Stock Annex: Norway lobster (*Nephrops norvegicus*) in Division 7.b, Functional Unit 17 (west of Ireland, Aran grounds)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Norway lobster
Working group:	Working Group for the Celtic Seas Ecoregion (WGCSE)
Created:	October 2015 (IBPNEPH, 2015)
Authors:	
Last updated:	2016
Last updated by:	Jennifer Doyle (WGCSE, 2016)

A. General

A.1. Stock definition

Nephrops is limited to muddy habitat, and requires sediment with a silt and clay content of between 10–100% to excavate its burrows, and this means that the distribution of suitable sediment defines the Three geographically discrete mud patches; the Aran Ground, Galway Bay and Slyne Head all of which lie within the ICES assessment area Functional Unit 17 (FU17) and are shown in Figure A.1.

The spatial extent of these *Nephrops* grounds in FU17 has been re-defined using 2006–2014 integrated VMS-logbook data using the methods described in Gerritsen and Lordan (2011) and also incorporating available backscatter data from the Irish National seabed mapping programme (www.infomar.ie). *Nephrops* directed activity was defined for VMS pings where >30% of daily operational landings was reported to be *Nephrops*. Table 1 shows all the data available to redefine the ground boundaries in FU17. The revised polygons were manually drawn and the area calculated using different projections in ArcGIS 10. The average of these calculations was accepted as the area of each ground (Table 2). The discrete grounds areas are subject to revision as more seabed mapping and new VMS data becomes available. Any revisions to survey area should be considered by WGNEPS. The shapefiles of the FU17 ground are available at: http://www.isde.ie and also http://data.marine.ie/downloads/fisheries/NephropsGrounds.zip.

The Functional Unit for assessment covers ICES rectangles 34–35 D9–E0 within 7.b.

Adult *Nephrops* probably only undertake very small-scale movements (a few 100 m). Recent studies in larval tracking models show that larval transfer may occur between the separate mud patches in FU17 as some patches are donors of larvae to adjacent grounds (O'Sullivan *et al.*, 2015).

A.2. Fishery

In recent years the *Nephrops* stock in FU17 are almost exclusively exploited by Irish vessels.

The *Nephrops* fishery 'at the back of the Aran Islands' can be considered the mainstay of the Ros a Mhíl fleet. Without this *Nephrops* fishery the majority of vessels in the fleet

would cease being economically viable (Meredith, 1999). The Irish fishery consists of entirely of otter trawl vessels. The majority of vessels use twin-rigs and 80 mm. Smaller vessels do use 70 mm with a SMP. Some vessels have using 90 mm. Vessels from Ros a Mhíl, Dingle, Union Hall, Dunmore East, Clogherhead and Kinsale mainly exploit the fishery.

The number of vessels involved in the fishery has been relatively stable over time (Figure A.2.1).

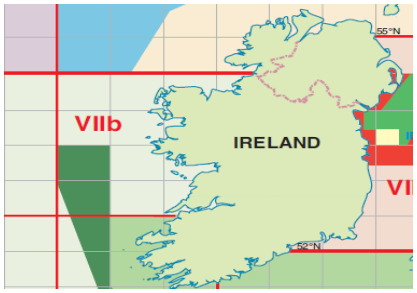
There have been also changes in fleet structure (Figure A.2.2) over time. At the start of the time-series vessel power was normally distributed around a mean of ~175 kw. Towards the end of the time-series the power frequency distribution has become increasingly bi-modal with the majority of vessels in the larger power mode which centres on 250 kws. The mean and modal power show increasing trends overtime. Most of the larger boats move freely between the *Nephrops* fisheries in FUs 15, 16, 20–22 and other areas depending on the tides and weather.

The fishery shows a distinctive seasonal pattern with highest landings, catches, lpue and cpue in April–June and October–November. The monthly landings time-series with the average pattern is shown in Figure A.2.3. The first period of elevated landings is associated with the emergence of females from their burrows post hatching of their eggs. The sex ratio during this period is biased towards females (Figure B.2.1). Females mature quickly during the early summer and spawning occurs in July and August. This is coincident with a decline in landings and cpue in the fishery. The Ros a Mhíl fleet traditionally tie up in August each year for maintenance and refurbishment.

Technical measures

The following TCMs are in place for *Nephrops* in 7 (excluding 7.a) after EC 850/98: Minimum Landing Sizes (MLS); total length >85 mm, carapace length >25 mm, tail length >46 mm. Mesh Size Restrictions; Vessels targeting *Nephrops* using towed gears having at least 35% by weight of this species on board will require 70 mm diamond mesh plus an 80 mm square mesh panel as a minimum or having at least 30% by weight of *Nephrops* on board will require 80–99 mm diamond mesh.

Mesh size (mm)	VII (Celtic Sea & West of Ireland)								
	Area VII Outside restricted areas				Celtic Sea Protection Zone				HAKE BOX
	70-79	80-89	90-99	100+	70-79	80-89	90-99	100+	100+
Twine thickness	4mm double or single 6mm								
Headline Panel (mm) (Beam Trawlers see footnote 1)	-	-	-	-	-	-	-	-	-
Square mesh panel (mm)	80	-	-	-	110	110	110	100	-
Maximum number of meshes in codend circumference	120	120	100	100	120	120	100	100	100
Catch Composition	-	Either - Or		-	Either - Or		-	-	-
Maximum % of cod allowed. (Council Reg 39/2013)	-	-	-	-	-	-	-	-	-
Maximum % cod, haddock, saithe allowed	-	-	30	-	-	-	30	-	-
Maximum % of hake allowed	20	20	20	-	20	20	20	-	-
Minimum % of saithe required	-	-	-	-	-	-	-	-	-
Minimum % of Nephrops required	35	30	-	-	35	30	-	-	-
Minimum % of Annex I List (see footnotes)	-	-	70 [2]	-	-	-	70 [2]	-	-
Minimum % of haddock, hake, whiting, megrim, monkfish, rays, saithe and Nephrops	-	-	-	-	-	-	-	-	-



Source: http://www.bim.ie/media/bim/content/downloads/BIM%20Fisheries%20Management%20Chart%202015.pdf

A.3. Ecosystem aspects

Physical oceanography

The Aran Ground is coincident with a pool of oceanic water, which is rich in nutrients and low in dissolved oxygen. The currents throughout the water column over the ground are generally weak although there is a well-documented bottom density front on the eastern flank of the ground (Nolan and Lyons, 2006). This is a seasonal feature, which establishes in May and persists until autumn. The front causes a persistent jet like flow from south to north close to the seabed through the *Nephrops* ground. The mean position of jet varies from year to year by up to 30 km. Timing and position of the jet may influence recruitment and settlement success of post-larval *Nephrops* since it could potentially advect larval from the area. Salinity differences, due to overwinter freshwater input, are thought to heavily influence the density structure and location of this front. Until a time-series of recruitment and jet dynamics is established it is not possible to draw any firm conclusions about the impact of this ecosystem feature on the stock and fishery. Potential sinks for advected larvae include Slyne head and possibly Galway Bay.

