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Surveys on Neon Flying Squid by Squid Jigging in the High Sea of Northwest Pacific Ocean

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Summary

Surveys conducted between 2021 and 2024 by R/V Songhang, Shanghai Ocean University's pelagic fishery resources survey vessel, revealed that the predominant squid species in the Northwest Pacific Ocean, which were Neon flying squid, Boreal clubhook squid, Boreopacific armhook squid, Clubhook squid and Luminous flying squid. Except for the neon flying squid, the other four squid species were bycatches for squid jigging. Catch data of R/V Songhang between 2021 and 2024 were mapped in this report to illustrate the fishery status. Basic Biological Characteristics of Neon flying squid, including the mantle length (ML) composition, body weight (BW) composition, ML-BW relationship, sexual maturity composition, and feeding ecology information were also detailed in this report. As China gradually improves and stabilizes the survey for NFS, the R/V Songhang's independent fisheries biology information will be provided as the basis for the NFS stock assessment.

Material and Methods

Jigging

The main squid jigging methods include hand-jigging and machine jigging. The squid jigging equipment consist of a jigging machine, the main line (No. 60 nylon line), the branch lines (No. 40 nylon line), fluorescent lures (soft plastic machine jigging hooks), and heavy hooks (stainless steel spindle-shaped hooks). The main operational parameters included anchoring the vessel, deploying the tail sail, activating the jigging machine at predetermined times and locations, and deploying the jigs to attract and capture squid. The detailed information are exhibited in Table 1.

Table 1 Information of squid jigging by R/V Songhang in the Northwest Pacific Ocean between 2021 and 2024.

Year	Jigging depth (m)	Start time	End time	Duration (h)	Number of hooks
2021	/	/	/	/	/
2022	100~150	17:50~18:00	21:00~22:40	3~4.5	8
2023	100~150	17:00~19:30	20:00~1:30	2.5~8.5	8
2024	50~150	17:30~18:00	21:30~22:30	3.5~5	8

Sampling

All catches were counted and photographed. The number and CPUE were recorded, along with relevant jigging machine data, including initial and final vessel positions, heading, jigging line speed, fishing depth, depth of underwater lights, and line entanglement conditions. Samples were stored in order according to the sampling time and transferred to the fish hold for freezing and preservation. All catch specimens were frozen and brought back to the laboratory for further biological analysis, which includes the measurement of mantle length, body weight, sexual maturity, feeding intensity, and basic information on stomach contents.

Fishing Status

Data on squid fisheries of R/V Songhang, Shanghai Ocean University's pelagic fishery resources survey vessel, from June to August each year between 2021 and 2024 in the Northwest Pacific Ocean were digitized and collated by the National Data Center for Distant-Water Fisheries of China at Shanghai Ocean University. The data encompassed fishing year, squid species composition, total catch, basic biological characteristics and basic feeding ecology information. Figure 1 shows the predominant squid species for the Northwest Pacific Ocean, which are Neon flying squid, Boreal clubhook squid, Boreopacific armhook squid, Clubhook squid and Luminous flying squid. The CPUE of squid jigging in 2022 ranged from 0 to 31.25. The largest CPUE reached 124.33 in 2023 and 64.80 in 2024 (Figure 2).

No Neon flying squid were caught in 2021, a total of 98 Neon flying squid were caught in 2022, 2574 Neon flying squid were caught in 2023 and 764 Neon flying squid were caught in 2024. The underlying biology and feeding ecology of the Neon flying squid was not examined due to the limited sample size. The spatial distribution of Neon flying squid predominantly lay within the coordinates 160°E-165°E, 40°N-45°N (Figure 3).

