Stock Annex: Norway lobster (*Nephrops norvegicus*) in Division 6.a, Functional Unit 13 (West of Scotland, the Firth of Clyde and Sound of Jura)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Norway lobster
Working Group:	Working Group for the Celtic Seas Ecoregion (WGCSE)
Created:	09 March 2009 (WKNEPH2009)
Authors:	
Last updated:	WGCSE, 2016
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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 Clyde area the *Nephrops* stock inhabits an area of muddy sediment extending throughout the Firth of Clyde, and another smaller area in the Sound of Jura, as shown in Figure B1-3. The two areas are separated by a large area of sandy gravely sediment around the Mull of Kintyre, and are treated as separate populations since they have differing population characteristics.

A.2. Fishery

Firth of Clyde

The Firth of Clyde *Nephrops* fishery is predominantly exploited by a dedicated *Nephrops* trawler fleet of approximately 100 vessels, with approximately 5% of the landings made by creel vessels. The 60 resident Clyde trawlers make about 95% of the *Nephrops* landings. Under the Scottish 'Inshore Fishing Order' of 1989 (Prohibition of Fishing and Fishing Methods), fishing with mobile gear is prohibited within the Firth of Clyde over weekends, and with vessels >70 feet (about 21 m) in length.

The trawler fleet that fishes the Firth of Clyde mostly consists of vessels between 10 and 20 m in length (mean overall length 14 m) and all trawlers use 80 mm single or twin rigs with square mesh panels (SMP) of at least 120 mm, in accordance with west coast emergency measures conditions (Council Reg. (EU) 43/2009).

The regular fleet is comprised of Scottish vessels, but some catches are taken by Northern Ireland and Republic of Ireland vessels. The major landing ports are Troon, Campbeltown, Girvan and Tarbert, but smaller landings are also made at Carradale, Largs

and Rothsay. The minimum landing size for *Nephrops* in the Clyde is 20 mm CL. Compliance with the minimum landing size is good, with samples suggesting only a very small undersized component in the landings (<2%).

Nephrops growth varies within the area, with low density animals growing to large sizes in the North, and with higher density animals reaching smaller sizes in the South. Far more *Nephrops* material (undersized individuals and 'heads' from tailed animals) is discarded in the South. Discarding usually takes place at sea and landings are made by category for whole animals (small, medium and large) and as tails. In poor weather or for the last haul of the day, discarding may take place within the harbour, thus increasing discard mortality.

Only a small fish bycatch is made in the Firth of Clyde, with whiting and cod being the most important species. The composition of the bycatch and discards varies within the Firth of Clyde, with more flatfish (common and long rough dab), echinoderms and crustaceans (other than *Nephrops*) caught in the North, while more roundfish (particularly whiting) are caught in the South. These differences reflect the different habitats and fish communities in the area.

The fishery is exploited throughout the year, with the highest landings are usually made between July and September. Vessels usually have a trip duration of one day, sailing to shoot before dawn, and carrying out 3–4 hauls of four hours per day.

Sound of Jura

The fishery for *Nephrops* in the Sound of Jura constitutes part of the Clyde FU, but is examined separately from the fishery within the Firth of Clyde, because of differences in the biological parameters of the *Nephrops* populations.

The fleet exploiting the Sound of Jura is also different to the Firth of Clyde, with vessels tending to be slightly smaller but more powerful. Most landings are taken by Scottish vessels, with a very small proportion taken by boats from the rest of the UK. The local trawler fleet consists of vessels between 9 and 16 m in length, and with a mean engine power of 185 kW. The main landing ports are Port Askaig, West Loch Tarbert and Crinan.

The minimum landing size for *Nephrops* in the Sound of Jura is 20 mm CL. *Nephrops* are found in high densities in this stock, but only grow to relatively small sizes. Discarding takes place at sea (this can be a high proportion of the catch by number, because of the small mean size of the animals caught), and landings are made by category for whole animals (small, medium and large) and as tails.

Catches of fish in the Sound of Jura area are generally poor, and *Nephrops* are clearly the target species, with only small bycatches of whitefish and flatfish. The fishery is exploited throughout the year, with highest landings usually made between April and June. Vessels usually have a trip duration of one day, with 3–4 hauls per day.

