Are Foraging Habits of Pacific Salmon Based on Food Habits?

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INTRODUCTION
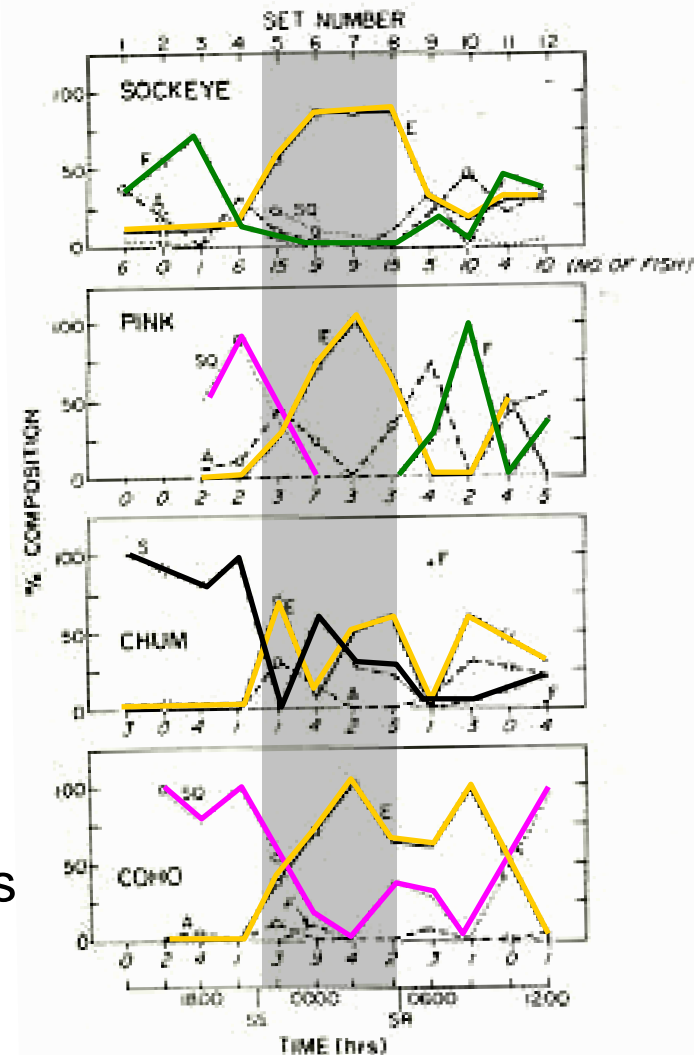
Feeding pattern of Pacific salmon
(LeBrasseur 1966; Kanno and Hamai 1971, etc.)

Coho · · · Nekton

Sockeye
}
Pink · · · Nekton-Zooplankton

Chum · · · Zooplankton

Dial variation in the feeding habits
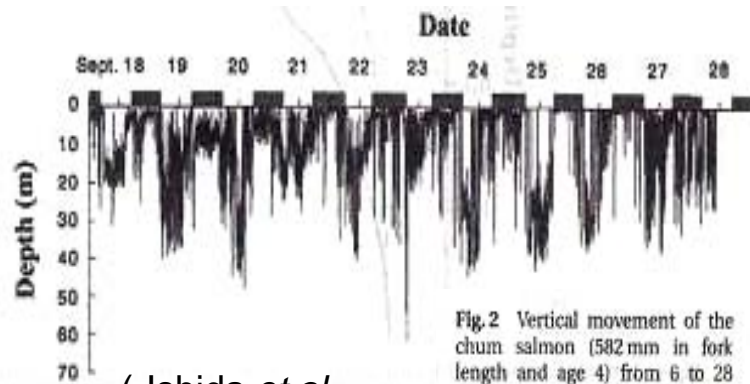(Pearcy et al. 1984; Davis et al. 2000; Volkov and Kosenok 2007)

Coho
Sockeye } · · · Daytime : Large prey
Pink   (e.g., Squid)
              Nighttime : Luminous animals
                                    (e.g., euphusiids)

Chum · · · Unclear

E: euphusiids,   **SQ**: squids,   **F**: fish,
S: salps,   (Pearcy et al. 1984)

Dial vertical movement (DVM) of Pacific salmon

(Manzer 1964; Mathidori 1968; Ishida et al. 2001; Walker et al. 2000; Walker et al. 2007)

Fig. 2 Vertical movement of the chum salmon (582 mm in fork length and age 4) from 6 to 28 September 1994. Shaded time zones indicate night.

