Distribution and Migration of Hoki *Macruronus novaezelandiae* (HECTOR) in Waters around New Zealand

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The deep-water fishing grounds around New Zealand are divided into EAST, NORTHWEST and SOUTH regions. Seasonal change of distribution, relationship between depth and length distribution, diel vertical migration are discussed in this paper. In the EAST region, the fish move from Chatham Rise and Chatham Island to Canterbury Bight from spring through autumn, and move to spawn in the areas between Mernoo Bank and Chatham Rise in winter. In the NORTHWEST region, the fish feed around North Island from spring through autumn, and move to spawn in the western coast of South Island in winter. In the SOUTH region, the fish feed in areas between Auckland Island and Campbell Island in spring and summer, migrate to the continental slope in autumn, and spawn around Stewart Island and Puysegur Bank in winter. Fish of various sizes live in the shallow areas of the continental slope, but in the deeper places, only the large ones can be found. Fish spend the day at depths near the bottom of the continental slope and migrate to the upper layers during the night. This is considered to be a kind of feeding migration connected with the diel vertical migration of the Myctophids.

Hoki are distributed widely in waters around New Zealand and to the southeastern part of Australia. Japanese trawlers began to fish in the waters around New Zealand in 1966, and hoki were caught since 1970. The catch of hoki reached the highest level of 54,000 tons in 1977, but decreased from 1978, and to 9,000 tons in 1980.

Some biological studies were conducted by Shuntov, Blagodyrov and Nosov, but there are still many things remain unknown. For example, the seasonal change of distribution, the diel vertical migration, the spawning season, the biological minimum size, feeding habit, growth and the problem of stocks are still obscure. The biomass and MSY are estimated by Blagodyrov and Nosov, but for the reason of deficiency of biological knowledge, the estimates differed significantly between these two papers.

Therefore, we conducted various studies on biological aspects of hoki, including distribution and migration, maturation and spawning, feeding habit, age and growth. Basing on these biological knowledges, we also examined the problem of stocks. This is the first paper in a series of studies on the biological aspects of hoki, and the seasonal change of distribution, relationship between depth and length distribution, the diel vertical migration are discussed here.

Materials and Methods

Three sets of trawl records from Japanese research-exploratory fishing vessels, KAIMON-MARU and SHINKAI-MARU were used. KAIMON-MARU (tonnage 2,518 GRT) worked in the New Zealand deep-water fishing areas from August 1974 to March 1975, while SHINKAI-MARU (tonnage 3,393 GRT) from April 1975 to March 1976 and from April 1976 to March 1977. In the trawl records, the catch and effect data, the length distribution data, and the biological measurement data were included.

For the studies of density distribution and seasonal change of distribution, catch per unit effort (CPUE in kg/hr) were calculated by areas (1/2 latitude by 1/2 longitude), and high density areas (the areas in which the value of CPUE is over 2,000 kg/hr) were examined. Also, the fish were determined to be matured or not by the state of maturity in the biological measurement data.

The relationship between depth and length distribution was examined by analysing the length distributions from various trawling depths. The
trawling depth was defined as the depth at the starting point of trawling. The length distribution data in 1975 and 1976 were recorded in total length, while that of 1974 was in anus length. So, we transform the anus length into total length by the following equation

\[ Y = 1.5536 + 2.3694X \]

(where, \( Y \) is total length in cm, and \( X \) anus length in cm) derived from the biological measurement data of 1974.

The diel vertical migration was investigated by analysing the change of CPUE of various fishing times and various fishing depths in three fishing areas. These three areas were 41°30'–42°S by 170°–170°30'E, 41°30'–42°S by 170°30'–171°E and 42°–42°30'S by 170°–170°30'E. The fishing time was determined as the moment of the middle point of the total trawling time.

**Results and Discussion**

**Seasonal Change of Distribution and Migration**

After inspecting CPUE and high-density areas, no significant change was found in the yearly concentration areas. Therefore, the data of 1974–1977 were pooled together, and the seasonal dis-

![Fig. 1. Major bathymetric features and studied regions of the New Zealand Plateau.](image-url)
Fig. 2. Seasonal distribution of CPUE of 1974–1976 pooled.

Fig. 3. Seasonal change of CPUE by fishing grounds. Open circles indicate mean values.
tribution of CPUE was shown in Fig. 2. From the figure, it can be seen that the fish concentrate in Bank Peninsula, Chatham Rise and the southeastern waters of Auckland Island in spring (September-November). In summer (December-February), the fish concentrate in Chatham Rise and the southeastern waters of Auckland Island, in Canterbury Bight in autumn (March-May), and in the western coast of South Island in winter (June-August).

Also, it is noticed from Fig. 2 that the fish distributed almost along the continental slope and the Subtropical Convergence. Therefore, after Tanaka,8 we express on a straight line the positions of areas from Canterbury Bight to Chatham Island in the EAST region, from Bruce Bay to Karamea in the NORTHWEST region, from Puysegur Bank to the southeastern offshore of South Island in the SOUTH region respectively, and examine the seasonal change of CPUE of corresponding areas (Fig. 3).

