Outline of the acoustic/midwater trawl survey for pelagic pollock in the international waters of the Bering Sea in the summer of 1987

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1987年のペーリング公海におけるスケトウダラ
を対象とした計量魚探／中層トロール調査の概要

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1. はじめに

水産庁は、1987年の夏に海洋水産資源開発センターに委託し、ペーリング公海海域（図1）において表・中層性スケトウダラを対象とした計量魚探／中層トロール調査を実施した。調査は2隻の北転船（第63瀬戸丸279トン及び第68北雄丸349.8トン）を用船し、8月6日から9月22日までの48日間実施された。このうち、調査を実施した期間は、8月13日～9月13日までの32日間であった。調査員は、第63瀬戸丸に永延幹男、第68北雄丸に後藤健彦がそれぞれ乗船し、計量魚探技術員として梅本春夫が第63瀬戸丸に乗船した。さらに、補助調査員として長崎大学水産学部学生が、各船に1名ずつ乗船した。

調査の目的は、1）ペーリング公海に夏季に生息するスケトウダラの現存量とその分布状態の把握、2）スケトウダラの標本採集、3）スケトウダラの分布と水温環境との関係を明らかにする、及び4）スケトウダラ稚仔魚と動物プランクトンの分布に関する情報の収集であった。これらの目的を達成するため、計量魚探システムと中層トロール網による調査、X B T観測及びノルパックネット調査が実施された。

調査から得られた資料及び結果は、「昭和62年度北太平洋微少割当魚種混獲対策調査報告書、水産庁、昭和63年3月、112 p．」として報告されている。ここでは、同報告書に基づいて調査の概要を報告するが、得られた基礎データについては同報告書を参照されたい。

報告に先立ち、調査の実施を担当された海洋水産資源開発センター、調査員として調査に従事された永延幹男氏、後藤健彦氏及び梅本春夫氏、並びに調査船の運航と調査の実施に多大な協力をいただいた第63瀬戸丸及び第68北雄丸の乗組員各位にお礼申し上げる。

2. 調査の方法

ペーリング公海を緯度30°，経度1°の小区画に分割し、合計52区の調査区画を設定した（図2）。これらの各区画を図2に示すように北東・南西方向の対角線上に沿って、1日1区画ずつ調査した。第63瀬戸丸はペーリング公海の西側域を、第68北雄丸は東側域をそれぞれ担当した。1区画内では、通常魚探、計量魚探、中層トロール、X B T、及びノルパックネットによる調査を、図3に示した順序で実施した。区画15で両船は合流し、合流後計量魚探システムと中層トロ
3. 調査結果

1) 計量魚探観察

公海水域内におけるスケトウダラの密度分布は、25 - 200 m層を平均してみると、公海の南東部と北西部で高く、北東部と南西部で低い傾向がみられる（図4）。水深50m層にみると、25 - 50 m層及び50 - 100 m層では北西部が広範囲に高く、南東部が低くなっている（図5 - 1）。100 - 120 m層では特に寄った分布はみられず、全体的に低い（図5 - 2）。120 - 140 m, 140 - 160 m, 及び160 - 180 mの各層も特徴的な分布はみられないが、水深が増すにつれて分布密度が高くなっていた（図5 - 2, 3）。180 - 200 m層における密度は全水深階層中最も高く、水平的には南東部において特に高かった（図5 - 4）。これらのことから、スケトウダラの分布密度は南東部の水深180 - 200 m層で高く、水深が浅くなるに従って全体的に低くなる傾向があるといえる。

東西方向における密度の鉛直分布をみると、水深100 m以浅では西側が高く、水深が深くなる
ると東側が高くなっている（図6）。また、南北方向では、北側では浅い水深で密度が高く、南側では深い水深で密度が高かった（図6）。

公害県内における計量魚採取による調査水域は全体の78%であったが、そのなかにおけるスケトウダラの資源尾数は113億尾、現存量は910万トンと推定された（表1）。このうち、北雄丸担当の南東水域が724万トン、濱善丸担当の北西水域が186万トンで、南東側は北西側よりも約4倍多かった。水深別には、水深が深くなるに従って急激に現存量が増大し、180－200m層における現存量は、全推定値の57%を占めた。