(Ishida *et al*. 2001)

Daytime ： 0 ～ 40m or 60m
Nighttime ： 0 ～ 10m

- They move vertically in both layers

- Chum move vertically wider than other species.

OBJECT

Using stomach-content analysis,
we resolved foraging habits of Pacific salmon, especially
the relationship of vertical distribution between salmon and
their prey organisms.

MATERIALS AND METHODS

Sampling and Stomach Content Analysis
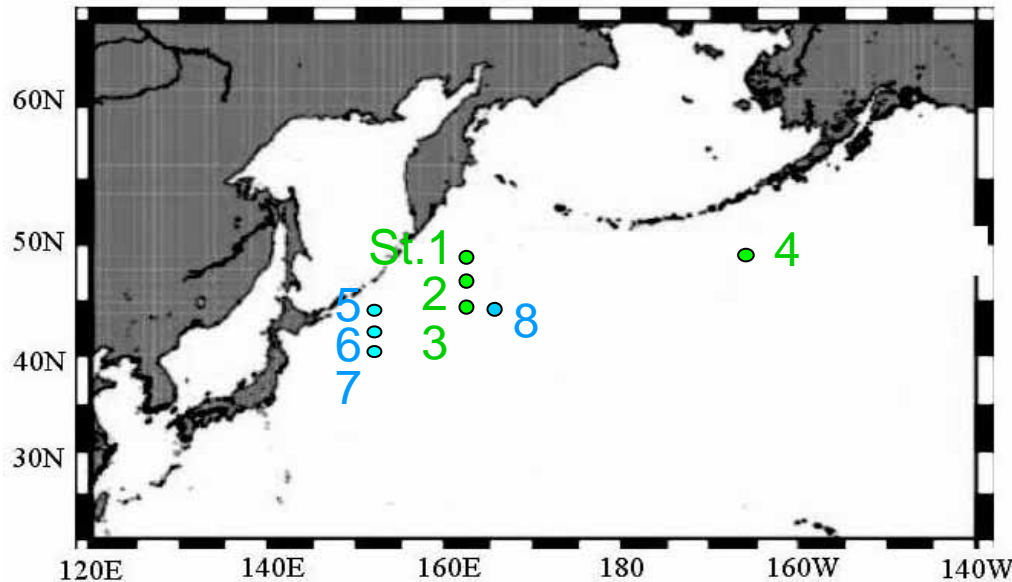
Number of samples		
	Pink	Chum
St. 1	0	18
2	0	25
3	0	10
4	0	18
5	8	0
6	20	0
7	30	0
8	25	0

● Sampling period
  St. 1 ~ 4: 2006, June and July,
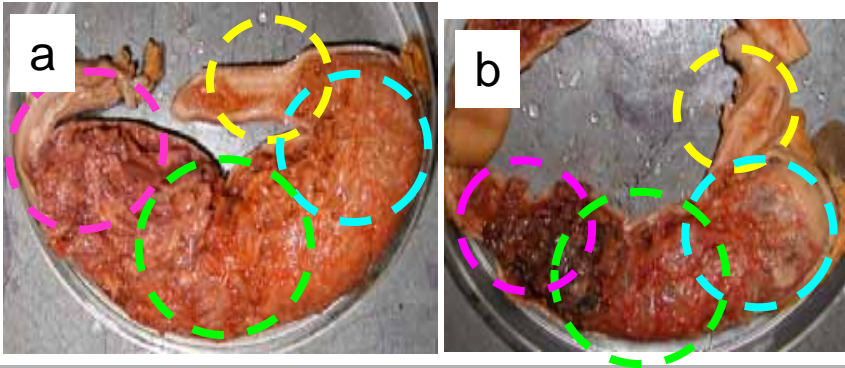 St. 5 ~ 8: 2007, May and June.
● Gear
  Drifting gillnet (Set: before sunset, Haul: after sunrise), hook/line
  on the t/v Oshoro-maru
● Stomach content analysis
  Prey items were
  classified to the lowest identifiable taxon,
  and recorded the position and the digestion level in the
  stomach.

