Stock Annex for *Nephrops* in FU13, Clyde

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Clyde *Nephrops* (FU 13)
Date:	09 March 2009
Updated:	May 2013 (WGCSE)
Revised by	Sarah Clarke/Carlos Mesquita

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 120 vessels, with less than 4 % of the landings made by creel vessels. The 90 resident Clyde trawlers make about 90 % 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), with a mean engine power of 185 kW. Almost half the fleet was built during the 1960s, with less than 20 % built after 1979. Most vessels use single otter trawls with a 80 mm mesh codend. 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 by-catch is made in the Firth of Clyde, with whiting and cod being the most important species. The composition of the by-catch 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 highest landings 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 4 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 (which are virtually all local to the area), 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.

Vessels employing twin-rig gear are generally larger and more powerful than those using single rig trawls (15 m and 220 kW compared to 13 m and 160 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 by-catches 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 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. Additional UK legislation has also been applied in the southern areas of the Firth of Clyde in recent years, aimed at protecting the aggregating cod in the south of the Clyde during February, March and April.

A.3. Ecosystem aspects

No information on the ecosystem aspects of this stock has been collated by the Working Group.

B. Data

B.1. Commercial catch

Length and sex compositions of *Nephrops* landed from the Firth of Clyde are estimated from port sampling in Scotland. Length data from Scottish sampling are applied to all catches and raised to total international landings. Rates of discarding by length class are estimated for Scottish fleets by on-board sampling, and extrapolated to all other fleets. The proportion of discarded to landed *Nephrops* changes with year, often determined by strong year classes. Discard sampling started in 1990, and for years prior to this estimates have been made based on later data. Landings and discards at length are combined (assuming a discard survival rate of 25%) to removals. Due to differences in catchability between sexes removals are raised separately for each sex.

Landings show a sharp increase from 2006 (Figure B1-1 and Table B1-1). However this may be an artefact due to improved reporting of landings data due to the introduction of the buyers and sellers regulations in the UK in 2006. In addition, logsheet recording of 'hours fished' is known to be erratic as it is a non-mandatory field on the logsheet It is therefore not clear whether the observed LPUE inter-annual trends are actually indicative of real trends in LPUE.

Males contribute more to the landings than females (Figure B1-2).

Mean length data for *Nephrops* above and below 35 mm CL, are shown in Figure B1-3. This size was chosen for all the Scottish stocks examined as the general size limit above which the effects of discarding practices and the addition of recruits were likely to be small.

B.2. Biological

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.

SUMMARY

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)

Proportion of F and M prior to spawning was specified as zero to give estimates of spawning stock biomass at January 1.

B.3. Surveys

The burrowing nature of *Nephrops*, and variable emergence rates mean that trawl catch rates may bear little resemblance to population abundance. An underwater TV survey has been developed, estimating *Nephrops* population abundance from burrow density raised to stock area. A random stratified sampling design is used, on the basis of British Geological Survey sediment strata and latitude (Tuck *et al*., 1999) (see Figure B1–3). The survey provides a total abundance estimate, and is not age or length structured. A series of annual underwater TV surveys are available since 1995 for the Firth of Clyde and Sound of Jura. 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. Such gaps in the series make interpretation of any trends from the data difficult. The number of valid stations in the survey have 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 10 stations have been considered valid each year for the Sound of Jura (area 383 km^2). Confidence intervals around the abundance estimates have remained relatively stable through the time period.

UWTV relative to absolute conversion factors.

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 Clyde are:

	Time period	Edge effect	detection rate	species identification	occupancy	Cumulative absolute conversion factor
FU 13: Clyde	<=2009	1.19	0.75	1.25	1	**1.19**

B.4. Commercial CPUE

Landings-per-unit-effort time-series are available from the following fleets:

Scottish trawl gears: Landings and effort data for Scottish trawl gears are used to generate a non standardized LPUE index. LPUE is estimated using officially recorded effort (days absent from port). 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

C. Assessment: data and method

Model used: UWTV Based Approach to generate catch options

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).

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

1. Survey indices are worked up annually resulting in the TV index.
2. Apply the Absolute Conversion Factor (see section B3). 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 F0.1, F35%SpR and Fmax. These values are estimated by Benchmark 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.

E. Medium-Term Projections

None presented

F. Long-Term Projections

None presented

G. Biological Reference Points

Under the ICES MSY framework, exploitation rates which are likely to generate high long-term yield (and low probability of overfishing) have been evaluated and proposed for each *Nephrops* functional unit. Owing to the way *Nephrops* are assessed, it is not possible to estimate F_{MSY} directly and hence proxies for F_{MSY} have been determined. Three stock-specific candidates for F_{MSY} ($F_{0.1}$, $F_{35\%SPR}$, and F_{max}) were derived from a length-based per recruit analysis (these may be modified following further data exploration and analysis).

