Inter-specific Relations Surrounding the Three Species of Embiotocid 
Fishes in the Zostera marina Belt of Odawa Bay*1

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Inter-specific relations concerning three species of embiotocid fishes, Ditrema viridis, Ditrema temmincki and Neoditrema ransonneti, in the Zostera belt of Odawa Bay are discussed in the present paper. From the seasonal changes in fish fauna appearing in the Zostera belt, the utilization of the Zostera belt as a habitat of fishes was examined. D. viridis and D. temmincki are members of year-round residents and N. ransonneti is one of the seasonal residents. The O+ age group of D. viridis and D. temmincki have high probability to come into contact with other year-round residents, especially Rudarius ercodes, which occur frequently in the catch and are predominant in the Zostera belt. These fishes tend to reduce competition for the same food resources by means of different seasonal population fluctuation or segregation of microhabitat. The O+ age of N. ransonneti mainly use the Zostera belt as a spawning or nursery ground.

In the previous papers,1-4) various aspects of the ecology of embiotocid fishes such as habitat, distribution, growth, reproduction, feeding ecology and population fluctuation have been examined. However, these studies were restricted only to the population ecologies of each species.

The present study was planned to investigate the ecological relations between the embiotocid fishes and other major fish species in the Zostera belt community.

Materials and Methods

The samples used in this study were collected from June 1974 to July 1977 in Odawa Bay. Catch sample by each tow operation was sorted into species and numbers of each species were enumerated. Body length and weight of all sampled fish were measured in co-operation with collaborating members. Diving observations were sometimes conducted during the tow operations.

Results and Discussion

Pattern of Seasonal Occurrence

During the towing program (234 tows from June 1974 to July 1977) in the Zostera belt of Odawa Bay, 9643 individuals of about 130 species of marine fishes were caught. The monthly occurrence frequency of the main fish species are shown in Fig. 1. The most dominant fish was Rudarius ercodes by number and Leiognathus nuchalis by weight. As shown in Fig. 1, we can separate species into two groups; one is the species group encountered all year round (i.e. year-round residents) and the other is species group encountered only within a limited season (i.e. seasonal residents). The latter is further divided into 5 seasonal types, that is spring, summer, autumn, winter and irregular (Table 1). The percentage occurrence in the total catch of year-round residents both in number and in weight averages about 50% in any year. Both D. viridis and D. temmincki belong to the former group and N. ransonneti belongs to the latter (especially, spring type resident).

Simultaneous Occurrence Coefficient with the Embiotocid Fishes

The catch samples of embiotocid fishes were divided into three developmental stages on the basis of their mean body length and some aspects of their internal morphological characteristics. These three developmental stages can be separated by months as follows; juvenile and young stage: May-August, immature stage: September-December, and adult stage: January-April.

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Fig. 1. Monthly variations of the relative abundance of the catch of major fishes during the three years from June 1974 to July 1977. Each frequency (percentage) for each month is expressed in values relative to three years’ total catch of each species.

Table 1. The type of utilization of the Zostera belt as a habitat of fishes

<table>
<thead>
<tr>
<th>Year-round residents</th>
<th>D. viridis, D. temmincki, Syngnathus schlegeli, Sillago sihama, Platoshus anguillaris, Rudarias ecoredes, Fugu pardaalis, Hypodytes rubripinnis, Leiothradnus mouchalis, Engraulis japonica</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonal residents</td>
<td>D. viridis, D. temmincki, Syngnathus schlegeli, Sillago sihama, Platoshus anguillaris, Rudarias ecoredes, Fugu pardaalis, Hypodytes rubripinnis, Leiothradnus mouchalis, Engraulis japonica</td>
</tr>
<tr>
<td>Spring</td>
<td>Pelamis plagiolaris, Trachurus japonicus, Pogrus major, Sphyraena japonica, Sebastes inermis, Navodon modestus</td>
</tr>
<tr>
<td>Spr.-Sum.</td>
<td>Pelamis plagiolaris, Trachurus japonicus, Pogrus major, Sphyraena japonica, Sebastes inermis, Navodon modestus</td>
</tr>
<tr>
<td>Summer</td>
<td>Pelamis plagiolaris, Trachurus japonicus, Pogrus major, Sphyraena japonica, Sebastes inermis, Navodon modestus</td>
</tr>
<tr>
<td>Sum.-Aut.</td>
<td>Pelamis plagiolaris, Trachurus japonicus, Pogrus major, Sphyraena japonica, Sebastes inermis, Navodon modestus</td>
</tr>
<tr>
<td>Autumn</td>
<td>Pelamis plagiolaris, Trachurus japonicus, Pogrus major, Sphyraena japonica, Sebastes inermis, Navodon modestus</td>
</tr>
<tr>
<td>Aut.-Win.</td>
<td>Pelamis plagiolaris, Trachurus japonicus, Pogrus major, Sphyraena japonica, Sebastes inermis, Navodon modestus</td>
</tr>
<tr>
<td>Winter</td>
<td>Pelamis plagiolaris, Trachurus japonicus, Pogrus major, Sphyraena japonica, Sebastes inermis, Navodon modestus</td>
</tr>
<tr>
<td>Win.-Spr.</td>
<td>Pelamis plagiolaris, Trachurus japonicus, Pogrus major, Sphyraena japonica, Sebastes inermis, Navodon modestus</td>
</tr>
<tr>
<td>Irregular season</td>
<td>Pelamis plagiolaris, Trachurus japonicus, Pogrus major, Sphyraena japonica, Sebastes inermis, Navodon modestus</td>
</tr>
</tbody>
</table>

