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# Geographical and Vertical Distribution of Larval Stage Short-finned Squid (*Illex illecebrosus*) in the Northwest Atlantic[1]

by

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SPECIAL SESSION ON SQUIDS

## Abstract

A joint survey of squid resources in the Northwest Atlantic was conducted by Japan, Canada, and the USA during January - March 1982 aboard the Japanese R/V KAIYO MARU. The data collected during the survey provided a unique opportunity to describe the geographical and vertical distributions of larval stage Illex illecebrosus (Family Ommastrephidae). Larvae were widely distributed in areas where surface water was warmer than about 13° C, and were most abundant in the water layers above the thermocline along the northern edge of the Gulf Stream. The Gulf Stream is considered to play an important role in the transport of these larvae. Larval transport and the timing and location of spawning for this species are discussed.

[1] Contribution No. 231, Far Seas Fisheries Research Laboratory

## Introduction

The short-finned squid, _Illex illecebrosus_ (LeSueur), occurs widely in the Northwest Atlantic from Florida northward to Newfoundland and Labrador. The fisheries for this species have developed dramatically since the early 1970's with annual catch attaining a peak of 180,000 metric tons in 1979 (NAFO 1981). Short-finned squid is one of the most economically important species for Japanese, Spanish, Italian and Cuban fleets operating in the Northwest Atlantic waters, and is also important to the Canadian fleet.

The life history of short-finned squid can be divided into three periods: 1) the early growth period from egg to pre-recruit young, 2) the feeding/growth period on the continental shelf, and 3) the spawning period including emigration to the spawning site. Considerable biological information exists on the feeding and growth period on the shelf (Squires 1967, Amaratunga _et al_. 1979, Durward _et al_. 1979, Amaratunga 1980, Dawe and Drew 1981, and Lange and Sissenwine 1981). Canada and the USSR have recently conducted several research surveys in the waters off the Scotian Shelf and the Grand Banks and obtained information on the distribution of the juvenile and young adult squid (Amaratunga _et al_. 1980, Dawe _et al_. 1981, Froerman _et al_. 1981, and Dawe _et al._ 1982). Roper and Lu (1979) obtained 14 specimens of larval and juvenile short-finned squid from the waters between Cape Hatteras and Georges Bank. Spawning and larval development in captivity were described by Durward _et al._ (1979) and O'Dor _et al._ ( 1981 and 1982). However, information on spawning and larval _Illex illecebrosus_ is still insufficient to identify the reasons for and factors influencing annual fluctuations in abundance.

To obtain biological and oceanographic information related to short-finned squid during the breeding and early growth periods in oceanic waters, a Japan/Canada/USA joint squid survey was conducted using the Japanese R/V KAIYO MARU during January-

March 1982. In the present paper, geographical and vertical distributions of larval Illex illecebrosus are described, and the season and location of spawning are discussed.

## Materials and Methods

The Japan/Canada/USA joint squid survey was conducted aboard the 2,540 gross ton Japanese R/V KAIYO MARU. This joint squid survey was composed of two cruises, the first from 16 January to 5 February 1982 and the second from 11 February to 5 March 1982. A total of 91 bongo net (Model 1271, 0.5 mm mesh) tows were made between 57$^{o}$ W and 74$^{o}$ W latitude and between 35$^{o}$ N and 45$^{o}$ N longitude varying from shelf water to the Sargasso Sea (Figure 1 and Appendix Table 1). A double oblique bongo net tow at depths of 0-200 m was made at each of 31 and 28 stations during the first and second cruises, respectively. The towing methods followed Marine Monitoring, Assessment, and Prediction Program (MARMAP) standard procedures (Posgay and Marak 1980). In addition, depth-stratified tows using a bongo net equipped with an opening-closing apparatus were made at four stations where fairly large numbers of larvae were taken in the double oblique tow. At each of those four stations, five depth strata (surface, 0-50 m, 50-100 m, 100-200 m, and 200-300 m from the surface) were sampled for 15 minutes each during both the daytime and at night. Frequent problems with the opening-closing apparatus resulted in insufficient data for the 100-200 m and the 200-300 m layers. Further details on the methods and operations of the survey are described in the cruise report (Japan Fisheries Agency 1982).

The collected samples were preserved in 5% formalin solution. Rhyncoteuthion type larvae were identified to species according to Roper and Lu (1979) based primarily on the suckers on the tip of the proboscis, photophores on the eyes and the liver, and the shape of the liver. Specimens identified as Illex illecebrosus included both Rhynchoteuthion larvae and a few individuals (about 2%) just entering the juvenile stage.

These very young juveniles are treated as 'larvae' in this paper.

