
Colm Lordan¹, Jennifer Doyle¹, Ross Fitzgerald¹, Seán O’Connor¹, Marcin Blaszkowski¹ and Sarah Simpson².

¹ Fisheries Ecosystems Advisory Services, The Marine Institute, Renvyle, Oranmore, Galway, Ireland.
² Agri-Food and Biosciences Institute (AFBI), Fisheries and Aquatic Ecosystems Branch, Newforge Lane, BT9 5PX, Belfast, Northern Ireland (UK).

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Abstract
This report provides the main results and findings of the fifth underwater television survey of the various Nephrops patches in Functional Unit 19. The survey was multi-disciplinary in nature collecting UWTV, CTD, multi-beam and other ecosystem data. In 2014 a total 40 UWTV stations were successfully completed. The mean density estimates varied considerably across the different patches. The 2014 raised abundance estimate of 636 million burrows was a 31% increase from the 2013 estimate. Taking into account the uncertainty (CV of 15%) this is not significantly different from abundance estimates since 2011. Using the 2014 abundance and recent mean weight and discard parameters would imply total catches of 1119 t fishing at F_{msy} in 2015. Based on recent discard patterns which are high in this area; 715 t would be landings and 404 t would be discards. Two species of sea pen were observed; Virgularia mirabilis and Pennatula phosphorea, both species have been observed on previous surveys of FU19.

Key words: Nephrops norvegicus, stock assessment, geostatistics, underwater television (UWTV), benthos, CTD.

Suggested citation:
Introduction
The prawn (*Nephrops norvegicus*) are common in the Celtic Sea occurring in geographically distinct sandy/muddy areas where the sediment is suitable for them to construct their burrows. The *Nephrops* fishery in VII is extremely valuable with landings in 2012 worth around €80 million at first sale. The Celtic Sea area (Functional Units 19-22) supports a large multi-national targeted *Nephrops* fishery mainly using otter trawls and yielding landings in the region of ~6,000 t annually. Over the last decade reported landings from FU19 have been at around 800 t (ICES, 2014a). The 2013 landings of 780 t are estimated to be worth €4.1 million at first sale. The *Nephrops* fishery in FU19 occurs on several spatially discrete mud patches which are spread out over a vast area (Figure 1).

It is well documented that *Nephrops* spend a great deal of time in their burrows and their emergence behaviour is influenced by many factors; time of year, light intensity and tidal strength. Underwater television surveys and assessment methodologies have been developed to provide a fishery independent estimate of stock size, exploitation status and catch advice for several *Nephrops* stocks around Ireland (ICES, 2009, 2011). This stock was benchmarked by ICES earlier this year and the UWTV survey assessment methodology was considered to be appropriate for this stock (ICES, 2014b). The survey was multi-disciplinary in nature; the specific objectives are listed below:

1. To obtain 2014 quality assured estimates of *Nephrops* burrow densities from several of the discrete mud patches of *Nephrops* ground in FU19.
2. To collect ancillary information from the UWTV footage collected at each station such as the occurrence of sea-pens, other macro benthos and fish species and trawl marks on the sea bed.
3. To collect oceanographic data using a sledge mounted CTD.

This report details the final UWTV results of the 2014 FU19 survey and also documents other data collected during the survey. The 2014 abundance are used to generate catch options for 2015 in line with the recommendations and procedures outlined in the stock annex for FU19 (ICES, 2014a,b).

Material and methods
The spatial extent of the *Nephrops* grounds in FU19 has previously been defined using 2006-2008 integrated VMS-logbook data using the methods described in Gerritsen and Lordan (2011) (Figure 1). The ground boundaries were revised at the benchmark this year and historical survey abundance estimates were revised accordingly (ICES, 2014b). The discrete patches have been named as: Bantry Bay, Galley Ground 1-4, Cork Channels and Helvick 1 & 2. These are shown as polygons in Figure 1. The area of each ground polygon was calculated in Arcgis10 using different projections and an average value used (Table 1).

