

A photograph of a dolphin leaping from the water, creating a large splash. The dolphin is captured mid-air, with its body arched and its tail fluke visible. The water is a vibrant blue-green color, and the splash is white and frothy. The background shows the surface of the ocean with gentle ripples.

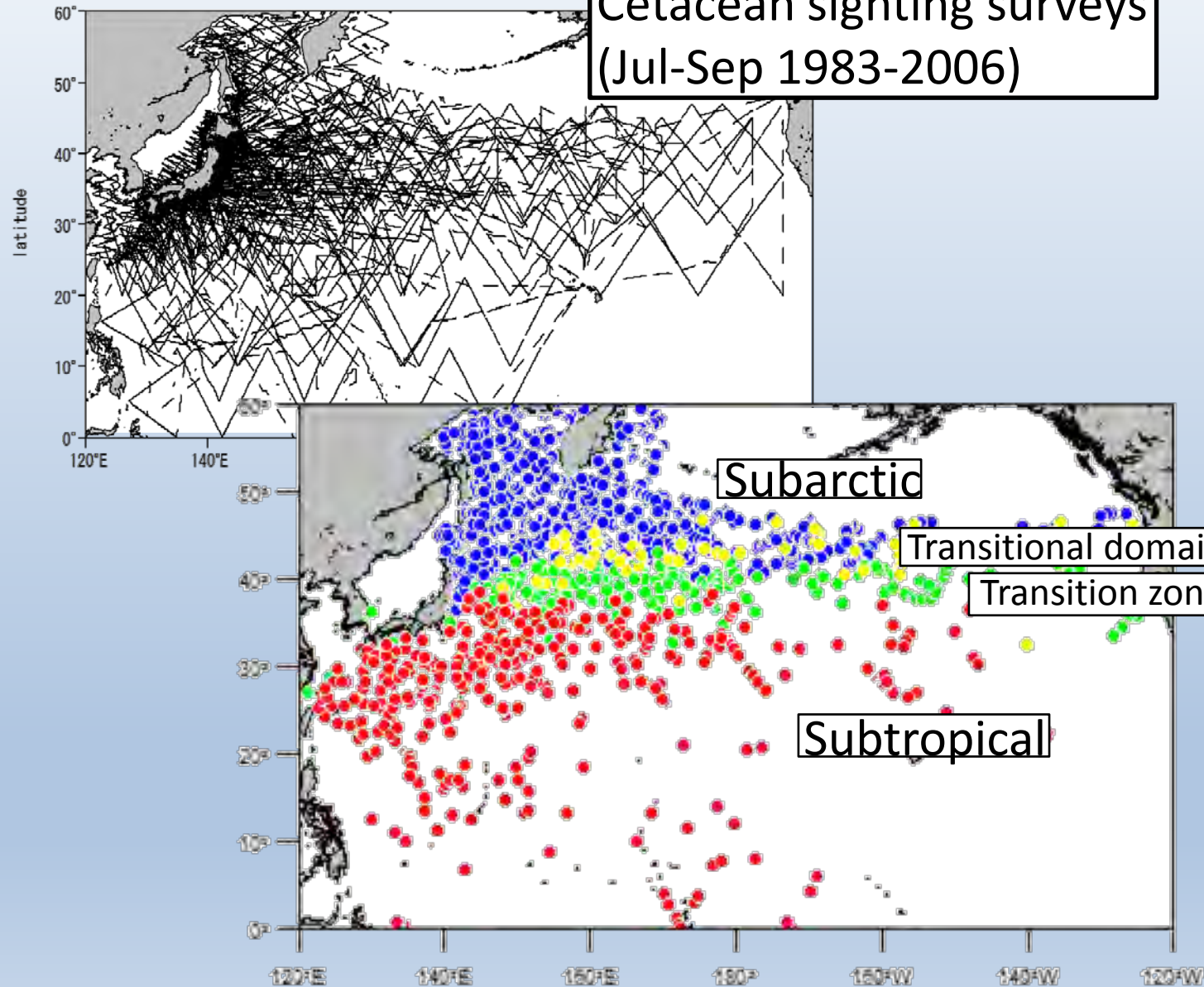
# **Spatio-temporal variations in the stable carbon and nitrogen isotopic compositions of Delphinidae species in the western North Pacific**

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# Biogeography of small odontocetes

Cetacean sighting surveys  
(Jul-Sep 1983-2006)



● Dall's porpoise



● Northern right whale dolphin



● Short-beaked common dolphin



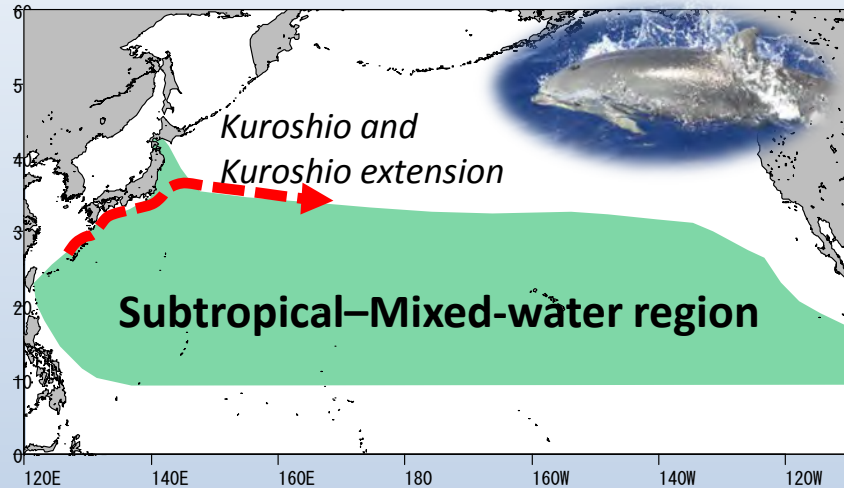
● Pantropical spotted dolphin

(Kanaji et al. 2016 Fisheries Oceanography)