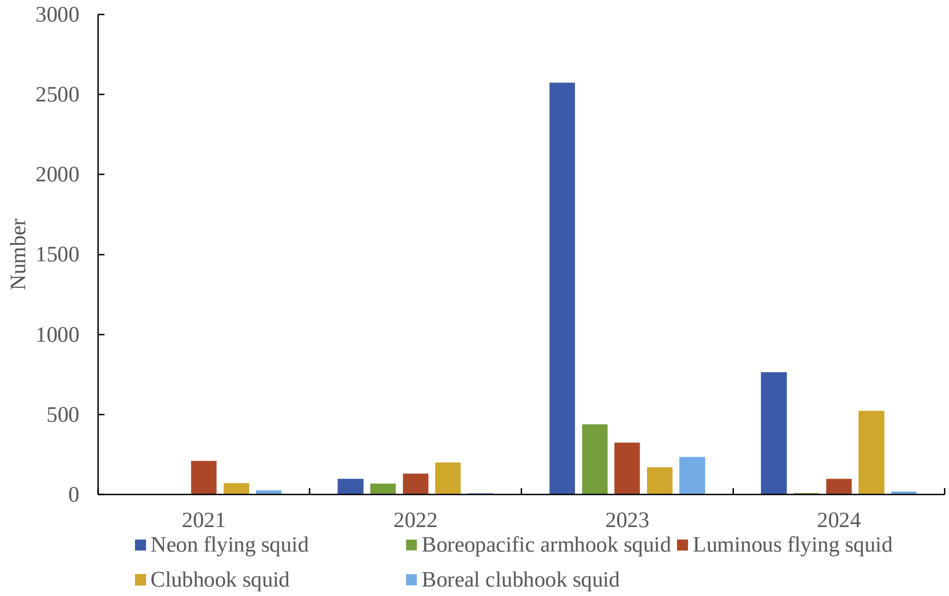


Figure 1 Catch of squid species in the Northwest Pacific Ocean by R/V Songhang between 2021 and 2024