In 2014 UWTV stations were randomly picked within each using the “Create Random Points” tool in ArcToolbox of ArcGIS10. The sampling effort, i.e. numbers of stations, on each ground was determined by relative area.
The 2014 FU19 survey took place on RV Celtic Voyager between the 18-27th of August together with the survey of the Smalls which has been reported elsewhere (Lordan, et. al., 2014). Surveys in other years were generally between June-September. The protocols used were those reviewed by WKNEPHTV 2007 (ICES, 2007) and used in all other grounds surveyed by Ireland. Station depths ranged from 38 metres in Bantry Bay to 115 metres in the Galley Grounds. At each station the UWTV sledge was deployed and once stable on the seabed a 10 minute tow was recorded onto DVD. Vessel position (DGPS) and position of sledge (using a USBL transponder) were recorded every 2 seconds. The navigational data was quality controlled using an “r” script developed by the Marine Institute (ICES, 2009b). In 2014 the USBL navigational data was used to calculate distance over ground for all stations.

In line with SGNEPS recommendations all scientists were trained/re-familiarised using training material and validated using FU22 reference footage prior to recounting at sea (ICES, 2009b). There is no FU19 specific reference footage available yet. Individual’s counting performance in 2014 against the reference counts was measured by Linn’s concordance correlation coefficient (CCC). A threshold of 0.5 was used to identify counters who needed further training. Once this process had been undertaken, all recounts were conducted by two trained “burrow identifying” scientists independent of each other on board the research vessel during the survey. During this review process the visibility, ground type and speed of the sledge during one-minute intervals were subjectively classified using a classification key. In addition to the numbers of Nephrops burrows complexes (multiple burrows in close proximity which appear to be part of a single complex which are only counted once), Nephrops activity in and out of burrows was also counted by each scientist for each one-minute interval. Following the recommendation of SGNEPS the time for verified recounts was 7 minutes (ICES, 2009b).

Notes were also recorded each minute on the occurrence of trawl marks, fish species and other species. Abundance categories of sea-pen species were also recorded due to OSPAR Special Request (ICES 2011). A key was devised to categorise the densities of seapens based SACFOR abundance scale (Table 2) after ICES (2011). Finally, if there was any time during the one-minute where counting was not possible, due to sediment clouds or other reasons, this was also estimated so that the time window could be removed from the distance over ground calculations. The “r” quality control tool allowed for individual station data to be analysed in terms of data quality for navigation, overall tow factors such as speed and visual clarity and consistency in counts (Figure 2). Consistency and bias between individual counters was examined using Figure 3. There is some variability between counters but no obvious bias or excessive deviations.

The recount data were screened for one minute intervals with any unusually large deviation between recounts. Means of the burrow and Nephrops recounts were standardised by dividing by the survey area observed and correcting for the various biases (Table 3). The USBL was used to calculate distance over ground of the sledge. The field of view of the camera at the bottom of the screen was estimated at 75cm assuming that the sledge was flat on the seabed (i.e. no sinking). This field of view was confirmed for all tows using lasers during the 2014 survey. Occasionally the lasers were not visible at the bottom of the screen due to sinking in very soft mud (the
impact of this is a minor under-estimate of densities at stations where this occurred). A global mean density and summary statistics (Number of Stations, Standard Deviation, Standard Error, 95% Confidence Intervals and CV) were estimated for all stations and multiplied by the total area given in Table 1 to estimate the raised abundance estimate with confidence intervals. The same approach was used last year. Prior to 2013 some other adjustments were made to account for incomplete survey coverage. Details of these are given in previous survey reports (Lordan, et al., 2013).

A CTD profile was logged for the duration of each tow using a calibrated Seabird SBE 37. The sensor takes readings every 5 seconds and is processed to calculate an average bottom temperature and salinity for each cast.

