 57°30′ circles of latitude, and to the west by the 8°W meridian. Out with the functional unit, a mixed fishery for gadoids and *Nephrops* takes place on Stanton Bank, to the southwest of the Outer Hebrides.

A.2. Fishery

The South Minch *Nephrops* fishery is predominantly exploited by *Nephrops* trawlers, although about 20% of landings are made by creel vessels, which has increased in recent years. About 90% of trawler landings are made by vessels targeting *Nephrops*, and 25% of landings were made by twin-rig vessels in 2012.

Two distinct fleets operate in the South Minch, landing into the two main ports of Oban and Mallaig. Inshore, a fleet of smaller vessels including creel boats operated throughout the year, while some larger twin riggers fish further offshore. Most of these boats are thought to fish for *Nephrops* at some time. The local Mallaig fleet tend to fish closer to shore on harder ground and land better quality *Nephrops* than visitor boats. Most boats land once or twice per week. There are very few vessels (2–3) that landed on a daily basis. During the winter months, fishing activity is usually reduced in the South Minch due to the weather and small boats are often restricted to trawling in the sheltered sea-lochs.

There was a continued pattern of visiting east coast vessels which arrived around April/May and stayed for approximatley five months. The east coast vessels tend to be larger than the local ones, and carry out longer trips.

The minimum landing size for *Nephrops* in the South Minch is 20 mm CL and less than 1% of animals are landed under size. Discarding takes place at sea and landings are made by category for whole animals (small and large) and as tails. The main bycatch species are whiting and haddock, with whiting in particular featuring heavily in discards. Of the non-commercial species caught, poor cod, Norway pout and long rough dab contribute significantly to the discards.

The fishery is exploited throughout the year, with the highest landings usually being made in the spring and summer. A seasonal sprat fishery often develops in November and December, which is targeted by vessels of all sizes (including those that usually target *Nephrops*). Some vessels also turn to scallop dredging when *Nephrops* catches or prices drop.

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 measures additional 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. For 2012, this regulation effectively limits vessels targeting *Nephrops* with 80–99 mm mesh size to 200 days at sea per year. The use of square mesh and headline panels are compulsory in this fishery and in addition vessels fishing with gear <100 mm within ICES Area 4.a (within the CRZ) must fish exclusively with any of the highly selective fishing gears specified in Annex C of the scheme rules.

Additional Scottish legislation (SSI No 2000/226) applies to twin trawlers operating North of 56^0N, 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. From 2009 onwards under the west coast emergency measures a square meshed panel of 120 mm was also required (Council Reg. (EU) 43/2009).

A.3. Ecosystem aspects

Owing to its burrowing behaviour, the distribution of *Nephrops* is restricted to areas of mud, sandy mud and muddy sand. Within the South Minch functional unit these substrates are distributed according to prevailing hydrographic and bathymetric conditions.

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. A more continuous extensive area of sediment suitable for *Nephrops* occurs further offshore to the west. Figure B1-3 shows the distribution of sediment in the area.

B. Data

B.1. Commercial catch

Landings for FU12 provided through national laboratories are presented in Table B1-1, broken down by country and by gear type. Landings from this fishery are predominantly reported from Scotland, with low levels reported from the rest of the UK and Ireland. Total reported Scottish landings in 2015 were 3339 tonnes (plus 22 tonnes from other UK vessels and 33 tonnes from Ireland), consisting of 2681 tonnes (80%) landed by trawlers and 658 tonnes (20%) landed by Scottish creel vessels. The

proportion of creel caught landings has remained relatively stable over the last five years.

In 2015 WGCSE agreed that effort should be reported in Kw days as this is likely to be more informative about changes in the actual fleet effort. Effort shows an overall decreasing trend since 2003 but there are peaks in 2008 and 2012 which can be attributed to visting North Sea trawlers, (Figure B1-1) and then effort falls to levels comparable with 2011. Note that the effort time-series range (2000–2015) does not match with the more extensive year range available for landings due to a lack of reliable effort data in the Marine Scotland Science 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 (Howard and Hall, 1983). 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.