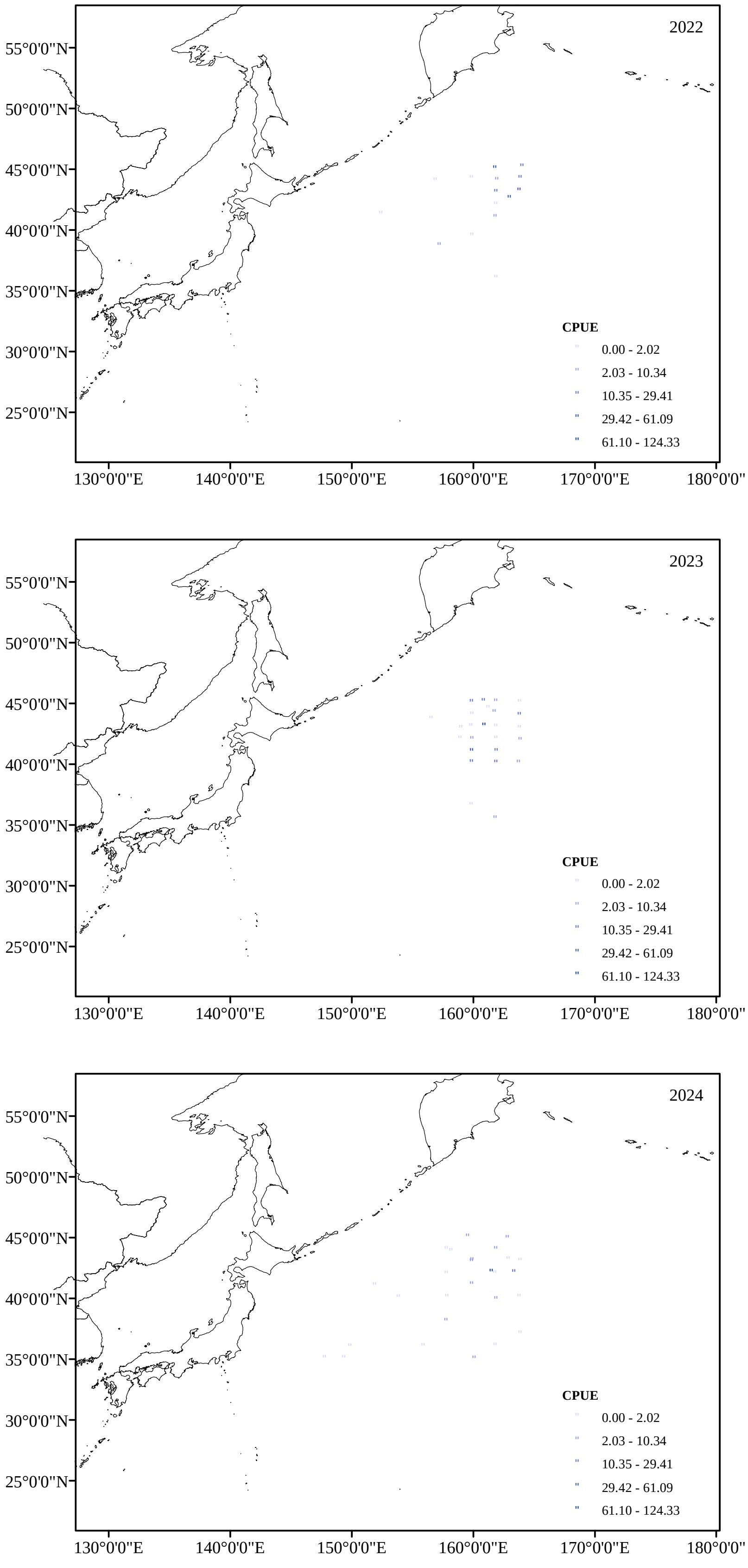


Figure 2 CPUE of squid jigging in the Northwest Pacific Ocean by R/V Songhang between 2022 and 2024

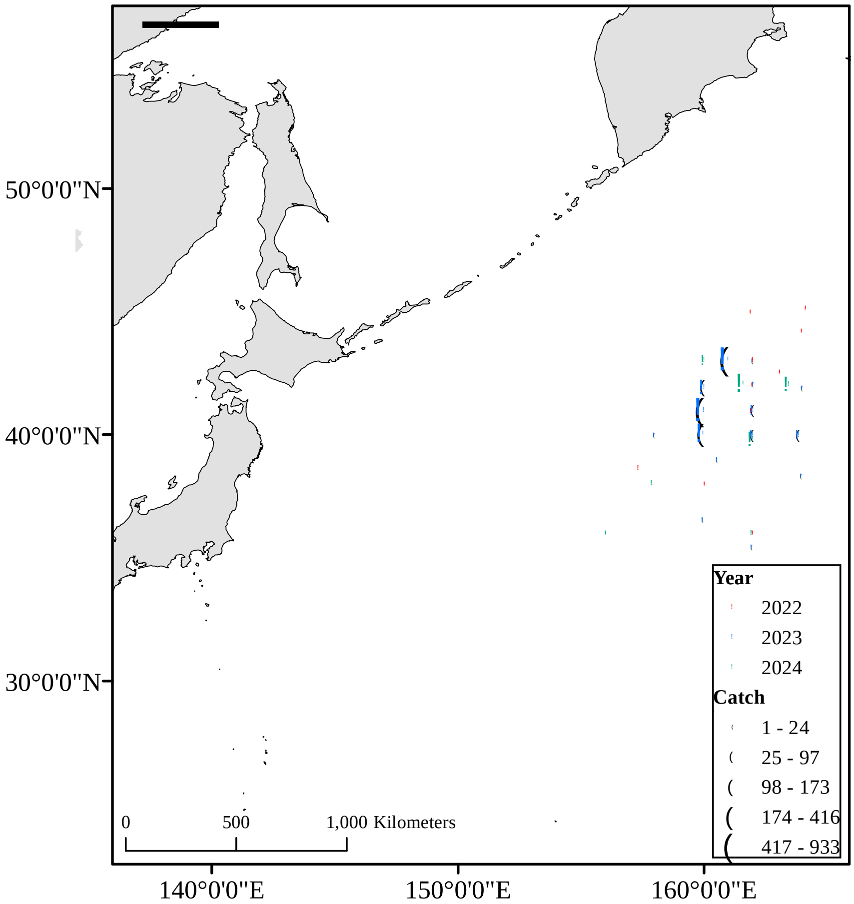
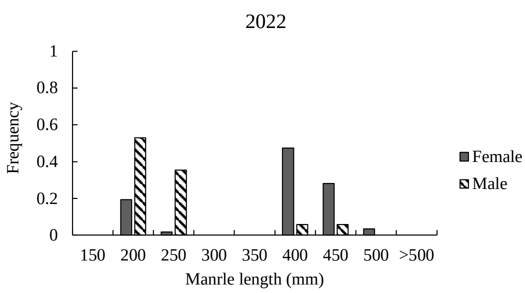


