The pelagic squid assemblage of the Kerguelen Axis

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**Abstract:** Squids are increasingly acknowledged as an ecologically important group in Southern Ocean ecosystems, and most are represented exclusively by endemic species due to the biological barrier of Antarctic Polar Front. However, there are still large gaps in their now-known biogeographic components, especially the population diversity in the Indian sector. We thus present a first evaluation of diversity and distribution of the squid populations in the Kerguelen Plateau, based on a whole science survey of Kerguelen Axis conducted between January and February 2016. A total of 801 squid specimens were collected from 40 stations, at depths from the surface to 1000 m and were identified to seven taxa from six families, in which six species are highly endemic to the Southern Ocean. We examined geographic niche breadth of these species in terms of their distributions across stations and with depth. All of these species exhibited a broad niche breadth, being the Shannon-Wiener’s niche breadth index (*Bi*) from 1.91 to 8.43. Variations of diversity index were estimated in a range of 0.39-1.56, and most of the peak diversity stations were found at the short deep-sea slope area and deep-sea basin. This variation was consistent with the bathymetric gradient of depth, though the relationship was not statistically significant. In addition, the highest diversity was detected in the top 200 m of the water column, with an occurrence > 50% for most species at this depth stratum. This study preliminary demonstrates the squids’ population composition and occurrence in the Kerguelen Plateau, with new insights into their endemicity and diversity in this biologically important area.

**Keyword:** Squids; Biodiversity; Endemicity; Kerguelen Plateau; Southern Ocean.

**Materials and methods**

***Investigation area***



Fig.1 Position of sample sites. *S1…S40* indicate the sample stations. Stations were classified into three ecology categories: Deep-sea basin (DSB), short deep-sea slope (SDL) and long deep-sea slope (LDS).

***Data collection***

***Diversity and niche overlap indices***

The Shannon-Wiener diversity index (*H’*) {Shannon, 1948 #3464; Shannon, 1949 #3471} was used to calculate the squid taxa within each sample station and each depth stratum by the following formula, respectively:

$H^{'}=-\sum\_{i=1}^{s}p\_{i}Ln(p\_{i})$ with $p\_{i}=\frac{n\_{i}}{\sum\_{i=1}^{s}n\_{i}}$,

Where *ni* is the number of individuals of the *i*th species in the sample and *S* is the number of taxon. This index has been proved to be a popular species diversity index due to its simplicity and because sample size has little effect on the index {Spellerberg, 2008 #3467}.

Meanwhile, this equation of Shannon-Wiener diversity index was also to estimate the niche breadth for each species, known as niche breath index (*B’*) {Hu, 2016 #3472}, where the *S* is changed as the number of sample stations.

The Pianka’s overlap index (*O’*) {Pianka, 1973 #3470} was used to estimate the niche overlap among the squid taxa by the following formula:

$$O\_{i}=^{\sum\_{j=1}^{S}P\_{ij}P\_{ik}}/\_{\sqrt{\sum\_{j=1}^{S}P\_{ij}^{2}\sum\_{j=1}^{S}P\_{kj}^{2}}}$$

where *Pij* and *Pik* are the proportions of the *jth* sample station used by the *ith* and the *kth* species respectively, and *S* is the number of sample stations.

***Data analysis***

**Results**

**Species composition**

The 801 cephalopod species collected comprised at least seven species in six families (Table 1). Six of the seven species are high Antarctic endemics whose range extends as far north as the sub-tropic front, while the *Bathyteuthis abyssicola* is cosmopolitan distribution with the range extending into Antarctic waters {Rodhouse, 2014 #3076}. Dominant species were *Galiteuthis glacialis* and *Psychroteuthis glacialis*, which accounted for 68.79% and 11.24% of the total collection, respectively.

Table 1 Composition of cephalopod taxa

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Taxon | Abbreviation | Number | Percentage | Depth | Range | Ecology |
| Bathyteuthidae*Bathyteuthis abyssicola* | Baa | 25 | 3.12 | 2356\* | C-APF | MELe |
| Brachioteuthidae*Slosarczykovia circumantarctica* | Slc | 35 | 4.37 | 23456\* | A-SAF | EMB |
| Cranchiidae*Galiteuthis glacialis* | Gag | 551 | 68.79 | 23456 | A-STF | BMLe |
| *Mesonychoteuthis hamiltoni* | Meh | 20 | 2.50 | 2\*345 | A-APF | BNb |
| Mastigoteuthidae*Mastigoteuthis psychrophila* | Map | 56 | 6.99 | 456\* | A-APF | MB |
| Psychroteuthidae*Psychroteuthis glacialis* | Psg | 90 | 11.24 | 2356\* | A-SAF | MBNb |
| Neoteuthidae*Alluroteuthis antarcticus* | Ala | 19 | 2.37 | 23456\* | A-APF | M |
| UD |  | 5 | 0.62  | 6 |  |  |

Range: A-APF, Antarctic endemics extending north to the Antarctic Polar Front (APF); A-SAF, Antarctic endemics extending north to the Sub-Antarctic Front (SAF); A-STF, Antarctic endemics extending north to the Sub-Tropical Front(STF); C-APF, Cosmopolitan extending south of the APF. Ecology: E, epipelagic; M, mesopelagic; B, bathypelagic; Le, lower epipelagic; Nb, near bottom. Depth: 2, 1000~800m; 3, 800~600m; 4, 600~400m; 5, 400~200m; 6, 200~0m. \* indicates the occurrence >50% at the depth strata. UD, unidentified taxon due to only mantle left.

