Stock Annex: Norway lobster (*Nephrops norvegicus*) in Division 9.a, Functional Unit 30 (Atlantic Iberian waters East and Gulf of Cadiz)

Stock specific documentation of standard assessment procedures used by ICES.

Stock	Gulf of Cadiz (Division 9.a, FU 30)
Working Group	WGBIE
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A. General

A.1. Stock definition

The *Nephrops* stock from FU30 comprises the Spanish waters of the Gulf of Cadiz, defined as the Spanish Suratlantic Region. The western limit of the stock is at the Portuguese border, on the Guadiana River estuary, whereas the eastern border is at the Gibraltar Strait. The Gibraltar Strait separates the Gulf of Cadiz from the Mediterranean Sea and is considered a natural border. On the other hand, the Guadiana River does not seem to be a real boundary for splitting possibly different populations (FUs 29 and 30). This stock limit was decided mainly on management considerations, without any clear biological basis. Possible differences and exchange rates across FUs 29 and 30 should be studied. Tagging experiments and genetic studies could provide valuable information in this respect.

Within FU 30, *Nephrops* grounds correspond to muddy and sandy areas ranging between 200–700 m depth. High fishing effort is particularly carried out around 500 m (Ramos *et al*., 1996).

A.2. Fishery

A.2.1. General description

Nephrops in FU 30 is exploited mostly by Spanish trawlers. The bottom trawl fleet of the Gulf of Cadiz is characterized by the multispecifity of its landings (Sobrino, 1994; Jiménez, 2002; 2004). The fleet operates mainly from four coastal localities: Isla Cristina, Sanlúcar de Barrameda, Puerto de Santa María, Huelva, Ayamonte. Huelva was the most important *Nephrops* landing port until 2002, but landings from Isla Cristina and Puerto de Santa María became larger than Huelva landings from that year onwards (Vila *et al*., 2005). Information obtained from the Port of Ayamonte in 2010 showed that *Nephrops* landings at this port represent 31% of the total *Nephrops* landings from the bottom trawl fleet in FU 30 for the 2002–2009 period. Ayamonte and Isla Cristina were the main *Nephrops* landing ports since 2009. The fishery takes place throughout the year, with the highest landings usually being made in the spring and summer with high values from April to September (Jiménez, 2002; Vila, 2004). *Nephrops* represents 1.5% of the total trawl landings from the area.

Two main métiers were identified among the trawlers in the past (STECF, 2003). The most common group normally fish in shallow waters (30–100 m) with a mixture of target species (sparids, cephalopods, wedge sole, hake and horse mackerel). The oth-

er group operates between 90 and 500 m of depth, targeting mainly blue whiting, shrimp, horse mackerel, hake and Norway lobster.

A fleet conversion developed by the public administration at the end of the 1990s homogenized considerably this fleet regarding its technical characteristics and fishing capacity. Jiménez *et al*. (2004) observed a direct relationship between the capacity of vessel mobility and the bathymetric situation of the fishing. After the fleet conversion, a larger number of vessels could access the more remote and deeper fishing grounds, resulting in an increase of *Nephrops* directed effort and landings from 2000 to 2004. At present, a unique and highly multispecific métier (OTB_MCD≥55_0_0) was identified in the Gulf of Cadiz since 2007 (Castro *et al*., 2007; Castro *et al*., 2011). This métier is defined as bottom otter trawl targeting a variety of crustaceans, cephalopods and demersal fish using a mesh size of 55 mm (rose shrimp, *Nephrops*, tiger shrimp, spottail shrimp, Octopus, squids, cuttefish, hake, mullets, sparids, wedge sole, sole, Horse-mackerel within others). Nevertheless, *Nephrops* grounds are allocated far away from ports and the fleet decide when they want to go fishing *Nephrops*.

As *Nephrops* is caught in a multispecies bottom trawl fishery, the increases in the abundance of other valuable species in this fishery, such as the rose shrimp (*Parapenaeus longirostris*) are believed to have led to a change in the objectives of the fishery, as rose shrimp achieves a higher market value and its fishing grounds, less deep (90–380 m) and closer to the coast, are easier to reach.

Discards are negligible and are mainly related to quality (broken or soft shells).

2.2.2. Fishery management regulations

Nephrops is managed in the area by an annual TAC (applying to the whole of ICES Division 9.a) and technical measures.