Prey position in stomach

Cardia, Pre-fundus, Post-fundus, Pyloric

- Score of prey(i)

  $SP(i,j,k) = 1 / N$

- Total score of prey(i)

  $TSP(i,j) = \sum SP(i,j,k)$

- Prey position in stomach

  $PPS(i,j) = TSP(i,j) / \sum TSP(i,j)$

I: prey items, **j**: stomach portion
k: stomach sample, **N**: Number of species   in
    a portion of a stomach sample

SP(i,j,k)

	Pyloric	Post-fundus	Pre-fundus	Cardia
a	*N. cristatus* **(1)**	*N. cristatus* **(1)**	*N. cristatus* **(0.5)** euphausiids **(0.5)**	euphausiids **(1)**
b	*N. cristatus* **(1)**	*N. cristatus* **(0.5)** squids larva **(0.5)**	*N. cristatus* **(1)**	amphipods **(1)**

TSP(i,j), ∑TSP(i,j)

	Pyloric	Post-fundus	Pre-fundus	Cardia
N. cristatus	2	1.5	1.5	
Euphausiids			0.5	1
Squids larva		0.5		
Amphipods				1
∑TSP(i, j)	2	2	2	2

$PPS_{(N.\ cristatus,\ Pyloric)} = 1$

$PPS_{(N.\ cristatus,\ Post\text{-}fundus)} = 0.75$

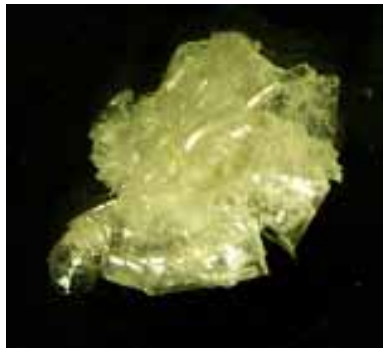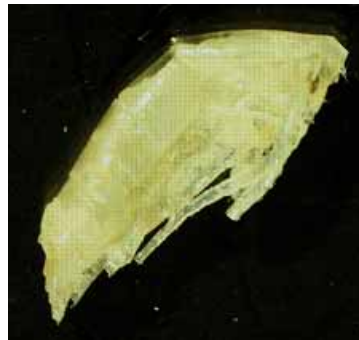$PPS_{(Squids\ larva,\ Post\text{-}fundus)} = 0.25$

· · ·

Digestion level

Digestion level

1: Sample can't be distinguished as individual because of their shell or muscle broken

2: Semi-digested chitinous shell or muscle present. They can be counted number but have difficulty to classify speacies.