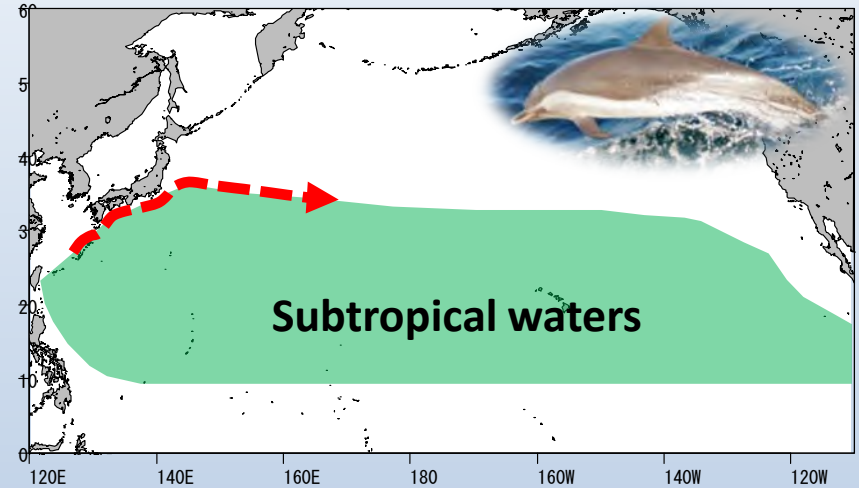


# Biogeography of small odontocates in subtropical and adjacent waters

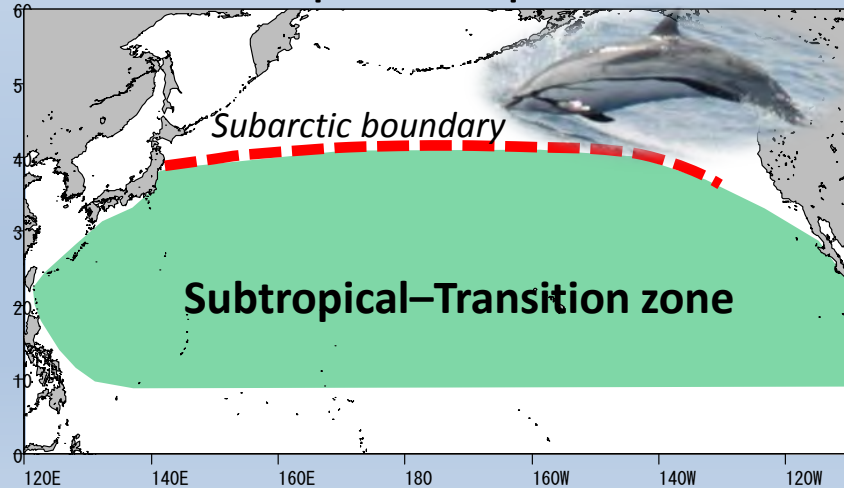
Common bottlenose dolphin



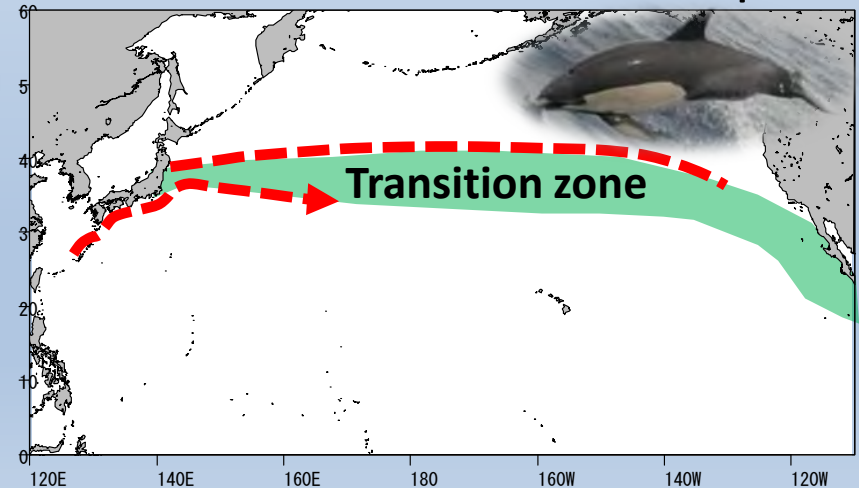
Pantropical spotted dolphin



Striped dolphin



Short-beaked common dolphin



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 inter-specific 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