An additional 39 tows with midwater trawl gear in depths ranging from the surface to 1,000 m (and one tow to 1,745 m) and 15 stations using squid jigging equipment were completed in an attempt to capture mature adult I. illecebrosus.

## Results

More than 1,000 specimens of short-finned squid were caught during the survey. Figure 1 shows the number of larvae caught by each of the double oblique bongo net tows. The schematic distribution of water-types in relation to bongo stations is also shown in Figure 1 based on Satellite Sea Surface Temperature Charts modified by observed oceanographic data. Larvae occurred widely in the areas occupied by warmer water-types (i.e. the Sargasso Sea water, Gulf Stream, warm core eddies and slope water) between 72°W and 59°W. However, large catches (more than 10 individuals per tow) were mainly observed along the northern edge of the Gulf Stream and in the boundary zone between the Gulf Stream and slope water. The single exception to this was one large catch taken within a warm core eddy.

Water temperature profiles obtained with expendable bathythermograph (XBT) at each bongo station are shown in Figure 2. Larvae were not caught at stations where the surface temperature was lower than 13° C. Catches of 10 individuals or more were taken at stations characterized by high surface temperature (over 16.5° C) and a strong thermocline in the layers between about 50 and 200 m (except one station). These stations were all situated either at the northern edge of the Gulf Stream or in the boundary zone. The one exception (Station 28) was located in a warm core eddy which was north of the meandering Gulf Stream.

The results of the depth-stratified sampling by bongo net are shown in Figures 3 and 4 (note that incomplete samples were obtained for some stations at depths greater than 100 m, due to problems with the opening-closing apparatus). Catch rates (number of larvae caught per 1,000 $m^3$ of filtered water) at Station 10 (opening-closing apparatus functioned properly) were higher in the layers above the thermocline than in those below the thermocline. As noted previously, a strong thermocline was usually observed at stations where the number of larvae caught exceeded 10. It is suggested, therefore, that most of the larvae were distributed in the warmer water above the thermocline.

Catch rates by depth layers in the daytime and at night are shown in Figure 4. In the daytime, the larvae were most abundant in 50-100 m and less abundant in the 0-50 m strata, while few larvae were caught at the surface. Catch rates at night were relatively homogeneous over the depth strata shallower than 100 m. These catch rates suggest a diel movement of larvae based on a more uniform distribution above the thermocline at night, and a descent from the surface layer to relatively deeper waters during the daytime.

No adult I. illecebrosus were taken with the midwater trawl or the squid jigging equipment indicating that they were probably distributed somewhere outside the survey area.

## Discussion

Roper and Lu (1979) described three types of Rhynchoteuthion larvae and identified type C' as the short-finned squids, Illex illecebrosus. Durward et. al. (1979) reported that larvae of Illex illecebrosus hatched in the laboratory resemble Rhynchoteuthion type C'. However, type C' larvae also include a taxonomically related species, I. oxygonius, which is found in coastal Northwest Atlantic waters from New Jersey to Florida. The large number of type C' larvae taken during the present joint survey were regarded as I. illecebrosus, however, since most were taken from the offshore waters far eastward of the known range of I. oxygonius.

Roper and Lu (1979) obtained 14 specimens of larval and juvenile I. illecebrosus from a large number of samples collected by the MARMAP Program of the National Marine Fisheries Service (NMFS) and by the Deepwater Dumpsite 106 Program of the

Smithsonian Institution. The present collection of more than 1,000 specimens within 2 months suggests that this joint survey encompassed the hatching season and distributional range of the larval squid better than earlier surveys. This collection coupled with information on the ocean currents in the surrounding waters and estimates of the incubation time of the eggs offers some evidence as to the spawning season and area for I. illecebrosus.

Larvae were first caught on 19 January, and a considerable number were continuously taken until 15 February. No large catches were obtained after the latter date even though seven additional tows were made in the boundary zone between the Gulf Stream and the slope water where large catches had previously been taken.

O'Dor et al. (1981) reported that eggs of short-finned squid required incubation of 11 days at 14° C and 8 days at 21° C. Durward et al. (1979) observed that newly hatched larvae were about 1 mm in mantle length. All the larvae caught during this joint survey were greater than 1.9 mm in mantle length and were therefore not newly hatched. However, since the appearance of larvae declined rapidly during this survey, it is assumed that the larval period is short. Therefore, it is suggested that the peak of the spawning season is sometime in January.