2）中層トロール調査

両船で合計144回の曳網を実施し、合計58,370kgを漁獲した（表2）。このうち、98%がスケトウダラで、スケトウダラ以外の魚種ではホテイウオが比較的多く全漁獲量の1.4%を占めた。水域別には、北雄丸担当の南東水域が48,543kg、濱善丸担当の北西水域が8,718kgであった。南東側は北西側よりも5.6倍漁獲が多かったが、この差は両船の中層トロール網の漁獲性能の差も含まれている。

後で報告のように、2隻の調査船の中層トロール網の比較試験結果によれば、北雄丸の漁獲性能は濱善丸より昼間で約2倍高い。そのため、濱善丸のCPEUを2倍にしてCPEUの地力的分布をみると、北西側で低く、南東側で高いという計量魚採調査結果とはほぼ類似した傾向がみられる（図7）。

CPEUの銭直分布の傾向も計量魚採調査の結果と類似しており、CPEUは150－200mの水深帯で最も高く、水深が浅くなればほど低かった（図8）。

漁獲されたスケトウダラの体長組成は、範囲が36－58cm、モードが46－48cm、平均体長が47.0cm、平均体重が805gで（図9）、Okada（1986）が報告した1977－79年の夏季調査の結果と変わらなかった。

3）船間比較試験

(a) 計量魚採システム

データの解析は古野電気機に依頼したが、2つのシステム間に特定の関係はみられなかった。しかし、この間の記録をみると、魚群反応が薄く、単体反応が散在しているのみで、船間比較の対象としては不適当であった。したがって、得られたデータを比較しても、それがシステム間の差を表わしているとは言えないと結論された（古野電気機・笹倉藤喜氏からの私信）。

(b) 中層トロール網

昼夜別にそれぞれ15回、合計30回の比較操業を行った。その結果、平均すると北雄丸の漁獲は、濱善丸の漁獲を昼間で2.0倍、夜間で1.6倍上回った（表3）。スキャンマー社製の音響的測定装置で測定した結果によれば、濱善丸の中層トロール網の網口高さと網口幅は、平均的にそれぞれ50m及び30mであった。北雄丸については測定装置を用意できなかった。
が、漁労長の話では網長の大きさは漁労丸の中層トロール網より小さいとのことである。
したがって、両船の漁獲性能の違いは、それぞれ漁場する中層トロール網の網長面積の違いでは説明できず、網の全体的な構造の違いに起因するものと考えられる。

4) X B T観測

全52点の観測点及び東西方向（A線、57°N）及び南北方向（B線、180°）における水温鉛直断面分布をみるための定線を図10に示した。各点における観測は、水深350mまで行った。

0－200m層における平均水温の分布をみると、全体的な傾向は東側で高く、西側で低い傾向を示している（図11）。これは、アリューシャン列島水域の東側から北上してくるアラスカ海流の影響により（Dodimead et.al.,1963）、東側が西側に比較して相対的に高温になっていることによるものと考えられる。

魚群密度が高かった150－200m層の水温水平分布をみると、150mでは2.5℃以下の冷水域がみられるが（図12－A）、200mになると3.0℃以上の暖水域が拡がる（図12－B）。

57°N線に沿った東西方向における水温鉛直分布からは、水深50m付近に季節蘊層が発達していることがわかる（図13－A）。この蘊層は、西側ではサプな鉛直勾配を示すが、東側の海域に向かって緩やかな勾配となる。蘊層の下層には4℃以下の冷水層がみられるが、この冷水層は西側では良好発達しているが、東側ではほとんど発達していない。冷水層の下層では水温が上昇し、特に東側の海域では4℃以上の暖水が200m以深に発達している。

経度180°線に沿った南北断面では、北側の150m層に2.5℃以下の水温極層がみられ、南に向かって次第に暖かくなり、200m以深には4℃以上の暖水が張り出している（図13－B）。

計測観測及び中層トロール調査の結果と対比させてみると、スタウラザの鉛直分布は、50－200m層に発達している冷水層と対応して高い密度を示しているようである。密度分布が特に高い水域は、第2水温蘊層の下層に暖水層が強く張り出している水域と一致していた。