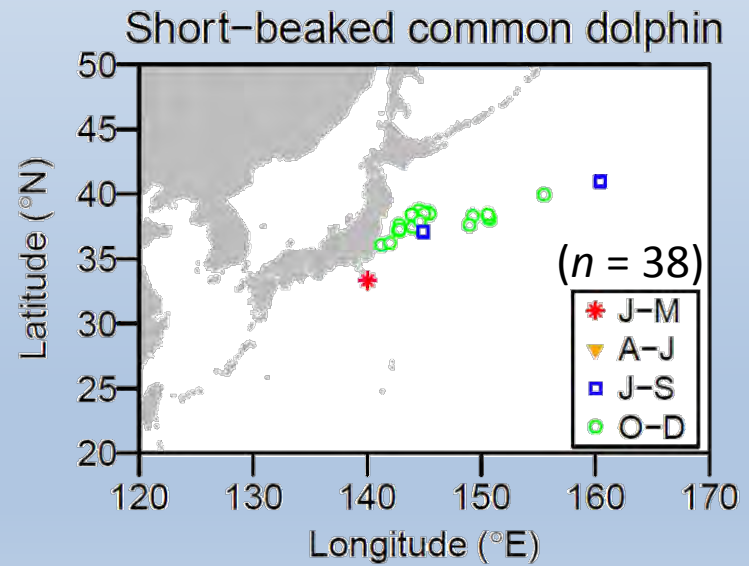
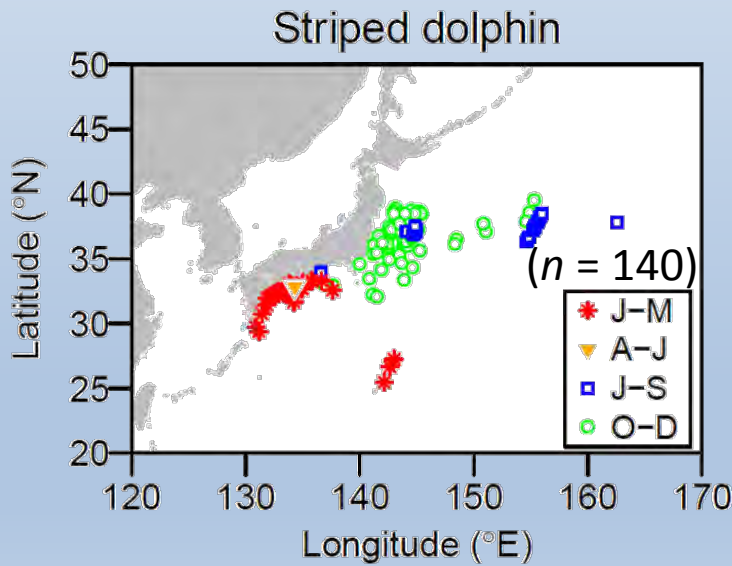
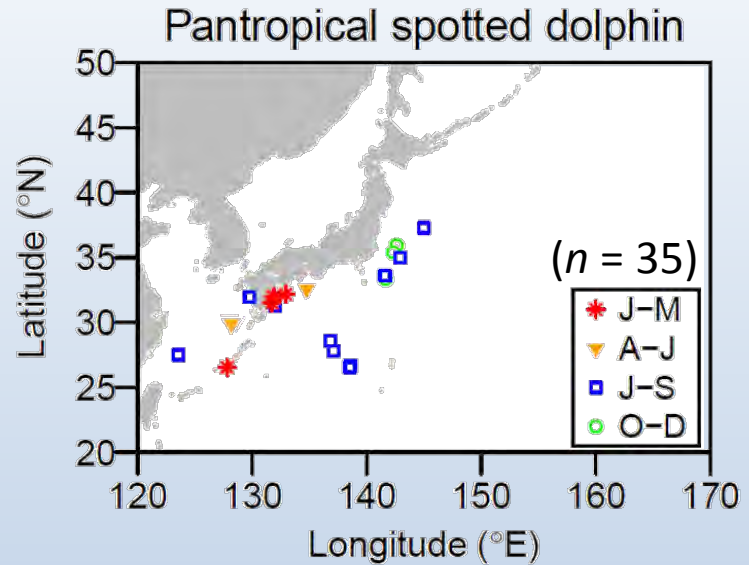
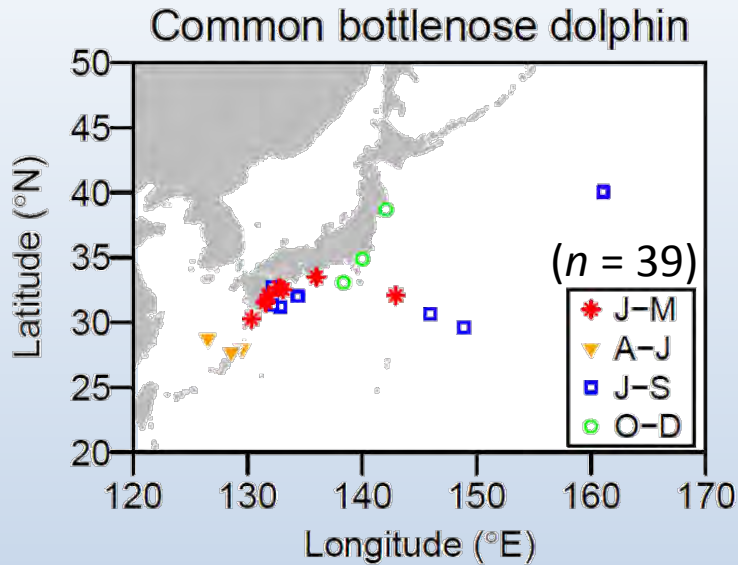
# Skin biopsy samples

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 ( $\delta^{13}\text{C}$ ) and nitrogen stable isotope ratio ( $\delta^{15}\text{N}$ )

# Sampling positions



Total 252 samples were collected between 1993 and 2015 during the North Pacific cetacean sighting surveys