O'Dor et al. (1981) reported that the normal development of the embryo of the short-finned squid appears to require a minimum temperature of 10° - 13° C. Water-types for spawning are, therefore, limited to the southern part of the slope water, the Gulf Stream, warm core eddies, and the Sargasso Sea. As described previously, larvae were caught in these warmer water types and were most abundant in the northern edge of the Gulf Stream, including the boundary zone. These results suggest that spawning occurs in the boundary zone and/or the Gulf Stream. If spawning occurred in the center or southern part of the Gulf Stream, the eggs and larvae should have been accumulated in the northern edge of the Stream by the convergence effect of the current. On the other hand, if the larvae were hatched in the slope water and/or in the warm core eddy, they would not be found in the Gulf Stream and the Sargasso Sea water beyond the boundary. Thus the Gulf Stream, especially its northern edge, and the boundary zone constitute the most likely spawning sites based on water-type.

The current velocity was highest in the northern edge of the Gulf Stream and in the boundary zone, averaging 2.9 knots at the surface. If the eggs incubated for at least 10 days, they would have drifted about 700 nautical miles prior to hatching. The larvae caught at the west end of the survey area could have originated off the Florida Peninsula. However, since the eggs and larvae would not necessarily remain in the strongest current, the actual distance transported could be considerably less. It is, therefore, suggested that the major spawning site lies in the Gulf Stream and/or the boundary zone between the west end of the survey area (72 °W) and the waters off Florida.

Lange and Sissenwine (1981) reported that this species may spawn in the summer as well as in the winter off the northeastern United States, and Roper and Lu (1979) found larvae during most of the year in that area. However, the major component of this stock, especially that portion which immigrates onto the continental shelf off Canada in late spring and summer (Squires, 1967 and Amaratunga 1980) and which leaves the shelf in autumn, is believed to spawn in the off-shelf waters during winter. The timing and location of spawning discussed above would apply to the bulk of the stock,

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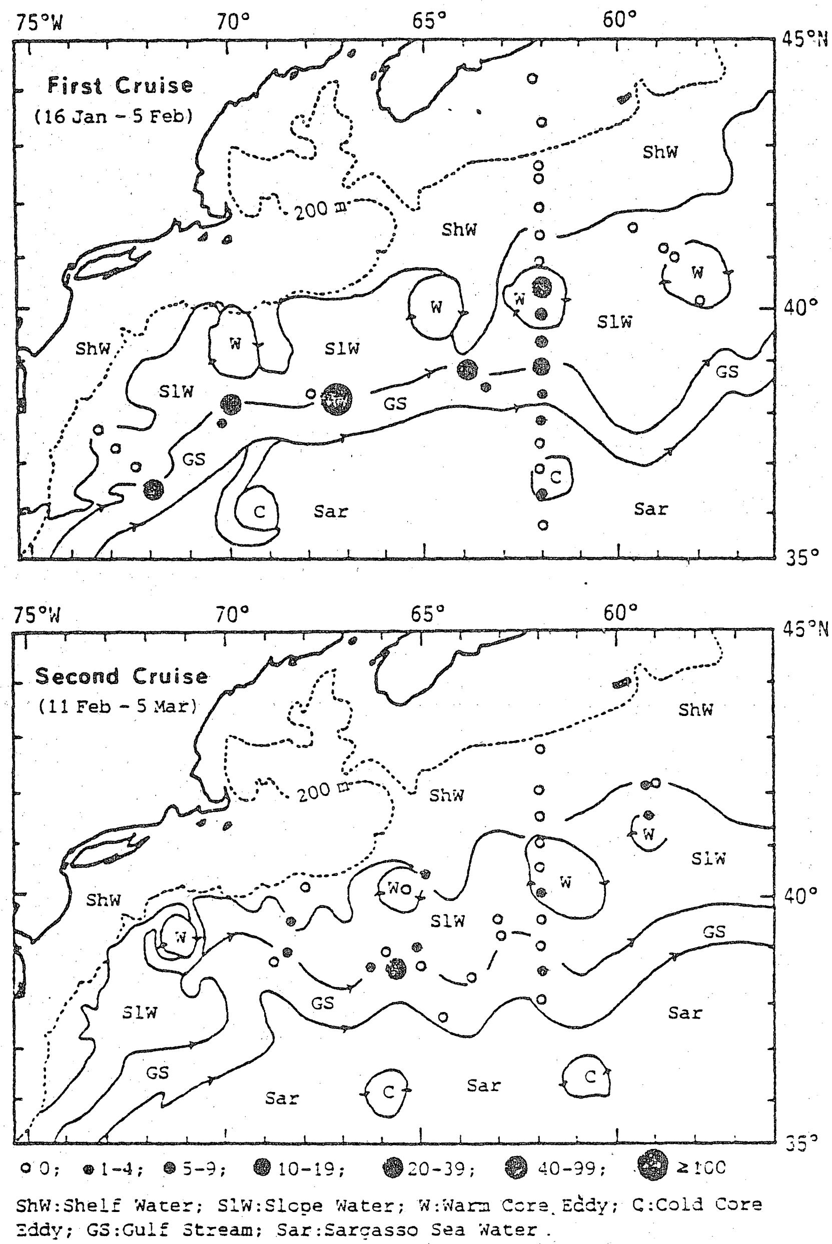


Figure 1. The number of short-finned squid larvae caught by 0-200 m double oblique bongo net. The distribution of each water-type was schematically drawn based on the oceanographic data observed and Satellite Sea Surface Temperature charts.