For both areas 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 Clyde FU comprises two distinct patches in the Firth of Clyde and the Sound of Jura, to the east and west of the Mull of Kintyre respectively. The hydrography of the two subareas differs, with the Sound of Jura characterised by stronger tidal currents and the Firth of Clyde exhibiting features of a lower energy environment with a shallow entrance sill. Owing to its burrowing behaviour, the distribution of *Nephrops* is restricted to areas of mud, sandy mud and muddy sand. Within the two distinct patches these substrates are distributed according to prevailing hydrographic and bathymetric conditions. The available area of suitable sediment is smaller in the Sound of Jura, occupying only the deepest parts of the Sound, while in the Firth of Clyde these sediments predominate. Figure B1-3 shows the distribution of sediment in the area.

B. Data

B.1. Commercial catch

Landings statistics for FU13 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, although Northern Ireland contributed 16% in 2015. Creel landings have generally increased in the most recent years (although fell slightly in 2015) but remain at a low level compared to other gears and to the creel fisheries elsewhere on the west coast of Scotland.

Statistical rectangle 40E4 covers parts of both the Firth of Clyde and the Sound of Jura. The allocation of landings to the two components of FU13 relies in part on the fishery office having detailed knowledge of where vessels have been fishing within 40E4. A sudden decline in landings from the Sound of Jura in 2001 did not seem to be associated with a sudden change in fishing practices and may instead be due to changes in fishery office recording practices. For this reason, the commercial landings data are now presented for the combined Firth of Clyde and Sound of Jura.

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 but was stable through 2010 to 2012 (Figure B1-1). Note that the effort time-series range (2000–2015) do not match with the more extensive year range available for landings due to a

Although assessments based on detailed catch analysis are not presently carried out, examination of length compositions can provide a preliminary indication of exploitation effects. Length compositions of Scottish landings and discards are obtained during monthly market sampling and quarterly on-board observer sampling respectively. In both sexes the mean sizes have been fairly stable over time in this FU. Examination of the tails of the distributions above 35 mm shows no evidence of reductions in relative numbers of larger animals.

Sex ratio in this FU shows some variation but males generally make the largest contribution to the annual landings. This occurs because males are available throughout the year and the fishery takes place in all quarters, although effort is reduced during the winter months because of poor weather. 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). 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.

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)	73 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)	73 mm	Adapted from Bailey and Chapman (1983)
Natural mortality - M	0.3	As for males
Size at maturity	25 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*. A random stratified sampling design is used, on the basis of British Geological Survey sediment strata (Tuck *et al*., 1999). The survey provides a total abundance estimate, and is not age or length structured. 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).

A series of annual underwater TV surveys are available since 1995. Whilst the survey in the Clyde has been continuous, the TV survey for the Sound of Jura was not conducted from 1997 to 2000, 2004 and 2008. The number of valid stations has remained relatively stable throughout the time period. An average of 36 stations have been sampled in each year, and then raised to a stock area of 2081 km^2 for the Firth of Clyde, and an average of ten stations have been considered valid each year for the Sound of Jura (area 383 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 this FU are:

	Time period	Edge effect	Detection rate	Species identification	Occupancy	Cumulative absolute conversion factor
FU 13:	<=2009	1.19	0.75	1.25	1	1.19

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 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.

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 the Firth of Clyde subarea of FU13, the absolute density observed on the UWTV survey is generally high (average of over 0.8 m^{-2} for entire series and around 1.0 m^{-2} for the last five years suggesting the stock has relatively high productivity. In addition, the fishery in this area has been in existence since the 1960s and the population and biological parameters have been studied numerous times (Bailey and Chapman, 1983; Tuck *et al*., 1997; Tuck *et al*., 1999). Historical harvest ratios in this FU have been generally high at or above F_{MAX}. An appropriate F_{MSY} proxy is considered therefore to be the total population F_{MAX} which is predicted to deliver an $F_{35\%SpR}$ of about 22% for males; considered precautionary for this species.

Yield per recruit analysis is not yet available for the Sound of Jura subarea of this FU and so proxies from the Firth of Clyde are used. The absolute density observed on the UWTV survey is generally high (average of about 0.9 m^{-2} over the time-series and around 1 m^{-2} over the last five years) suggesting the stock has relatively high productivity. A number of studies have investigated biology and the area is acknowledged as having high abundance for many years. However, the time-series of TV data is more fragmented and sampling is at a relatively low level; confidence intervals are larger. The fishery in this area has been in existence since the 1960s but in recent times has operated at a low level and harvest ratios in this FU have been low. An appropriate F_{MSY} proxy is considered therefore to be the total population $F_{35\%SpR}$ which is predicted to deliver an $F_{35\%SpR}$ of about 25% for males; above the level considered precautionary for this species.