Results

The summary statistics for the various discrete Nephrops patches within FU19 are given in Table 4. Figure 4 and Figure 5 shows the variability in density between minutes and operators (counters) for each station. These show that the burrow estimates are fairly consistent between minutes and counters. The 2014 mean adjusted\(^1\) density estimates for these vary considerably from the lowest observed in Helvick 2 ground of 0.03 (burrow/m\(^2\)) to the highest observed estimate of 0.82 (burrow/m\(^2\)) at Galley Ground 2. The mean density for most patches showed an increase compared with 2013 and the relative densities were similar.

The time series of summary statistics for FU19 are given in Table 5 and Figure 6. The 2014 raised abundance estimate of 636 million burrows is a 31% increase from the 2013 estimate. The CV or RSE for the 2014 survey was 15% which is below the upper limit <20% recommended by SGNEPS (ICES, 2012).

Sea-pen distribution across the FU19 Nephrops grounds is mapped in Figure 7. Two species were identified from the video footage as Virgularia mirabilis and Pennatula phosphorea. Trawl marks were noted at 13% of the stations surveyed and were only noted for some minutes of the total duration of the station footage. The sea bed temperature and salinity data collected during the survey on the Galley 4 grounds and at Cork Channels is shown in Figure 8. Data were also collected at the other sites but these are not plotted as the area of these grounds is <150 km

Discussion

In response to the WKNEPH 2012 recommendations Ireland reviewed survey effort in FU15, 17 and 22 and reallocated survey effort to FU16, 19 and 20-21 (ICES, 2012). The main aim was to achieve some UWTV survey coverage for the main Nephrops grounds fished in ICES sub-area VII whilst maintaining the accuracy and acceptable precision for existing survey series. Several discrete mud patches with fished Nephrops populations have been identified in FU19 and surveys since 2011 have had reasonable coverage and precision. Scientific knowledge of the spatial distribution of

\(^1\) Note the “adjusted” density estimates in this report are adjusted by dividing by 1.3 (Table 3) to take account of edge effect over estimation of area viewed during UWTV transects (see Campbell et al 2009).
the *Nephrops* habitat and population in this area is developing thanks to new multibeam data, more extensive VMS data and information from the fishing industry particularly for inshore areas.

This stock was benchmarked at WKCELT in 2014. The ground boundaries were revised using the best available information. Recent sampling and trawl survey data were reviewed in detail. New reference points were estimated and the approach for providing catch options was established in a new stock annex (ICES, 2014b).

The stock has been exploited around the proposed $F_{msy}$ proxy of 8.1% in recent years. The 2013 estimated harvest rate was above $F_{msy}$ but the stock size has increased significantly in 2014. Fishing at $F_{msy}$ in 2015 would imply total catches of 1119 t of which 715 t would be landings and 404 would be discards (25% of the discards are assumed to survive). The various other catch options are presented in Table 7.

An important objective of this UWTV survey is to collect various ancillary information. The occurrence of trawl marks on the footage is notable for two reasons. Firstly, it makes identification of *Nephrops* burrows more difficult as the trawl marks remove some signature features making accurate burrow identification more difficult. Secondly, only occupied *Nephrops* burrows will persist in heavily trawled grounds and it is assumed that each burrow is occupied by one individual *Nephrops* (ICES 2008). The frequency of trawl marks observed on these grounds was relatively low although they are extensively fished. The CTD data collected, over time will augment the knowledge base on habitat and oceanographic regime. The temperatures and salinities observed are similar to those on other surveys in 2014. Monitoring the occurrence and frequency of sea-pens observed on these *Nephrops* patches is important in the context of OSPAR’s designations of sea-pen and burrowing megafauna communities as threatened. The same two species of sea-pens were observed on previous surveys of FU19. Monitoring *Nephrops* stock and the benthic habitat is also important in the context of the MFSD indicators (e.g. sea floor integrity).

The main objectives of the survey were successfully met. The UWTV footage quality was excellent and in 2014 and all of the *Nephrops* patches within FU19 were successfully surveyed. The multi-disciplinary nature of the survey means that the information collected is highly relevant for a number of research and advisory applications.

**Acknowledgments**

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References


Figure 1: Stations completed on the 2014 FU19 Nephrops UWTV survey and area polygons of the discrete Nephrops grounds.