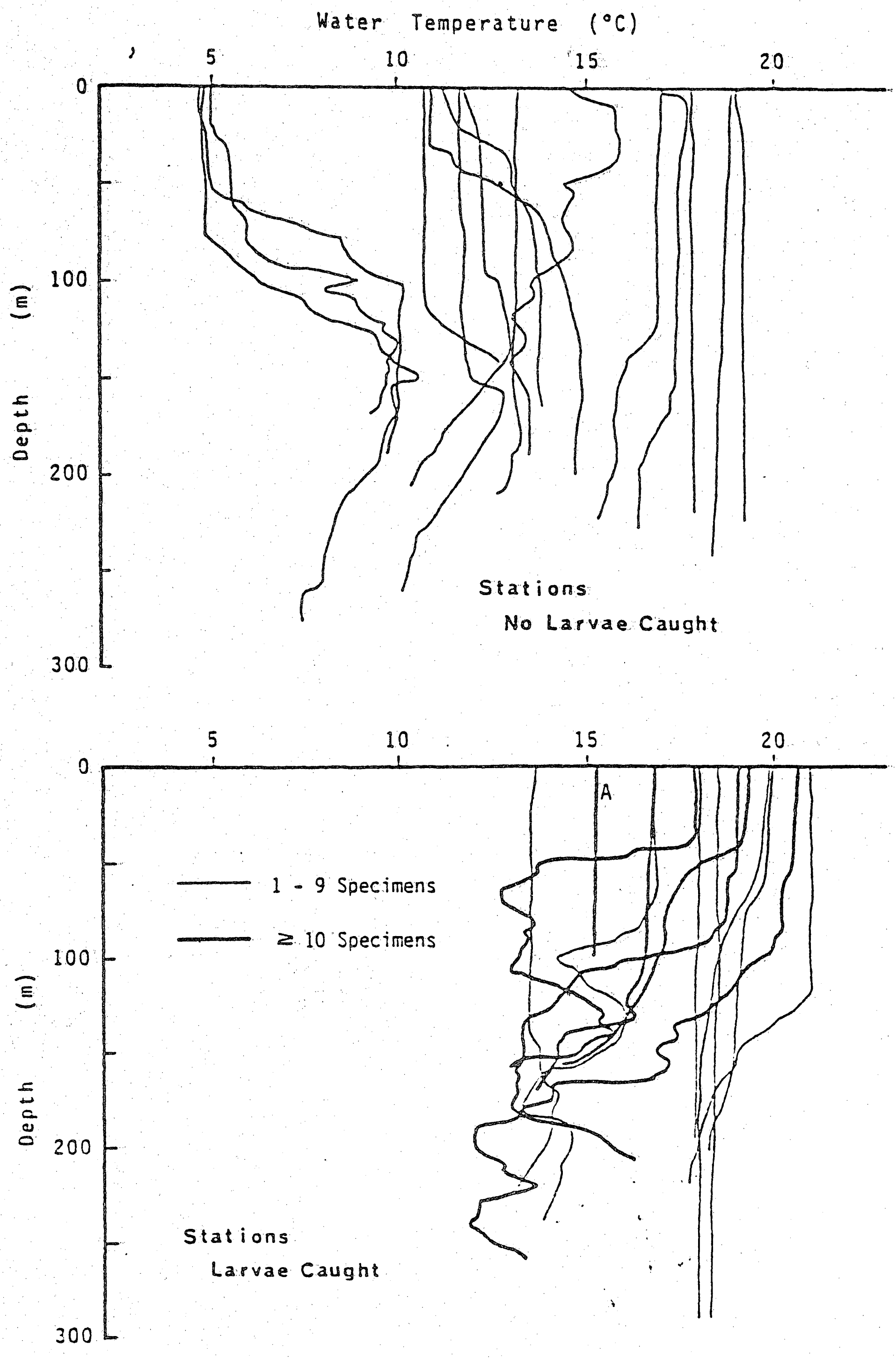


Figure 2. Water temperature profiles observed by X-BT at the stations where double oblique bongo tows were made during the first cruise. (A- indicates station in a warm core eddy.)

