Occurrence of Two Cohorts in Young of the Year of *Nibea albiflora* in the Ariake Sound and Comparison of their Growth and Changes in Body Composition*1

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Changes in size, water content and C/N ratio were examined on young *Nibea albiflora* distributed in the Ariake Sound to elucidate their growth and body condition which might decide the success of recruitment. The specimens were collected from the head of the Ariake Sound and the mouth area of rivers which drain to the sound. The youngs occurred twice a year, in June and August. The cohort occurring early grew fast attaining about 150 mm in standard length by the end of the year, whereas the other was as small as 60-70 mm. The C/N ratio decreased initially with growth, and increased afterward in fall, and the water content decreased consistently. The early changes were thought to be characteristic of young stages and the ones in fall due to the accumulation of energy to overwinter. The body component analysis revealed that the cohort occurring early stores enough energy in fall facing the first winter, whereas the other fails to do that, probably due to food scarcity in the habitat. Local populations of young *N. albiflora* having different growing conditions were found to exist in the sound.

*Nibea albiflora* (Richardson) is a medium-sized croaker, found both along the coasts of southern Japan and Po Hai (Gulf of Chihli) to the South China Sea. In Japan, the fish is abundantly distributed in the Seto Inland Sea1) and the Ariake Sound.2) The population in the Seto Inland Sea has been investigated in respect of its age and growth,1) maturity and spawning3) and food habits.4) As for the population in the Ariake Sound, which is thought to be isolated from that of the Seto Inland Sea, maturation and early life history have been investigated.3)

*N. albiflora* is one of the most commercially important fishes in the Ariake Sound. It is caught with a variety of fishing gear all the year round, although the fishing ground changes seasonally, and is landed to local fish markets. The fish fetches a high price compared with other sciaenid fishes which are usually used as materials for fish paste.

In the Ariake Sound, which covers an area of 1700 km², there is a single isolated population of *N. albiflora* which completes its whole life cycle in the sound.5) Spawning takes place at the innermost shallow areas from April to August, and the postlarvae and young juveniles come to brackish waters in river mouths. After staying there for some time, they gradually move to the deeper areas as they grow, changing their food from small to large sized animals, mainly Crustacea.5)

The previous paper5) on the early life history of this fish in the Ariake Sound revealed that the long reproductive period brings about a great variation in size at the end of their first year. This variation might also be caused by growing conditions during the early stages of development and this might be important in deciding the success of recruitment and the status of the sequent population. However, the growth at early stages in this fish has not been studied from this viewpoint in any locality.

This paper presents a study of growth during the first year, with special reference to growing conditions.

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Materials and Methods

Study Site

The Ariake Sound (Fig. 1) is located on the west coast of Kyushu. The basin is deep from the mouth to the center, ranging from 30 m to more than 100 m deep, except for the coastal areas. The slope at the head area is gradual and shallow waters at the innermost coastal regions are wide. Many streams drain into the sound, especially at the head regions causing the water there and in the tidal reaches in rivers to be brackish with frequent and large fluctuations of sea water concentration. The tidal range in this area is the largest in the seas around Japan and the water current is rather strong in the spring tide. The water of the sound goes up the lower reaches of rivers during flood tide, and during ebb tide it goes out along the channel.

Collections

In order to collect samples, we accompanied fishermen on board their boats at various times from 1981 to 1983. They operated two kinds of stownets called “ankou-ami” and “koumori-ami”, a traditional blanket net called “teoshi-ami” and a kind of set net called “takehaze”.

The first three are operated on spring tide days when tidal currents are strong enough from high tide to low tide in the channels in the mouth area of rivers and shallow waters a little bit off river mouth.

The fishermen we accompanied mainly operated at the mouth area of the Shiota River (33°07′N; 130°08′E) which is located in Kashima and drains to the head of the Ariake Sound. The last type of net “takehaze” was set at a comparatively deep area (about 4 m deep at low tide) about 5 km off the river mouth. They catch small fishes and shrimps which have been carried into the nets by the tidal currents. Since the mesh sizes used for these nets were small, many juvenile fishes were caught. We sorted *N. albiflora* specimens out of the catches on board and carried some of them in an ice-box to the laboratory.