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)	66 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	25 mm	Adapted from Bailey and Chapman (1983)
FEMALES		
Immature Growth		
Growth – K	0.16	Adapted from Bailey and Chapman (1983)
Growth - L(inf)	66 mm	Adapted from Bailey and Chapman (1983)
Natural mortality - M	0.3	As for males

Size at maturity	25 mm	Adapted from Bailey and Chapman (1983)
Mature Growth		
Growth – K	0.06	Adapted from Bailey and Chapman (1983)
Growth - L(inf)	59 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 1995 to present with the survey usually taking place in May/June. On average, approximately 35 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 (5072 km^2).

From the work presented at the 2012 SGNEPS meeting (ICES, 2012) it was decided by the group that a CV (relative standard error) of <20% was an acceptable precision level for UWTV survey estimates of abundance. CVs for this FU are lower than the precision level agreed but generally higher than those estimates for FU11 and FU13. This is related to the high variance associated with the sandy mud strata.

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 South Minch are:

	Time period	Edge effect	detection rate	species identification	occupancy	Cumulative absolute conversion factor
FU 12: South Minch	<=2009	1.37	0.85	1.1	1	1.32

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

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 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).

For this FU, the absolute density observed in the UWTV survey-series is intermediate (average of just over 0.42 m^{-2}) suggesting the stock has moderate productivity. In addition, the fishery in this area has been in existence since the 1960s and the population has been studied numerous times (Afonso-Dias, 1998; Howard and Hall, 1983). Historical harvest ratios in this FU have been variable but generally around the $F_{35\%SpR.}$ The WG concluded that combined sex $F_{35\%SpR}$ is an appropriate F_{proxy} for South Minch FU12 *Nephrops*. This is slightly below F_{MAX} in males and is predicted to result in about 27% SPR for males; in excess of the 20% considered precautionary lower bound.

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 12.3% to 11.7%.

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 1016 million individuals.

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

			F_{BAR}(20–40 mm)		HR (%)	SPR (%)		
		F_{MULT}	M	F		M	F	T
$F_{0.1}$	M	0.22	0.13	0.06	7.8	40.9	60.8	48.5
	F	0.44	0.27	0.12	13.8	23.8	43.7	31.4
	T	0.25	0.15	0.07	8.7	37.4	57.7	45.2
F_{MAX}	M	0.42	0.25	0.12	13.3	24.8	44.8	32.5
	F	1.1	0.67	0.31	26.8	9.9	23.6	15.2
	T	0.54	0.33	0.15	16.1	19.8	38.7	27.1
$F_{35\%SpR}$	M	0.28	0.17	0.08	9.6	34.5	54.9	42.3
	F	0.64	0.39	0.18	18.3	16.9	34.8	23.8
	T	0.38	0.23	0.11	12.3	27.0	47.3	34.8

Harvest ratio reference points:

	Male	Female	Combined
F_{MAX}	13.3	26.8	16.1
$F_{0.1}$	7.8	13.8	8.7
$F_{35\%SpR}$	9.6	18.3	12.3

	Type	Value	Technical basis
MSY	MSY $B_{trigger}$	1016 million individuals	Bias-adjusted lowest observed UWTV survey estimate of abundance
Approach	F_{MSY}	11.7% 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 were 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 FU12 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.

I. References

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Table B1-1. *Nephrops*, South Minch (FU12), Nominal Landings of *Nephrops*, 1981–2015, as officially reported.