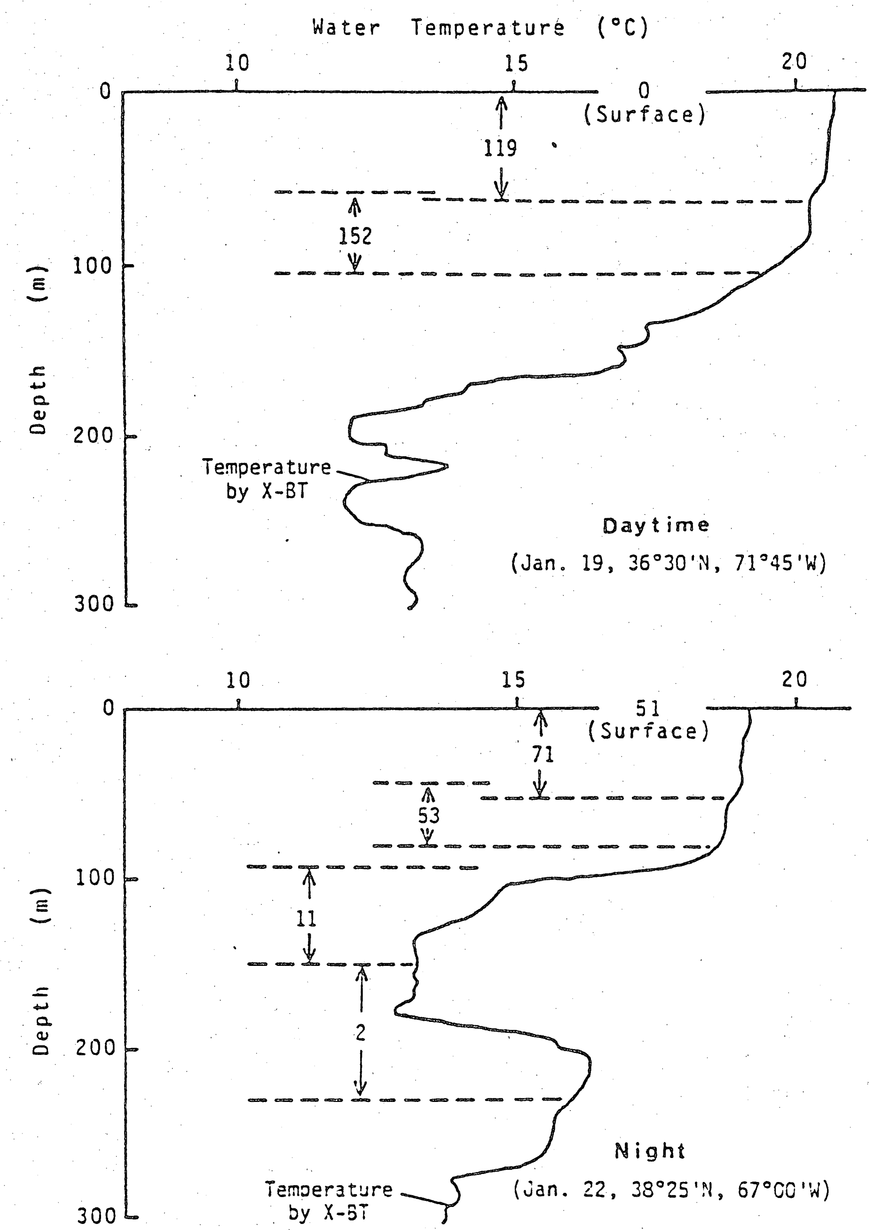


Figure 3. The number of short-finned squid larvae caught per 1,000 m$^3$ of filtered water, during daytime at night, by depth stratified bongo net, and the associated temperature profile.