Most collections in 1981 and 1982 were centered at the river mouth areas where small individuals were exclusively distributed. In order to cover larger ranges, we used a series of old specimens which had been collected mainly with “takehaze” in 1960. Moreover, to elucidate the local difference in growing conditions between nursery habitats, we made collections of young *N. albiflora* with “teoshi-ami” from an area off Isahaya at the innermost area of the Isahaya Bay (Fig. 1, off the mouth of the Honmyo River) in 1983.
Measurements and Chemical Analyses

The standard length of the specimens collected was measured and the body components were analyzed.

The wet weight of the specimens for chemical analysis was determined after removing water from the body surface with paper wipes. The specimens were then dried at 60°C in a drying oven until a constant dry weight was reached. The dried bodies obtained in 1981 were ground individually in a mortar. The ones collected in 1982 and 1983 were pooled in a size group and each group was ground together.

The range of size-groups for fish 15 mm and less was three millimeters, and that for fish larger than 15 mm, five millimeters. In order to get an adequate amount for analysis and to smooth the expected individual diversity, many specimens were pooled for small size-classes and fewer for large size-classes: 10 to 40 individuals for size-classes smaller than 20 mm; 5 to 10 for 20 to 40 mm; and 3 to 5 for larger classes. However, in some cases only a small number of specimens were available and data were obtained from size-classes containing fewer individuals than the individual numbers mentioned above.

There is an inverse relation between lipid and water percentages in fish body, the former decreasing and the latter increasing with extension of the starvation period.5-7) The lowering of the carbon/nitrogen (C/N) ratio with the consumption of lipid and the consequent increase of the protein ratio and the rise of the water content were thought to be good indicators of the change of nutritive condition with the extension of starvation period in young fish.5-8)

We measured water, carbon and nitrogen contents for all specimens, and for those examined in 1981 the total lipid content was also measured. We determined the carbon and nitrogen contents of the specimens collected in 1982 and 1983 and the larger specimens taken in 1981, using about 50 mg of powdered dry fish for each size group, with a CN Corder (Model MY-500, Yanagimoto MFG. CO., LTD.). For the small specimens collected in 1981, a CHN Corder (Model MY-2, Yanagimoto MFG. CO., LTD.) was used. The total lipid content was determined by carrying out ether lipid extractions on 1 to 2 g of each sample using a Soxhlet extractor.

The specimens used for measurements of carbon, nitrogen and total lipid contents in 1981 were collected from Kashima and Isahaya. In 1982 with 661 specimens from Kashima, and in 1983 with 181 specimens from Kashima and 67 specimens from Isahaya, measurements of carbon and nitrogen contents were carried out.

Results

Growth

Standard length frequency distributions of the young collected in 1960 and 1982 were seasonally examined as shown in Figs. 2 and 3, respectively. Young juvenile *N. albiflora* first appear in the shallow areas around river mouths, and after
staying there some time, they gradually move to deeper areas as they grow. Only a few specimens larger than 90 mm were caught in 1982 when the sampling efforts were focused at the river mouth area. In 1960, when some collections were made at somewhat deeper areas, plenty of larger specimens were caught.

Young juveniles were recruited twice within the spawning season extending from late April to August. They first appeared in June and grew rapidly reaching 40 to 80 mm in August, when the second cohort appeared. In and after August, the first cohort decreased in number in the catch, especially in shallow areas, although the decrease was not reflected in the specimen numbers. This represents their dispersal to the deeper areas presumed previously. The first cohort seemed to attain around 150 mm in November and December, probably growing fast till October and slowly thereafter.

The second cohort, which occurred late, did not have enough time to grow in the warm season, reaching only around 60 mm by October. Then, their growth rate slowed down and they reached around 60 or 70 mm in December. However, the growth during fall, estimated in the limited shallow area might have been underestimated because of their movement away from this area as they grow.