	UK Scotland						
year	*Nephrops* trawl	other trawl	creel	subtotal	other UK	Ireland	total
1981	2,966	254	432	3,652	0	0	3,652
1982	2,925	206	421	3,552	0	0	3,552
1983	2,595	362	456	3,413	0	0	3,413
1984	3,229	477	594	4,300	0	0	4,300
1985	3,096	424	488	4,008	0	0	4,008
1986	2,694	288	502	3,484	0	0	3,484
1987	2,928	418	546	3,892	0	0	3,892
1988	3,544	364	555	4,463	10	0	4,473
1989	3,846	338	561	4,745	0	0	4,745
1990	3,732	263	435	4,430	0	0	4,430
1991	3,596	342	503	4,441	1	0	4,442
1992	3,478	209	549	4,236	1	0	4,237
1993	3,609	194	650	4,453	5	0	4,458
1994	3,742	264	405	4,411	3	0	4,414
1995	3,443	717	508	4,668	14	0	4,682
1996	3,108	417	469	3,994	1	0	3,995
1997	3,518	329	493	4,340	3	1	4,344
1998	2,851	340	538	3,729	0	1	3,730
1999	3,165	359	514	4,038	0	14	4,052
2000	2,940	311	700	3,951	0	2	3,953
2001	2,823	391	768	3,982	0	9	3,991
2002	2,234	314	743	3,291	0	14	3,305
2003	2,812	203	858	3,873	0	6	3,879
2004	2,864	105	879	3,848	0	21	3,869
2005	2,812	46	955	3,813	1	34	3,848
2006	3,570	97	922	4,589	9	35	4,633
2007	4,437	21	959	5,417	19	35	5,471
2008	4,433	12	896	5,341	2	13	5,356
2009	3,346	24	900	4,270	4	11	4,285
2010	2,836	19	969	3,824	16	6	3,846
2011	2,876	11	783	3,670	23	9	3,702
2012	3,159	32	773	3,964	19	6	3,989
2013	2,490	543	729	3,762	13	1	3,776
2014	2,067	422	637	3,126	32	17	3,175
2015*	2,173	508	658	3,339	22	33	3,394