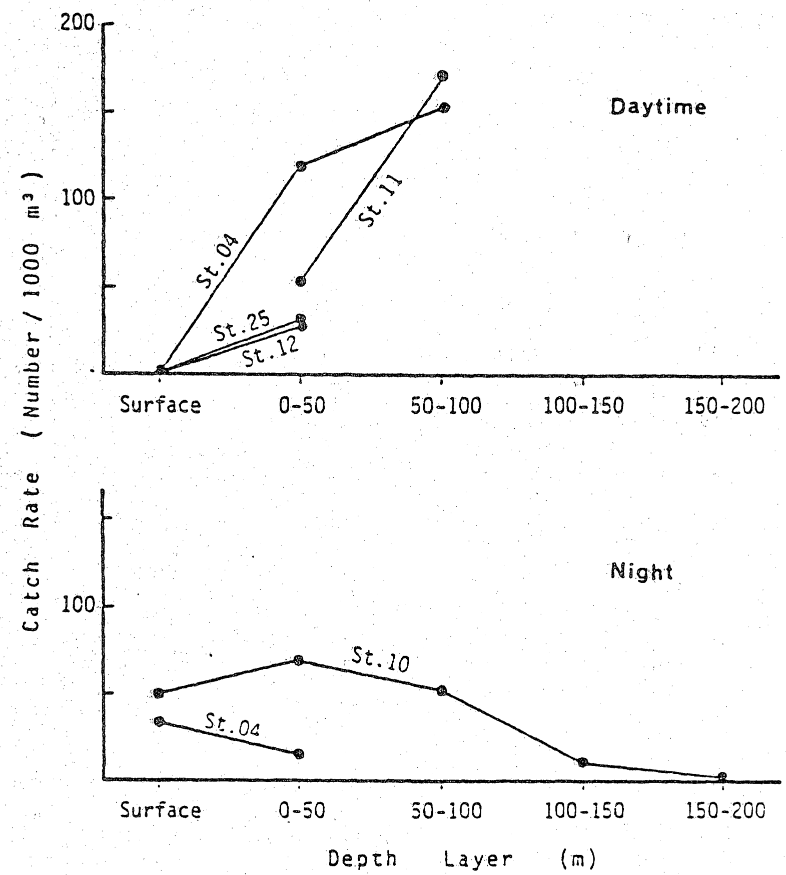


Figure 4. Number of short-finned squid larvae caught per 1,000 $m^3$ of filtered water, by depth, during daytime and night.

Appendix Table 1. Station data for bongo net tows during Japan/Canada/USA joint survey by R/V Kaiyo Maru in January-March, 1982.