Figure 2: r - tool quality control plot for station 136 (Galley Grounds 3) FU19 2014 UWTV survey.
Figure 3: Scatter plot analysis of counter trends during FU19 2014 UWTV survey.
**Figure 4:** Plot of the variability in density between minutes for each station FU19 2014 UWTV survey.

**Figure 5:** Plot of the variability in density between operators (counters) for each station FU19 2014 UWTV survey.
Figure 6: Time series of raised abundance estimates (in millions of burrows) for FU19. No survey data from 2007 to 2010.

Figure 7: Stations where seapens were observed during the FU19 2014 UWTV survey.
Figure 8: Bottom temperature and salinity data collected during the 2014 survey.
### Table 1: Area calculations for the various *Nephrops* grounds in FU19 (ICES, 2014b).

<table>
<thead>
<tr>
<th>Ground Name</th>
<th>Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bantry</td>
<td>121.52</td>
</tr>
<tr>
<td>Cork Channels</td>
<td>562.01</td>
</tr>
<tr>
<td>Galley Grounds 1</td>
<td>60.86</td>
</tr>
<tr>
<td>Galley Grounds 2</td>
<td>76.74</td>
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<tr>
<td>Galley Grounds 3</td>
<td>133.94</td>
</tr>
<tr>
<td>Galley Grounds 4</td>
<td>925.10</td>
</tr>
<tr>
<td>Helvick 1</td>
<td>33.09</td>
</tr>
<tr>
<td>Helvick 2</td>
<td>59.52</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,972.78</strong></td>
</tr>
</tbody>
</table>

### Table 2: Key for classification of Seapen abundance as used on Irish UWTV surveys.

<table>
<thead>
<tr>
<th>Number/Min</th>
<th>Common</th>
<th>Frequent</th>
<th>Occasional</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20-200</td>
<td>2-19</td>
<td>&lt;2</td>
</tr>
</tbody>
</table>

**Species**

- Virgularia mirabilis
- Pennatula phosphorea
- Funiculina quadrangularis

### Table 3: Cumulative bias factors for each *Nephrops* stock surveyed by UWTV method.

<table>
<thead>
<tr>
<th>FU</th>
<th>Edge effect</th>
<th>Burrow detection</th>
<th>Burrow identification</th>
<th>Burrow occupancy</th>
<th>Cumulative Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>3&amp;4 Skagerrak and Kattegat (IIa)</td>
<td>FU3</td>
<td>1.3</td>
<td>0.75</td>
<td>1.05</td>
<td>1.1</td>
</tr>
<tr>
<td>6: Farn Deeps</td>
<td>FU6</td>
<td>1.3</td>
<td>0.85</td>
<td>1.05</td>
<td>1.2</td>
</tr>
<tr>
<td>7: Fladen</td>
<td>FU7</td>
<td>1.45</td>
<td>0.9</td>
<td>1.05</td>
<td>1.35</td>
</tr>
<tr>
<td>8: Firth of Forth</td>
<td>FU8</td>
<td>1.23</td>
<td>0.9</td>
<td>1.05</td>
<td>1.18</td>
</tr>
<tr>
<td>9: Moray Firth</td>
<td>FU9</td>
<td>1.31</td>
<td>0.9</td>
<td>1.05</td>
<td>1.21</td>
</tr>
<tr>
<td>10: Noup</td>
<td>FU10</td>
<td>1.31</td>
<td>0.9</td>
<td>1.05</td>
<td>1.21</td>
</tr>
<tr>
<td>11: North Minch</td>
<td>FU11</td>
<td>1.38</td>
<td>0.85</td>
<td>1.1</td>
<td>1.33</td>
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<tr>
<td>12: South Minch</td>
<td>FU12</td>
<td>1.37</td>
<td>0.85</td>
<td>1.1</td>
<td>1.32</td>
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<td>13: Clyde</td>
<td>FU13</td>
<td>1.19</td>
<td>0.75</td>
<td>1.25</td>
<td>1.19</td>
</tr>
<tr>
<td>14: Irish Sea East</td>
<td>FU14</td>
<td>1.3</td>
<td>0.85</td>
<td>1.05</td>
<td>1.2</td>
</tr>
<tr>
<td>15: Irish Sea West</td>
<td>FU15</td>
<td>1.24</td>
<td>0.75</td>
<td>1.15</td>
<td>1.14</td>
</tr>
<tr>
<td>16: Porcupine</td>
<td>FU16</td>
<td>1.26</td>
<td>0.95</td>
<td>1.05</td>
<td>1.26</td>
</tr>
<tr>
<td>17: Aran</td>
<td>FU17</td>
<td>1.35</td>
<td>0.9</td>
<td>1.05</td>
<td>1.3</td>
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<td>19: South Coast</td>
<td>FU19</td>
<td>1.25</td>
<td>0.9</td>
<td>1.15</td>
<td>1.3</td>
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<td>20&amp;21 Labadie</td>
<td>FU20</td>
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<td>0.9</td>
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<td>22: Smallis</td>
<td>FU22</td>
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<td>34: Devil’s Hole</td>
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Table 4: Detailed summary statistics for the various *Nephrops* patches in FU19 over the time series. (N = number of stations, Mean Density (no/m²) is adjusted for the bias correction factor in Table 3, sd, se and ci are the standard deviation, standard error and 95% confidence intervals on the mean density).