Temperature and salinity time–series

An emerging time-series of temperature and salinity data are available for a transect through the Aran Grounds (Nolan and Lyons, 2006). In all years since 1999 (except 2001) the 53°N section has exhibited positive anomalies in temperature of between 0.2°C and 2°C (Figure A.3.1). In 2001, the temperature anomaly from the long-term climatology was zero. Years with lower temperature anomalies seem to coincide with years of strongly negative salinity anomalies (e.g. 2001 and 2005, 2006) perhaps reflecting the limited influence of ENAW on the section in those years as the section is dominated by coastal discharges from the Loire and Shannon. Salinity anomalies along 53°N range from -0.3 to +0.1 psu over the period. The freshest years were 2001, 2005 and 2006. In 2000, 2003 and 2004 ENAW has a stronger influence on the salinity structure and positive anomalies in salinity from the long-term climatology are the result. The higher UWTV abundance in 2003 and 2004 is coincident with the warmest anomaly but the time-series remains too short to draw definitive conclusions. CTD data collected during the TV surveys is relatively easy to collect and will augment the knowledge base on habitat and oceanographic regime.

Sediment distribution

There is a growing body of information on the spatial extent of the sediment suitable for *Nephrops* from UWTV surveys, seabed mapping programmes and the fishing industry. Figure A.3.2 depicts contour and post plots of the a) mean size (phi) and classification based on the Friedman and Sanders (1978) scales and b) sorting (σ_g) of the sediments on the Aran Grounds based on PSA results from samples collected from 2002–2006 UWTV surveys. The majority of the ground has similar mean particle size at around 4–5 μm. There are some patches of softer silt towards the middle of the ground.

Bathymetry

Figure A.3.3 is bathymetry of the Aran grounds obtained from seabed mapping programmes. The eastern flank of the ground shallows up quickly but the majority of the ground is gradually deepening from around 100 m to 110 m with the deepest parts to the southwest. Station depths at Galway Bay are relatively shallow average depth of

40 metres whereas at Slyne Head average depth is 118 metres. Coastal bathymetry data are available from INSS programme and is updated regularly (www.infomar.ie).

B. Data

B.1. Commercial catch

Prior to 1988 landings data for this fishery are only available to the WG for France. Since 1988 reported landings data for the Irish fleet were obtained from EU logbooks. The quality of landings data is not well known. In earlier, years there are no landings from Ireland although there was probably some catch. The quality of historic landings data are not well known but they are perceived to be reasonably accurate. Irish landings data are available from 1989. The time-series of French landings commences in the late 1980s. UK landings are also available from 1989.

Landings statistics for the Irish fleet are obtained from EU logbooks since 1995. Vessels record daily retained catches in operations and make a declaration of total landings on return to port. Since 2012, most vessels in the fleet have been using electronic logbooks (EC Regulation 1224 of 2009 and 404 of 2011). Vessels are required to electronically report catches on board in each 24 hour period.

B.2. Sampling data

Landings length and sex compositions were estimated from port sampling by Ireland (between 1995–2001). There was a perception during this period that that discarding was not significant. In 2002 a new catch self-sampling programme was put in place. This involves unsorted catch and discard samples being provided by vessels or collected by observers at sea on discard trips. Sampling effort is stratified monthly. The national sample raising procedures for FU17 were reviewed and fully documented through an r markdown document (Lordan, WD2, ICES, 2015). Up to now unsorted catch samples were partitioned into landings and discards using a quarterly on-board retention ogive. During the review it became apparent that the number of quarterly samples was insufficient to derive quarterly ogives. In practice a number of *ad hoc* fill-ins were often made to solve this problem. Also while there have been significant changes in the retention ogives over the recent few years there is no evidence that there are consistent quarterly differences. **The IBP concluded that annual discard ogives should be used instead of quarterly ones in the raising.** These are applied to quarterly length distributions and raised to total quarterly landings before aggregation. A further raising procedure is applied to raise the annual sampled Irish data to international landings (this also addresses quarters with missing length samples).

The length–weight regression parameters given in Table B.2.1 are used to calculate sampled weights and appropriate quarterly raising factors. The quality of the sampling has not yet been qualitatively assessed in terms of precision and accuracy.

Nephrops landings and discards from the Aran Grounds have not been sampled for the majority of 2006 and all 2007 due to a lack of cooperation by the industry. However, sampling resumed in 2008 and the intensity and coverage is considered the best to date.

Fish and other bycatches in the fishery have been collected by on-board observers since 1994. The number of trips is variable over time with a gap in the series in 2006 and 2007.

B.2. Biological

Biological parameters for this stock are outlined in Table B.2.1.

Length–weight

Mean weights-at-age for this stock are estimated from studies on Scottish stocks by Pope and Thomas (1955). This relationship was examined in 2003 and it seemed appropriate. Given the variability in length–weight parameters found in Allan *et al*., 2009 it would be worth monitoring these more closely in the future. No update to these were made at IBPNEPH 2015.

Mean weights over the time-series 2002 to 2014 for Aran grounds (Figure B.2.1) displayed a seasonal trend in the females where this is related to emergence of females from the burrows in summer to mate. IBPNEPH recommend that mean weights be updated and reviewed annually by WGCSE.

Natural mortality

A natural mortality rate of 0.3 was assumed for all age classes and years for males and immature females, with a value of 0.2 for mature females. The lower value for mature females reflects the reduced burrow emergence while ovigerous and hence an assumed reduction in predation. Cod are not common on the Aran Grounds but other potential predators include dogfish, monkfish megrim and gurnards. Stomach contents data on the Irish GFS could be used to examine this in the future. The accuracy of these assumptions is unknown but the same assumptions are made for most *Nephrops* stocks (WKNEPH 2009 and 2013a). No changes in these parameters were made at IBPNEPH 2015.

Sex ratio

Previous *Nephrops* working groups have highlighted stability in sex ratio as an important indicator for *Nephrops* stocks. As for mean weight a cyclical pattern is evident which is linked to female emergence behaviour (Figure B.2.2).

IBPNEPH recommend that sex ratio indicators be updated and reviewed annually by WGCSE.

Maturity

Female

The L_{50} of females using a macroscopic visual maturity scale is known to vary depending sampling month (Lordan and Gerritsen, 2006). The L_{50} in June–August was chosen as the most appropriate estimate given the maturity schedules observed (Figure B.2.2).

An updated analysis was available at IBPNEPH 2015 and the female L_{50} were estimated as 22 CL mm from 2008–2014 sampling data (Figure B.2.3). This is similar to other *Nephrops* stocks in the Celtic Sea (ICES, 2014).

Male

No update to male maturity was made at IBPNEPH 2015.The same maturity is assumed as for female L_{50}.

Discard survival

Given the trip durations (~five days average) and behaviour of the fleet the majority of discards on the Aran Grounds are returned to the sea over suitable sediment. The proportion scavenged by birds is probably quite low. Tow durations, volume of catches, prolonged sorting on deck and low density of *Nephrops* on the seabed probably results in relatively low discard survival. This is estimated to be around 25% in line with other *Nephrops* stocks in the Celtic Sea. No changes in these parameters were made at IBPNEPH 2015.

B.3. Surveys

UWTV

Since 2002 Ireland has conducted underwater television survey (UWTV) annually on the main *Nephrops* grounds, Aran grounds. Indicator camera stations are also carried out on the adjacent grounds of Galway Bay and Slyne Head weather and time permitting. The surveys were based on a randomised fixed grid design. The methods used during the survey were similar to those employed for UWTV surveys of *Nephrops* stocks around Ireland and elsewhere and are documented by WKNEPHTV (ICES, 2007), WKNEPHBID (ICES, 2008), SGNEPS (ICES, 2009, 2010, 2012a) and WGNEPS (2013b, 2014). Up to date UWTV survey reports are available at: http://oar.marine.ie/handle/10793/911.