| St. no. | Tow no. | Tow 1) method | Date | Day/ Night | Locality Lat(N) | Locality Lon(W) | Sampling depth(m) | No. of Illex caught R | T | J | Total 2) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **First Cruise** | | | | | | | | | | | |
| 01 | B01 | DO | 82.01.18 | N | 37°41' | 73°17' | 0-142 | - | - | - | -( -) |
| 02 | B02 | FD | 18 | D | 37°20' | 72°45' | Surface | - | - | - | -( -) |
| 02 | B03 | DO | 18 | D | 37°20' | 72°46' | 0-204 | - | - | - | -( -) |
| 03 | B04 | DO | 18 | N | 36°59' | 72°19' | 0-262 | - | - | - | -( -) |
| 04 | B05 | DO | 19 | N | 36°29' | 71°50' | 0-260 | 17 | 6 | - | 23( 37) |
| 04 | B06 | FD | 19 | D | 36°29' | 71°49' | Surface | - | - | - | -( -) |
| 04 | B07 | FD | 19 | D | 36°31' | 71°46' | 0-60 | 34 | 7 | 1 | 42(111) |
| 04 | B08 | FD | 19 | D | 36°31' | 71°43' | 57-102 | 59 | 6 | 1 | 66(120) |
| 04 | B09* | FD | 19 | D | 36°34' | 71°26' | 89-155 | - | - | - | -( -) |
| 04 | B10 | FD | 19 | D | 36°30' | 71°41' | Surface | - | - | - | -( -) |
| 04 | B11 | FD | 19 | D | 36°30' | 71°39' | 0-61 | - | - | - | -( -) |
| 04 | B12* | FD | 19 | N | 36°31' | 71°33' | 0-182 | 2 | - | - | 2( 3) |
| 04 | B13* | FD | 19 | N | 36°32' | 71°30' | 0-120 | 3 | - | - | 3( 3) |
| 04 | B14 | FD | 20 | N | 36°45' | 71°25' | 0-70 | 9 | 1 | - | 10( 12) |
| 04 | B15* | FD | 20 | N | 36°46' | 71°24' | 57-148 | - | - | - | -( -) |
| 04 | B16* | FD | 20 | N | 36°48' | 71°22' | 0-219 | 7 | 3 | - | 10( 15) |
| 04 | B17 | FD | 20 | N | 36°50' | 71°21' | Surface | 7 | 1 | - | 8( 14) |
| 04 | B18 | FD | 20 | N | 36°46' | 71°23' | Surface | 1 | - | - | 1( 1) |
| 04 | B19* | FD | 20 | N | 36°46' | 71°20' | 0-55 | - | - | - | -( 4) |
| 04 | B20 | FD | 20 | N | 36°49' | 71°19' | 44-91 | 5 | 3 | - | 8( 11) |
| 04 | B21* | FD | 20 | N | 36°51' | 71°17' | 0-141 | 14 | 2 | - | 16( 22) |
| 04 | B22 | FD | 20 | TD | 36°53' | 71°13' | 23-60 | 17 | 2 | - | 19( 19) |
| 06 | B23 | DO | 20 | N | 37°44' | 70°24' | 0-221 | 2 | 1 | - | 3( 3) |
| 07 | B24 | DO | 21 | N | 38°15' | 69°55' | 0-161 | 9 | 2 | - | 11( 21) |
| 07 | B25 | FD | 21 | T | 38°16' | 69°50' | Surface | - | - | - | -( -) |
| 09 | B26 | DO | 21 | D | 38°27' | 67°54' | 0-190 | - | - | - | -( -) |
| 10 | B27 | DO | 21 | N | 38°22' | 67°22' | 0-207 | 63 | 2 | - | 65(108) |
| 10 | B28 | FD | 22 | N | 38°25' | 67°11' | Surface | 20 | 2 | - | 22( 48) |
| 10 | B29 | FD | 22 | N | 38°26' | 67°07' | 0-52 | 21 | 10 | 2 | 33( 76) |
| 10 | B30 | FD | 22 | N | 38°30' | 67°03' | 44-80 | 21 | 2 | - | 23( 42) |
| 10 | B31 | FD | 82.01.22 | N | 38°30' | 66°59' | 92-150 | 2 | - | - | 2( 5) |
| 10 | B32 | FD | 22 | N | 38°29' | 66°54' | 153-230 | 1 | - | - | 1( 1) |
| 11 | B33 | FD | 22 | D | 38°32' | 66°31' | 0-32 | 16 | 2 | - | 18( 41) |
| 11 | B34 | FD | 22 | D | 38°32' | 66°26' | 47-70 | 56 | 23 | - | 79(159) |
| 11 | B35 | FD | 22 | D | 38°32' | 66°22' | 91-122 | 1 | - | - | 1( 1) |
| 12 | B36 | FD | 23 | D | 38°38' | 66°10' | 0-40 | 8 | 5 | 2 | 15( 21) |
| 12 | B37 | FD | 23 | D | 38°38' | 66°08' | Surface | - | - | 1 | 1( 1) |
| 12 | B38* | FD | 23 | D | 38°38' | 65°47' | 0-118 | 4 | 1 | - | 5( 11) |
| 15 | B39 | DO | 26 | D | 38°56' | 63°54' | 0-169 | 7 | 3 | - | 10( 26) |
| 16 | B40 | DO | 26 | D | 38°36' | 63°22' | 0-290 | 1 | - | 1 | 2( 2) |
| 19 | B41 | DO | 28 | D | 35°50' | 61°58' | 0-219 | - | - | - | -( -) |
| 20 | B42 | DO | 28 | N | 36°27' | 61°59' | 0-189 | - | - | 1 | 1( 4) |
| 21 | B43 | DO | 29 | N | 36°59' | 62°01' | 0-232 | - | - | - | -( -) |
| 22 | B44 | DO | 29 | D | 37°30' | 62°01' | 0-240 | - | - | - | -( -) |
| 23 | B45 | DO | 29 | D | 37°58' | 62°01' | 0-290 | - | - | - | -( 2) |
| 24 | B46 | DO | 29 | N | 38°30' | 62°00' | 0-198 | - | - | - | -( 1) |
| 25 | B47 | DO | 30 | N | 38°57' | 61°55' | 0-155 | 3 | 1 | 1 | 5( 14) |
| 25 | B48 | FD | 30 | D | 38°57' | 61°32' | Surface | - | - | - | -( -) |
| 25 | B49 | FD | 30 | D | 38°57' | 61°28' | 0-41 | 7 | 7 | - | 14( 26) |
| 26 | B50 | DO | 31 | N | 39°30' | 62°01' | 0-219 | 1 | - | - | 1( 5) |

Appendix Table 1 (continued).