# Statistical Analyses

Carbon ( $\delta^{13}\text{C}$ ) and Nitrogen ( $\delta^{15}\text{N}$ ) 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**,

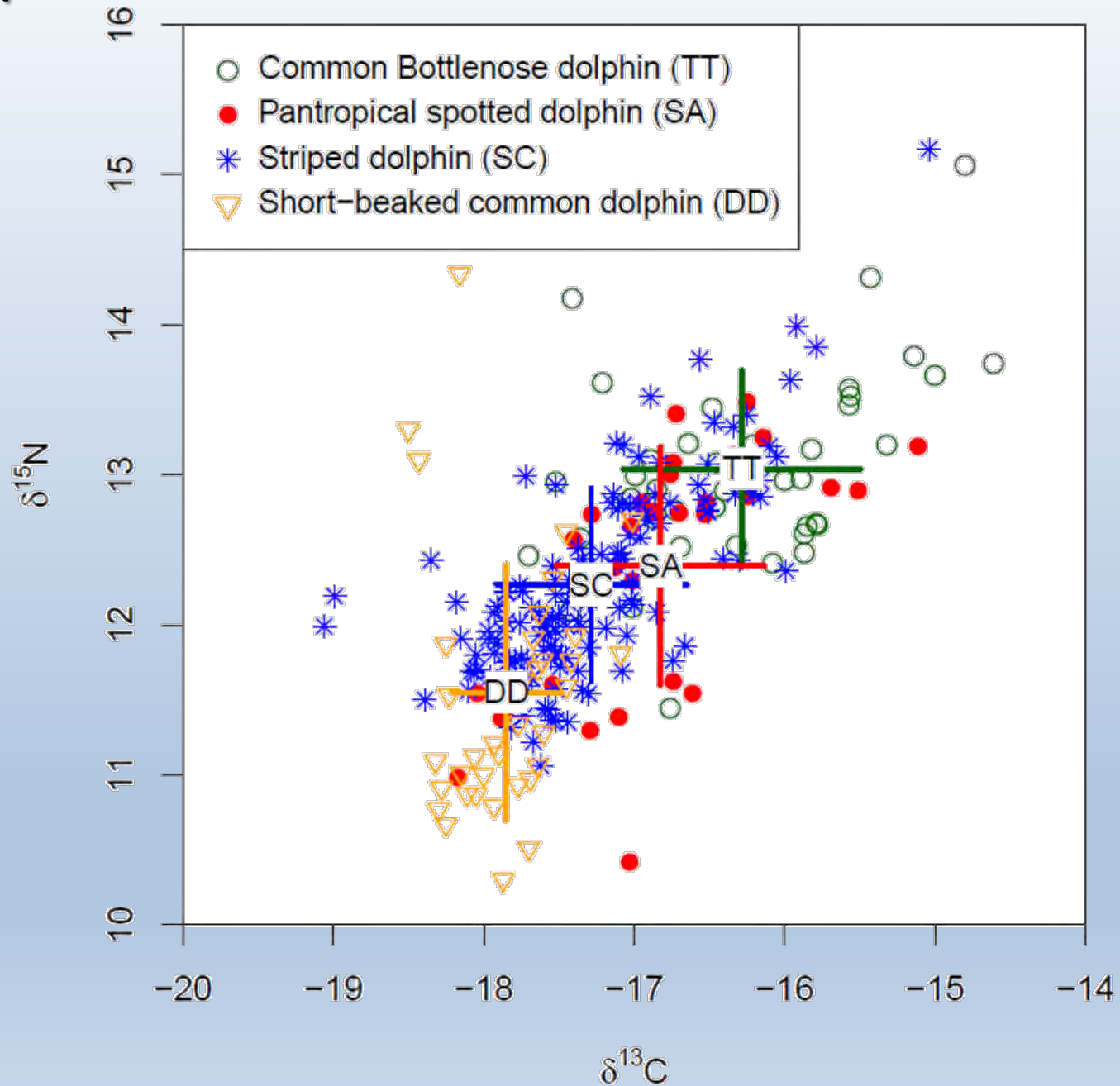
Because,

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



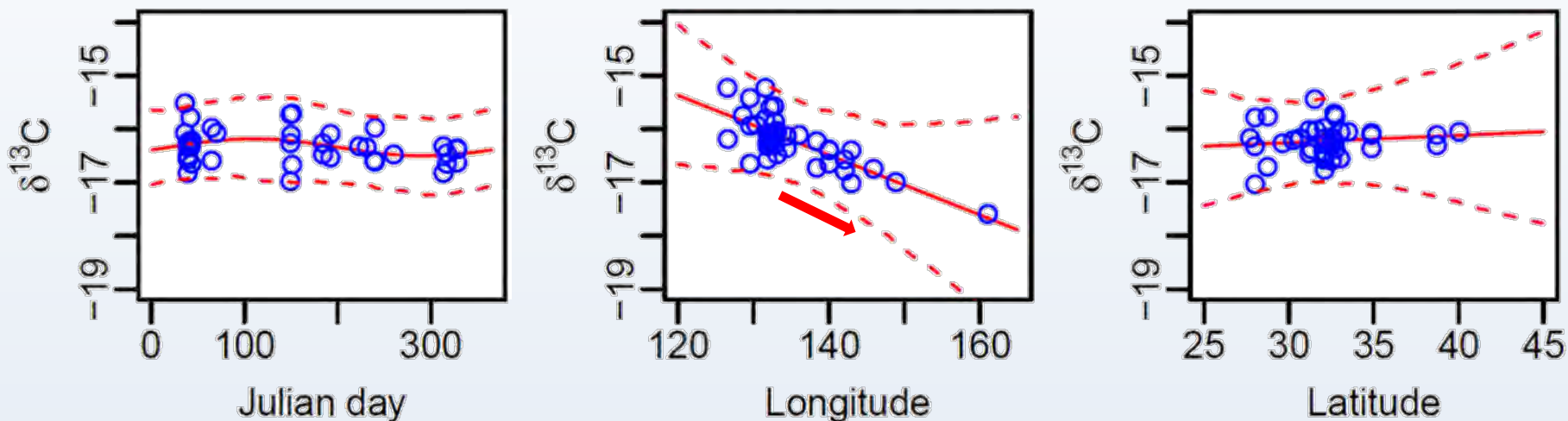