UWTV Survey relative to absolute conversion factors

A number of factors are suspected to contribute bias to the surveys. 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, the biases associated with the estimates of *Nephrops* abundance in the Aran Grounds are:

	Time period	Edge effect	detection rate	species identification	occupancy	Cumulative bias
FU17: Aran	<=2009	1.35	0.9	1.05	1	1.3

IBPNEPH concluded that an UWTV based approach should apply for this stock and that WGCSE and WGNEPS review survey results when available.

IBTS

There is one IBTS- GFS catching *Nephrops* in FU 17: Irish groundfish survey-Q4: IGFS-WIBTS-Q4 commenced in 2003 (Stokes *et al.,* 2014). The data can be useful as additional indicators of trends in recruitment, mean size and sex ratio for this *Nephrops* stock and should be checked by WGCSE.

B.4. Commercial effort

The lpue and effort series is based on the same criteria for FU15, 16, 17, 22 and 20–21 (30% landings threshold) and will be contingent on the accuracy of landings data reported in logbooks.

The efficiency of vessels has improved significantly since 1995 with increased twin rigs initially and now quad rigs since 2012. Net designs and on-board technology have also

improved dramatically. These factors are not well documented in a way that can be readily used to standardise and lpue time-series. IBPNEPH concluded that effort should be reported in the WGCSE report in KWdays. Lpue should be reported in KG/kwdays in the knowledge that the trend is likely to be a biased underestimate because it is not adjusted for efficiency or behavioural changes.

C. Assessment: data and method

Model used: UWTV Based Approach to generate catch options.

Software used: Bell method.

New MSY explorations were carried out at the current IBP for FU17. A SCA (separable cohort analysis, model Bell) was used to estimate sustainable stock-specific Harvest Ratio reference points. The input data, code and output diagnostics are available in the IBP SharePoint site. All settings used were the same as previous with the exception of the discard survival percentage.

Most of the setting and initial parameters were as previously documented in the stock annex.

Discard survival: **25%**

FemMature<-c(22,23) L_{25} /L_{50} for female maturity.

MalMature<-c(22,23) L_{25}/L_{50} for male maturity.

n.indivs<-c(430) TV survey index: three year average reference period 2013–2015.

surv.time<-c(0.66) Fraction of year surveys occurs.

TV.sel<-c(16.5,17) TV selectivity.

alpha<-0.001 Survey weighting: 0.001 (low).

f.range<-c(0, 0.01, seq(0.05, 4, 0.05)) F.range for estimating the Yield per Recruit.

discard.weight<-c(1) discard weighting.

The model also has five initial parameters to estimate:

1) initial population size at the smallest length class equal sex distribution assumed.
2) Length at 25% selection.
3) Multiplier on L_{25} to give L_{50}.
4) Fishing mortalities at full selection for males and immature females.
5) Fishing mortality at full selection for mature females.

initial.parameters <- c(1.5,21.5, 1.15,0.4,0.3).

Additional parameters required such as the von Bertalanffy growth parameters, natural mortality and weight–length parameters by sex are required. These parameters are given in text table below.

Input parameters for FU17 SCA.

Parameter	Males	Immature Females	Mature females
L_∞	60	60	56
K	0.16	0.16	0.08
Natural Mortality	0.3	0.3	0.2
Discard Survival	25%	25%	25%
A	0.000322	0.000684	0.000684
B	3.207	2.963	2.963

The SCA model was fitted to a moving three year window of average length–frequency distributions.

IBPNEPH concluded that the most recent length–frequency distributions were the most reflective of the selection and size distributions in the fishery. Because of the following factors:

- The observed burrow density has declined from high (>0.8 individuals/m^2) at the start of the series to medium density (~0.3 individuals/m^2) towards the end of the time-series.
- The nature of the fishery has also changed from a continuous fishery throughout the year to a fishery which is more concentrated on periods of high catch rates.

D. Catch option table based on UWTV surveys

1) The total abundance is caulculated by summing the geostatistical abundance estimate from Rgeos for the Aran grounds and the abundance estimates for Galway Bay and Slyne which are calculated using the mean density for the areas calculated at IBPNeph 2015.

2) Generate mean weight in landings and discards using the raising proceedures and length–weight parameters outlined in Section B.2. Review changes in mean weight at WGCSE. Mean weights from 2008 should be used in the calculation of catch options unless there is a rationale to use a more recent time frame.

3) The last three years should be used for estimating the discard proportion in number and the dead discard rate.

4) The catch option table should include the harvest ratios associated with fishing at combined sex $F_{0.1}$, $F_{35\%\ SpR}$ and F_{MAX}.

5) Multiply the survey abundance by the harvest ratio to give the number of total removals.

6) Create a landings number by applying the discard ratio (dead discard rate) and multiply by the mean weight of landings to calculated a landings biomass.

7) Discards are calculated by applying 1- the discard ratio and multiply by the mean weight of discards. Discards that apportioned into dead and surviving discard components.

8) In the context of the Landings Obligation all discards are assumed to be landed so discard survival is assumed to be zero and catch options are

calculated on that basis. This will need to be kept under review as the LO is implemented.

E. Medium-term projections

F. Long-term projections

G. F_{MSY} reference points

The reference points derived by IBPNEPH and reviewed by WKMSYRef4 (ICES CM 2015/ACOM:58. 187 pp) are given in text table below:

A harvest ratio consistent with a combined sex $F_{0.1}$ is considered an appropriate proxy for F_{MSY}. The $F_{0.1}$ estimate from the 2012–2014 is proposed as the best value to use since it is based on the most recent data and is the most conservative of the last three reasonable fits. These should remain under review by WGCSE and may be revised should improved data become available.

For *Nephrops* stocks MSY $B_{trigger}$ has been defined as the lowest stock size from which the abundance has increased. This was defined at IBPNEPH and corresponds to the abundance observed in 2008 rounded to the nearest 10 = 540 million individuals.

Ref Point	2012–2014
HR0.1.Male	7.7
HR0.1.Female	10.1
HR0.1.Comb	8.5
HRmax.Male	14.1
HRmax.Female	20.1
HRmax.Comb	16.3
HR35.Male	11.6
HR35.Female	12.2
HR35.Comb	12.2

H. Other issues

H.1 Historical overview of previous assessment methods

Age-structured XSA assessment for this stock was carried *Nephrops* WG in 2003 (ICES, 2003). The results were considered unreliable for several reasons most importantly; inadequate historical sampling of catch, growth and natural mortality assumptions and concern about accuracy of tuning data. Since then the focus has been on developing a time-series of UWTV survey data as the basis of assessment and advice for this stock.

WGCSE 2009

Several exploratory SCAs (Separable cohort analysis) (see WKNEPH, 2009) were carried out at WGCSE 2009 in an attempt to derive suitable reference points for this stock. These used 2008 sampling data only and several different growth and mortality parameters assumptions. The results of these exploratory SCAs were not presented as the model fit was not good. WKNEPH 2009 also failed to get an adequate SCA model

fit. This may be due to some inappropriate growth and mortality assumptions or due to using only 2008 data in the analysis.

WGCSE 2010

Defined reference MSY points and the UWTV approach was to provide catch options based on an F_{MSY} proxy = $F_{35\%Spr}$ = 10.5. The abundance estimate used only included the Aran grounds not Galway Bay and Slyne Head because of uncertainty about the areas of those patches.

I. References

Fernand, L., Nolan, G.D., Raine, R., Chambers, C.E., Dye, S.R., White, M. and Brown, J. 2006. The Irish coastal current: A seasonal jet-like circulation. *Continental Shelf Research*, Vol. 26, Issue 15, 1775–1793.