5) ノルパックネット調査

X B T観測点とはほぼ同じ地点で合計52回の採集を行った。魚類の卵稚仔と動物プランクトンを選別する作業を行った結果、スタウラザの稚仔魚は採集されていなかった。このことは、公海水域にはこの時期ノルパックネットで採集できるような大きさの稚仔魚は分布していないかった可能性を示している。一方、遊泳力がかなり発達した幼魚が分布している可能性については、今後表層層を速く速度で曳網できる比較的大型の採集用具を用いて調査する必要がある。

4. 現存量推定値に関する若干の検討

先に報告したように、計測観測調査の結果から、公海水域の78％に相当する調査実施水域における夏季のスタウラザ現存量は、910万トンと推定された。計測観測調査の結果は、同時に実施した中層トロール網による調査結果と比較し、水深が深くなるに従って現存量が増大すること、及び南北水域の方が北西水域より現存量が多いことなどおおむね傾向は一致する。しかし、詳
細に検討してみるいくつかの問題点が指摘される。主要な問題点とは、1）資源密度の水深的及び鉛直的変化が、中層トロール調査から得られたCPE分布と比較してかなり大きい。鉛直分布を例にとると、水深150 - 200 m層における中層トロール網のCPEは、100 - 150 mの水深帯の1.5 - 2.2倍であるが、計量魚探調査の結果では14.6 - 22.2倍であった。2）調査実施水深の8.4％しか占めていない1つの調査区画（1区画は経度1°、緯度30´）の160 - 200 mの水深帯における現存量が突出して大きく、全推定値の51％を占めている。

水中音響学的な観点からは、この調査中に用いられた計量魚探機のパラメータのうち、スレッシュを環境の設定に問題があった可能性が指摘されている（水産工学研究所、古澤昭彦氏からの私信）。調査に用いたタイプの計量魚探システムの場合、一定のスレッシュを与えるとエコーレベルが浅深で過小、深深で過大になる傾向がある（古澤・他、1988）。調査では、雑音が大きかったことから、55 dBとかなり高いスレッシュ値が設定されており、スレッシュ効果と雑音が、調査結果にかなり影響を与えたのではないかと考えられる。

以上の点から、1987年夏季の公海における現存量推定値については、未解決の問題が含まれていると判断されることから注意して用いる必要がある。
References


Table 1. Estimated biomass (t) of pelagic pollock from Japanese acoustic survey in the international waters of the Bering Sea in the summer of 1987 (data from Fisheries Agency of Japan, 1988).

<table>
<thead>
<tr>
<th></th>
<th>25-200m</th>
<th>25-50m</th>
<th>50-100m</th>
<th>100-120m</th>
<th>120-140m</th>
<th>140-160m</th>
<th>160-180m</th>
<th>180-20m</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Hamayoshi maru</td>
<td>1,859,771</td>
<td>46,215</td>
<td>90,567</td>
<td>31,854</td>
<td>69,375</td>
<td>141,471</td>
<td>290,595</td>
<td>1,189,802</td>
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<td>Hokuyu maru</td>
<td>7,243,307</td>
<td>35,943</td>
<td>30,468</td>
<td>34,881</td>
<td>234,182</td>
<td>923,174</td>
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<td>4,023,910</td>
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<td><strong>Total</strong></td>
<td>9,103,078</td>
<td>82,158</td>
<td>121,035</td>
<td>66,735</td>
<td>303,557</td>
<td>1,064,645</td>
<td>2,249,844</td>
<td>5,213,712</td>
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<table>
<thead>
<tr>
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<th>Hokuyu maru No. 68</th>
<th>Hamayoshi maru No. 63</th>
<th>Total</th>
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<tr>
<td>No. of tows</td>
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<td>72</td>
<td>144</td>
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<td>Towing time (minute)</td>
<td>4,320</td>
<td>4,320</td>
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<td>Total catch (kg)</td>
<td>48,830</td>
<td>9,540</td>
<td>58,370</td>
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<tr>
<td>Pollock</td>
<td>48,543 (99.4%)</td>
<td>8,718 (91.4%)</td>
<td>57,261 (98.1%)</td>
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<tr>
<td>Smooth lumpsucker</td>
<td>267 (0.5%)</td>
<td>577 (6.0%)</td>
<td>844 (1.4%)</td>
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<td>Squids</td>
<td>7 (0.0%)</td>
<td>10 (0.0%)</td>
<td>17 (0.0%)</td>
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<tr>
<td>Jellyfish</td>
<td>8 (0.0%)</td>
<td>216 (2.3%)</td>
<td>224 (0.4%)</td>
</tr>
<tr>
<td>Others$^2/$</td>
<td>5 (0.0%)</td>
<td>19 (0.0%)</td>
<td>24 (0.0%)</td>
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</table>