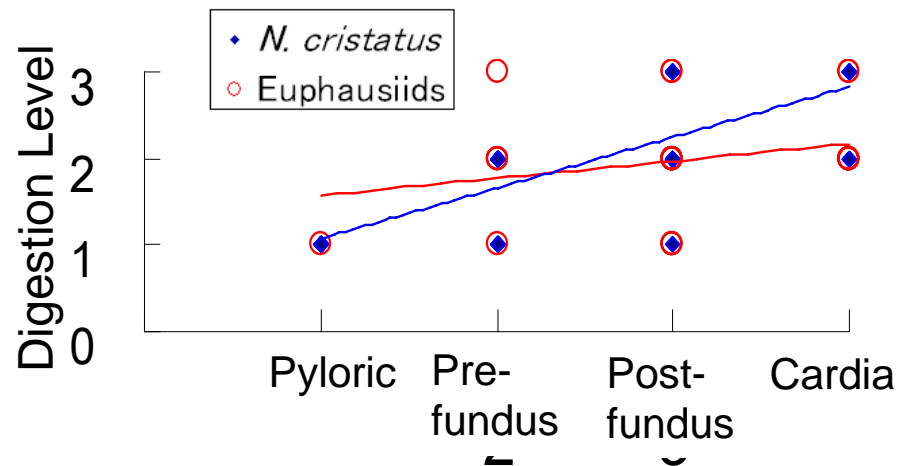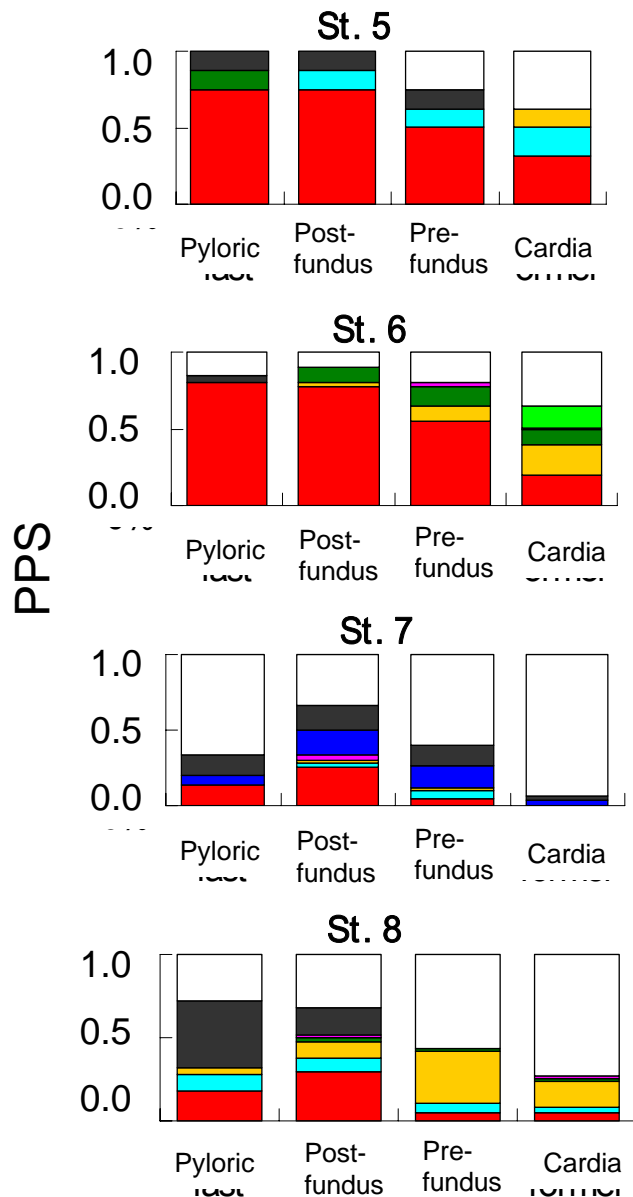3: Complete chitinous shell or muscle present. It is easy to classify species.
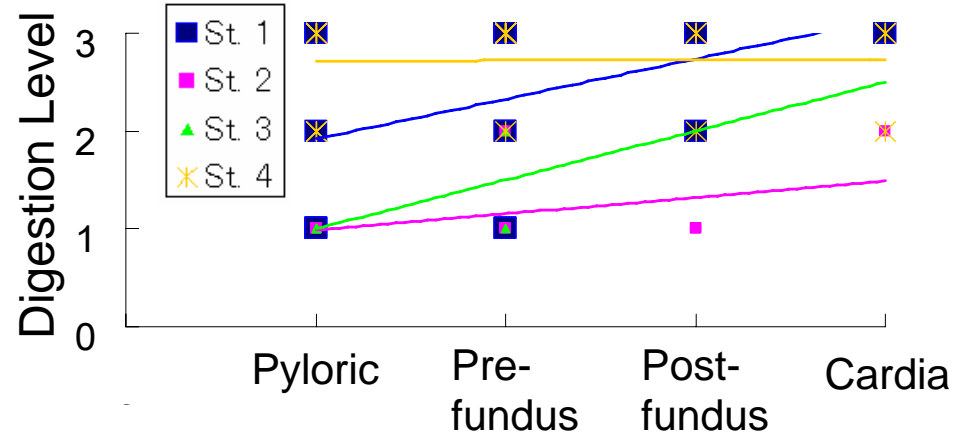
1