*** Provisional.**

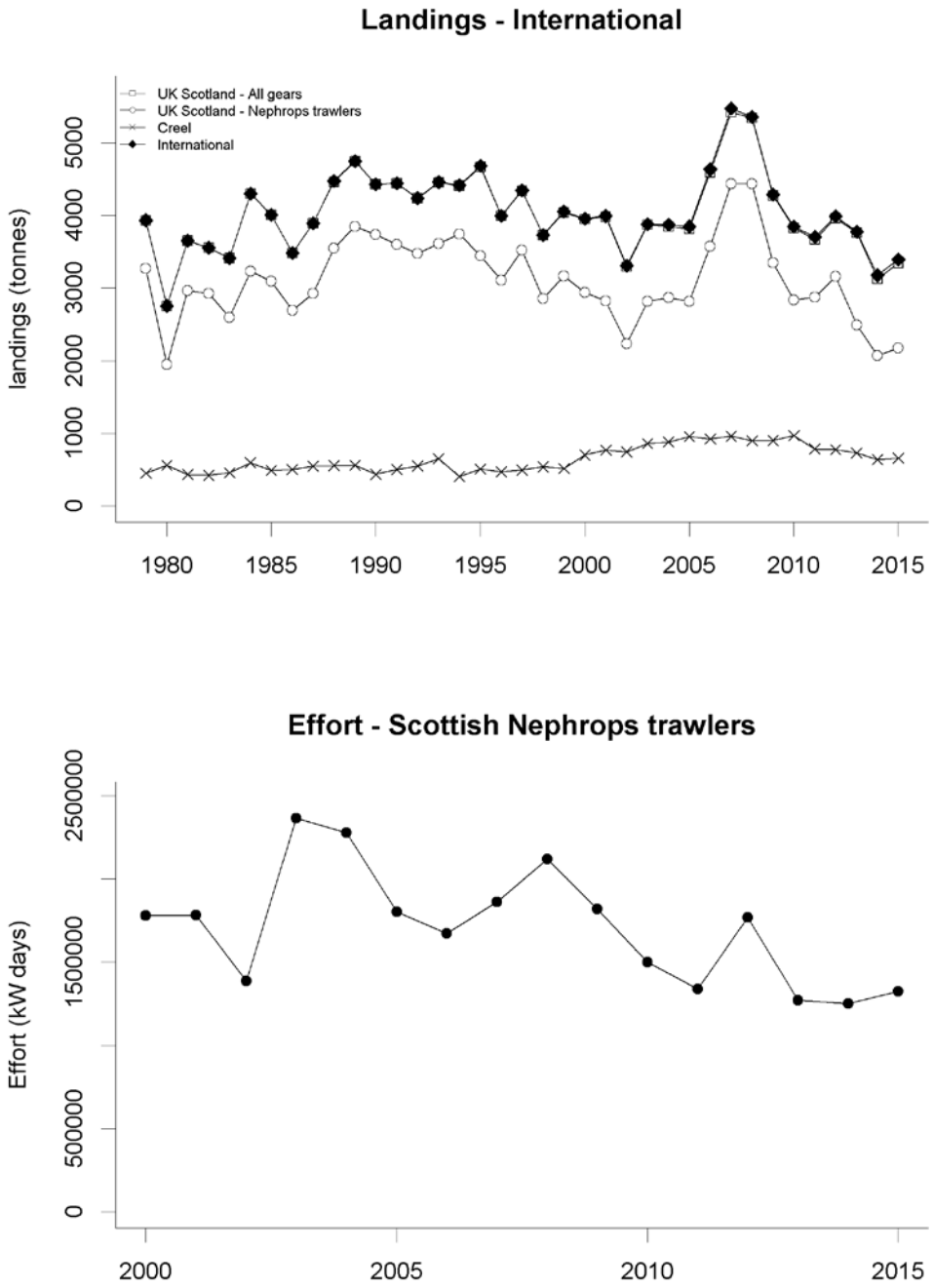

Figure B1-1. ***Nephrops,*** **South Minch (FU12). Long-term landings and effort.**