| St. no. | Tow no. | Tow[1)] method | Date | Day/ Night | Locality Lat(N) | Lon(W) | Sampling depth(m) | No. of Illex caught R | T | J | Total[2)] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 | B51 | DO | 31 | N | 40°04' | 62°00' | 0-240 | - | 1 | - | 1( 7) |
| 28 | B52 | DO | 31 | D | 40°32' | 61°59' | 0-110 | 10 | 8 | 1 | 19( 33) |
| 29 | B53 | DO | 31 | D | 41°01' | 62°00' | 0-210 | - | - | - | -( -) |
| 30 | B54 | DO | 31 | N | 41°30' | 61°58' | 0-164 | - | - | - | -( -) |
| 31 | B55 | DO | 02.01 | N | 41°59' | 62°00' | 0-190 | - | - | - | -( -) |
| 32 | B56 | DO | 01 | D | 42°31' | 62°02' | 0-166 | - | - | - | -( -) |
| 33 | B57 | DO | 01 | D | 42°45' | 62°01' | 0-275 | - | - | - | -( -) |
| 34 | B58 | DO | 02 | DT | 40°17' | 57°57' | 0-223 | - | - | - | -( -) |
| 35 | B59 | DO | 03 | N | 41°05' | 58°30' | 0-220 | - | - | - | -( -) |
| 36 | B60 | DO | 03 | D | 41°15' | 58°47' | 0-202 | - | - | - | -( -) |
| 37 | B61 | DO | 03 | DT | 41°38' | 59°36' | 0-118 | - | - | - | -( -) |
| 40 | B62 | DO | 04 | D | 43°31' | 61°58' | 0-50 | - | - | - | -( -) |
| 41 | B63 | DO | 04 | N | 44°22' | 62°11' | 0-154 | - | - | - | -( -) |
| Second Cruise | | | | | | | | | | | |
| 42 | B64 | DO | 82.02.12 | N | 40°08' | 67°59' | 0-180 | - | - | - | -( -) |
| 43 | B65 | DO | 14 | D | 39°27' | 68°25' | 0-179 | - | 1 | - | 1( 1) |
| 44 | B66 | DO | 14 | N | 38°48' | 68°31' | 0-175 | 2 | - | - | 2( 3) |
| 45 | B67 | DO | 15 | N | 38°40' | 68°47' | 0-188 | - | - | - | -( -) |
| 47 | B68 | DO | 15 | N | 38°41' | 65°27' | 0-168 | 10 | 5 | - | 15( 22) |
| 49 | B69 | DO | 16 | N | 38°56' | 65°09' | 0-189 | 1 | - | - | 1( 1) |
| 50 | B70 | DO | 16 | D | 40°06' | 65°24' | 0-180 | - | - | - | -( -) |
| 51 | B71 | DO | 82.02.16 | N | 40°16' | 65°00' | 0-195 | - | - | - | -( -) |
| 54 | B72 | DO | 17 | N | 42°44' | 62°00' | 0-173 | - | - | - | -( -) |
| 56 | B73 | DO | 18 | N | 42°00' | 62°00' | 0-225 | - | - | - | -( -) |
| 57 | B74 | DO | 18 | D | 41°31' | 61°59' | 0-190 | - | - | - | -( -) |
| 59 | B75 | DO | 18 | N | 41°01' | 61°57' | 0-200 | - | - | - | -( -) |
| 60 | B76 | DO | 18 | N | 40°29' | 61°58' | 0-170 | - | - | - | -( -) |
| 61 | B77 | DO | 19 | N | 39°52' | 62°12' | 0-200 | - | - | - | -( 2) |
| 62 | B78 | DO | 19 | D | 39°29' | 62°01' | 0-200 | - | - | - | -( -) |
| 63 | B79 | DO | 19 | D | 38°59' | 61°59' | 0-196 | - | - | - | -( -) |
| 65 | B80 | DO | 21 | N | 38°31' | 61°55' | 0-168 | - | - | - | -( 1) |
| 66 | B81 | DO | 22 | N | 38°05' | 61°54' | 0-181 | - | - | - | -( -) |
| 72 | B82 | DO | 25 | N | 42°04' | 59°19' | 0-163 | - | 1 | - | 1( 1) |
| 73 | B83 | DO | 25 | D | 42°12' | 58°58' | 0-171 | - | - | - | -( -) |
| 74 | B84 | DO | 25 | D | 41°29' | 59°13' | 0-170 | 2 | 1 | - | 3( 3) |
| 75 | B85 | DO | 28 | D | 39°30' | 63°05' | 0-194 | - | - | - | -( -) |
| 76 | B86 | DO | 28 | D | 39°11' | 63°04' | 0-150 | - | - | - | -( -) |
| 77 | B87 | DO | 03.01 | N | 38°23' | 63°38' | 0-170 | - | - | - | -( -) |
| 78 | B88 | DO | 01 | D | 37°37' | 64°29' | 0-220 | - | - | - | -( -) |
| 79 | B89 | DO | 02 | N | 38°34' | 64°55' | 0-220 | - | - | - | -( -) |
| 80 | B90 | DO | 02 | D | 38°58' | 65°50' | 0-180 | - | - | - | -( -) |
| 81 | B91 | DO | 02 | N | 38°35' | 66°24' | 0-205 | 1 | 1 | - | 2( 4) |
| | | | | | Total | First Cruise | | 428 | 101 | 11 | 540(1030) |
| | | | | | | Second Cruise | | 16 | 9 | - | 25( 39) |
| | | | | | | Total | | 444 | 110 | 11 | 565(1069) |

* opening-closing apparatus troubled

1) DO: double oblique tow, FD: depth-stratified tow

2) numbers caught by one net of Bongo Net (materials preserved in Japan) and total numbers by both nets (including the materials preserved in Canada and USA) in parentheses, R: Rhynchoteuthion, T: Transition, J: Juvenile