# C-N map



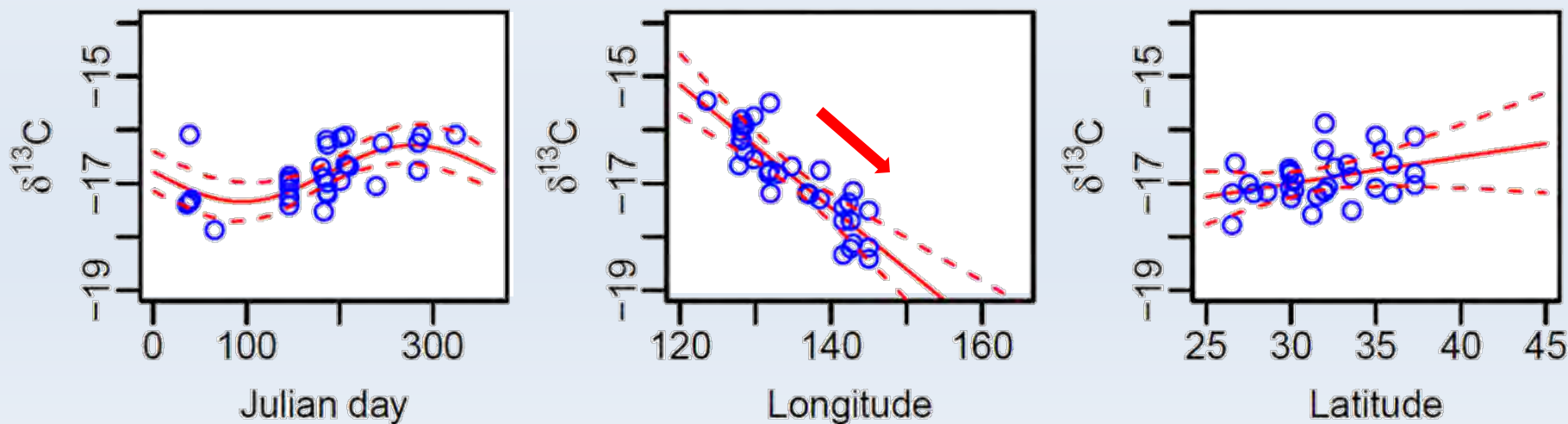


# Carbon isotope ratio—spatiotemporal variation (1)

## Common bottlenose dolphin

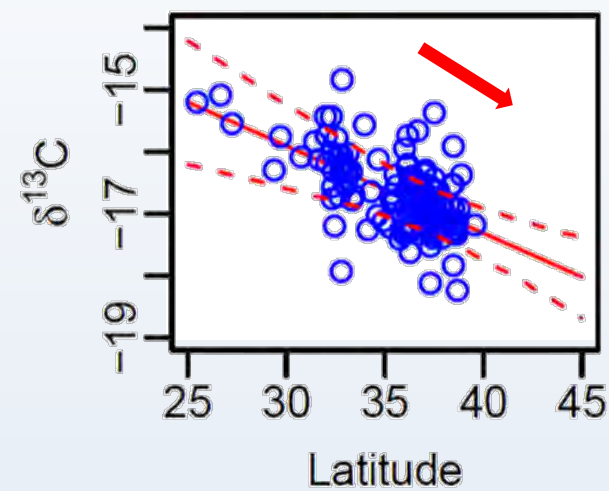
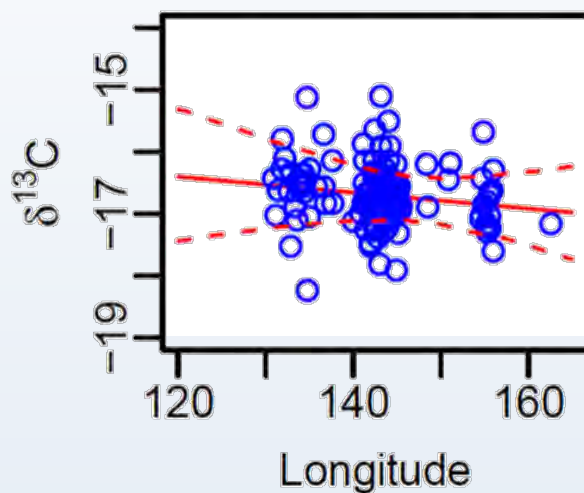
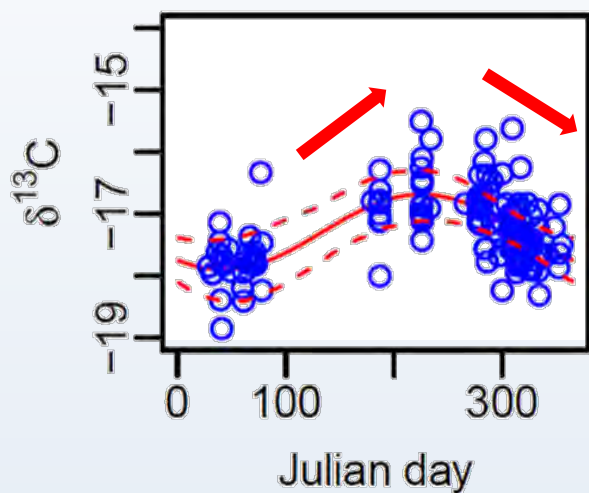