In the EAST region, the fish concentrated in the middle part of Chatham Rise and the waters around Chatham Island in spring. In summer, the dense concentration in the middle part of Chatham Rise was still observed, and the fish in Mernoo Bank and Canterbury Bight increased markedly. In autumn, the fish in waters around Chatham Island decreased, and those in Chatham Rise decreased as well. On the contrary, dense concentration was found in Canterbury Bight. In winter, small concentration between Mernoo Bank and Chatham Rise was found. From this seasonal change of concentration, it is considered that the fish move from Chatham Rise and Chatham Island to Canterbury Bight from spring through autumn. And in winter, the fish move to the areas between Mernoo Bank and Chatham Rise.

This pattern of migration has also been stated by Myntov.9 But he pointed out that the fish migrate from spring through summer and move back to Chatham Rise in autumn. As for this, we believe the fish still remained in Canterbury Bight in autumn, since dense concentration was found there in that season. Also, Myntov thought the range of migration is as far south as the southern part of the continental slope of South Island or even Campbell Plateau. But there was no concentration in the southeastern coast of South Island or Campbell Plateau in summer, except a small one in Pukaki Rise. We are not sure the fish in Pukaki Rise belong to those in the EAST region or those in the southern and southeastern part of Auckland Island. Further study is needed to clarify this problem. Nevertheless, the fish in the EAST region are not considered to migrate as far south as the southern part of South Island. In winter, the fish are thought to move back to the areas between Mernoo Bank and Chatham Rise to spawn, because they were found to be matured by the inspection of gonad (unpublished), and high concentration of macroplankton formed there in the season.9 After spawning, the fish move to Chatham Rise and Chatham Island, so, the concentrations in these two areas were observed.

In the NORTHWEST region, almost no concentration of fish was found from spring through autumn. But in winter, dense concentration of fish formed between Karamea and Hokitika Canyon. According to the study of maturation and spawning, the matured fish aggregated in these areas to spawn. According to Patchell,10 the fish move gradually toward the mesopelagic zone of the continental slope in late August, and disperse afterwards. We are not sure where the fish go after dispersing. But Patchell11 pointed out that the fish feed around North Island in summer and migrate to the western coast of South Island to spawn. In sum, the fish in the NORTHWEST region are considered to feed in waters around North Island from spring through autumn and migrate to spawn in the western coast of South Island in winter.

In the SOUTH region, the fish in Puysegur Bank and the southeastern offshore of South Island increased gradually from spring through winter and from spring through autumn respectively. By the study of maturation and spawning, these two areas are known to be spawning grounds in the spawning season of winter. In spring and summer, dense concentration of fish was found in the southern and the southeastern waters of Auckland Island. Since no matured fish had been found in these areas, the places are believed to be feeding grounds. In sum, the fish in the SOUTH region are considered to feed in areas between Auckland Island and Campbell Island in spring and summer, migrate to the continental slope in autumn and spawn around Stewart Island and Puysegur Bank in winter.

Relationship between Depth and Length Distribution
The values of CPUE in various depth intervals
are shown in Fig. 4. From this figure, it can be seen that the fish are distributed mainly at depths between 200 to 1,000 m on the continental slope. Also, the fish of the EAST region and the NORTHWEST region occupy mostly depths between 400 to 600 m, while those of the SOUTH region 600 to 800 m.

The length distributions in various depth intervals are shown in Fig. 5. From this figure, it is observed that the range of length distribution is wider at depths between 200 to 400 m and 400 to 600 m, and fish of various sizes, from small one (23 cm) to larger one (122 cm), were found. While at depths between 600 to 800 m, the range of length distribution became narrow, and the fish under 38 cm (EAST), 50 cm (NORTHWEST), 56 cm (SOUTH) were not found. Furthermore, at depths between 800 to 1,000 m, only the fish beyond 77 cm (EAST), 71 cm (NORTHWEST) were found. From this result, it is considered that fish of various sizes inhabit the shallow places of the continental slope, but in the deeper places, only the larger ones live.

**Diel Vertical Migration**

According to Fig. 6, in which the CPUE of
Fig. 6. CUPE in various depth zones, by time of trawling. Open circle, 400–600 m Cross, 600–800 m Closed circle, 800–1000 m Vertical line, site of geometric mean for each time interval of trawling n, number of operation GM, geometric mean for depths 400–600 and 600–800 m.

Various trawling times in various depth intervals is shown, some of the CPUE of daytime fishing (the trawling held during 06–10, 10–14 and 14–18 of the day) were over 10,000 kg/hr (the geometric mean was 1,293, 3,121 and 3,475 kg/hr respectively). But none of the CPUE of night time fishing (the trawling held during 18–22, 22–02 and 02–06 of the night) was over 10,000 kg/hr (the geometric mean was 710, 780 and 666 kg/hr respectively).

Besides, the density of the day at depths from 400 to 600 m (the geometric mean of CPUE was 2,065, 5,794 and 6,837 kg/hr respectively) was higher than that of the night (the geometric mean of CPUE was 1,692, 2,004 and 1,454 kg/hr respectively) for the corresponding time of trawling. In the same way, the density of the day at depths from 600 to 800 m (the geometric mean was 580, 445 and 639 kg/hr respectively) was higher than that of the night (the geometric mean was 205, 189 and 433 kg/hr respectively) for the corresponding times of trawling.

The above fact may be attributed to the behavior of diel vertical migration, that is, the fish spend the day at depths near the bottom of the continental slope and migrate to the upper layers during the night. From the study of feeding habit, it is known that the Myctophids is one of the most important foods of hoki. And since the diel vertical migration is one of the most striking features of the Myctophids that the diel vertical migration of hoki is assumed to be a kind of feeding migration connected with the diel vertical migration of the Myctophids.

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