Spatial differences in biological characteristics of *Loligo forbesi* (Cephalopoda: Loliginidae) in the Northeast Atlantic

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Abstract:

Biological data collected in *Loligo forbesi* during a series of EU funded programs were analyzed using a common set of statistical tools to evaluate large scale variation in the Atlantic. Monthly samples collected in Scotland, English Channel, Portugal and Azores and analyzed with similar protocols enabled to record a common set of basic biological variables (length, weight, sex, sexual maturity stage, gonad weight and reproductive system weight). In each area, basic variables are used to compute compound variables which describe the relationship between biological variables (like parameters of the length-weight relationships, or length-at-maturity) the seasonal variation of indices (like sex-ratio, proportion of maturity stages or average gonado-somatic index) and the synchronicity of life history (like the number of months with a majority of mature -or immature- specimen in the population).

Differences in length-weight relationships were studied with ANCOVA-like methods. Length-at-maturity were estimated via GLM procedures fitting a logistic function with binomial errors. Seasonal variations in sex ratio and proportions of maturity stages were tested with Chi-square tests and other temporal aspects of life history were compared with non-parametric tests. Significant geographical differences were discussed in the light of published population life-cycles, latitudinal gradients and genetic differences between Azores and continental shelf populations.

Key-words: *Loligo forbesi*, biological samples, statistical differences, geographical comparisons.
1. Introduction

Biological characteristics of the common squid *Loligo forbesi* have already been presented in a number of papers, each one devoted to a particular fishing ground (Guerra and Rocha, 1994; Moreno et al., 1994, Pierce et al., 1994a; Porteiro et al., 1994). However, published information does not always provide all the elements necessary to test statistical differences across the species range.

During the period 1989-1999 the European Union has funded a series of cephalopod projects (FAR, AIR, FAIR) which included biological sampling of fishery landings. A composite database has been assembled which enables to apply homogeneous statistical procedures to test population parameters.

The objective of this analysis is to contribute to the review of *Loligo forbesi* biological variation. From a fishery point of view biological differences are useful to take into account in the identification of management units. Three biological characteristics - sex-ratio, length-weight relationships, length-at-maturity relationships - are compared in five different fisheries (Fig. 1).

2. Materials & Methods

2.1. Sex-ratio

Chi-square tests are applied to the number of males and females collected with simple random sampling. In addition to the overall sex-ratio per site seasonal differences are sought separately in each area by comparing monthly samples.

2.2. Length/weight relationships

Power models are applied to log-transformed length/weight data for four fishing areas in the Northeast Atlantic. The model is of the form: \( W = aL^b \) where \( W \) is the weight (in grams) and \( L \) is the dorsal mantle length (in millimeters) of a squid. Analysis of variance are performed with the "lm" procedure implemented in S-plus. Linear modeling techniques test differences in origin ordinates (a) and in slopes (b). All models are based on ordinary least-squares method.

2.3. Length-at-maturity relationships

Relationships between mantle length and sexual maturity are only studied in females to avoid problems with the plurimodal length composition observed in mature males.

GLM modelling is applied to fit logistic curves with binomial distribution of errors. The regression procedure includes weights which correspond to the number of studied females in each length-class. Fitted lines and 95% confidence intervals are plotted and length-at-50% mature (DML50) confidence intervals are computed using a complementary module (Venables and Ripley, 1998).

3. Results

3.1. Sex-ratio

An overview of spatial differences (Fig. 2) indicates that this variable can be biased towards predominance of males. At the monthly scale, deviations from a balanced ratio are either not significant (English Channel) or without clear seasonal pattern (Portugal, Moreno et al., 1994). Scotland samples suggest predominance of females during periods of breeding activity (Pierce et al., 1994a).

3.2. Length/weight relationships
In female, allometric coefficients show no statistical difference between sites, except for Scotland and the English Channel (Fig. 4, Table 1). Origin ordinates in Scotland are different from all others, maybe due to the higher samples number. L/W relationships in males are significantly different between all fisheries (Fig. 4, Table 2). Note that the allometric coefficient is much smaller in Azores squids.

3.3. Length-at-maturity relationships

Length at maturity (DML50) does not show significant differences between northern fisheries (Scotland and the English Channel) or between southern fisheries (Portugal and Azores). DML50 is significantly higher in the south than in the north (Fig. 5).

4. Discussion-conclusion

Differences in biological characteristics are difficult to analyze as they can be biased by various problems (fishing gear, sample size, inter-annual trends). Length weight relationships indicate that males from the Azores show much lower allometric coefficient (b) than other samples, this is in agreement with previous morphological studies (Pierce et al., 1994b). However, within continental shelf samples differences also occur in a context of genetic homogeneity (Shaw et al., 1999).

5. References

Table 1: Regression coefficients and analyse of variance for length/weight relationships of *Loligo forbesi* female from different fishing areas.

<table>
<thead>
<tr>
<th>Sites</th>
<th>n</th>
<th>$R^2$</th>
<th>a</th>
<th>Anova</th>
<th>b</th>
<th>Anova</th>
</tr>
</thead>
<tbody>
<tr>
<td>NW Scotland</td>
<td>7419</td>
<td>0.99</td>
<td>0.127</td>
<td></td>
<td>2.492</td>
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<tr>
<td>Portugal</td>
<td>544</td>
<td>0.98</td>
<td>0.154</td>
<td>***</td>
<td>2.476</td>
<td></td>
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<tr>
<td>English Channel</td>
<td>690</td>
<td>0.96</td>
<td>0.164</td>
<td></td>
<td>2.448</td>
<td></td>
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<tr>
<td>Azores</td>
<td>447</td>
<td>0.90</td>
<td>0.174</td>
<td></td>
<td>2.438</td>
<td></td>
</tr>
<tr>
<td>NW Spain</td>
<td>64</td>
<td>0.97</td>
<td>0.175</td>
<td></td>
<td>2.408</td>
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</tr>
</tbody>
</table>

*** P < 0.001, --- no significant

Table 2: Regression coefficients and analyse of variance for length/weight relationships of *Loligo forbesi* male from different fishing areas.

<table>
<thead>
<tr>
<th>Sites</th>
<th>n</th>
<th>$R^2$</th>
<th>a</th>
<th>Anova</th>
<th>b</th>
<th>Anova</th>
</tr>
</thead>
<tbody>
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<td>0.98</td>
<td>0.154</td>
<td>***</td>
<td>2.459</td>
<td>***</td>
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<tr>
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<td>***</td>
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<td>***</td>
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<tr>
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<td>0.95</td>
<td>0.274</td>
<td>***</td>
<td>2.253</td>
<td></td>
</tr>
<tr>
<td>NW Spain</td>
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<td>0.87</td>
<td>1.183</td>
<td>***</td>
<td>1.899</td>
<td>***</td>
</tr>
</tbody>
</table>

*** P < 0.001, * P < 0.05, --- no significant
Figure 1: Map showing *Loligo forbesi* sampling locations in Northeast Atlantic fisheries.
Figure 2: Overview of spatial differences in sex-ratio. ** significant deviation from the equilibrium 1:1, -- no significant deviation.

Figure 3: Example of seasonal variation in sex-ratio: the Chi-2 test indicates no significant difference.
Figure 4: Length/Weight relationships of male and female *Loligo forbesi* from different fisheries.

Figure 5: Length-at-maturity of female *Loligo forbesi* from different fisheries. Confidence intervals (95%) are included.