The extent of co-occurrence of several species of fishes was analysed by using the following formula;

\[ C_{ij} = \frac{n_{ij}}{F_j} \]

where \( C_{ij} \), \( n_{ij} \) are the simultaneous occurrence coefficient and the simultaneous occurrence frequency of \( i \) fish species with the embiotocid fish species \( j \), and \( F_j \) is the occurrence frequency of the embiotocid fish species \( j \). For each location within the bay, the simultaneous occurrence coefficient of various fishes with \( D. \ viridis \) was calculated for each developmental stage (Fig. 2). \( D. \ viridis \) in
Inter-specific Relations among Embiotocid Fishes

Fig. 2. Simultaneous occurrence coefficient with D. viridis for each of its developmental stage. Re: Rudarius ercodes, Dt: Ditrema temmincki, Ss: Syngnathus schlegeli, Fp: Fugu pardalis, Ln: Leiognathus nuchalis.

1) D. viridis in all developmental stages is closely associated with Rudarius ercodes at all locations.
2) In the young stage, simultaneous occurrence coefficients of D. temmincki, Leiognathus nuchalis, Fugu pardalis and Syngnathus schlegeli keep constant values around 0.5 in all parts of the bay.
3) In the immature stage, the coefficients of year-round residents abruptly drop down in the central parts of the bay.
4) In the adult stage, the values of the coefficient except for Leiognathus nuchalis tend to decrease from the mouth to the inner parts of the bay.

The first point reveals that Rudarius ercodes is the fish which has the closest connection with D. viridis in all developmental stages. The fourth point suggests that Syngnathus schlegeli and D. temmincki have the same reproduction pattern as D. viridis, because these adults enter into the bay in winter and spawn or give birth to young in spring in the mouth area. The second and third points suggest that D. viridis in young stage would live together with many kinds of year-round residents and then as they grow older, they may shift their habitats to the inner parts of the bay.

Values of the simultaneous occurrence coefficient with D. temmincki show a similar trend as that with D. viridis, and hence figure is not shown here.

For the case of the simultaneous occurrence coefficient with N. ransonneti (Fig. 3), the following characteristic features were observed:

1) In the young stage, N. ransonneti is closely associated with D. viridis, D. temmincki and Rudarius ercodes at all locations.
2) In this stage, N. ransonneti also co-occurs both with year-round residents and spring-summer residents (Trachurus japonicus, Sphyraena japonica and Navodon modestus, etc.).
3) In the adult stage, N. ransonneti inhabits only in the mouth and central part of the bay and lives together both with the year-round residents.
### Table 2. Life history aspects of major fishes around the *Zostera* belt of Odawa Bay