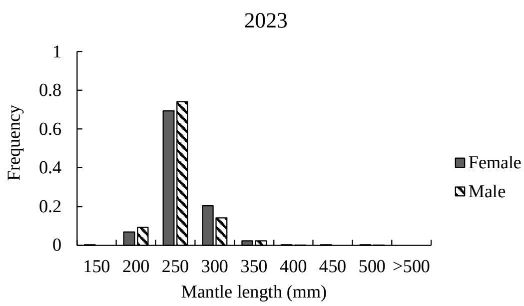
Figure 3 Distribution of Neon flying squid in the Northwest Pacific Ocean by R/V Songhang between 2022 and 2024

Basic Biological Characteristics

Mantle length composition

Figure 4 shows the mantle length (ML) composition of Neon flying squid caught by R/V Songhang in the Northwest Pacific Ocean between 2022 and 2024.The ML of Neon flying squid primarily ranged from 200 to 250 mm for male individuals and the ML for female individuals ranged from 400 to 450 mm in 2022. The ML of Neon flying squid concentrates in the range of 250 to 300 mm in 2023 while it shifted to the range of 200 to 250mm in 2024.





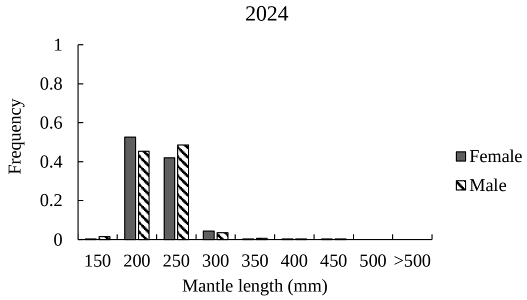


Figure 4 Mantle length composition of Neon flying squid caught by R/V Songhang between 2022 and 2024

Body weight composition

Figure 5 shows the body weight (BW) composition of squid species caught by R/V Songhang in the Northwest Pacific Ocean between 2022 and 2024. The Neon flying squid individuals mainly weighed over 1200 g in 2022. The BW of Neon flying squid primarily ranged from 150 to 450g in 2023 and 2024.

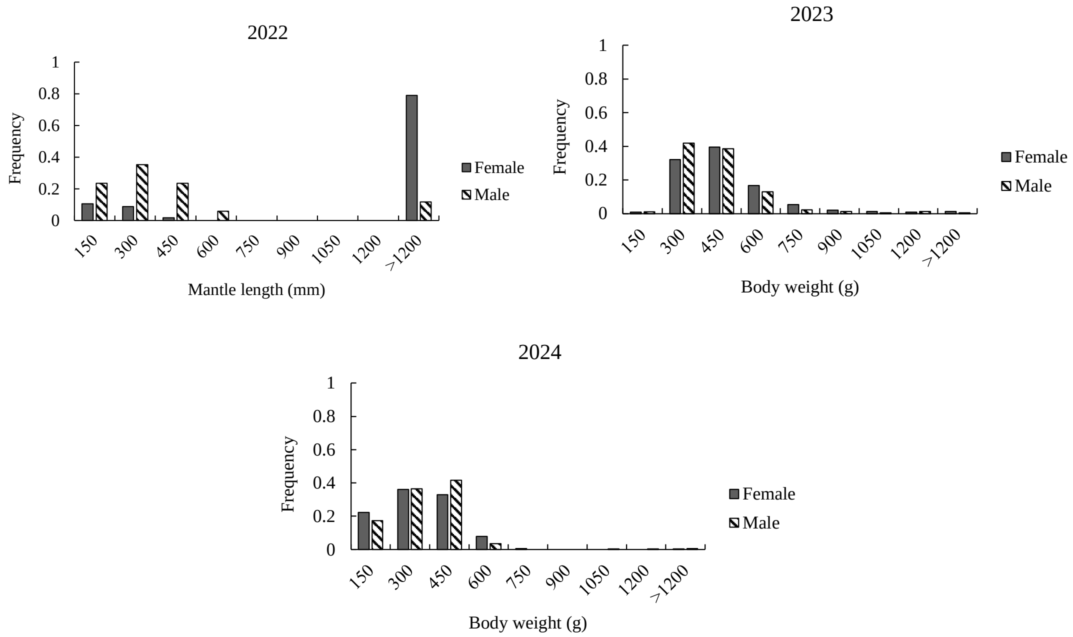


Figure 5 Body weight composition of Neon flying squid caught by R/V Songhang between 2022 and 2024