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 16.4% 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 the Firth of Clyde (bias adjusted lowest observed UWTV abundance) is calculated as 579 million individuals. An MSY $B_{trigger}$ was not previously proposed for FU13 (SJ) as there were few points in the survey series (due to missing years). WKMSYREF4 stated that the survey series is now considered to be of sufficient length to allow the B_{loss} (abundance in 1995) to be proposed as the MSY $B_{trigger}$. This results in a value of 160 million (ICES, 2015).

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

Firth of Clyde

	TYPE	VALUE	TECHNICAL BASIS
MSY	MSY $B_{trigger}$	579 million individuals	Bias-adjusted lowest observed UWTV survey estimate
Approach	F_{MSY}	11.7% harvest rate	Equivalent to F_{MAX} combined sex. F_{MSY} proxy based on length based Y/R.

Sound of Jura

	TYPE	VALUE	TECHNICAL BASIS
MSY	MSY $B_{trigger}$	160 million individuals	Bias-adjusted lowest observed UWTV survey estimate
Approach	F_{MSY}	14.5% harvest rate	Equivalent to $F_{35\%SpR}$ combined sex. F_{MSY} proxy based on length based Y/R.

H. Other Issues

There are concerns over the accuracy of historical landings and effort data and due to this, the final assessment adopted is independent of official statistics. Harvest ratios since 2006 are also considered more reliable due to more accurate landings data reported under new legislation.

One of the main issues for this FU is the problem of not being able to split the landings between the Sound of Jura and Firth of Clyde. This means that we are unable to provide harvest ratios for the two subareas separately. What is currently provided is not actually a harvest ratio for either sub area; but is likely more representative of the Firth of Clyde. This has an impact on the quality of the assessment but not on the forecast.

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Table B1-1. *Nephrops*, Clyde (FU13), Nominal Landings of *Nephrops*, 1981–2015, as officially reported.

	UK Scotland				other UK	total
year	*Nephrops* trawl	other trawl	creel	subtotal		
1981	2498	404	66	2968	0	2968
1982	2372	169	79	2620	0	2620
1983	3889	121	52	4062	14	4076
1984	3070	153	77	3300	10	3310
1985	3921	293	65	4279	7	4286
1986	4073	176	79	4328	13	4341
1987	2860	82	64	3006	3	3009
1988	3507	107	43	3657	7	3664
1989	2577	184	35	2796	16	2812
1990	2731	121	23	2875	34	2909
1991	2844	145	26	3015	23	3038
1992	2530	247	9	2786	17	2803
1993	3200	110	5	3315	28	3343
1994	2503	50	28	2581	49	2630
1995	3766	131	26	3923	64	3987
1996	3880	108	27	4015	42	4057
1997	3486	46	26	3558	63	3621
1998	4540	79	39	4658	183	4841
1999	3476	29	37	3542	210	3752
2000	3142	63	75	3280	137	3417
2001	2890	65	95	3050	132	3182
2002	3075	53	105	3233	151	3384
2003	2954	20	119	3093	80	3173
2004	2619	8	88	2715	258	2973
2005	3148	5	94	3247	148	3395
2006	4356	1	179	4536	244	4780
2007	6069	4	221	6294	366	6660
2008	5320	3	184	5507	416	5923
2009	4304	1	191	4496	283	4779
2010	5162	5	211	5378	465	5843
2011	5664	9	219	5892	540	6432
2012	5617	4	203	5824	863	6687
2013	4708	4	212	4924	511	5435
2014	4769	1	258	5028	1178	6206
2015*	4012	17	206	4235	898	5133

