Spatio-temporal variations in the stable carbon and nitrogen isotopic compositions of Delphinidae species in the western North Pacific

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Biogeography of small odontocetes

Cetacean sighting surveys (Jul-Sep 1983-2006)

Subarctic

 Transitional domain

 Transition zone

Subtropical

(Kanaji et al. 2016 Fisheries Oceanography)
Biogeography of small odontocetes in subtropical and adjacent waters

Common bottlenose dolphin

Pantropical spotted dolphin

Subtropical–Mixed-water region

Subtropical waters

Striped dolphin

Short-beaked common dolphin

Subarctic boundary

Transition zone

The distributional patterns represent only for summer months
Motivations

**Hypothesis**
Even if habitats overlap considerably, resource partitioning is expected to occur to a certain degree in order to reduce interspecific competitions

**Three dimension of resource partitioning**
- **space (geographic location and habitat type)**
  Species specific spatial distributions has been known for summer
- **time (year, season and day)**
  Temporal changes of habitat utilization patterns are unknown
- **diet (trophic position and prey type)**
  Diet information is also limited in the coastal waters

**Stable isotopes: time-integrated trophic information**
Characterize habitat and resource partitioning among dolphin species
Skin biopsy samples

During sighting surveys, skin biopsy samples were collected opportunistically using small stainless steel biopsy tips with either pole or crossbow.

Skin samples were used for analyzing carbon ($\delta^{13}C$) and nitrogen stable isotope ratio ($\delta^{15}N$).
Total 252 samples were collected between 1993 and 2015 during the North Pacific cetacean sighting surveys.
Statistical Analyses

Carbon ($\delta^{13}C$) and Nitrogen ($\delta^{15}N$) stable isotope ratio were analyzed in relation to spatiotemporal variables.

**Generalized linear mixed model (GLMM)**

$$\delta X_{ij} = f \text{ (day)} + \text{longitude} + \text{latitude} + a_i + \varepsilon_{ij}$$

The $f(x)$ is a periodic function to describe periodic seasonal patterns:

$$f(x) = a_1 \sin(2\pi x) + a_2 \cos(2\pi x)$$

$a_i \sim N(0, \sigma^2_{\text{Survey}})$: the $i$-th survey was considered as a random factor,

Because,

1. the areas covered and seasons differed among years
2. small sample size in each year
   → will make it difficult to discriminate actual year-to-year variations from random variations.
3. different methods for sample preservation were used
   → may affect stable isotope values

$\varepsilon_{ij} \sim N(0, \sigma^2)$: the normal error distribution was specified
Carbon isotope ratio—spatiotemporal variation (1)
Carbon isotope ratio—spatiotemporal variation (2)
Nitrogen isotope ratio—spatiotemporal variation (1)
Nitrogen isotope ratio—spatiotemporal variation (2)
Discussion

Conclusion
Spatiotemporal patterns of habitat utilization differed among species

Why isotope ratios were different among species?

Habitat range
short-beaked common dolphins are distributed north to the subarctic boundary, while the other species were distributed to farther south

Feeding ecology & body size
Common bottlenose dolphins eat wide variety of prey, including benthic and pelagic fish and squids, and their larger body size might enables to eat larger sized predatory fish.
Discussion

Why isotope ratio varied spatiotemporally?

Seasonal variation
Prominent for striped dolphins. According to northward migration, the dolphins may eat prey species grown large in high latitudes.

Longitudinal gradient
Coastal–offshore differences in $\delta^{13}C$ values between phytoplankton and benthic algae, and enhanced $\delta^{15}N$ in inshore regions due to anthropogenic nitrogen induced by wastewater and denitrification in the euphotic zone.

Latitudinal gradient (decrease in $\delta^{13}C$)
The $\delta^{13}C$ of phytoplankton decrease from equatorial waters to the pole because low growth rates in cool higher latitudes affects carbon isotopic discrimination.

Latitudinal gradient (increase in $\delta^{15}N$)
In the upstream waters of Kuroshio, the $\delta^{15}N$ is depleted by nitrogen-fixing blue-green algae, and the density of those algae decreases downstream.