ML-BW relationship

Figure 6 shows the ML-BW relationship of Neon flying squid caught by R/V Songhang in the Northwest Pacific Ocean between 2022 and 2024. The relationship between ML and BW was fitted with a power function：$BW=a(ML)^b$(Wang et al., 2023), where the value of the growth parameter b can be used as an indicator of the adaptability of marine organisms to changes in the ocean(Zhu et al., 2015). The value of the growth parameter b can be used as an indicator of the degree of cephalopod body fatness. The growth pattern of Neon flying squid was anisometric (b≠3). The growth parameter of Neon flying squid was larger than 3 in 2022, but it dropped below 3 in 2023 and 2024, which indicated that the body size of this species might be thinner than before.

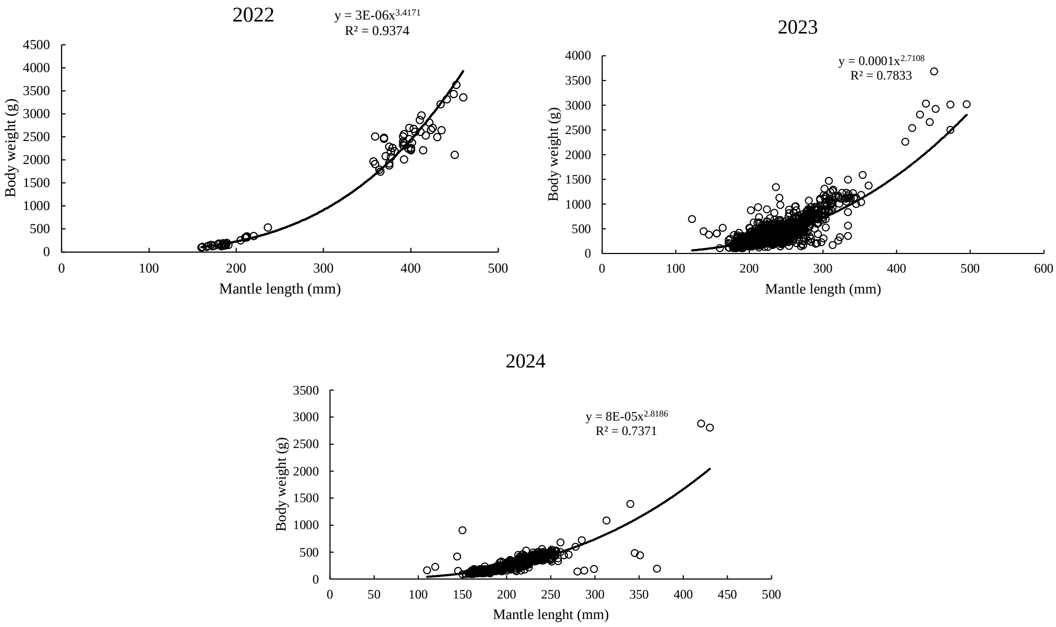


Figure 6 ML-BW relationships of Neon flying squid caught by R/V Songhang between 2022 and 2024

Sexual maturity composition

Figure 7 shows the sexual maturity composition of squid species caught by R/V Songhang in the Northwest Pacific Ocean between 2022 and 2024. The sexual maturity composition analysis indicated a higher percentage of sexually unmatured individuals in Neon flying squid whose sexual maturity was mainly concentrated in stages I and II. It can be observed that female individuals showed higher sexual maturity than males in 2022. The sexual maturity of both sexes were approximately the same in 2023 and 2024.