1/ Not including catch from net No. 21-1, because it was missed to record.
2/ Including 7 chum salmon, 6 chinook salmon, and 1 sockeye salmon.
Table 3. Comparative survey of midwater trawl gears for pelagic pollock between
Hamayoshi maru No. 63 and Hokuyu maru No. 68 in the international waters
of the Bering Sea in the summer of 1987. Data from Fisheries Agency of
Japan (1988).

<table>
<thead>
<tr>
<th>Date</th>
<th>Net No.</th>
<th>Catch (kg)</th>
<th>Ratio (A/B)</th>
<th>Date</th>
<th>Net No.</th>
<th>Catch (kg)</th>
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<td>B</td>
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<td>2.01</td>
<td></td>
<td>6,691.1</td>
<td>4,196.6</td>
</tr>
</tbody>
</table>

A: Hokuyu maru No.68
B: Hamayoshi maru No.63
Fig. 1. Survey area, international waters, of the Japanese acoustic/midwaters trawl survey by Hokuyu maru No. 68 and Hamayoshi maru No. 63 in the Bering Sea in the summer of 1987.
Fig. 2. Division of survey area for the Japanese acoustic/midwater trawl survey by Hokuyu maru No. 68 and Hamayoshi maru No. 63 in the international waters of the Bering Sea in the summer of 1987.
Fig. 3. Outline of the survey in each block for the Japanese acoustic/midwater trawl survey in the international waters of the Bering Sea in the summer of 1987.

F : Normal echo sounder
T : Midwater trawl (60 minutes x 3)
S : FQ-60 (90 minutes x 2)
P : XBT and Norpac net
Fig. 4. Density distribution of pelagic pollock averaged for 25-200 m depth zone from Japanese acoustic survey in the international waters of the Bering Sea in the summer of 1987 (Fisheries Agency of Japan, 1988).
Fig. 5-1. Density distribution of pelagic pollock in the 25-50 m and 50-100 m depth zones from Japanese acoustic survey in the international waters of the Bering Sea in the summer of 1987 (Fisheries Agency of Japan, 1988).
Fig. 5-2. Continued. The 100-120 m and 120-140 m depth zones.
Fig. 5-3. Continued. The 140-160 m and 160-180 m depth zones.
Fig. 5-4. Continued. The 180-200 m depth zone.
Fig. 6. Vertical density distribution of pelagic pollock along the east-west section (57°N) and south-north section (180°) from Japanese acoustic survey in the international waters of the Bering Sea in the summer of 1987 (Fisheries Agency of Japan, 1988).
Fig. 7. CPUE distribution of pelagic pollock from Japanese midwater trawl survey in the international waters of the Bering Sea in the summer of 1987. Data from Fisheries Agency of Japan (1988).
Fig. 8. Vertical CPUE distribution of pelagic pollock from Japanese midwater trawl survey in the international waters of the Bering Sea in the summer of 1987. Data from Fisheries Agency of Japan (1988).
Fig. 9. Size frequency distribution of pelagic pollock from Japanese midwater trawl survey in the international waters of the Bering Sea in the summer of 1987 (Fisheries Agency of Japan, 1988).
Fig. 10. Stations conducted XBT observation and Norpac net tow during Japanes acoustic/midwater trawl survey for pelagic pollock in the international waters of the Bering Sea in the summer of 1987 (Fisheries Agency of Japan, 1988).
Fig. 11. Horizontal distribution of mean water temperature from XBT observation during Japanese acoustic/midwater trawl survey for pelagic pollock in the international waters of the Bering Sea in the summer of 1987 (Fisheries Agency of Japan, 1988).
Fig. 12. Horizontal distribution of water temperature from XBT observation during Japanese acoustic/midwater trawl survey for pelagic pollock in the international waters of the Bering Sea in the summer of 1987 (Fisheries Agency of Japan, 1988).
Fig. 13. Vertical distribution of water temperature along the east-west section (57°N) and south-north section (180°) from XBT observation during Japanese acoustic/midwater trawl survey for pelagic pollock in the international waters of the Bering Sea in the summer of 1987 (Fisheries Agency of Japan, 1988).
TRANSLATION