*** Provisional.**

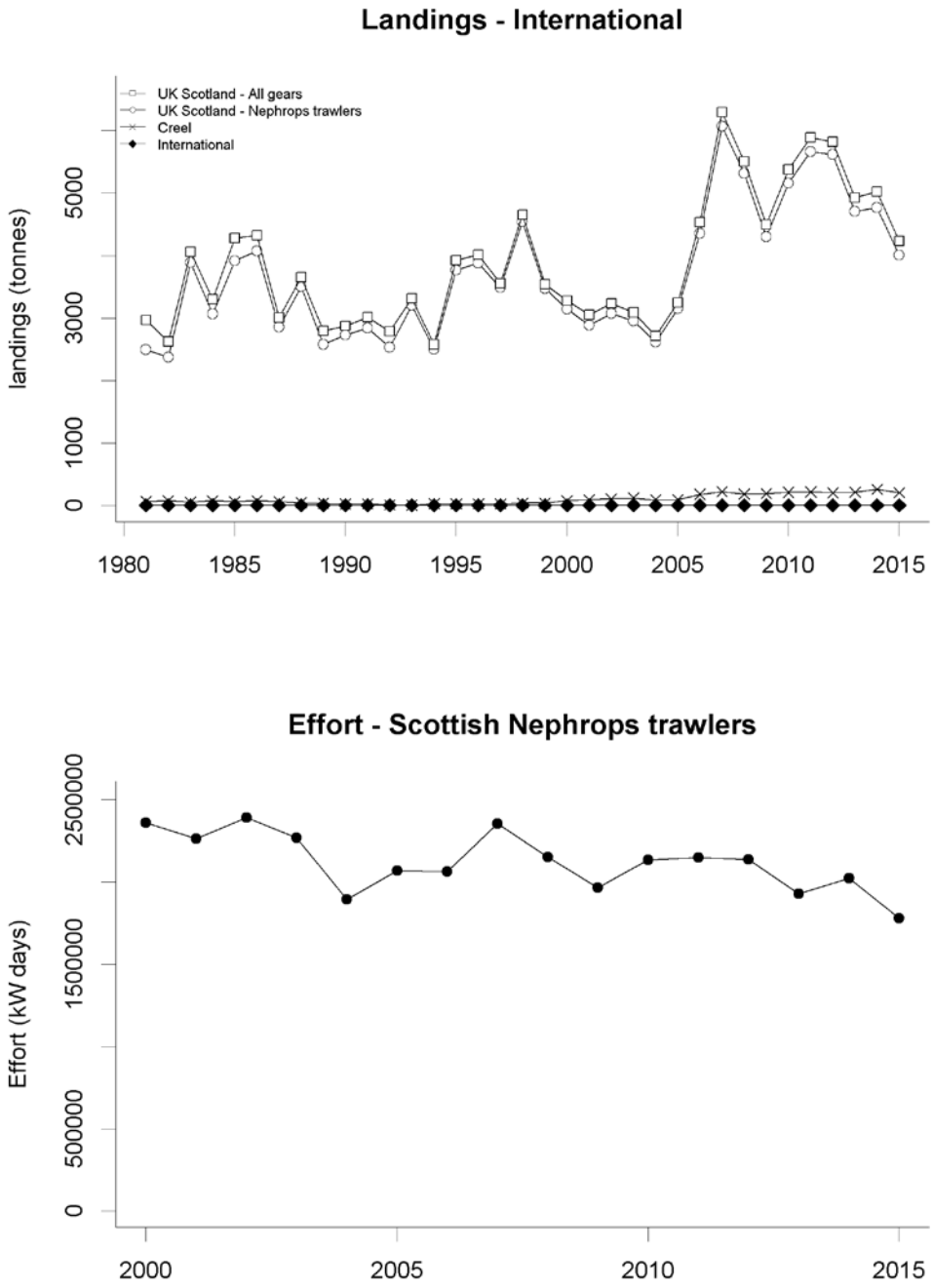

Figure B1-1. ***Nephrops*****, Clyde (FU13), Long-term landings and effort.**

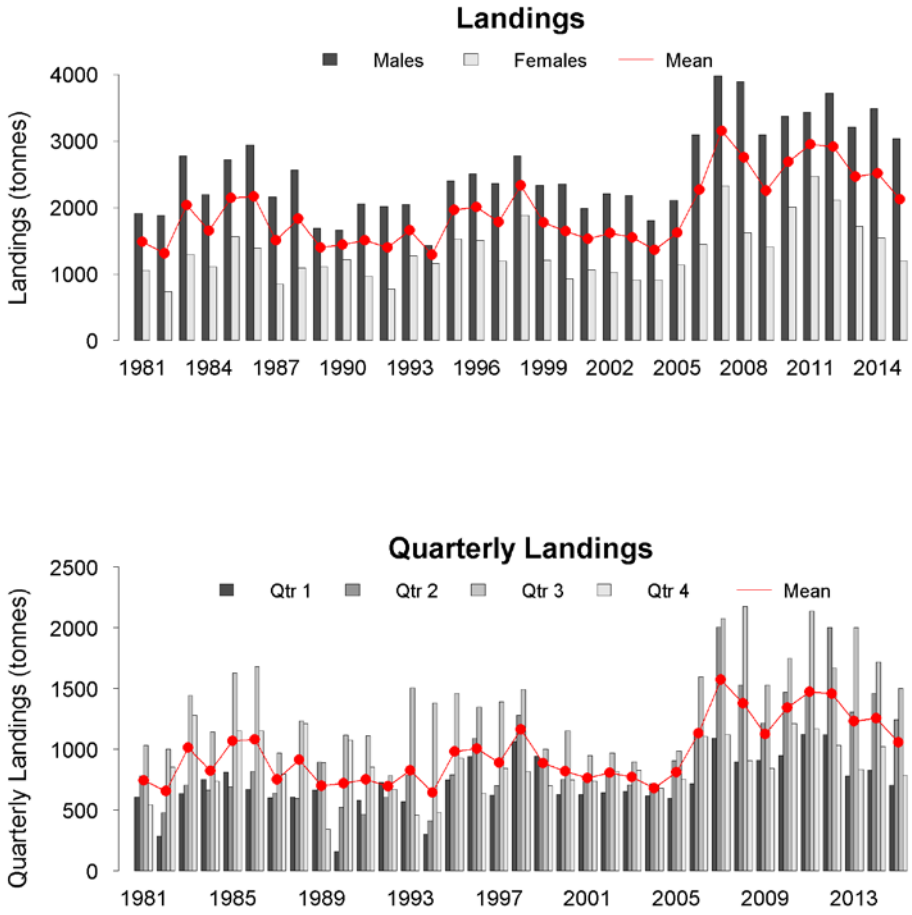

Figure B1-2. *Nephrops*, **Clyde (FU13). Landings by quarter and sex.**