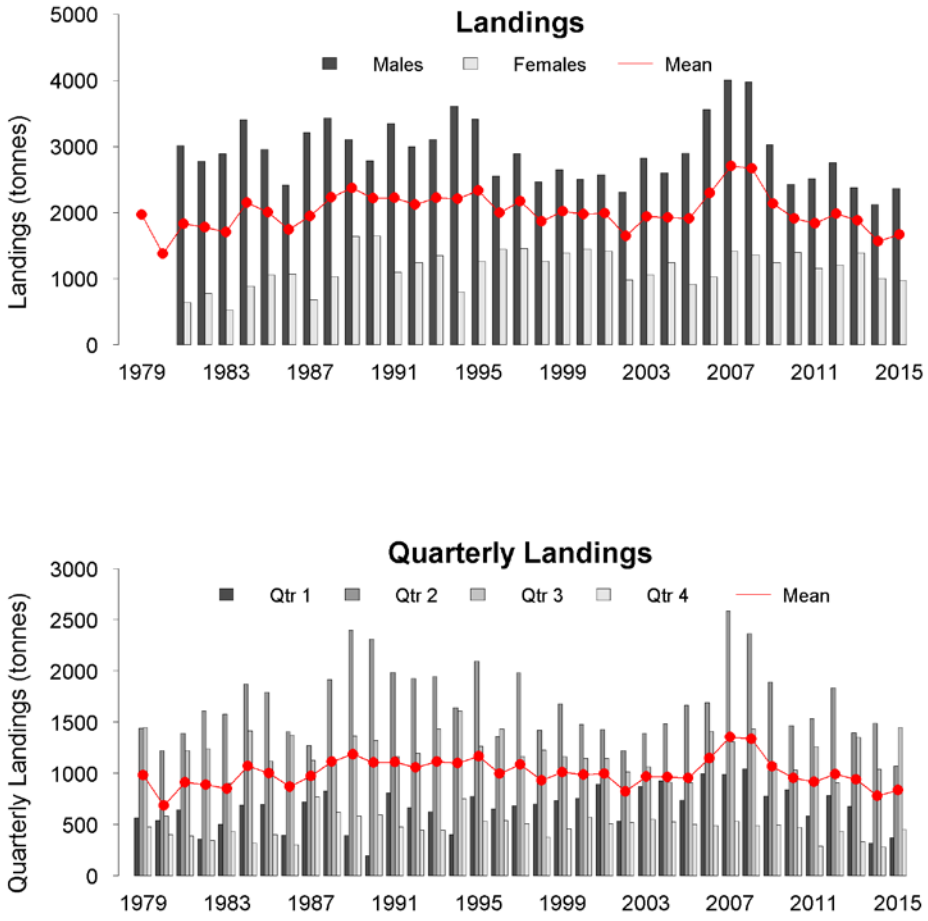

Figure B1-2. ***Nephrops,*** **South Minch (FU12).**

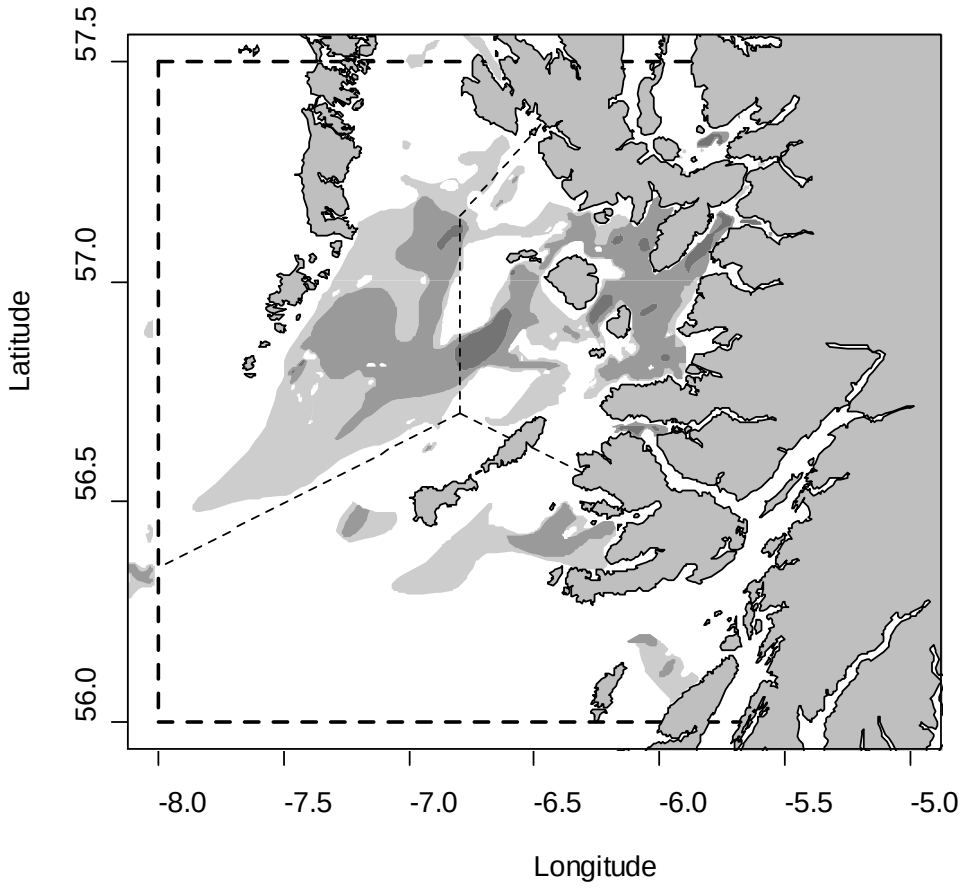

Figure B1-3. Sediment strata in the South Minch. Light Grey – Muddy sand, Grey – Sandy mud, Dark Grey – Mud. Light dashed lines represent spatial strata imposed on the sampling regime to ensure adequate spatial coverage.