There may be strong differences in relative exploitation rates between the sexes in many stocks. To account for this, values for each of the candidates have been determined individually for males, females, and the two sexes combined. The combined sex F_{MSY} proxy should be considered appropriate, provided that the resulting percentage of virgin spawner-per-recruit for males or females does not fall below 20%. If this happens a more conservative sex-specific F_{MSY} proxy should be picked instead of the combined proxy.

For the Firth of Clyde subarea of FU 13, 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 (shown in the table above) 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 (See Section 2.2).

The F_{MSY} proxy harvest rate values were calculated at the WKNEPH (ICES 2009) from the per-recruit analysis based on input parameters from a combined sex length cohort analysis of 2007–2009 catch-at-length data. All F_{MSY} proxy harvest rate and MSY $B_{trigger}$ values remain preliminary and may be modified following further data exploration and analysis.

Firth of Clyde

Harvest ratio reference points:

	Male	Female	**Combined**
F_{max}	13.6	34.0	**16.4**
$F_{0.1}$	8.7	21.1	9.7
$F_{35\%SpR}$	10.7	25.7	14.5

	Type	***Value***	***Technical basis***
MSY	MSY $B_{trigger}$	579 million individuals	Bias-adjusted lowest observed UWTV survey estimate
Approach	F_{MSY}	16.4 % harvest rate	Equivalent to F_{max} combined sex. Fmsy proxy based on length based Y/R.

Sound of Jura

Harvest ratio reference points:

	Male	Female	**Combined**
F_{max}	13.6	34.0	16.4
$F_{0.1}$	8.7	21.1	9.7
$F_{35\%SpR}$	10.7	25.7	**14.5**

	Type	***Value***	***Technical basis***
MSY	MSY $B_{trigger}$	Not defined	
Approach	F_{MSY}	14.5 % harvest rate	Equivalent to $F_{35\%SpR}$ combined sex. Fmsy proxy based on length based Y/R.

H. Other Issues

I. References

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Table B1-1 ***Nephrops*****, Clyde (FU13), Nominal Landings of** ***Nephrops*****, 1981–2012, as officially reported.**

Year	UK Scotland				Other UK	Total **
	Nephrops trawl	Other trawl	Creel	Sub-total		
1981	2498	404	66	2968	0	2968
1982	2373	171	79	2623	0	2623
1983	3890	120	53	4063	14	4077
1984	3069	154	77	3300	10	3310
1985	3921	293	64	4278	7	4285
1986	4074	175	79	4328	13	4341
1987	2859	80	65	3004	3	3007
1988	3507	108	43	3658	7	3665
1989	2577	184	35	2796	16	2812
1990	2732	122	24	2878	34	2912
1991	2845	145	25	3015	23	3038
1992	2532	246	10	2788	17	2805
1993	3199	110	5	3314	28	3342
1994	2503	49	28	2580	49	2629
1995	3767	132	26	3925	64	3989
1996	3880	111	27	4018	42	4060
1997	3486	44	25	3555	63	3618
1998	4539	81	40	4660	183	4843
1999	3475	29	38	3542	210	3752
2000	3143	63	76	3282	137	3419
2001	2889	67	94	3050	132	3182
2002	3074	53	105	3232	151	3383
2003	2954	20	117	3091	80	3171
2004	2659	18	90	2767	258	3025
2005	3166	14	95	3275	148	3423
2006	4446	0	0	4534	244	4778
2007	6129	0	0	6129	366	6495
2008	5382	2	197	5581	416	5997
2009	4305	0	189	4494	283	4777
2010	5050	0	186	5236	465	5701
2011	5672	0	219	5891	540	6431
2012*	5523	4	194	5721	863	6584