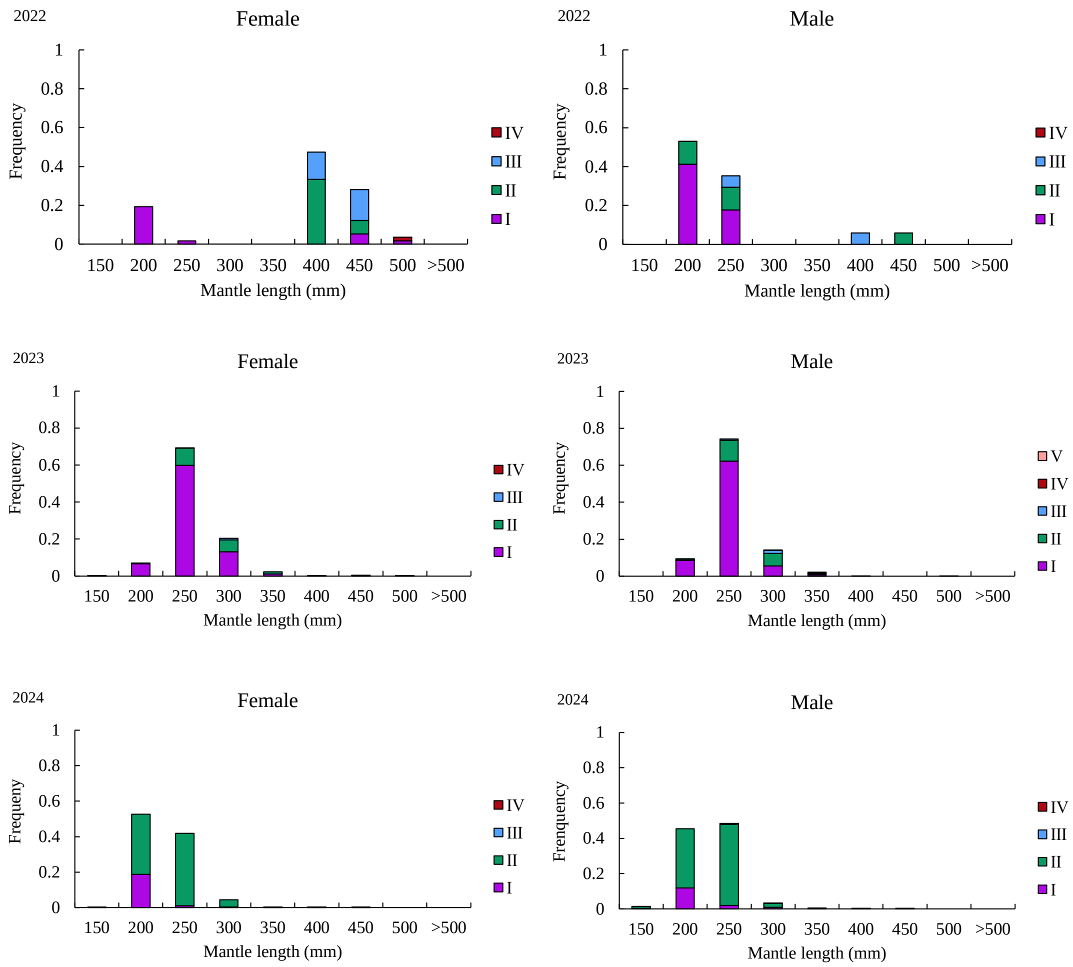


Figure 7 Sexual maturity composition of Neon flying squid caught by R/V Songhang between 2022 and 2024

Feeding ecology

Stable isotope analysis

Figure 8 presents the relationships between $\delta^{13}C$, $\delta^{15}N$, and mantle length (ML) of muscle samples contributed by Neon flying squid caught by R/V Songhang in 2022 and 2024 using a non-parametric locally weighted regression(LOESS). The $\delta^{15}N$ values exhibited an increasing trend between 0 to 200 mm and above 400 mm in 2022. The $\delta^{15}N$ values increased between 200 to 250mm in 2024. The $\delta^{13}C$ value showed an increase between 0 to 200 mm and a decrease above 400mm individuals in 2022. The $\delta^{13}C$ values decreased when the ML were below 200 mm and slightly increased between 200 to 250 mm. Figure 9 shows the standard Bayesian niche ellipses for the squid. The results indicate that at the 40% confidence interval, the standard ellipse area (SEA) was 0.34 for 2022 and 0.74 for 2024.

$\delta^{15}N$ values can be used to illustrate the trophic position of marine creatures(Zhou et al., 2024) while $\delta^{13}C$ values vary greatly with latitude and/or over inshore/offshore gradients(Kato et al., 2016). Overall, the $\delta^{15}N$ values of the squid exhibited an increasing trend. This suggested that as the predating ability grows stronger with their ML, the trophic level gradually increases. The $\delta^{13}C$ values showed a decreasing trend which indicates that the Neon flying squid undertake offshore migrations.