A recovery plan for southern hake and Iberian *Nephrops* stocks was approved in December 2005 and in action since the end of January 2006. This recovery plan includes a reduction of 10% in the hake F relative to the previous year and TAC set accordingly, within the limits of ±15% of the previous year TAC (Council Regulation (EC) No 2166/2005). Although no clear targets were defined for Norway lobster stocks in the plan, the same 10% reduction has been applied to these stocks effort and TAC. The number of allowed fishing days is set in each year regulations. However, the number of fishing days included in these regulations is not applicable to the Gulf of Cadiz (FU 30), which has a different effort management regime. The recovery plan target and rules have not been changed since it was implemented. ICES has not evaluated the current recovery plan for *Nephrops* in relation to the precautionary approach.

Different fishing plans for the Gulf of Cadiz have been established by the Spanish Administration since 2004 in order to reduce the fishing effort of the bottom trawl fleet (ORDENES APA/3423/2004, APA/2858/2005, APA/2883/2006, APA/2801/2007, ARM/2515/2009, ARM/58/2010, ARM/2457/2010, AAA/627/2013, AAA/1710/2014, AAA/????/1016. Last plan continue establishing a closed fishing season to 45 days, between 24 September and 7 November, plus five additional days to be selected by the ship owner during the duration of this Plan. The potential effect of the closed seasons on the *Nephrops* population has not been evaluated. In 2014, a modification of Fishing Plan for the Gulf of Cadiz (AAA/1710/2014) was established. This new regulation establishes an assignation of the *Nephrops* quotas by vessel.

For the bottom trawl fleet, the Gulf of Cadiz area had different regulations from the rest of statistical subdivisions in the Northeastern Atlantic, allowing the use of small-

er mesh sizes (40 mm). Nevertheless, an increase of mesh size to 55 mm or more was indefinitely implemented in the Spanish Fishing Plan established in 2009 (Orden ARM/2515/2009) in order to reduce discards of individuals below the minimum landing size.

The minimum landing size (MLS) for *Nephrops norvegicus* is 20 mm of carapace length. Few animals are caught under size.

A.3. Ecosystem aspects

Nephrops is a burrowing species and inhabits muddy sea beds on the continental shelf and upper slopes. Its distribution is more determined by ground type and sea temperature than depth. In this area, it is distributed between 200 and 700 m of depth approximately, in a patchwork configuration where the substrate is suitable. *Nephrops* are sedentary but they can leave their burrows to look for food and for reproduction.

After reaching sexual maturity, males molt more frequently than females, consequently growing faster. Mating takes place just after the females molt. Eggs are fertilized when they are laid and they attach under the female abdomen for a 4 to 5 month period. Berried *Nephrops* stay most of the time in their burrows. Larvae are pelagic for one month after hatching, then after metamorphosis the small *Nephrops* settle on the sea bed. The emergence pattern of the *Nephrops* females during the incubation period results in a different exploitation pattern for each sex. The spawning season occur in summer, mature females are observed in spring and summer while berried females appear starting from August (Vila *et al*., 2005). Females spent more time in their burrows during the autumn and winter.

Nephrops are omnivorous, but polychetes, crustaceans, molluscs and echinoderms are their favourite prey.

A comprehensive study into the role of Norway lobsters in the ecosystem would be particularly useful since a habitat of special interest has been observed in deeper waters of the Gulf of Cádiz (OSPAR, 2004). Methane-enriched fluid expelled through a submarine mound, probably formed as a mud volcano in this area, maintains a highly sensitive ecosystem (Díaz del Río *et al*., 2006).

Another topic that should be further investigated is the possible interaction between the stocks found in FU 29 and FU 30 (Cadiz). Exchanges between the two populations are likely to occur since there are no known physical/geographical constraints limiting this exchange. Aiming for a better understanding of the *Nephrops* population dynamics, tagging experiments and genetic studies would provide valuable information, which would help to support the issues dealt with during the assessment working groups.

B. Data

B.1. Commercial catch

Landings

Landings are reported by Spain and also minor quantities by Portugal. Spanish landings are based on sales notes which are compiled and standardized by IEO. Since 2013, trips from sales notes are also combined with their respective logbooks, which allow georeferencing the catches.