<table>
<thead>
<tr>
<th>Year</th>
<th>Ground</th>
<th>N</th>
<th>Mean Density (no/m²)</th>
<th>sd</th>
<th>se</th>
<th>ci</th>
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<td>2006</td>
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<td>0.21</td>
<td>0.18</td>
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<tr>
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<td>0.23</td>
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<td>0.09</td>
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<td>0.08</td>
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<td>0.03</td>
<td>0.04</td>
<td>0.03</td>
<td>0.39</td>
</tr>
</tbody>
</table>
Table 5: Final of results for UWTV surveys in FU19 from 2006-2014.

<table>
<thead>
<tr>
<th>FU</th>
<th>Year</th>
<th>Number of stations</th>
<th>Mean Density adjusted (burrow/m²)</th>
<th>Standard Deviation</th>
<th>Raised abundance estimate adjusted (million burrows)</th>
<th>Upper 95%CI on Abundance</th>
<th>Lower 95%CI on Abundance</th>
<th>CVs</th>
</tr>
</thead>
<tbody>
<tr>
<td>FU19</td>
<td>2006</td>
<td>6</td>
<td>0.21</td>
<td>0.18</td>
<td>408</td>
<td>789</td>
<td>26</td>
<td>36%</td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>No Survey Data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>35</td>
<td>0.34</td>
<td>0.26</td>
<td>665</td>
<td>842</td>
<td>488</td>
<td>13%</td>
</tr>
<tr>
<td></td>
<td>2012</td>
<td>40</td>
<td>0.30</td>
<td>0.18</td>
<td>594</td>
<td>708</td>
<td>480</td>
<td>9%</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>40</td>
<td>0.25</td>
<td>0.26</td>
<td>487</td>
<td>653</td>
<td>166</td>
<td>17%</td>
</tr>
<tr>
<td></td>
<td>2014</td>
<td>40</td>
<td>0.32</td>
<td>0.31</td>
<td>636</td>
<td>829</td>
<td>442</td>
<td>15%</td>
</tr>
</tbody>
</table>

Table 6: Inputs to FU19 management option table.