<table>
<thead>
<tr>
<th>Species</th>
<th>Developmental stage</th>
<th>Occurrence season</th>
<th>Microhabitat (layer)</th>
<th>Behaviour</th>
<th>Social relations</th>
<th>Main food</th>
<th>Feeding site</th>
<th>Data source of main food</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>S. schlegeli</em></td>
<td>Y. Ad.</td>
<td>Sp.-Wi.</td>
<td>C-B</td>
<td>D, B</td>
<td>C</td>
<td>Co. Cr.</td>
<td>B-C</td>
<td>5)*</td>
</tr>
<tr>
<td><em>H. rubripinnis</em></td>
<td>Y. Ad.</td>
<td>Sp.-Wi.</td>
<td>D</td>
<td>F</td>
<td>B-C</td>
<td>De. Po.</td>
<td>C-D</td>
<td>12)*</td>
</tr>
<tr>
<td><em>S. japonica</em></td>
<td>Y.</td>
<td>Sp.-Su.</td>
<td>A-B</td>
<td>A</td>
<td>A</td>
<td>Pi.</td>
<td>A</td>
<td>13)*</td>
</tr>
<tr>
<td><em>S. inermis</em></td>
<td>Y.</td>
<td>Sp.-Su.</td>
<td>B</td>
<td>C, F</td>
<td>C</td>
<td>Am. De.</td>
<td>C, D</td>
<td>Kasaoka Bay<em>3</em>4<em>5</em>6<em>7</em>8<em>9</em></td>
</tr>
</tbody>
</table>

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**Developmental stage**
- J: Juvenile, Y: Young, Im: Immature, Ad: Adult

**Occurrence season**
- Sp: Spring, Su: Summer, Au: Autumn, Wi: Winter

**Microhabitat and Feeding site**
- A: surface layer water above the vegetation, B: bottom layer water among the vegetation, C: surface of *Zostera* blades, D: surface of the substratum, E: substratum

**Behaviour**
- A: swimming rapidly, B: swimming slowly, C: floating, D: resting on *Zostera*, E: moving around bottom, F: staying on bottom

**Social relations**
- A: schooling, B: assembling, C: aggregating, D: solitary

**Food**
Inter-specific Relations among Species

The fishes inhabiting the Zostera belt are remarkably different from each other in seasonal occurrence, microhabitat, behaviour, social relations and diet, etc. (Table 2). The microhabitats of the fishes in the Zostera belt were reported in several works. According to this Table and on the basis of diving observations in this study, it was suggested that the microhabitat of the fish inhabiting the Zostera belt differs by species. For example, *Syngnathus schlegeli* lives on the leaf of Zostera marina, *Rudarius ercodes* inhabits the margin of the Zostera belt. On the other hand, *Fugu pardalis* and *Hypodytes rubripinnis* occur at the bottom. Thus, each species has a segregated habitat. Social relations and other life histories are also slightly different between the genus *Ditrema* and *Rudarius ercodes* (Table 2). Nevertheless, *Rudarius ercodes* seems to be the fish which has the closest connection with *D. viridis* and *D. temmincki* because amphipods form the main food items in common for *D. viridis*, *D. temmincki* and *Rudarius ercodes* (Table 2). The most severe inter-relation between species would be the competition for the same food resources. If the food resources (amphipods) were insufficient in the Zostera belt, competitive displacement would happen among these species. It is considered that this phenomenon does not come about in reality for two reasons:

1) As mentioned in previous papers, the co-occurrence season for the young of *D. viridis* and *D. temmincki* coincides with one in which food resources (amphipods) are most abundant in the Zostera belt. This causes the fishes to come into contact with other year-round residents, especially *Rudarius ercodes*, inhabiting dominantly in the Zostera belt. These fishes seem to reduce their interspecific competition by means of different seasonal population fluctuation or segregation of microhabitat. The O+ age population of *N. ransonneti* mainly uses the Zostera belt as a spawning or nursery ground and seems to come into contact with both year-round and seasonal residents only in a short time period.

Summary

1) The seasonal change of fish fauna appearing in the Zostera belt of Odawa Bay, Kanagawa Prefecture, is examined on the basis of catch in number per one tow operation.
2) *D. viridis* and *D. temmincki* are members of year-round residents and *N. ransonneti* is one of the seasonal residents.
3) O+ age population for *D. viridis* and *D. temmincki* have high probability to come into contact with other year-round residents, especially *Rudarius ercodes*, which co-occur frequently in the catch and predominate in the Zostera belt.
4) These fishes tend to reduce mutual competition for the same food resources by means of different seasonal population fluctuation or segregation of microhabitat.
5) The O+ age fish of *N. ransonneti* mainly use the Zostera belt as spawning or nursery ground and seem to come into contact with both year-round and seasonal residents only in a short time period.
References