Hehir, I., Doyle, J. , Lordan, C., O'Cuaig, M., Hannify, O., Fitzgerald, R., O'Connor, S., Keith, M., Murphy, A., Sheridan, M., and Vila, Y. 2014. Aran, Galway Bay and Slyne Head *Nephrops* Grounds (FU17) 2014 UWTV Survey Report and catch options for 2015. Marine Institute UWTV Survey report.

ICES. 2005. Using UWTV surveys to develop a conceptual ecosystem model of Aran Grounds *Nephrops* population distribution. ICES CM 2005/L:30 Annual Science Conference.

ICES. 2006. Report of the Workshop on *Nephrops* Stocks. Annex 6: Working Document by Lordan and Gerritsen. ICES CM 2006/ACFM:12.

ICES. 2007. Report of the Workshop on the use of UWTV surveys for determining abundance in *Nephrops* stocks throughout European waters (WKNEPHTV). ICES CM: 2007/ACFM: 14 Ref: LRC, PGCCDBS.

ICES. 2008. Report of the Workshop and training course on *Nephrops* Burrow Identification (WKNEPHBID). ICES CM: 2008/LRC: 03 Ref: ACOM.

ICES. 2008. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk andMegrim (WGHMM). ICES CM: 2008/ ACOM:07.

ICES. 2009b. Report of the Study Group on *Nephrops* Surveys (SGNEPS). ICES CM 2009/LRC: 15. Ref: TGISUR.

ICES. 2010. Report of the Study Group on *Nephrops* Surveys (SGNEPS). ICES CM 2010/ SSGESST:22.Ref: SCICOM, ACOM.

ICES. 2012. Report of the Study Group on *Nephrops* Surveys (SGNEPS). ICES CM 2012/SSGESST: 19. Ref: SCICOM, ACOM.

ICES. 2013. Report of the Working Group on *Nephrops* Surveys (WGNEPS). ICES CM 2013/SSGESST: 19. Ref: SSGESST:21.

ICES. 2014. Report of the Working Group on *Nephrops* Surveys (WGNEPS). ICES CM 2014/SSGESST: 19. Ref: SSGESST:20.

ICES. 2016. EU request to ICES to provide F_{MSY} ranges for selected stocks in ICES Subareas 5 to 10. *In* Report of the ICES Advisory Committee, 2016. ICES Advice 2016, Book 5, Section 5.2.3.1.

ICES. 2016. Report of the Workshop to consider F_{MSY} ranges for stocks in ICES categories 1 and 2 in Western Waters (WKMSYREF4), 13–16 October 2015, Brest, France. ICES CM 2015/ACOM:58. 187 pp.

Nolan,G.D. and Lyons. 2006. Ocean climate variability on the western Irish Shelf, an emerging time-series., K., *Proceedings of the ICES Annual Science Conference*, Theme Session C, C:28.

O'Sullivan D, Lordan C, Doyle J, Berry A, Lyons K. 2015. Metapopulation connectivity via larval transport of the Norway lobster *Nephrops norvegicus* in waters around Ireland: a modelled approach. Mar Ecol Prog Ser 534:95–106.

Stokes, D., Gerritsen. H., O'Hea, B., Moore, S.J. and Dransfeld, L. 2014. "Irish Groundfish Survey Cruise Report, 24 September–17 December, 2014", FEAS Survey Series; 2014/01. http://hdl.handle.net/10793/1064.

Table A.1.1. *Nephrops* in FU17. Data available to define discrete *Nephrops* grounds.

	Commercial Data		Seabed Mapping Data			Survey Data	
Ground	VMS	Observer Trip Data	Backscatter	Sediment	UWTV	Sediment	IBTS GroundFish
	2006–2014	1996–2014	Various	Various	2002–2014	Various	2003–2014
Aran	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Galway Bay	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Slyne Head	Yes	Yes	Yes	No	Yes	Yes	Yes

Table A.1.2. *Nephrops* in FU17. Area Calculations of *Nephrops* grounds and final average areas.

	ArcGIS10 Projections			
	Irish National Grid (km²)	Eckert VI (world) (km²)	Cylindrical Equal Area (km²)	Average (km²)
Aran	1202.99	1200.43	1202.64	1202.0
Galway Bay	79.03	78.87	79.02	79.0
Slyne Head	39.18	39.09	39.17	39.1

Table B.2.1. Biological Input Parameters for FU17 *Nephrops* Stock.

Parameter	Value	Source
Discard Survival	25%	IBPNEPH 2015 assumed in line with other stocks
MALES		
Growth - K	0.16	IBPNEPH 2015
Growth - L(inf)	60	IBPNEPH 2015
Natural mortality - M	0.3	assumed, in line with other stocks
Length/weight - a	0.000322	based on Scottish data (Pope and Thomas, 1955)
Length/weight - b	3.207	"
FEMALES		
Immature Growth		
Growth - K	0.16	IBPNEPH 2015
Growth - L(inf)	60	IBPNEPH 2015
Natural mortality - M	0.3	assumed, in line with other stocks
Size at maturity (L50)	24	IBPNEPH 2015
Mature Growth		
Growth - K	0.08	IBPNEPH 2015
Growth - L(inf)	56	IBPNEPH 2015
Natural mortality - M	0.2	assumed, in line with other stocks
Length/weight - a	0.000684	based on Scottish data (Pope and Thomas, 1955)
Length/weight - b	2.963	"