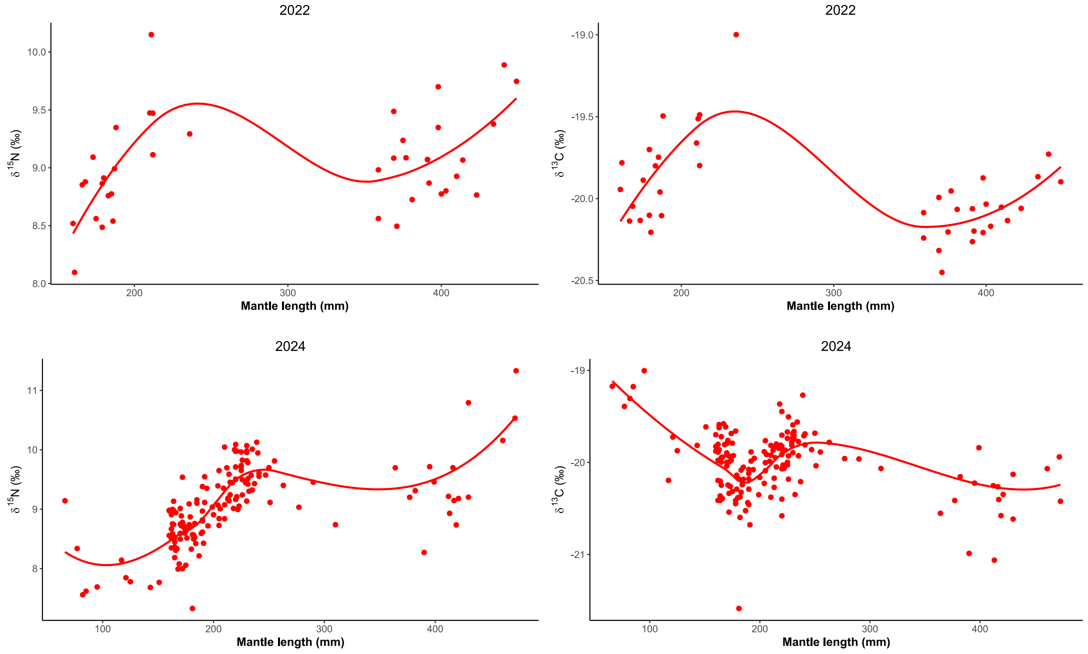


Figure 8 Relationship of Mantle length, δ13C and δ15N in Neon flying squid caught by R/V Songhang in 2022 and 2024

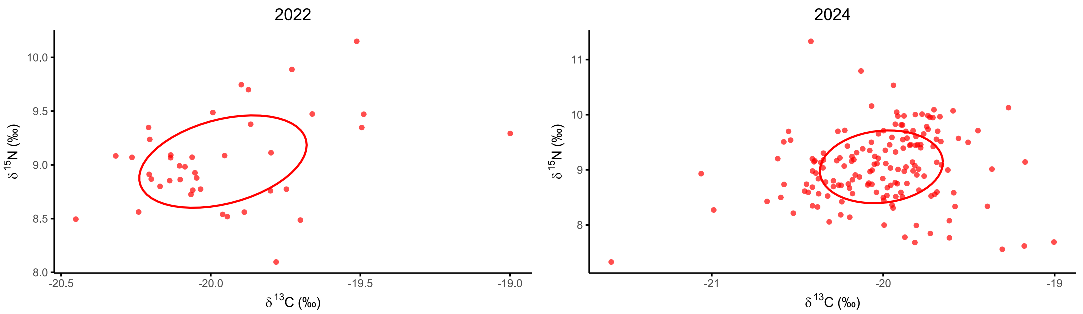


Figure 9 Trophic niche eclipse area of Neon flying squid caught by R/V Songhang in 2022 and 2024

Stomach content analysis

Figure 10 shows the result of high-throughput sequencing for the stomach content of Neon flying squid caught by R/V Songhang in 2022. The main prey species for the Neon flying squid are Pacific sardine (*Sardinops sagax*), Boreal clubhook squid (*Onychoteuthis borealijaponica*), Boreopacific armhook squid (*Gonatopsis borealis*) and firefly squid (*Watasenia scintillans*), exhibiting both high relative abundance and frequency of occurrence. Pacific krill (*Euphausia pacifica*) although having a relatively low abundance, showed a frequency of occurrence of 53.33%. *Notoscopelus caudispinosus* and duckbill barracudina (*Magnisudis atlantica*) had relatively high abundances but were found in only a single sample (Table 2).