OUTLINE OF THE ACOUSTIC/MIDWATER TRAWL SURVEY
FOR PELAGIC POLLOCK IN THE INTERNATIONAL WATERS
OF THE BERING SEA IN THE SUMMER OF 1987

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1988 August

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:
1. INTRODUCTION

Fisheries Agency of Japan assigned the Japan Marine Fishery Resource Research Center (JAMARC) in the summer of 1987 to conduct an acoustic and midwater trawl survey for pelagic pollock in the international waters of the Bering Sea (Fig. 1). The survey was conducted using two chartered land-based dragnet trawlers [Hamayoshi maru No. 63 (279 GT) and Hokuyu maru No. 68 (349.8 GT)] for 48 days from August 6 to September 22. Of those days, the periods in which the actual surveys were conducted were for 32 days from August 13 to September 13.

Dr. Mikio Naganobu was on board the Hamayoshi maru No. 63 as a researcher, and Mr. Takehiko Goto was on board the Hokuyu maru No. 68 as a researcher, and Mr. Haruo Umemoto was on board the Hamayoshi maru No. 63 as a technician of the quantitative echo sounder. Furthermore, one student of the Faculty of Fisheries, Nagasaki University was on board each vessel as an assistant researcher.

Objectives of this survey were as follows: 1) Grasp of biomass and distribution pattern of pollock in inhabiting the international waters of the Bering Sea in the summer; 2) Sampling of pollock; 3) Clarification of relationship between the distribution of pollock and ambient water temperature, and 4) Collection of information on pollock larvae and the distribution of zooplankton. In order to accomplish these objectives, surveys were conducted with a quantitative echo sounder system and midwater trawl nets and XBT observation and the Norpac net tow were also made.

Data and results obtained from the surveys were reported as "Report of Survey on Selective Trawls to Reduce the Bycatch of Low-quota Species in the North Pacific, 1987. Fisheries Agency of Japan, March 1988. 112 p." Although an outline of the survey is reported here, please see the above report for the basic data obtained.
In advance of reporting, I would like to express my sincere appreciation for the Japan Marine Fishery Resource Research Center which conducted the surveys, Dr. Mikio Naganobu, Mr. Takehiko Goto, and Mr. Haruo Umemoto who participated in the surveys as the researchers, and all crew members of the Hamayoshi maru No. 63 and Hokuyu maru No. 68 who offered a great deal of cooperation during the cruises and surveys of the research vessels.

2. METHOD OF SURVEY

The international waters of the Bering Sea were divided into a block of 30' latitude and 1° longitude and a total of 52 survey blocks were established (Fig. 2). As shown in Fig. 2, the survey was conducted in a block per day along a diagonal line of northeastward and southwestward direction. The Hamayoshi maru No. 63 took charge of the western side, and the Hokuyu maru No. 68 took charge of the eastern side of the international waters of the Bering Sea, respectively. Within a block, the surveys were conducted with the normal echo sounder, quantitative echo sounder, midwater trawl, XBT, and Norpac net (in the order shown in Fig. 3). Both vessels joined at Block 15, and then the comparative experiments on the quantitative echo sounder system and midwater trawl gear were conducted by both vessels.