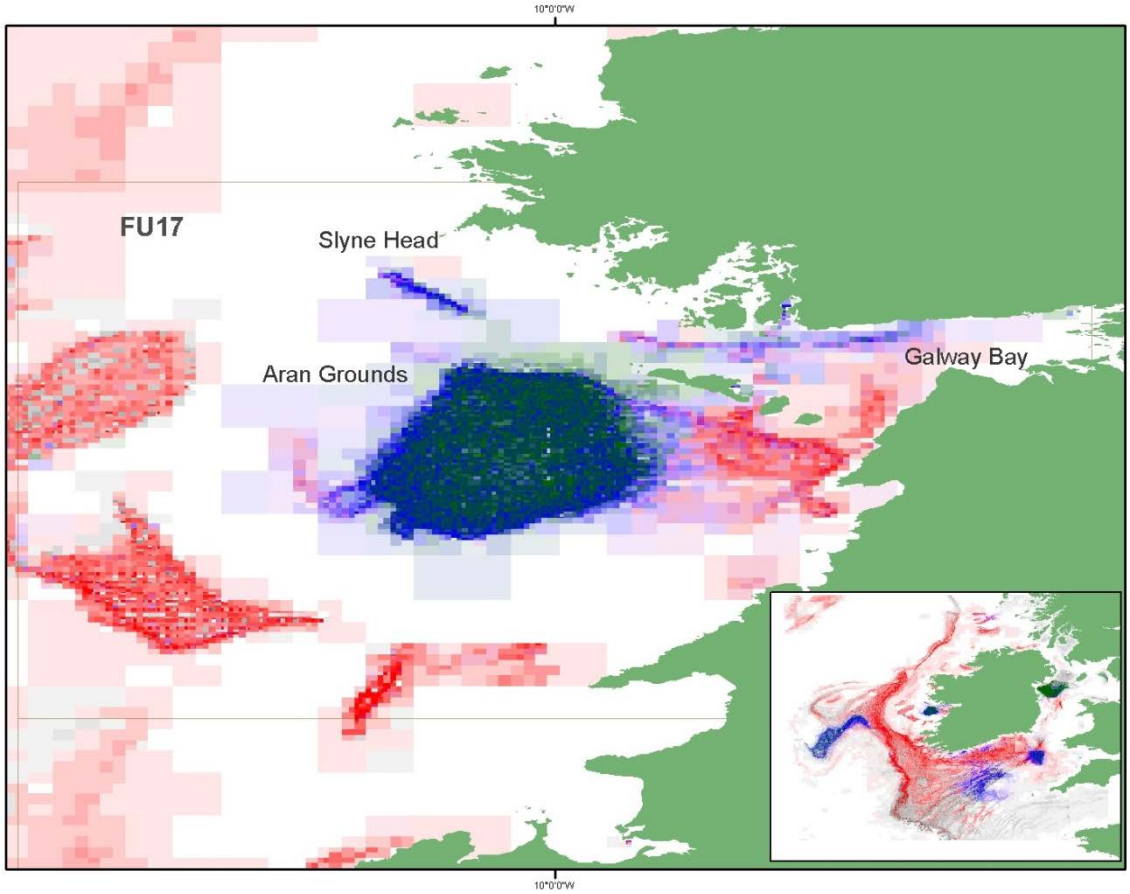


Figure A.1. Integrated VMS data (red=0% N*ephrops;* blue=50-60% *Nephrop,* Green=100% *Nephrops*).

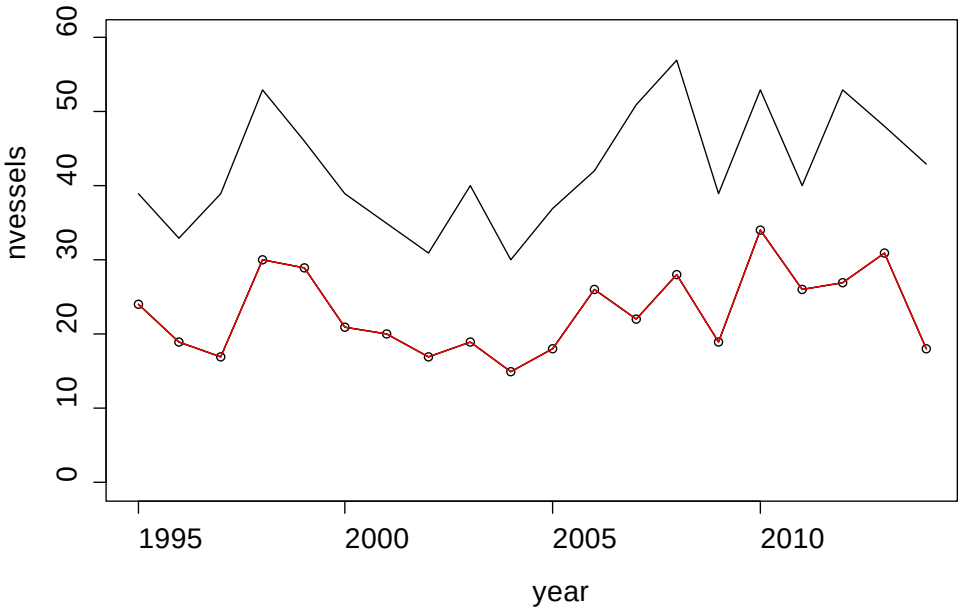


Figure A.2.1. Time-series of the number of Irish vessels reporting landings of *Neprhrops* from FU17 (red line landings >10 t threshold, black line all vessels).

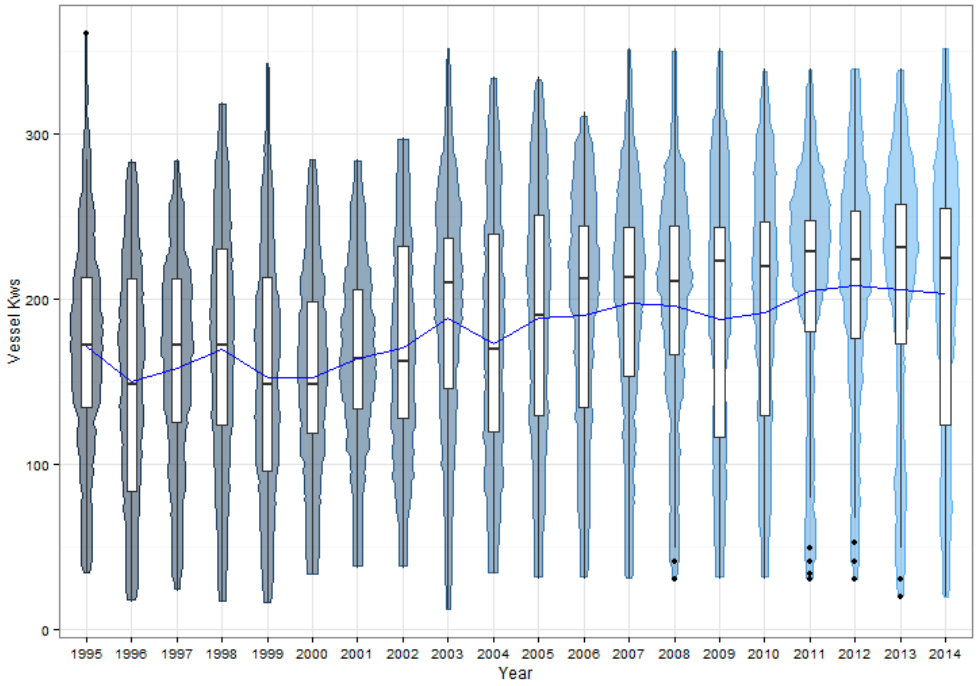


Figure A.2.2. Combined box and kite plot of vessel power on the Aran Grounds by year. The blue line indicates the mean.

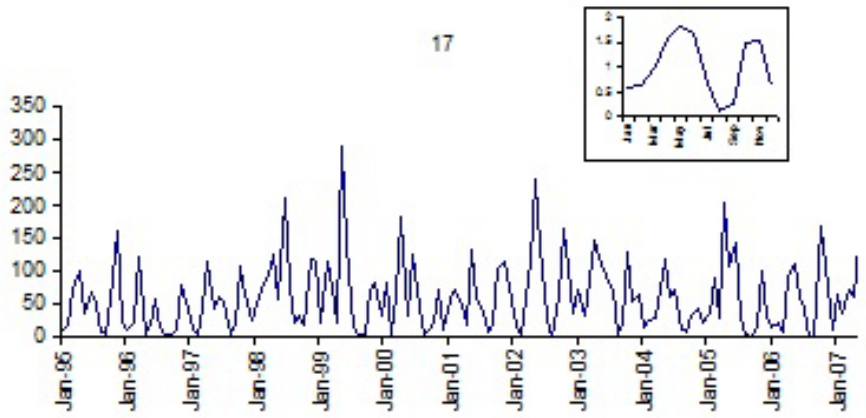


Figure A.2.3. Monthly landings of *Nephrops* from FU17 from 1995–2007. The inset shows the average pattern for all years.