## Pantropical spotted dolphin

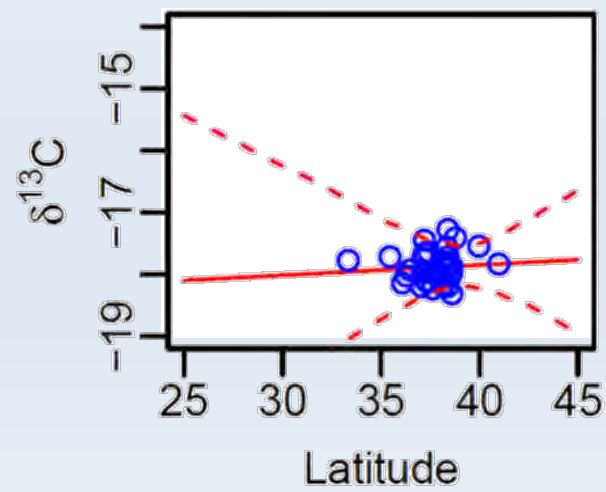
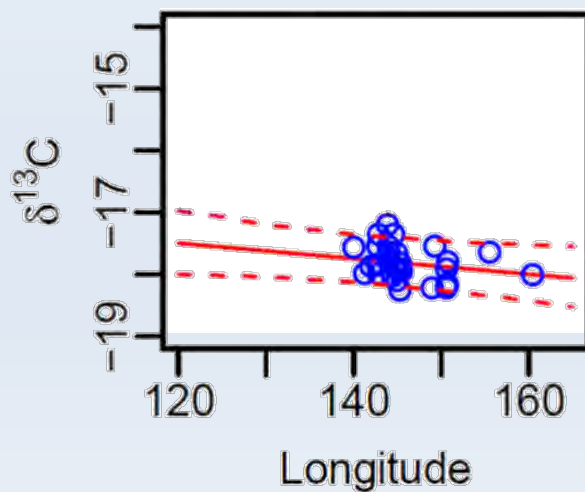
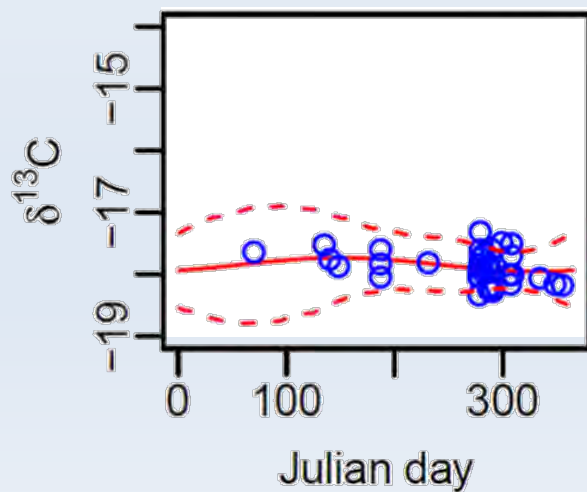