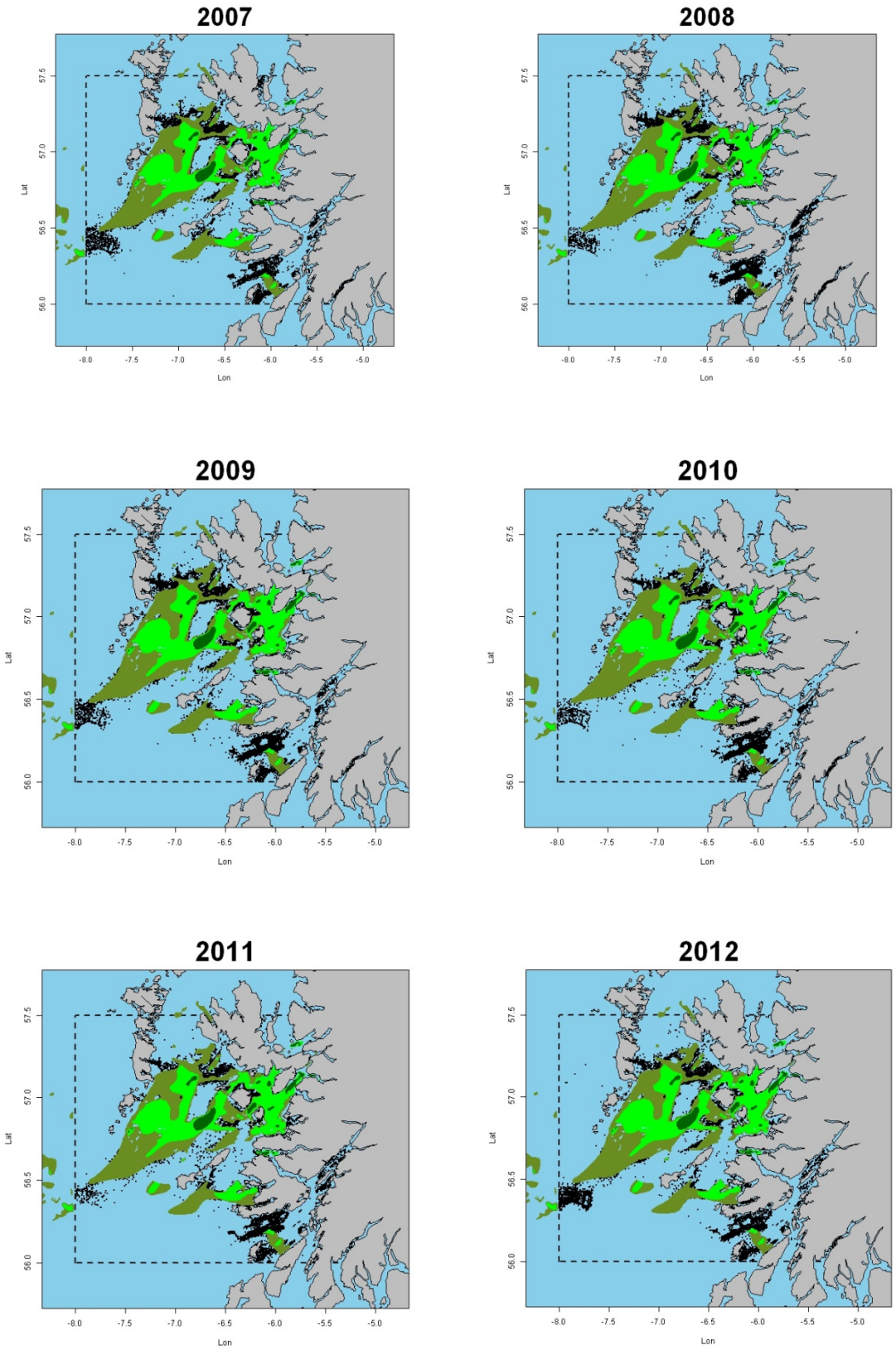

Figure 3.6.7. *Nephrops*, **South Minch (FU 12), comparison of area of** *Nephrops* **ground defined by BGS sediment distribution (green shaded overlay) and by distribution of VMS pings (shown by black dots, underlay) recorded from** *Nephrops* **trawlers >15 m length for 2007–2012. VMS data filtered to exclude vessel speeds >4.5 knots.**