2

3

RESULTS

Stomach content position of pink salmon

PPS

St. 5

| | Pyloric | Post-fundus | Pre-fundus | Cardia |

St. 6

| | Pyloric | Post-fundus | Pre-fundus | Cardia |

St. 7

| | Pyloric | Post-fundus | Pre-fundus | Cardia |

St. 8

| | Pyloric | Post-fundus | Pre-fundus | Cardia |

Legend:
- ☐ Empty
- ■ Unidentified
- ■ Chaetognath
- ■ Pteropods
- ■ Squid larva
- ■ Fishes
- ■ Euphausiids
- ■ Amphipods
- ■ Copepods

Digestion Level

- ◆ *N. cristatus*
- ○ Euphausiids

X-axis: Pyloric — Pre-fundus — Post-fundus — Cardia

	R	slope	T	P
N. cristatus	0.805**	0.586	1.981	0.001**
Euphausiids	0.281	0.198		

- ●Stomach contents of pink salmon changed *N. cristatus* → Euphausiids.
- ●*N. cristatus* was fed on for long period.
- ●Euphausiids was fed on for short period.
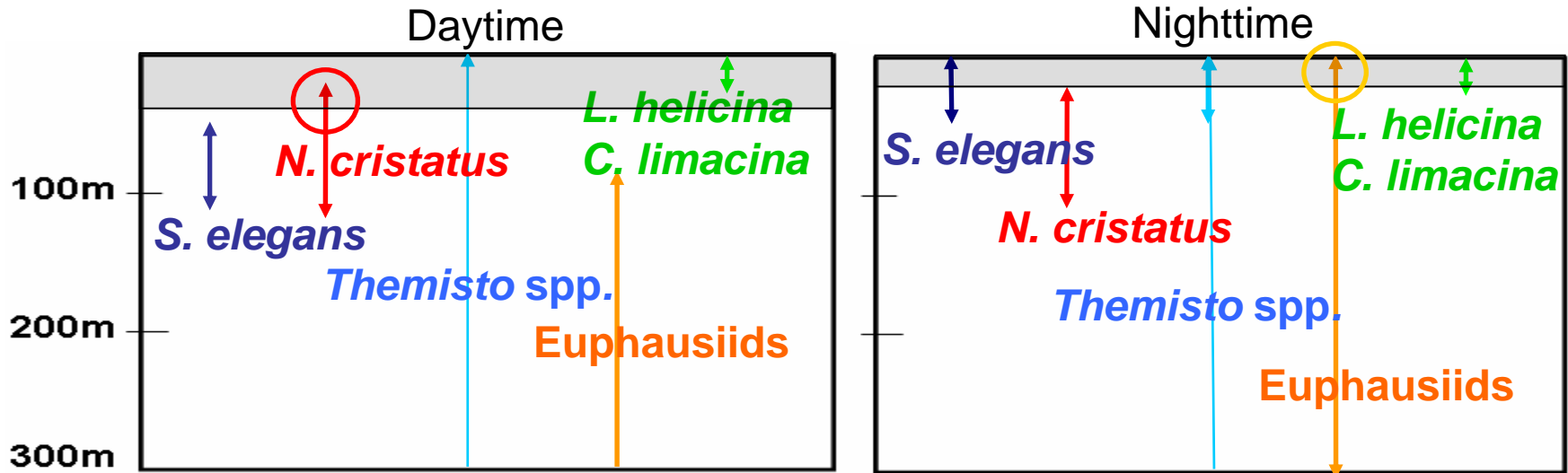
Stomach content of chum salmon

St. 1
St. 2
St. 3
St. 4

PPS

Legend:
- Empty
- Unidentified
- Fishes
- *R. angelini*
- Euphausiids
- Jelly fishes
- Amphipods
- Pteropods