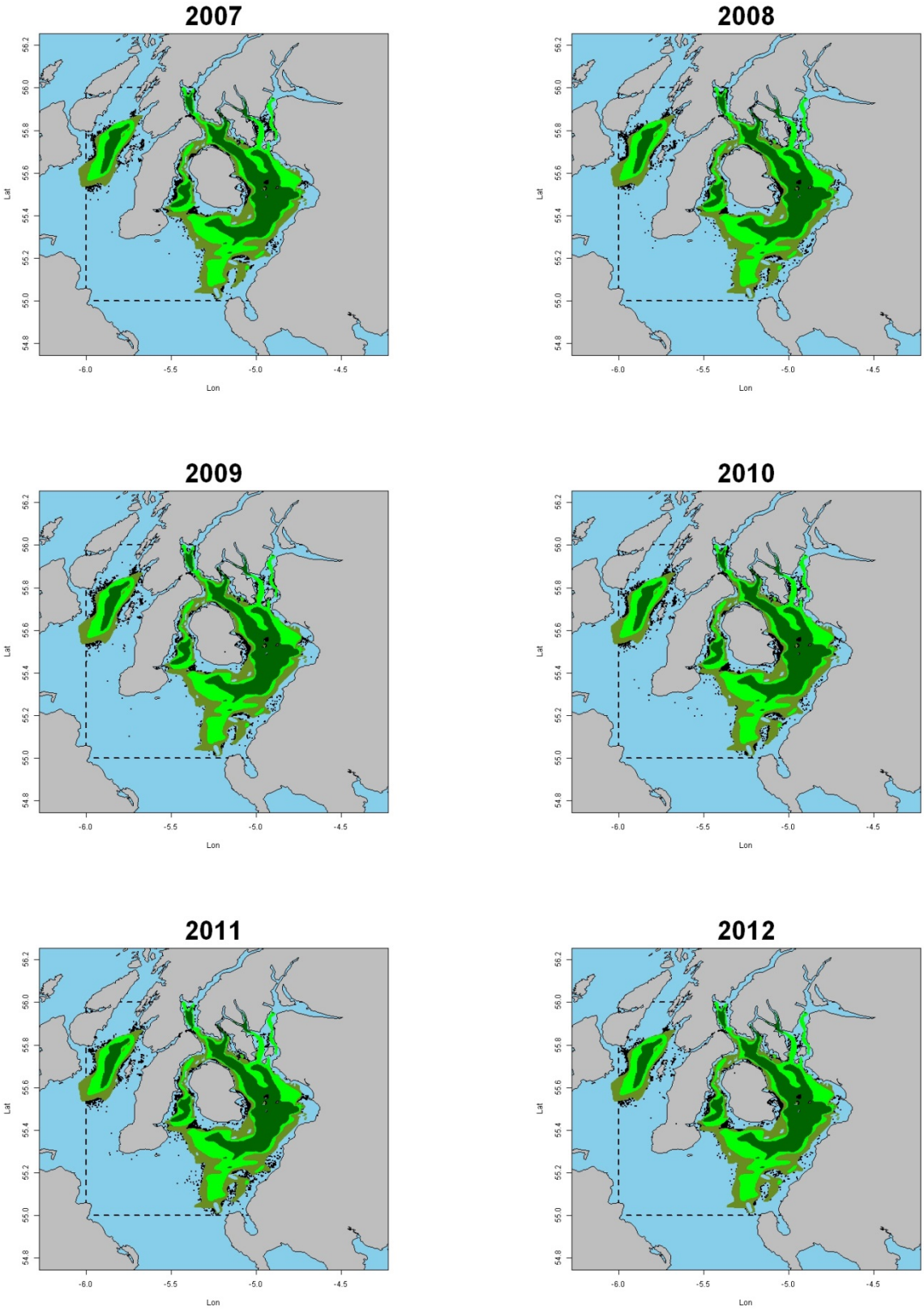

Figure 3.7.8. *Nephrops*, **Clyde (FU13), comparison of area of** *Nephrops* **ground defined by BGS sediment distribution (green shaded overlay) and by distribution of VMS pings (shown by black dots, underlay) recorded from** *Nephrops* **trawlers >15 m length for 2007–2012. VMS data filtered to exclude vessel speeds >4.5 knots.**

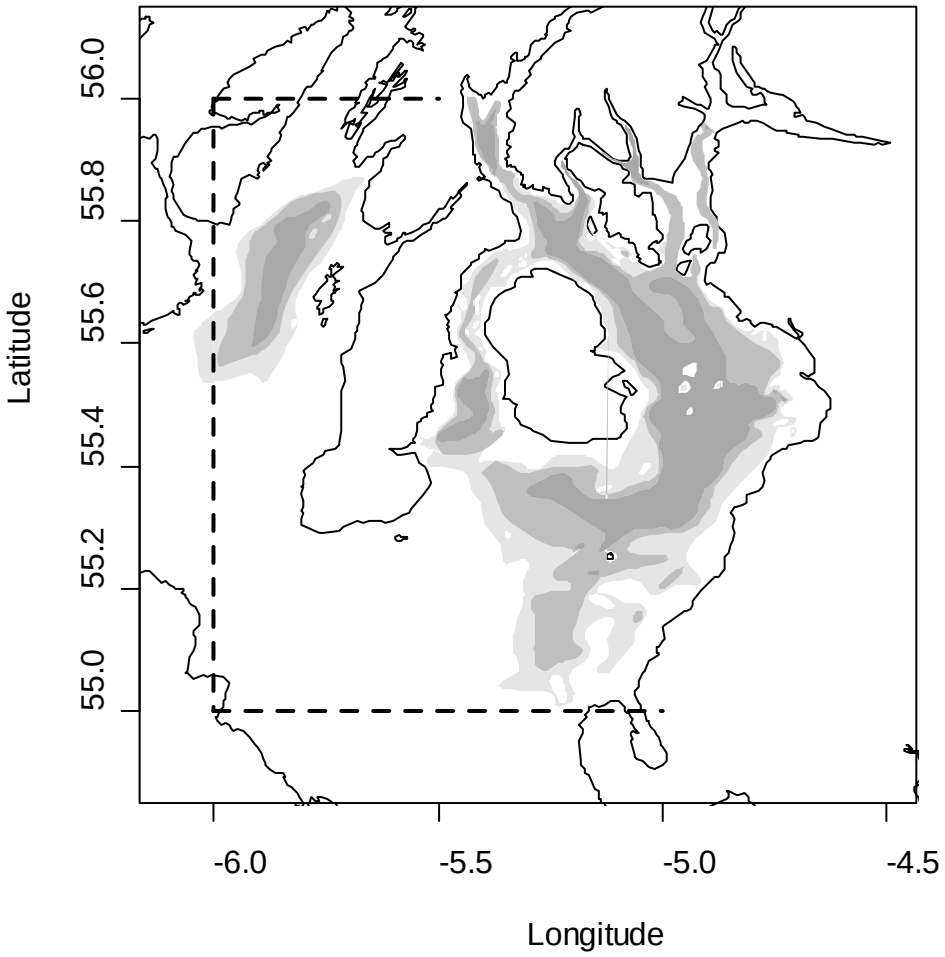

Figure B1-3. Distribution of suitable sediments in Clyde. Light grey - muddy sand; medium grey - sandy mud; dark grey - mud.