Landings dropped dramatically in last period (2013–2015), which was caused for a penalty applied by European commission because the TAC was exceeded in 2012. *Nephrops* fishery was closed almost all year in 2013 and a TAC reduction in the next three years was applied (2013–2015).

Discard

An annual Spanish Discard Sampling Programme under the EU DCR has been carried out in FU 30 since 2005. Until 2008, fishing trips in the bottom trawl métier were sampled by on-board observers during the *Nephrops* fishing season (summer). The discard sampling scheme covers the whole year since 2009 (Reg. EC 1343/2007). The discard is considered negligible in this FU.

B.2. Biological

B.2.1. Maturity

Size at first maturity in females was estimated in 2004 (Vila *et al*., 2005). Females' carapace length at first maturity was 29.4 mm. A histology study on female gonads was carried out, in order to compare macro and micro maturity scales. Results of this study showed that females with ovaries in stage II present oocytes beginning the vitellogenesis process (early vitellogenic oocytes) (Vila *et al*., 2012). These females will spawn over the spawning season so they could be considered as mature individuals. A size at first maturity was estimates using two criteria depending on females with ovaries in stage II (ovaries developing) are considerate as individuals mature (criteria 1) or immature (criteria 2). Size at first maturity according to criteria 1 was 25.6 mm and 28.6 mm for criteria 2. A description of methodology used is documented in a WD presented in WKNEP 2016 (Vila, 2016).

Additionally, measurements of appendix masculine have being carried out from 2009–2010 and 2012–2016 period with the aim of obtaining the size of onset of sexual maturity in males, following the methodology of McQuaid *et al*. (2006). The breakpoint range between 25.9 mm CL in 2016 and 41.5 mm CL in 2015. Results are coherent yearly except for 2015 where the breakpoint is extremely high. Methodology and results are detailed in a WD presented in WKNEP 2016 (Vila, 2016). The breakpoint for all years pooled was estimated in 30.7 mm CL (standard error=0.566).

B.2.2. Length–weight relationship

Length–weight relationship in both sexes was estimated in 2004 (Vila *et al*., 2005). Carapace length (CL) and total weight (W) relationships were $W=0.0004909*CL^{3.1018}$ for males, $W=0.0007881*CL^{2.9657}$ for females and $W=0.0006*CL^{3.0237}$ for both sexes. A new L–W relationship was estimated in 2016 using 2009–2013 and 2015–2016 periods with all pooled data ($W=0.000845*CL^{2.953452}$ for males, $W=0.001873*CL^{2.726119}$ for females). See WD presented in WKNEP 2016.

B.2.3. Von Bertalanffy growth parameters

Von Bertalanffy growth parameters (VBGP) were estimated for both sexes using empirical relationships (Vila, 2016). The asymptotic length (CL_∞) was estimated as $CL_\infty=CL_{max}/0.95$ (Pauly, 1984) and the *Nephrops* auximetric relationship (Pauly *et al*., 1996) were used to obtain k-growth parameter (Log K= -1.8614 Log CL_∞+ 0.7526 for males; Log K= -1.2359 Log CL_∞+ 0.0574 for females). The CL_∞ estimate was 66 mm and 61 mm for males and females, respectively and the k-growth was 0.167 for males and

0.122 for females (see WD presented in WKNEP 2016). However, more studies about growth are necessary.

B.2.4. Natural mortality

A natural mortality rate of 0.3 is assumed for all age classes and years for males and immature females and a value of 0.2 for mature females based in Morizur (1982). The lower value for mature females reflects the reduced burrow emergence while ovigerous and hence an assumed reduction in predation. In WKNEP 2016, natural mortality was estimated by the Hierarchical Mean Length and Effort Model for 2005–2015 period. Natural mortality was estimated in for 0.46 males and 0.36 for females but this issue must be investigated in a near future.

B.2.5. Length composition of landed and *Nephrops* discarded in commercial fisheries

Annual length compositions of the commercial landings of *Nephrops* for both males and females are available since 2001. The sampling followed a multistage stratified random scheme by month in the port of Huelva for the period 2001–2005. These data were raised to the total landings from FU 30. Inconsistencies were found in this series (Silva *et al*., 2006), due to the fact that not all commercial categories were sampled before 2004. In 2006, a new sampling scheme was introduced, which included sampling in other ports (Isla Cristina, El Puerto de Santa María and Sanlúcar de Barrameda) and excluded the port of Huelva because the landings in this port decreased. The sampling data were raised to the total landings by market category, port, month and area.