Digestion Level plot legend:
- St. 1
- St. 2
- St. 3
- St. 4
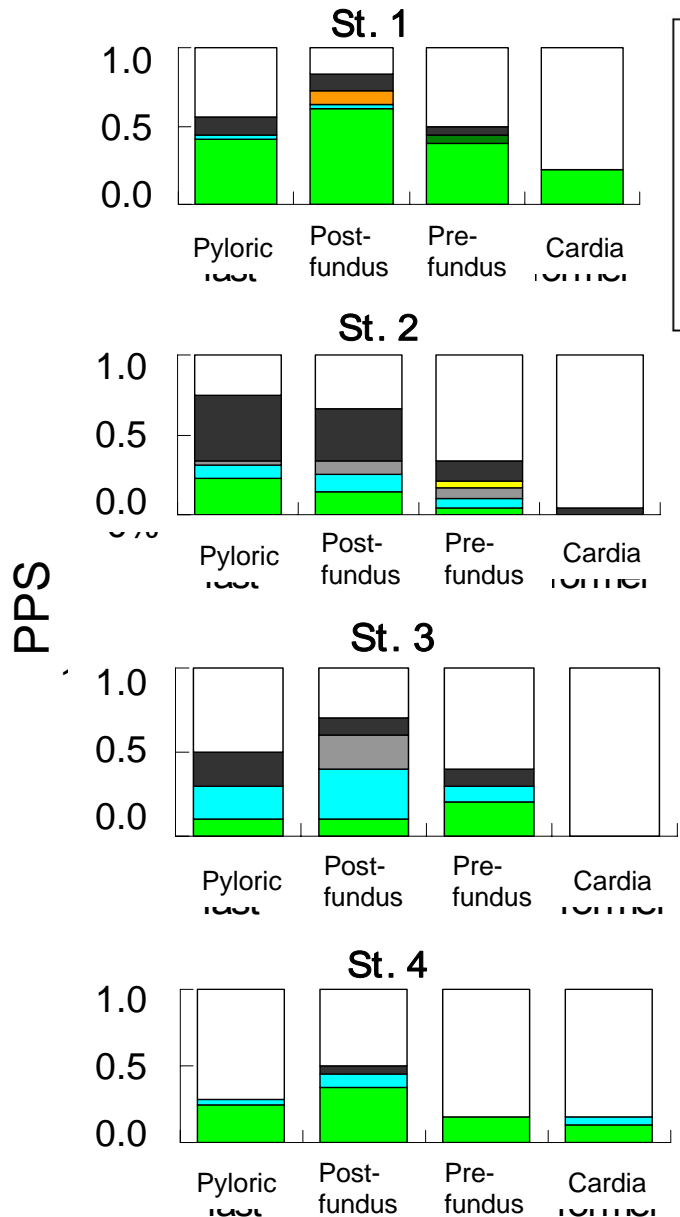
		St. 1	St. 2	St. 3	St. 4
R		0.479*	0.444	0.577	0.013
Slope		0.410	0.167	0.500	0.006
P_{slope}	St. 2	0.295	-	-	-
	St. 3	0.906	0.412	-	-
	St. 4	0.046*	0.318	0.327	-
$P_{constant}$	St. 2	0.191	-	-	-
	St. 3	0.401	0.623	-	-
	St. 4	0.016*	<0.001**	0.011*	-

● Difference of feeding period between Sts. 1-3 and St. 4.

DISCUSSION

Relationship of diel vertical distribution between pink salmon and their prey animals