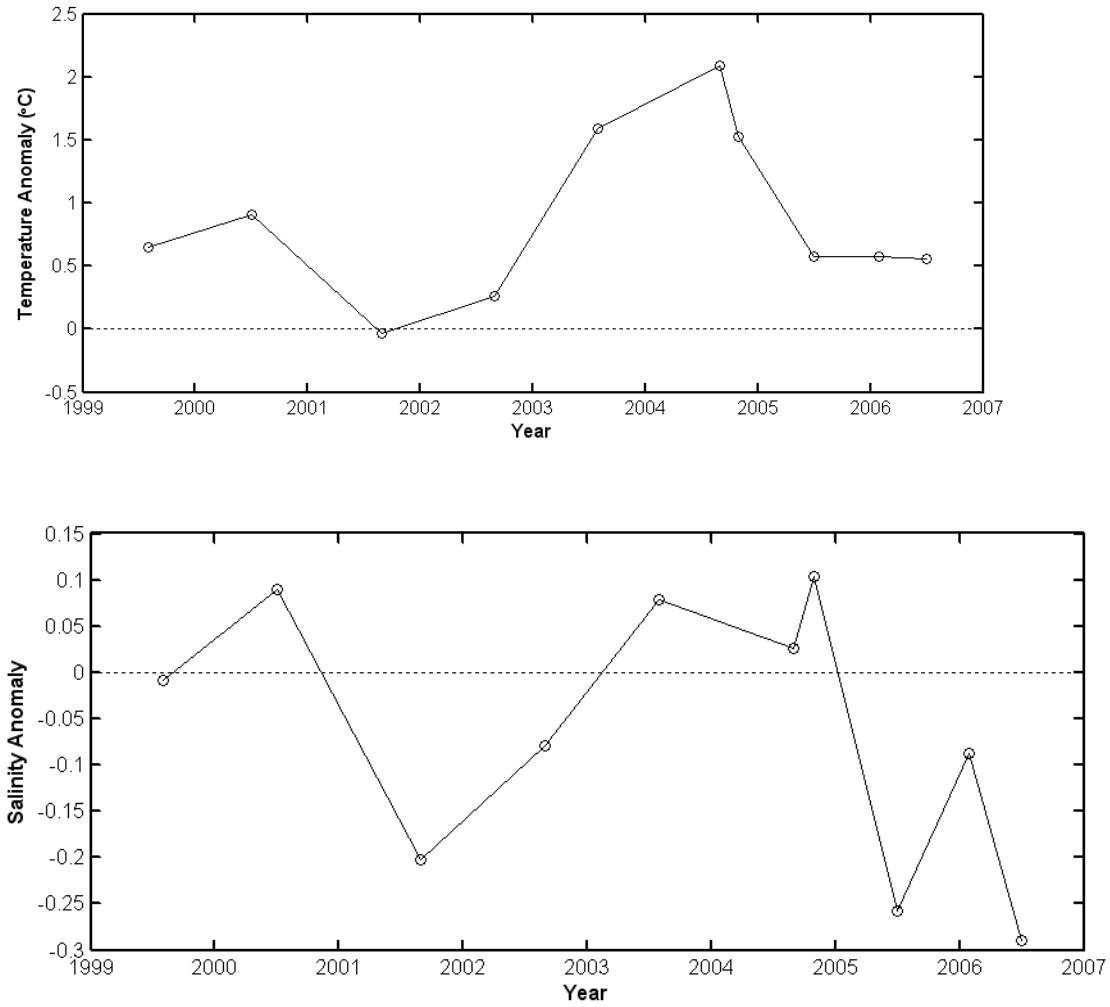


Figure A.3.1. Anomalies in temperature (upper panel) and salinity (lower panel) for the 53°N section running through the Aran Grounds (1999–2006).

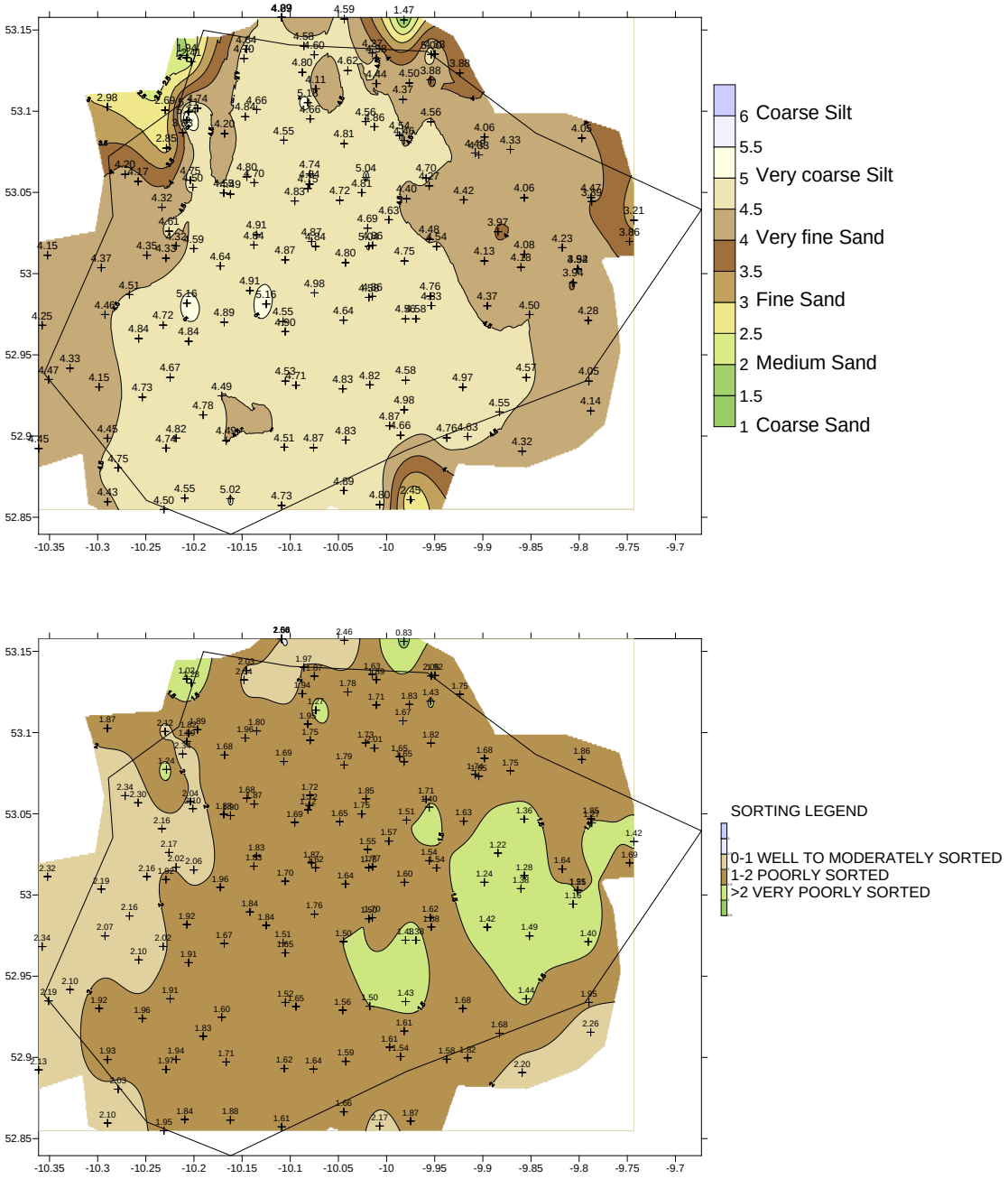


Figure A.3.2. Contour and post plots of the a) mean size (phi) and classification based on the Friedman and Sanders (1978) scales and b) sorting (σ_g) of the sediments on the Aran Grounds based on PSA results from samples collected from 2002–2006.