The pan-European biological sampling program of commercial fish catch evolved from a stock-based (DCR 2002-2008) to a métier-based sampling scheme (DCF 2009–now). The aim of this change was to move towards an integrated management which includes ecological aspects. Since 2009 concurrent sampling is carried out, as required by the DCR. With this sampling strategy, fishing trips of the bottom trawl métier (OTB_MCD>=55_0_0) are sampled on board vessels from the main landings ports in the Gulf of Cadiz, in order to ensure the widest geographical coverage. However, a higher proportion of observed trips are likely to not cover *Nephrops* catches mainly in first and four quarter (outside of the *Nephrops* fishing season) whereas when *Nephrops* sampling were carried out in harbour in the past, the length distribution of landings were covered in all months. In addition, high numbers of refusals are recorded. These facts together with the low number of individuals sampled by sex could be affecting to the length distribution obtained where the global sex-ratio remain stable about 50% in the time-series, when the percentage of males should be higher. The random sampling does not assure length distributions in all quarters. The random sampling should be enforcing with samplings directed to *Nephrops* in order to obtain length distributions that cover the whole of the year.

Information on discards is not taken into account in the estimation of the total catch length distribution due to the low level of discards.

B.3. Surveys

IBTS

Two groundfish surveys are carried out annually in the Gulf of Cadiz in March (SP-GFS-cspr-WIBTS-Q1, since 1994) and November (SP-GFS-caut-WIBTS-Q4, since

1997). A stratified random sampling design with five bathymetric strata, covering depths between 15 and 700 m, is used, with one hour hauls during the day.

Neither of these surveys is carried out during the main fishing period of *Nephrops* (April–September). Berried females are hidden in their burrows in autumn, so only the index from the March survey is considered potentially representative of stock abundance.

UWTV

An exploratory *Nephrops* UWTV survey on the Gulf of Cadiz fishing grounds (IS-UNEPCA) was carried out in 2014 within the framework of a project supported by Biodiversity Foundation (Spanish Ministry of Agriculture, Food and Environment) and European Fisheries Fund (EFF) (Vila *et al*., 2014). Nowadays, IEO is carried out yearly UWTV survey in the Gulf of Cadiz (FU 30) in June since 2015.

The surveys are based on a randomized isometric grid design with stations spaced 4 nm. The method used during the surveys are according to WKNEPHTV (ICES, 2007), WKNEPHBID (ICES, 2008), SGNEPS (ICES, 2009, 2010, 1012) and WGNEPS (2013, 2014, 2015). A description of UWTV surveys carried out in FU 30 since 2014 is documented in a WD presented in WKNEP 2016 (Vila *et al*., 2016).

UWTV Survey relative to absolute conversion factors

A number of factors are suspected to contribute bias to UWTV surveys (ICES, 2007). In order to use the survey abundance estimate as absolute it is necessary to correct for these potential biases. The main bias is the "edge effect" which is a moderate source of overestimation when deriving *Nephrops* population size from underwater TV surveys. This bias is related to the counting of burrow complexes which lie mainly outside the viewed track. The field of view of the camera is 0.75 cm and the expert judgment of the mean burrow diameter is 27 cm. The estimated edge effect bias using the simulation approach suggested by Campbell *et al*., (2009) is established in 1.24. Other bias identifies are the "burrow detection" and "burrow identification regarding to visibility quality and the presence of other burrowing macrobenthic species, respectively. The burrow detection rates were thought to be relatively high due to good water clarity. Burrow identification could be overestimated since some squat lobsters were observed at burrow entrances. Regarding to the "occupancy", is assumed that 100% of burrows are occupied for an individual of *Nephrops*. The proposed cumulative correction factor for the Gulf of Cadiz was 1.28 (Table 1).

	Edge effect	Detection rate	Species identification	Occupancy	Cumulative bias
FU30: Gulf of Cadiz	1.24	0.90	1.15	1	1.28

WKNEPS concluded that UWTV approach should be apply for this stock and the WGBIE and WGNEPS review survey results when available.

B.4. Commercial cpue

The estimate of *Nephrops* directed effort corresponds to daily fishing trips for which *Nephrops* represent at least 10% of the total landings in weight.