In the quantitative echo sounder survey, the echo integrator system of FQ-70 which was manufactured in the Furuno Denki Co., Ltd., was used, but the whole system could not be taken aboard two vessels, because of preparation and space problems. Therefore, the FQ-60 which only records the echo data onto a tape were set up on board of both vessels, and analysis of data was conducted on shore. Frequency and output power of the transducer was 88 kHz and 1 kw, respectively, and it was towed by 4 knots in a depth of 15 m from the stern. The survey of 90 minutes a time in each block was conducted twice, and the data of a total of 180 minutes (corresponds to 12 miles) were collected.
It is necessary to know the target strength (TS) of pollock in order to estimate stock density and biomass of pollock from the echo data obtained. As we could not measure the target strength directly in this survey, we estimated the target strength of pollock using the following equation according to Miyanohana (1986):

\[ TS = 66.6 + 20 \log L \]

where \( L \) : Fork length (cm)

Analysis was conducted by each block and target strength by each block was calculated by substituting the average length of fish caught by the midwater trawl net for this equation. The integral layer that was set ranges from 25 m to 200 m and 200 m and deeper was omitted, because of scanty response of echo sounder.

In the survey with the midwater trawl net, both vessels used their own midwater trawl nets, 3 towings per block were conducted. Towing time of each operation was 60 minutes and towing speed was 3 knots. The first and third towing were conducted in depths which had a relatively high density and the second towing was conducted in depths which had a low density.

One Norpac net tow, vertically from the depth of 150 m, as well as XBT observation was conducted in each block.

In the inter-ship comparative experiment of quantitative echo sounder system and midwater trawl net, a parallel survey was conducted at the interval of both vessels of 0.3 miles along the track lines which were set randomly in Blocks 24 and 36. The surveys were conducted by day and night and a total of 28 data sets were collected for the quantitative echo sounder system and a total of 30 data sets were collected for the midwater trawl net.
3. RESULTS OF SURVEY

1) Quantitative Echo Sounder Survey

On an average of 25 m to 200 m layers, density distribution of pollock in the international waters of the Bering Sea tend to be high in the southeastern and northwestern parts of the international waters and low in the northeastern and southwestern parts (Fig. 4). Judging from the density distribution by depth class, in the depths of 25 m to 50 m and 50 m to 100 m layers, it was extensively high in the northwestern part and was low in the southeastern part (Fig. 5-1). In depths of 100 m to 200 m layer, any particular biased tendencies were not observed, and were generally low (Fig. 5-2). Although a distinctive distribution was not observed in depths of 120 m to 140 m, 140 m to 160 m, and 160 m to 180 m layer, the density distribution of pollock became higher, as the depth became deeper (Fig. 5-2 and 5-3). Density in depths of 180 m to 200 m layer was highest in all density distributions by depth class, and horizontally it was extremely high in the southeastern part (Fig. 5-4). On the basis of this evidence, it may safely be said that the density distribution of pollock was high in depths of 180 m to 200 m of the southeastern part, as a depth becomes shallower, it generally expands, but there was a tendency for the density distribution of pollock in the northwestern part to become higher than that in the southeastern part.

Vertical distribution of density of pollock from east to west was high in the western side in depths of 100 m and shallower layers, and was high in the eastern side, as the depth became deeper (Fig. 6). Furthermore, in direction from south to north, the density of pollock was high in the shallower depths in the northern side and was high in the deeper depths in the southern side (Fig. 6).
Although the area in which the survey was conducted by the quantitative echo sounder in the international waters of the Bering Sea accounted for 78% of the whole area, the population number of pollock in that area was estimated to be 11,300 million and the biomass was estimated to be 9.1 million t (Table 1). Of those, the biomass of pollock in the southeastern area which was conducted by the Hokuyu maru No. 68 was 7.24 million t and was 1.86 million t in the northwestern area which was conducted by the Hamayoshi maru No. 63. Biomass of pollock in the southeastern side was about 4 times larger than that in the northwestern side. By depth, the biomass of pollock increased rapidly, as a depth becomes deeper, and the biomass in depths of 180 m to 200 m accounted for 57% of the total estimated value.