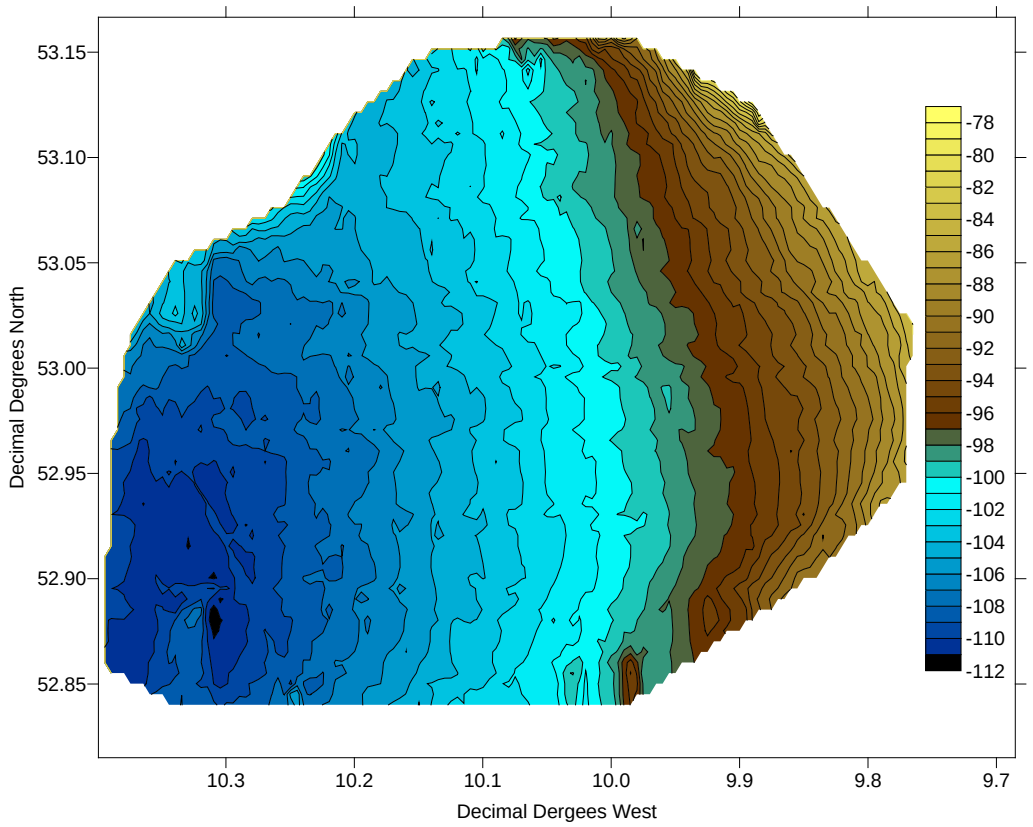


Figure A.3.3. The bathymetry of the Aran grounds.

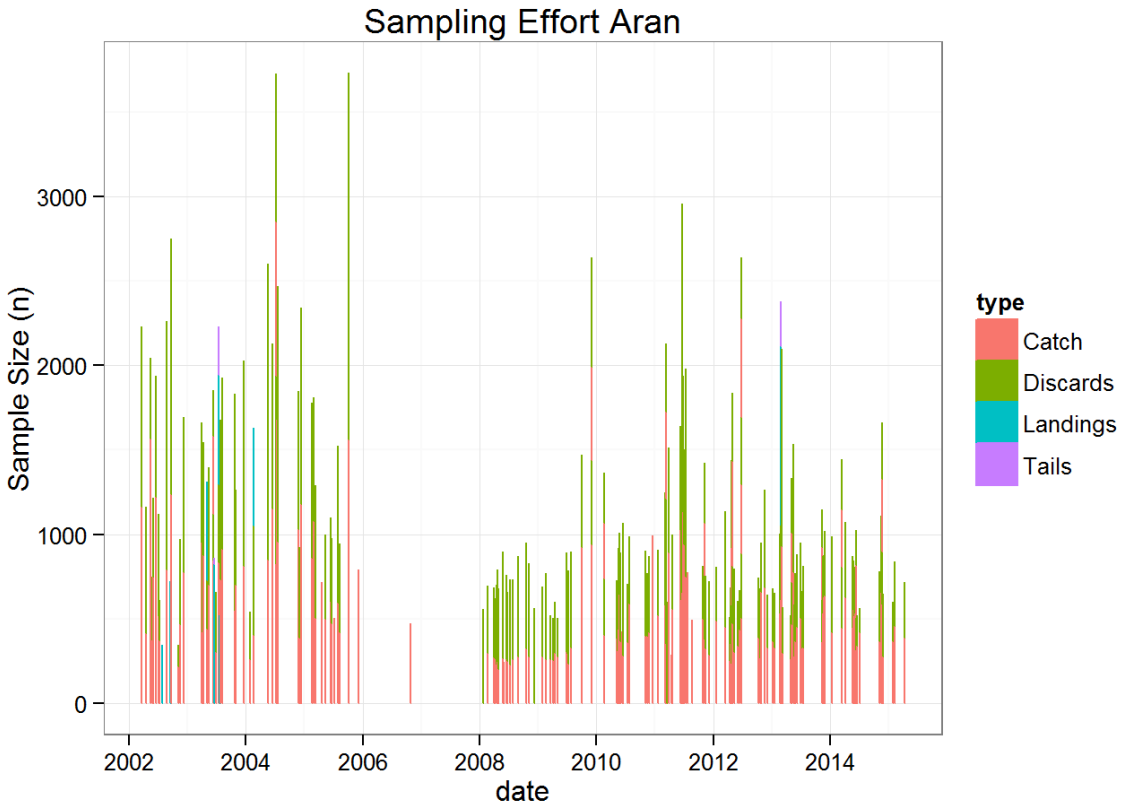


Figure A.2.3. Sampling effort on Aran grounds from 2002–2014.