Neon fly squid's preference on Pacific sardine may be attributed to the high abundance of sardine resources in the Northwest Pacific in summer and the spatial overlap in habitat between the two species(Pearcy et al., 1996). The high similarity in diel vertical migration patterns between the squid and myctophid fishes is likely one of the main reasons for the squid's predation on Myctophidae(Watanabe et al.,1999). Overall, the feeding habits of Neon flying squid showed high connectivity to the consistency of the preys' habitat. (Wang et al., 2024)

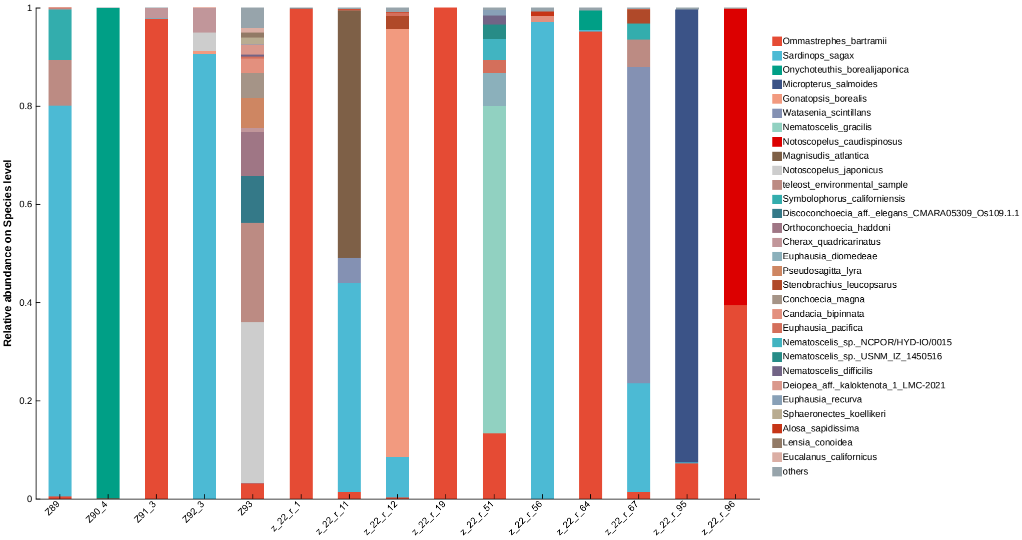


Figure 9 Prey species composition of Neon flying squid caught by R/V Songhang in 2022

Table 2 The top 20 prey species with percentage of relative abundance in the stomach contents of Neon flying squid in 2022

Prey species	Percentage of abundance/%	Occurrence rate/%	Rank
Sardinops sagax	24.900	73.33	1
Onychoteuthis borealijaponica	7.678	13.33	2
Gonatopsis borealis	6.490	13.33	3
Watasenia scintillans	5.115	20	4
Nematoscelis gracilis	4.862	6.67	5
Notoscopelus caudispinosus	4.558	6.67	6
Magnisudis atlantica	3.747	6.67	7
Notoscopelus japonicus	2.639	13.33	8
Symbolophorus californiensis	1.091	13.33	9
Discoconchoecia spp.	0.735	6.67	10
Orthoconchoecia haddoni	0.648	6.67	11
Euphausia diomedeae	0.507	6.67	12

Pseudosagitta lyra	0.384	6.67	13
Euphausia pacifica	0.351	53.33	14
Stenobrachius leucopsarus	0.349	13.33	15
Conchoecia magna	0.336	6.67	16
Nematoscelis spp.	0.327	6.67	17
Candacia bipinnata	0.317	13.33	18
Nematoscelis difficilis	0.193	13.33	19
Euphausia recurva	0.163	13.33	20

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