Nutritional Condition

We used 13 specimens (85 mm to 145 mm in standard length collected from August to November, 1981, from Kashima and Isahaya) to confirm the reliability of methods to assess the nutritional condition. For each of these fish, we determined the dried body condition factor (dried body weight × 10³/SL²) and the C/N ratio, as well as the commonly used condition factor based on wet weight, and examined the correlation of these with the total lipid content of the body.

Neither the wet body condition factor nor the dried body condition factor has a good correlation with the total lipid content (r=0.18 and 0.53, respectively), showing that weight alone is of little use as an indicator of fish body condition due to the changes of the water content and other factors as demonstrated in other fish.
Fig. 7. Seasonal changes of C/N ratio in young *N. albiflora*. Sizes of the circles show the number of specimens pooled in a size group. Closed circles, first cohort; open circles, second cohort.

Fig. 8. Seasonal changes of water content in young *N. albiflora*. Symbols as in Fig. 7.

The relationship between the C/N ratio and the total lipid content is shown in Fig. 4. The highly significant correlation ($r=0.95$) shows that the C/N ratio is a good indicator of nutritional condition as the energy stores.

Using specimens collected from August to November 1982, we examined the change of nutritional condition with growth. The relationships of the C/N ratio and the water content to standard length are shown in Figs. 5 and 6, respectively. The C/N ratio was high in young juveniles and gradually decreased with growth until they reached about 110 mm in length. Large individuals (>120 mm) collected in September showed values as high as those of young juveniles. The water content decreased with growth, fast in young juveniles up to 30 mm and in young larger than 110 mm, and gradually in young of intermediate sizes.

Changes of the C/N ratio and the water content were seasonally examined with individuals collected in 1982 as shown in Figs. 7 and 8, respectively. The C/N ratio of both cohorts changed similarly, that is, they decreased first, and then increased. When both cohorts were almost of the same size, 40 to 80 mm in length, the C/N values bottomed out. The value of the first cohort increased with time from the bottom, seemingly attaining 4.0 to 4.5 by the end of the year, although we did not have enough specimens to be sure of the increase in fall and winter. The second cohort similarly showed an increase of the C/N value in
Fig. 9. Changes of C/N ratio (open circles) and water content (closed circles) with size of *N. albiflora* for the specimens collected on October 20, 1983 from the mouth of the Shiota River and an offshore point. Sizes of the circles show the number of specimens pooled in a size group.

fall and winter. However, the second cohort did not attain as high a level of the C/N value as the first in winter, because of the delayed onset of the increase in fall. The water content for both cohorts decreased with time. The first cohort, which started this change earlier, decreased the value drastically and reached a much lower level in the fall than the second cohort did.

According to the changes of the C/N value and the water content, it seems that the young of *N. albiflora* store energy in the course of growth in fall, facing the first winter, and that the second cohort, which has a comparatively short life before winter, fails to store enough. However, enough specimens were not available from both cohorts in fall and winter in 1982 to be sure of this.

On October 20, 1983, collections were carried out with “teoshi-ami” at the Shiota River mouth and with “takehaze” which was set in a comparatively deep area about 5 km off the river mouth to cover a large range of specimen size. Changes with fish size of the C/N ratio and the water content for the two collections are shown together in Fig. 9. This reveals that the larger individuals which had already moved offshore had accumulated much nutrition, while the smaller ones which had occurred late and were still in the river mouth area had not accumulated enough, confirming the difference of the energy stores between the two cohorts mentioned above.

Young of *N. albiflora* are distributed all over the muddy shallow coastal areas in the Ariake Sound. They are likely to be distributed in the areas near the river mouths, forming local groups which would not intermingle with each other, at least in early stages. In order to elucidate the local differences of growing conditions, the body condition of the young from an area off Kashima collected on August 9, 1983 was compared with that of those collected two days later from an area off Isahaya. From the geographical location of the two areas these two groups are not considered to intermingle with each other.

C/N ratios of the two groups are shown in Fig. 10. The ratios were significantly higher in the Isahaya specimens than those in the Kashima specimens (P<0.01, covariance analysis). This examination shows that groups of the young locally separated in a population sometimes have different growing conditions from others, probably due to the spatially different food availability.