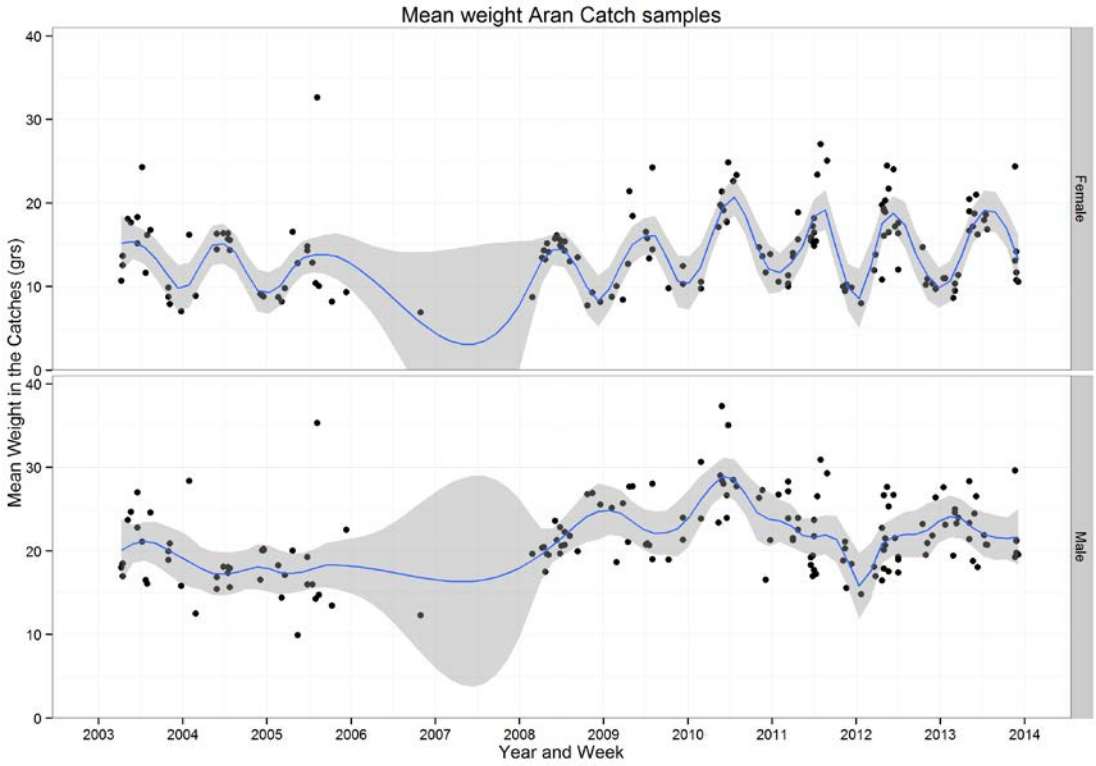


Figure B.2.1. Mean weights (grs) for male and females from catch samples from Aran Grounds.

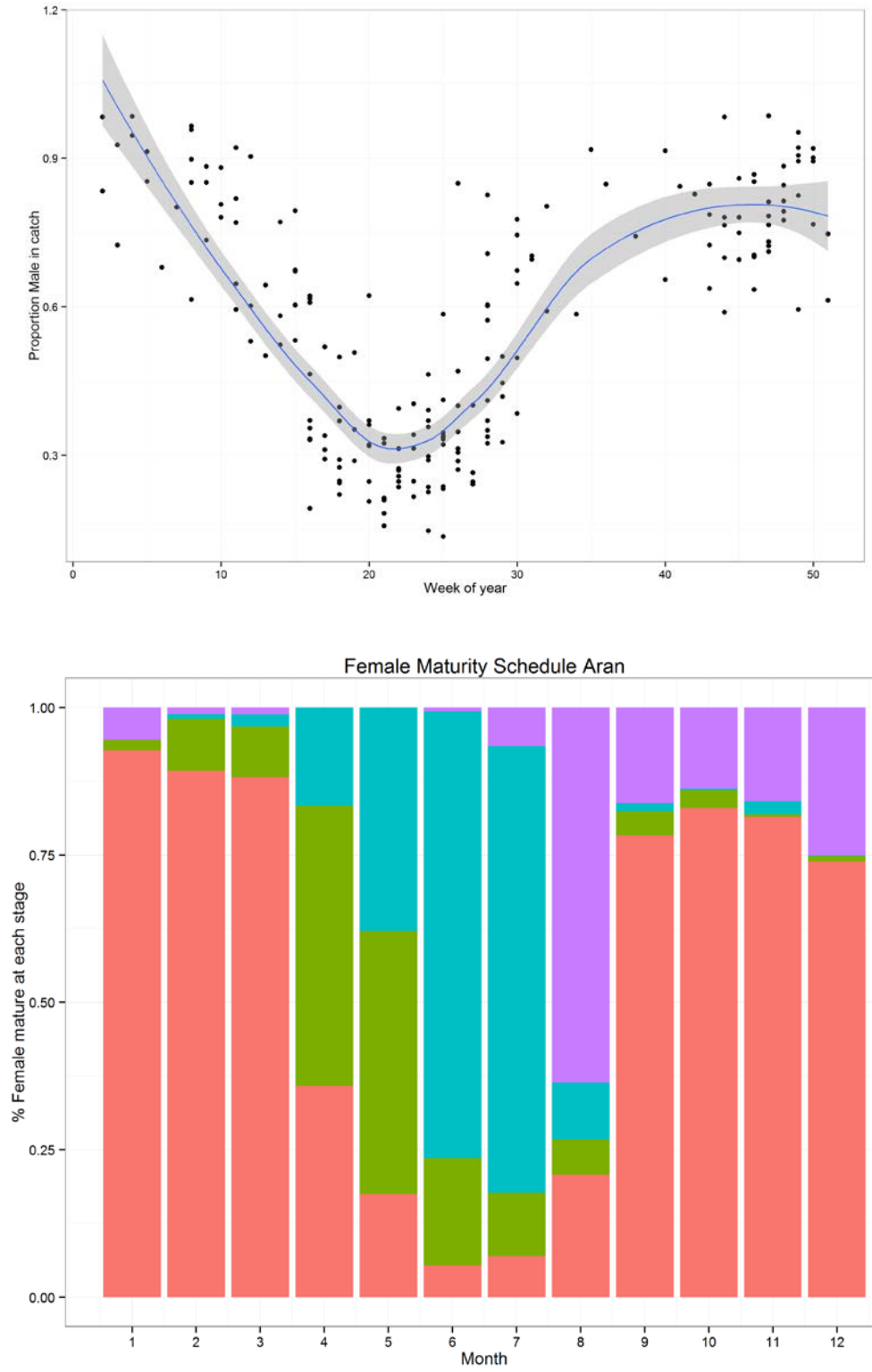


Figure B.2.2. The upper panel shows the sex ratio in sampled catches 2008–2014 (loess smoother). The low panel shows the female maturity schedule i.e. percentage at each maturity stage by month.

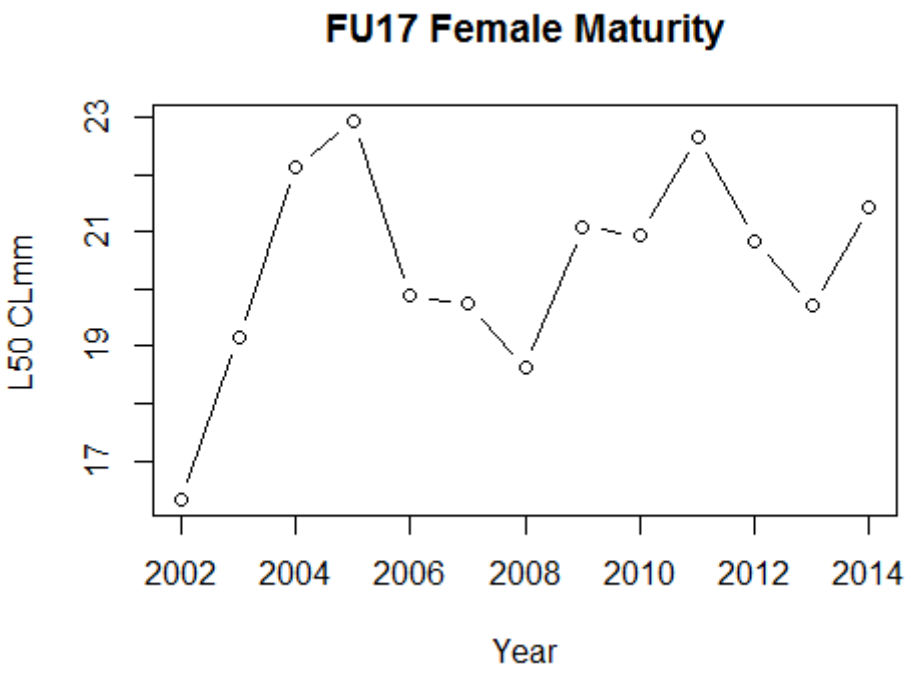


Figure B.2.3. L_{50} of mature females for selected months June–August by year.