* provisional ** Total also includes Rep. of Ireland

*** Provisional.**

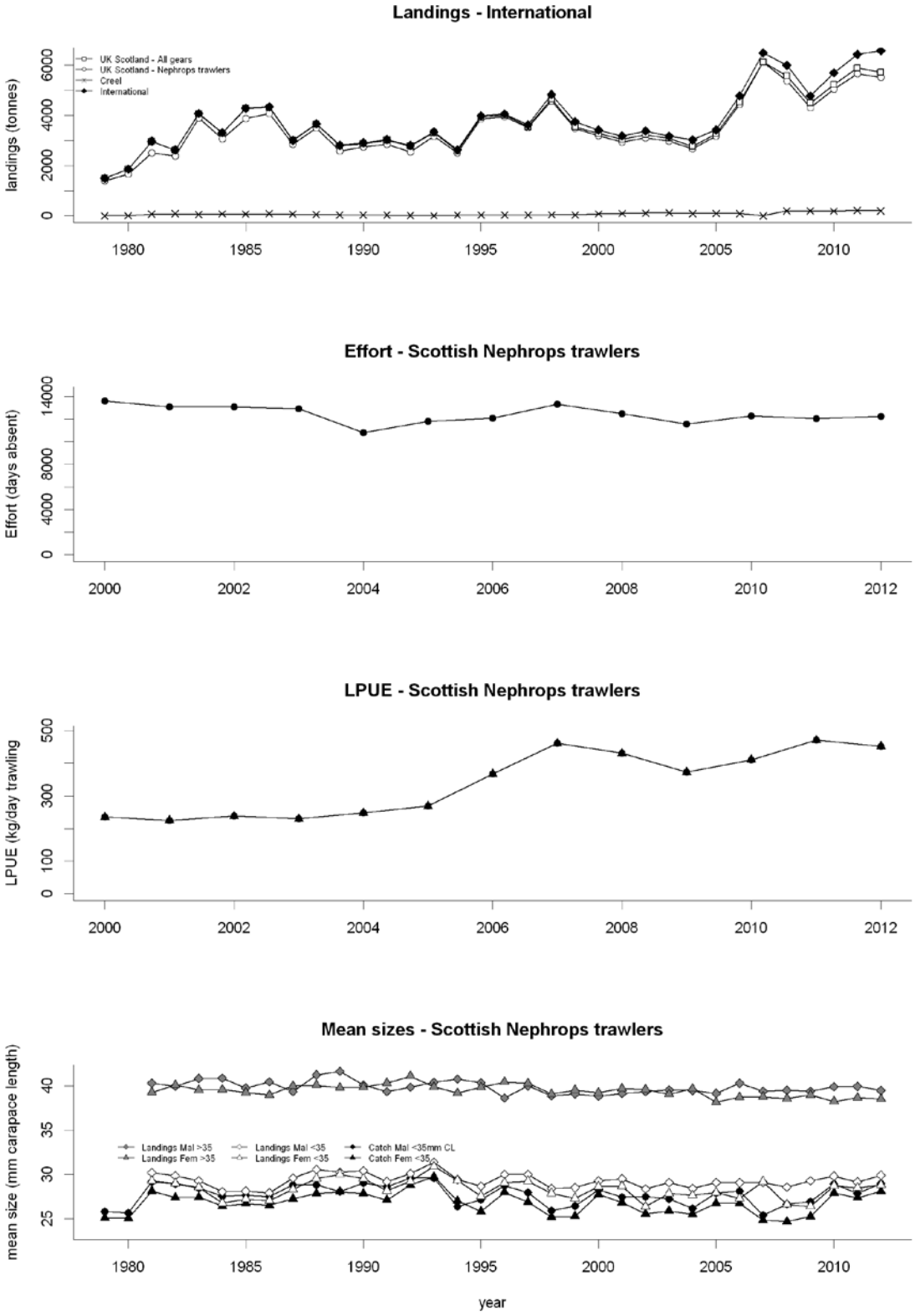

Figure B1-1. ***Nephrops*****, Clyde (FU13), Firth of Clyde subarea. Long-erm landings, effort, lpue and mean sizes. The interpretation of the lpue series is likely to be affected by the introduction of the "buyers and sellers" regulations in 2006.**