Discussion

The two cohorts of young of a single year represented here did not occur by chance. Although sampling surveys were not carried out in series through a season as in 1960 and 1982, their occurrence was found in every year in which the collection was attempted: 1961, 1966, 1967, 1981 and 1983.

The occurrence of more than one cohort of young in a year has been shown in many species of fish. Two cohorts from spring and autumn spawners have been known in *Glossanodon semi-fasciata* and *Cololabis saira*, although it has
been argued that the two spawners of the former are from different races. In these cases, the occurrences of the cohorts are clearly separated from each other in time, and it can be said that these species have two reproductive seasons.

More than one larval or juvenile cohort in a spawning season as shown here in *N. albiflora* have also been reported in some fishes. In some of those cases, multiple spawning peaks were believed to bring about the multiple cohorts of young. The cohort of *Rhodeus ocellatus* occurring early was reported to be from early spawners composed of old year classes and the one occurring late from young late spawners. According to our work on *N. albiflora*, it is likely that the two cohorts come from two spawning peaks, but we need to undertake more detailed examinations to be sure of it.

The water content decreased consistently with growth as known in fishes (Fig. 6). The C/N ratio first decreased and then turned to increase (Fig. 5). These changes can be explained as a matter of range of size or season. The decrease of both the water content and the C/N ratio before attaining 50 mm might be characteristic of early stages, when the juvenile *N. albiflora* inhabiting river mouths and the adjacent shallow waters show marked changes in morphology and feeding habit. They gradually move to the deeper areas with growth and the large young inhabit the areas of around 5 m deep (at low tide) with the adults by fall. The changes after attaining 120 mm might be due to the accumulation of energy for the severe cold season, which the adults also generally perform in fall.*

The adults and large young of *N. albiflora* are reported to feed in fall on the shrimps *Metapenaeus joyneri* and *Acetes japonicus*. *M. joyneri* is mainly distributed in very shallow areas in its young stages and moves to deeper offshore areas as it grows, while *A. japonicus* moves offshore in late fall. It is likely that these foods are not available to the second cohort, because the shrimps are too large in size to eat for the small juveniles when they just occur in the shallow areas. When the young predators grow up to a considerable size there, the preys have moved to the deeper areas, where the first cohort devours them. This bad timing of occurrence as well as the shorter time for growth before winter in the second cohort results in the inferior size and lower energy stores illustrated here as nutritional condition. Variable growth and/or nutritional condition in young stages influenced by food availability have also been reported in other fishes.

A considerable size difference in young in the first winter was noted in *Pleuronectes platessa* and *Sardina erythrophthalmus* and *Leuciscus cephalus*. Survival of young *Micropterus dolomieu* during the first winter is thought to be a function of their size and the length of starvation period. Maki reported that small individuals in an under-yearling population of *Gnathopogon caerulescens* were thought to be lost from the population during the first winter because of their inferior body condition. The winter mortality of juvenile *Salmo salar* is thought to be determined by nutritional insufficiency. The winter mortality of *Menidia menida* is thought to be size selective, favoring larger individuals.

We found from this study that the timing of *N. albiflora* reproduction generates a variable size and energy store in the young in fall. The second cohort having the small size and the poor energy stores may have difficulty in surviving during the first winter. However, we have found that some of the second cohort were successful in passing the first winter (unpublished data). More investigation is needed to decide whether the reproduction timing is related to the mortality in overwintering in this species.

Fish like *N. albiflora* which inhabit river mouth areas in young stages live accompanying the tidal movement of water between a river and adjacent shallow waters in the sea. The young fish in each river mouth area are likely to form a local group, subject to the circumstances which might change locally from time to time. The difference in body condition we found in young *N. albiflora* between the two localities suggests the existence of different growing conditions in the sound.

Lambert hypothesized that the cohort system is a "hedged bet" strategy that spreads the spawning effort over time to take advantage of a variable environment. For a population of young like *N. albiflora* which inhabits geographically complicated coastal areas and is separately distributed into local groups, another strategy might exist that spreads the spawning effort over space to take advantage of a variable environment.

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