**Species niche dimension**

The seven squid species exhibited a niche breadth index from 1.91 to 8.43, and had an overlap index from 0.08 to 0.68 in the spatial dimension (Table 2). *Galiteuthis glacialis* had the biggest niche breadth followed by *Psychroteuthis glacialis* and *Mastigoteuthis psychrophila*, and consequently these three species showed higher niche overlap, being the overlap index of 0.62 and 0.59 respectively between *G. glacialis* and *M. psychrophila* and between *G. glacialis* and *P. glacialis*.

Table 2 Niche breadth and overlap indices among squids in the Kerguelen Plateau. Abbreviations of species names are listed in Table 1.

|  |  |  |
| --- | --- | --- |
|  | Niche breadth index (*Bi*) | Niche overlap index (*Oi*) |
| Slc | Baa | Gag | Meh | Map | Psg |
| Slc | 3.27  |  |  |  |  |  |  |
| Baa | 3.28  | 0.17  |  |  |  |  |  |
| Gag | **8.43**  | 0.19  | 0.44  |  |  |  |  |
| Meh | 1.91  | 0.08  | 0.13  | 0.46  |  |  |  |
| Map | 5.52  | 0.14  | 0.32  | 0.62  | 0.27  |  |  |
| Psg | 6.49  | 0.11  | 0.49  | 0.59  | 0.23  | 0.55  |  |
| Ala | 1.99  | 0.22  | 0.35  | 0.49  | 0.19  | 0.29  | 0.38  |

**Diversity at stations**

Among the 36 stations with squids available, three stations were detected with only one species collected, being stations of *S*10, *S*22 and *S*25. In the rest stations with more than one squid species collected, the Shannon-Wiener diversity index (*H’*) was estimated in a range of 0.39-1.56, with a general index value of 1.15 (estimated as the index of the whole sampled area) (Fig. 2). The peak diversity was found in stations of *S*9, *S*11, *S*17, *S*20, *S*26, *S*28 and *S*31, being the indices > 1.2. The ANOVA revealed a significant higher diversity in these peak diversity stations than other stations (*F*=23.91, *P*=0.000024).

Among these peak diversity stations, species predominating by numbers was *Galiteuthis glacialis*, with a mean percentage of 51.16±7.65%, followed by *Psychroteuthis glacialis* (14.30±10.37%) and *Mastigoteuthis psychrophila* (11.99±5.87%) (Fig. 3a). In addition, even though most of peak diversity stations were found at the short deep-sea slope area and deep-sea basin, the mean diversity index was not significant different between each other of short deep-sea slope, deep-sea basin and long deep-sea slope (ANOVA: *F*=0.127, *P*=0.881) (Fig. 3b).

![D:\博士学位\ACE-CRC Visiting Schorlar\Researching papers\02 Diversity of Squids in Kerguelen Plateau\02 K-axis Pictures\Fig.2 Diversity index at station[01].tif]()

Fig.2 Shannon-Wiener diversity index (*H’*) of squids in relation to sample stations. *S.3*…*S.40* indicate sample stations.



Fig.3 Occurrence of squids at peak diversity stations (**a**) and mean Shannon-Wiener diversity index (*H’*) among sample areas (**b**). Abbreviations of species names are listed in Table 1; abbreviations of sample areas as following: DSB, deep-sea basin; SDS, short deep-sea slope; LDS, long deep-sea slope.

**Diversity at depth**

Three species, including *Alluroteuthis antarcticus, Galiteuthis glacialis* and *Slosarczykovia circumantarctica*,were found occurrence from -1000m to the surface, and *Mastigoteuthis psychrophila* was only collected above -600m depth (Fig. 4a). Most species were found at the depth stratum of -200-0m, with an occurrence of more than 50% (Fig. 4a)*.* The *Mesonychoteuthis hamiltoni* was most collected at the depth strata of 1000-800m, being a percentage of 50.1%, while *Galiteuthis glacialis* was more frequent in the depth strata of 1000-800m and 800-600m, with a combined occurrence of 54.67%.

The Shannon-Wiener index at depth ranged from 0.32 to 1.73, and the highest diversity was measured from 200-0m (ANOVA: *F*=14.169, *P*<0.0001), with an average index of 1.04±0.27 (Fig. 4b). Regarding the three ecology categories, there were not any statistical differences between each other at the same depth stratum (ANOVA: -1000- -800m, *F*=1.451, *P*=0.273; -600- -400m, *F*=1.440, *P*=0.410; -400- -200m, *F*=0.040, *P*= 0.850; -200- 0m, *F*=0.010, *P*=0.990), with an exception at the depth from -800m to -600m (ANOVA: *F*=7.334, *P*=0.024) (Fig. 4c).



Fig.4 The occurrence (**a**), Shannon-Wiener diversity index (H’) (**b**) and diversity at different ecology (**c**) of squids in relation to sample depth. At (**b**), horizontal lines indicate the average diversity measure at the respective depth stratum, vertical lines the standard deviation. “\*” indicates significant difference at *P*<0.05.

**Diversity at bathymetric depth**

Five of the seven squids were found an increasing trend along with the bathymetric gradients from -1500m to -5000m, but it was not statically significant (Fig. 5a). The occurrence of *Mesonychoteuthis hamiltoni* declined sharply with the bathymetric gradients (Pearson’s *r*=-0.79, *F*=14.75, *P*=0.0039), and *Psychroteuthis glacialis was* also found a decreasing trend but not significant with the bathymetric gradients (Pearson’s *r*=-0.047, *F*=0.054, *P*=0.82). Then the diversity along the bathymetric gradient of depth was positively linear increase with the increasing depth (Pearson’s *r*=0.25) (Fig.5b). However, the linear relationship was not significant (*F*=1.98, *P*=0.17).



Fig. 5 Relationship between Shannon-Wiener diversity index (H’) (**a**) and occurrence (**b**) of squids and the bathymetrical depth. Abbreviations of species names are listed in Table 1.