# Carbon isotope ratio—spatiotemporal variation (2)

## Striped dolphin

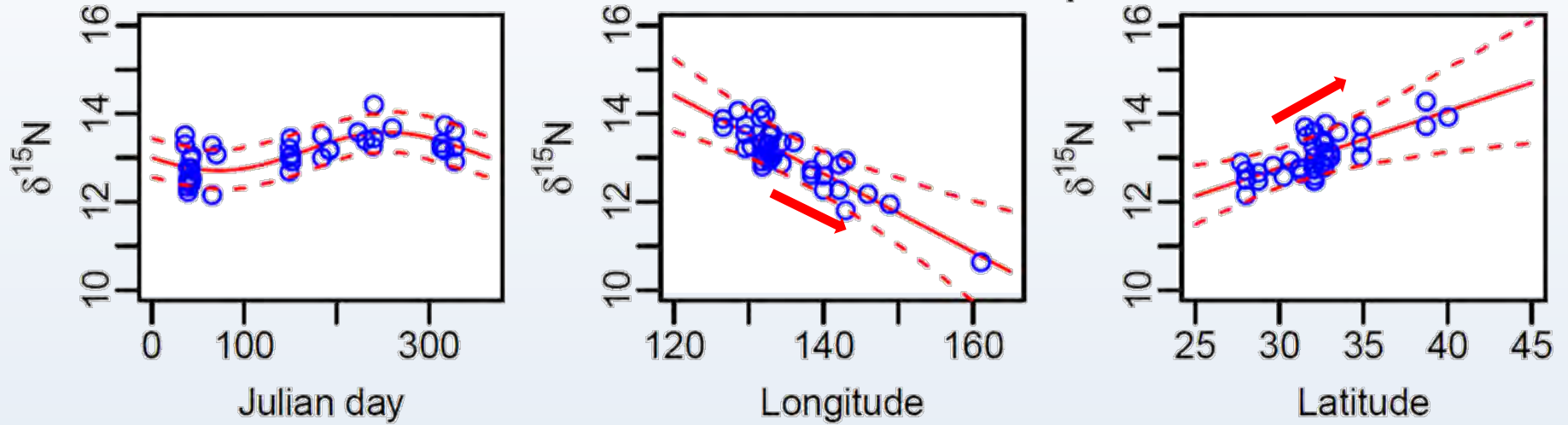


## Short-beaked common dolphin

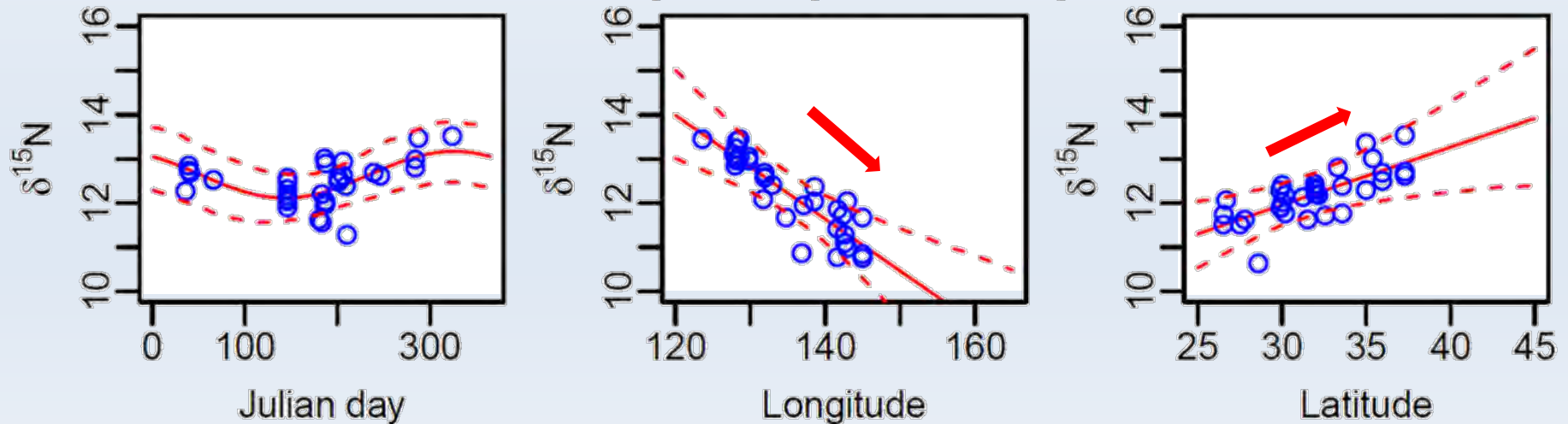


# Nitrogen isotope ratio—spatiotemporal variation (1)

## Common bottlenose dolphin

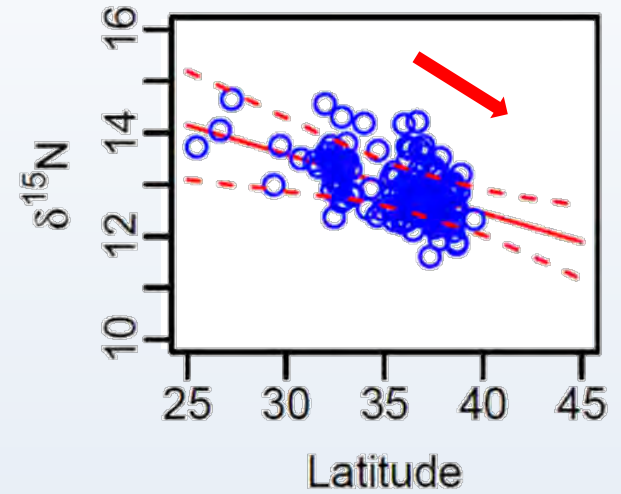
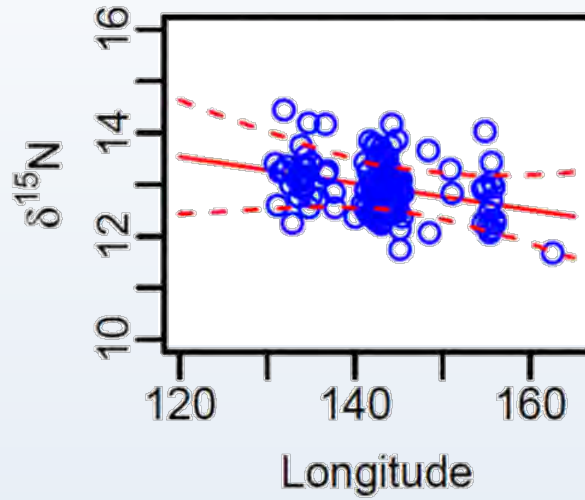
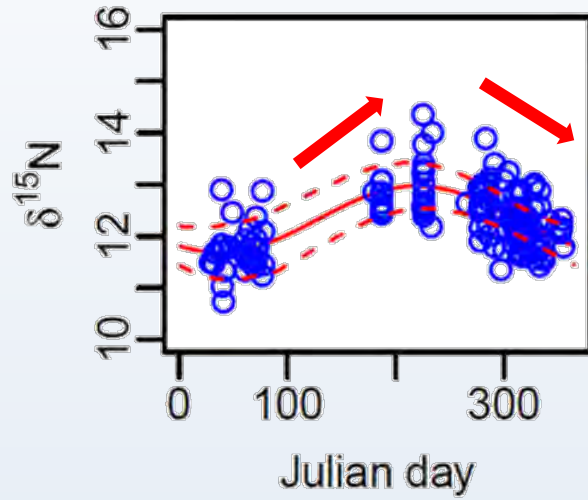