Stomach contents change: *N. cristatus* → Euphausiids

Daytime

Nighttime

L. helicina
C. limacina
N. cristatus
S. elegans
Themisto spp.
Euphausiids

100m
200m
300m

S. elegans
N. cristatus
Themisto spp.
L. helicina
C. limacina
Euphausiids

Distribution of salmon

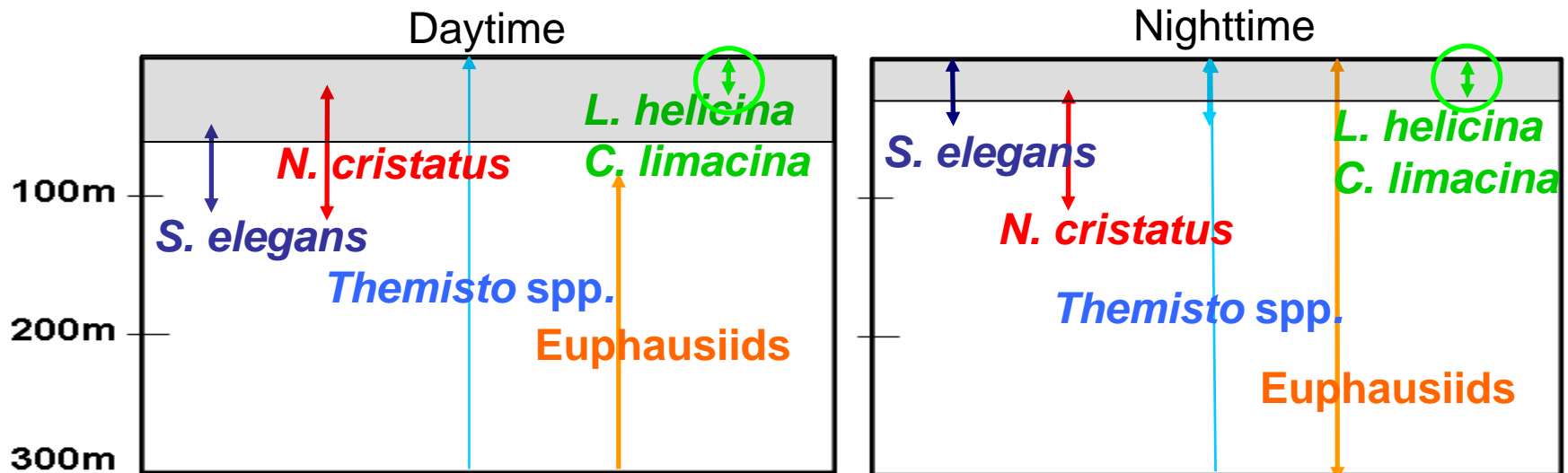Feeding activity rise : "sunrise→midday", "sunset→early-darkness"

(Volkov and Kosenok 2007)

Pink salmon fed on
N. cristatus during "sunrise → midday" in the deeper layer and
euphausiids during "sunset → early-darkness" in the surface layer.

Relationship of diel vertical distribution between Chum salmon and their prey animals

Chum salmon fed on pteropods at different time period between Sts. 1-3 and St. 4.

Daytime

Nighttime

L. helicina
C. limacina
N. cristatus
S. elegans
Themisto spp.
Euphausiids

S. elegans
L. helicina
C. limacina
N. cristatus
Themisto spp.
Euphausiids

100m
200m
300m

Distribution of salmon

Feeding activity rise : "sunrise→midday" and "sunset→early-darkness"

(Volkov and Kosenok 2007)

Chum salmon fed on pteropods
during both "sunrise→midday" and "sunset→early-darkness"
in the surface layer.

Relationship between distribution density of prey animals and digestion level of Pacific salmon

●Digestion level of *N. cristatus* fed on by pink salmon was changing.

●Digestion level of euphausiids fed on by pink salmon was not changing clearly.

N. cristatus   : low-density distribution
Euphausiids : high-density distribution (Takeuti 1972)

●Pink salmon fed on *N. cristatus* for long period.
●Pink salmon fed on euphausiids for short period.

Digestion level in each stomach portion
describes distribution density of prey animals.

Conclusion

Pink salmon are more opportunistic feeder than chum salmon. Chum salmon forage wide-vertically for food.

● Pink salmon feeding:

      - *N. cristatus*: "sunrise → midday" in the deeper layer

      - Euphausiids: "sunset → early-darkness" in the surface layer.

● Chum salmon feeding:

      - Pteropods: "sunrise→midday" and "sunset→early-darkness"

                   in surface layer.

● Chum move vertically wider than other species.(Volkov and Kosenok 2007)