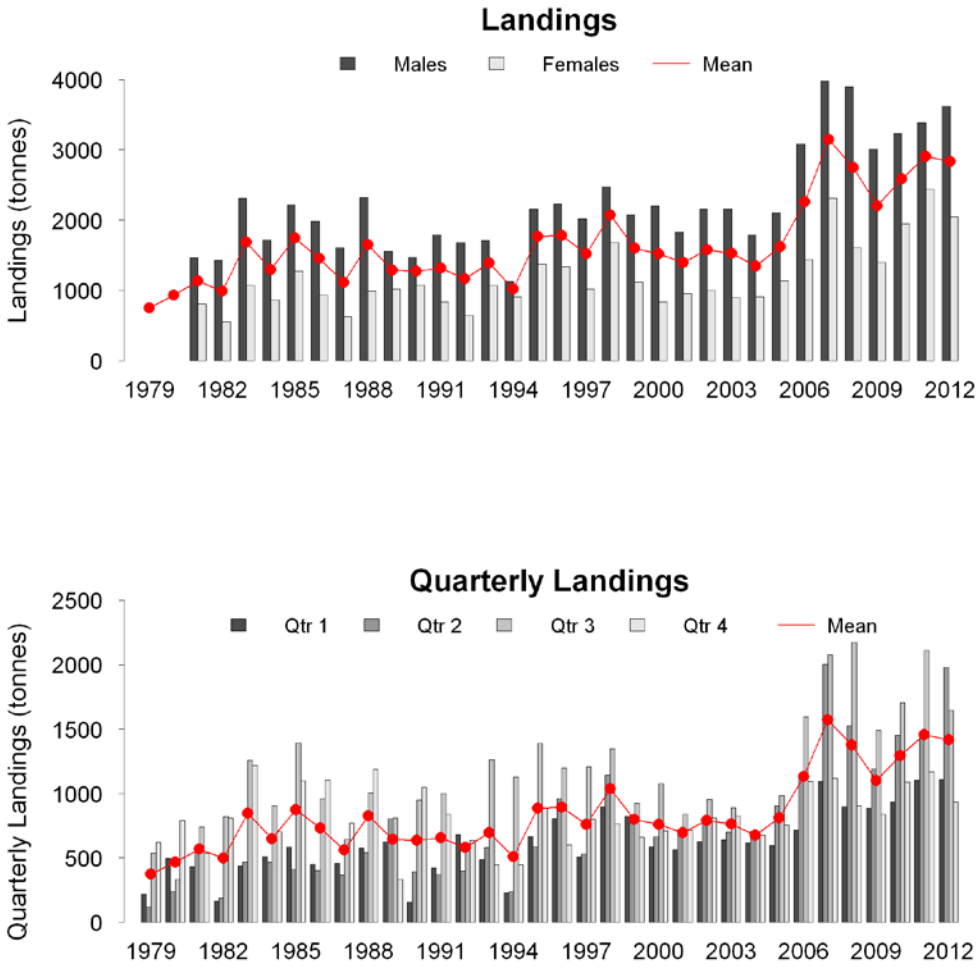

Figure B1-2. ***Nephrops*****, Clyde (FU13), Firth of Clyde subarea. Landings by quarter and sex from Scottish trawlers.**

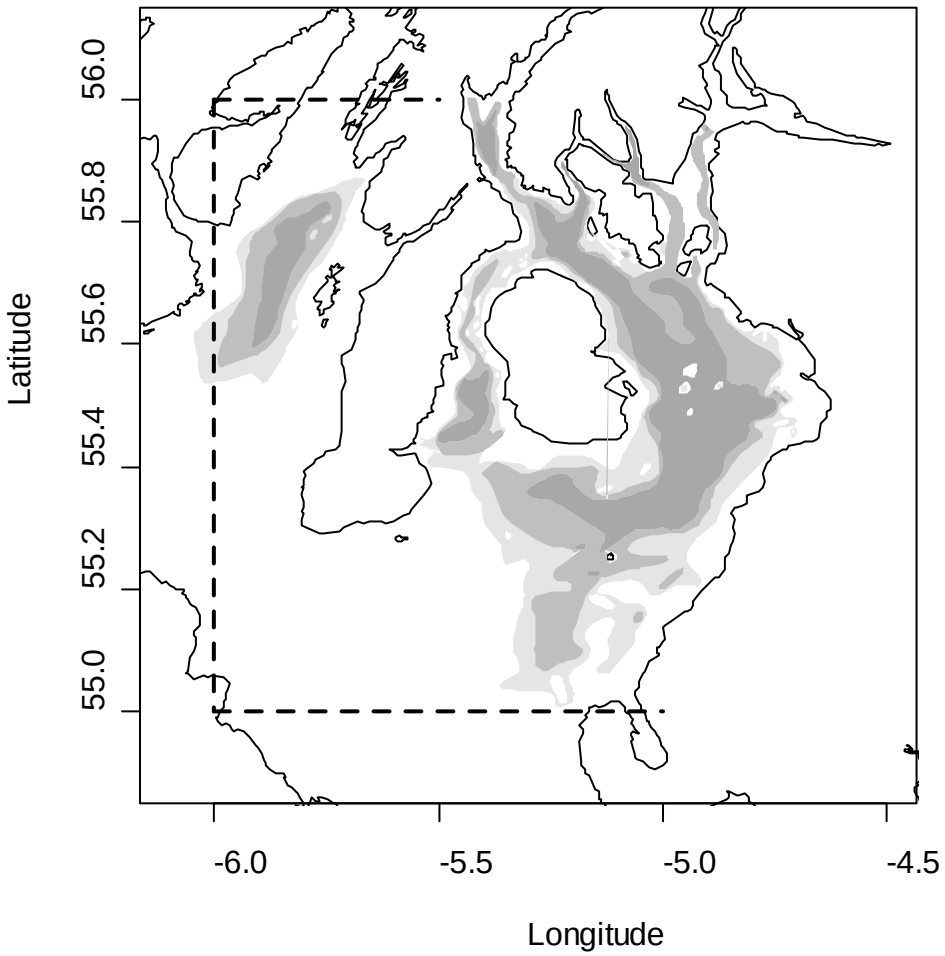

Figure B1-3. Distribution of suitable sediments in Clyde. Light grey - muddy sand; medium grey - sandy mud; dark grey – mud.