## Pantropical spotted dolphin

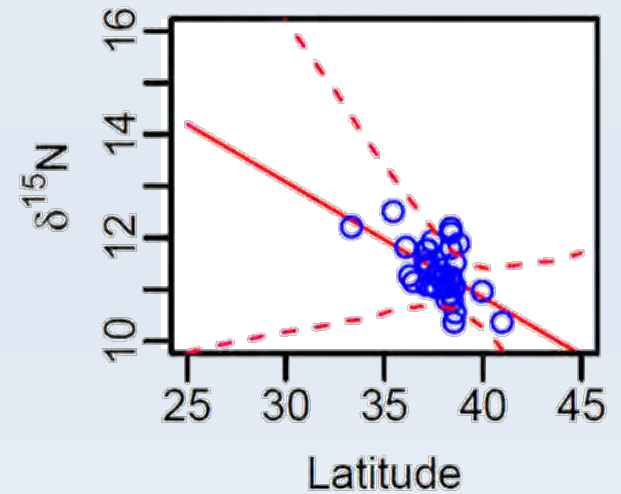
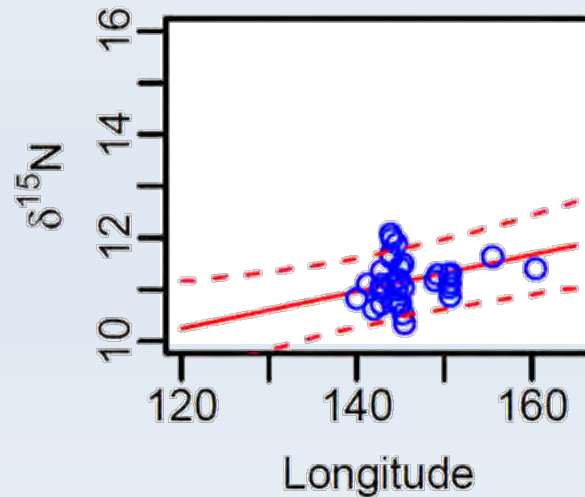
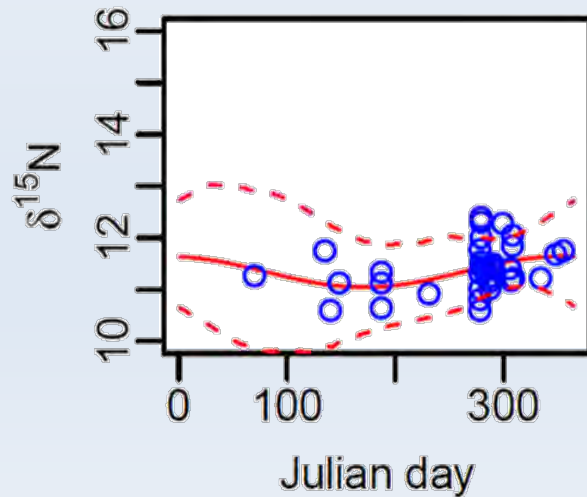


# Nitrogen isotope ratio—spatiotemporal variation (2)

## Striped dolphin



## Short-beaked common dolphin





# Discussion

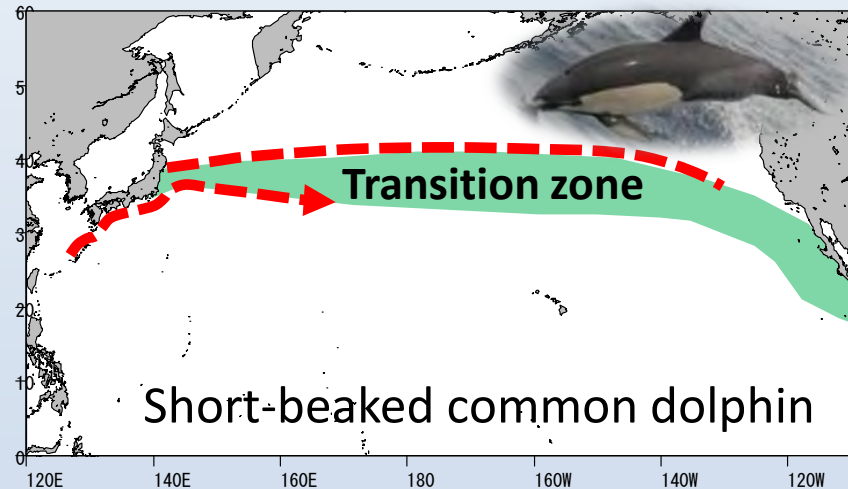
## Conclusion

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

### Latitudinal gradient (decrease in $\delta^{13}\text{C}$ )

The  $\delta^{13}\text{C}$  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 $\delta^{15}\text{N}$ )

In the upstream waters of Kuroshio, the  $\delta^{15}\text{N}$  is depleted by nitrogen-fixing blue-green algae, and the density of those algae decreases downstream