Some circumstances that have happened in the fishery since 2012 might increase the uncertainty associated to the commercial lpue index: low TAC in FU 30 during the last years, the special situation after the penalty in 2012 with a reduction of TAC for three years (2013–2015) and the assignment of quotas by vessel established in 2014 that might have cause unreported landings.

C. Assessment method and setting

C.1. Choice of stock assess model

In 2009 WKNEPH agreed that the bias corrected UWTV survey abundance estimates (considered as an absolute abundance index) could be used directly in the formulation of catch advice (ICES, 2009). Separable Cohort Analysis can be used to estimate sustainable stock specific Harvest Ratio reference points.

This is a statistical model that estimates recruitment, selectivity and fishing mortality by fitting to catch (and discards) by length and sex. The absolute abundance index is fitted to the total population numbers at the time of the survey. This is not strictly an assessment model as it operates on length frequencies under the assumption of equilibrium and residuals from the model should be examined for evidence of gross departure from this assumption before results are presented.

Multiplying the HR by the assessed stock abundance in number obtained from the UWTV survey provides a recommended number of removals. This may be converted to landings by subtracting dead discard and then multiplying by the expected mean weight in landings in order to produce landings biomass (ICES, 2009; ICES, 2013b).

UWTV surveys in FU 30 were evaluated by ICES Benchmark Workshop on *Nephrops* Stocks (WKNEP) in October 2016 (ICES, 2016a) which concluding that UWTV survey in this FU is appropriated for providing scientific advice on the abundance of this stock. However, poor fits in the length-frequency model, normally used for calculating F_{MSY} for category 1 *Nephrops* stocks, prevented its application to FU 30. In the absence of stock specific MSY harvest rates, ADGNEP 2017 concluded that the basis of advice for this stock should follow the category 4 approach for *Nephrops* stocks.

C.2. Model used of basis for advice

Model: *Nephrops* data-limited approach

The advice is based on the UWTV survey and precautionary harvest rate according to category 4. In the future if stock specific FMSY reference points can be estimated the stock will meet the requirements for category 1 assessment.

D. Short-term prediction

Not used.

E. Long-term projections

Not used.

G. Biological reference points

Proxies of MSY reference points were defined using the methods developed in WKLIFE and WKProxy (ICES, 2015; 2016). $F_{0.1}$, taken as proxy of $F_{MSY,}$ from length-

based analysis for the period 1994–2014 was 0.36 for males and 0.63 for females but the value of MSY $B_{trigger}$ proxy is not available.

WKNEP 2016 investigated propositions for new reference points on the basis of the new UWTV survey combining with the SCA model based on average length–frequency distribution 2012–2014. The runs of the cohort based models resulted in poor fits and in radically different population estimates compared to the TV abundance (differences of ~10 fold), coupled to high estimates of fishing mortality even at times where the fisheries were very small. So, harvest rates derived from the SCA lead to much larger recommended catches than experienced historically (ICES, 2016). WKNEP felt that these discrepancies were so great that there was a significant risk of the LCA derived estimates of fishery parameters and their associated MSY proxy points being biased. The problems could be amended to a variable extent in numerous ways, but in particular by increasing the natural mortality in the SCA model, which again would have an impact on the reference points and subsequently on the harvest rate to be recommended. On the other hand, the estimation of growth parameters in FU 30 is not robust.

Reference points were derived from the perception of the stock and historical experience from similar previously assessed stocks as a possible interim solution. Taken into account the fishery history, the HR ranging between 1.5% in recent years (2010–2012) and 4.0% when landings achieved the highest value (2003). The last period 2013–2015 is not considered because the situation of this fishery was abnormal due the very low TAC was limiting the fishery.

However, real specific reference points for this stock derived from the conventional method used in category 1 *Nephrops* stocks could not be obtained, so *Nephrops* in FU 30 was not considered a category 1 stock. So, in the *Nephrops* data-limited approach the estimated harvest rate is compared to FMSY harvest rate from other FUs.

H. Other issues

H.1. Historical stock development

No analytical assessment has been carried out for this stock in the past. The advice was based on fishery lpue and effort trends. Abundance survey index was to take account supporting the fishery information of the data.

Since 2012, the advice for this stock was based on fishery lpue that was use as indicator of the size of stock, according to the ICES data-limited approach (ICES, 2012). This stock was classified in the category 3.2.0 of the Data-Limited Stocks (DSL).

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