<table>
<thead>
<tr>
<th>Year</th>
<th>Landings in Number (millions) scaled</th>
<th>Discards in Number (millions) scaled</th>
<th>Removals in Number (millions) scaled</th>
<th>Dead discard rate (by number)</th>
<th>Adjusted Survey (millions)</th>
<th>Harvest Ratio</th>
<th>Landings (t)</th>
<th>Discards (t)</th>
<th>Mean Weight in landings (gr)</th>
<th>Mean Weight in discards (gr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>26.2</td>
<td>2.6</td>
<td>28.1</td>
<td>0.068</td>
<td>741</td>
<td>37</td>
<td>28.3</td>
<td>37</td>
<td>14.4</td>
<td>14.4</td>
</tr>
<tr>
<td>2007</td>
<td>30.8</td>
<td>1.5</td>
<td>31.9</td>
<td>0.036</td>
<td>957</td>
<td>26</td>
<td>31.1</td>
<td>26</td>
<td>17.0</td>
<td>17.0</td>
</tr>
<tr>
<td>2008</td>
<td>25.7</td>
<td>5.5</td>
<td>29.8</td>
<td>0.139</td>
<td>866</td>
<td>107</td>
<td>33.7</td>
<td>107</td>
<td>19.3</td>
<td>19.3</td>
</tr>
<tr>
<td>2009</td>
<td>27.3</td>
<td>17.8</td>
<td>40.6</td>
<td>0.328</td>
<td>833</td>
<td>258</td>
<td>30.5</td>
<td>258</td>
<td>14.5</td>
<td>14.5</td>
</tr>
<tr>
<td>2010</td>
<td>24.4</td>
<td>20.0</td>
<td>39.3</td>
<td>0.381</td>
<td>722</td>
<td>269</td>
<td>29.6</td>
<td>269</td>
<td>13.5</td>
<td>13.5</td>
</tr>
<tr>
<td>2011</td>
<td>24.3</td>
<td>30.7</td>
<td>47.3</td>
<td>0.487</td>
<td>665</td>
<td>7.1%</td>
<td>608</td>
<td>387</td>
<td>25.0</td>
<td>12.6</td>
</tr>
<tr>
<td>2012</td>
<td>29.2</td>
<td>33.0</td>
<td>54.0</td>
<td>0.459</td>
<td>594</td>
<td>9.1%</td>
<td>770</td>
<td>420</td>
<td>26.4</td>
<td>12.7</td>
</tr>
<tr>
<td>2013</td>
<td>28.5</td>
<td>33.4</td>
<td>53.6</td>
<td>0.468</td>
<td>487</td>
<td>11.0%</td>
<td>781</td>
<td>404</td>
<td>27.4</td>
<td>12.1</td>
</tr>
<tr>
<td>2014</td>
<td></td>
<td></td>
<td>636</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg 2011-13</td>
<td></td>
<td></td>
<td>0.471</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>26.25</td>
<td>12.48</td>
</tr>
</tbody>
</table>
Table 7: Management option table giving catch options for 2015 using the 2014 UWTV abundance estimate and recent mean weights and discard rates.

Basis: Absolute survey abundance index 2015 = 636 million (2014 index); Mean individual weight in landings (2011–2013) = 26.25 g; Dead discard rate (by number) = 47.1%; Mean individual weight in discards (2011–2013) = 12.48 g.

<table>
<thead>
<tr>
<th>Basis</th>
<th>Total catches*</th>
<th>Landings</th>
<th>Dead discards**</th>
<th>Surviving discards**</th>
<th>Harvest rate for L+DD</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSY approach</td>
<td>1119</td>
<td>715</td>
<td>303</td>
<td>101</td>
<td>8.1%</td>
</tr>
<tr>
<td>F&lt;sub&gt;2011-13&lt;/sub&gt;</td>
<td>1254</td>
<td>801</td>
<td>339</td>
<td>113</td>
<td>9.1%</td>
</tr>
<tr>
<td>F&lt;sub&gt;35%SpR&lt;/sub&gt;</td>
<td>2004</td>
<td>1281</td>
<td>542</td>
<td>181</td>
<td>14.5%</td>
</tr>
<tr>
<td>F&lt;sub&gt;max&lt;/sub&gt;</td>
<td>1700</td>
<td>1086</td>
<td>460</td>
<td>153</td>
<td>12.3%</td>
</tr>
</tbody>
</table>

Weights in tonnes.
* Total catches are the landings plus dead and surviving discards.
** Total discard rate is assumed to be 54.2% of the catches (in number, last 3 years average, 2011-2013), discard survival is assumed 25%