2) Midwater Trawl Survey

Both vessels conducted a total of 144 towings and total catch was 58,370 kg (Table 2). Of those, pollock accounted for 98% of the total, and for species other than pollock, smooth lumpsucker was of relatively high abundance and accounted for 1.4% of the total catch. By area, the catch was 48,543 kg in the southeastern area in which the Hokuyu maru No. 68 took charge and was 8,718 kg in the northwestern area in which the Hamayoshi maru No. 63 took charge. The catch in the southeastern side was 5.6 times larger than that in the northwestern side, and the difference of fishing efficiency with the midwater trawl nets of both vessels was also included in this difference.

As described later, according to the results of comparative experiments with the midwater trawl nets of two research vessels, a fishing efficiency of the midwater trawl net of the Hokuyu maru No. 68 was about twofold higher than that of the Hamayoshi maru No. 63 in the daytime. Thus, judging from the geographical distribution of CPUE values which double CPUE of the Hamayoshi maru No. 63, a similar tendency to the results of quantitative echo sounder, that is to say, it was observed that CPUE values are low in the northwestern side, and high in the southeastern side (Fig. 7).
The tendency of vertical distribution of CPUE was also similar to the results obtained from the quantitative echo sounder survey, and CPUE value was highest in depths of 150 m to 200 m, and became lower, as a depth became shallower (Fig. 8).

Length frequency distribution of pollock obtained ranged from 36 cm to 58 cm in fork length, and mode ranged from 46 cm to 48 cm, average fork length was 47.0 cm, and average body weight was 805 g (Fig. 9), and these results were similar to the results of surveys in the summers of 1977 to 1979 which were reported by Okada (1986).

3) Comparative Experiment between two vessels

(a) Quantitative Echo Sounder System

Although we entrusted the analysis of data to the Furuno Denki Co., Ltd., there were no specific relationships between two systems. However, judging from the echograms recorded during the survey, because the response of fish school was scanty and response of individual fish was scattered, it was inadequate to conduct inter-ship calibration with these data. Therefore, it was concluded that comparison of data obtained did not indicate the differences between the systems (personal letter from Mr. Toyoki Sasakura, Furuno Denki Co., Ltd.).

(b) Midwater trawl net

A total of 30 comparative operations, 15 operations each by day and night, was conducted. As the results of these operations, the catch of the Hokuyu maru No. 68 was twice as large as the catch of the Hamayoshi maru No. 63 in the daytime and was 1.6 times larger in the nighttime (Table 3). According to the results which were measured with the acoustic measurement system manufactured by the Scanmar Electric Co., Ltd., height and width of the net mouth of midwater trawl net equipped with the Hamayoshi maru No. 63 averaged 50 m and 30 m, respectively.
Although the acoustic measurement system was not able to be prepared on the Hokuyu maru No. 68, the fishing master said that size of the net mouth of the midwater trawl net was smaller than that of the Hamayoshi maru No. 63. Thus, it is judged that the differences of fishing efficiency of both vessels do not depend on the differences of the area of net mouth of midwater trawl nets belonging to each vessel, and it is considered that the differences result largely from the whole structural difference of midwater trawl nets.

4) XBT OBSERVATION

All 52 observation points and lines which show the vertical distribution of water temperature at the east to west direction (A line, 57°N) and the south to north direction (B line, 180°) were shown in Fig. 10. Observation at each point was conducted up to the depth of 350 m.

Horizontal distribution of the average water temperature in depths of 0 m to 200 m was generally high in the eastern side and low in the western side (Fig. 11). It is considered that water temperature in the eastern side rises, as compared to that in the western side under the influence of the Alaskan Stream which flows up to the north from the southeastern side of the Aleutian Islands region (Dodimead et al., 1963).

Judging from the horizontal distribution of water temperature in depths of 150 m to 200 m layer in which the density of fish schools was high, cold water area of 2.5°C and under in a depth of 150 m layer was observed (Fig. 12-A), and warm water area of 3.5°C and over was extended in a depth of 200 m layer (Fig. 12-B).

From the vertical distribution of water temperature at the east to west direction along a line of 57°N, it is known that a seasonal thermocline develops around the depth of 50 m (Fig. 13-A). Although this thermocline indicated a sharp vertical slope in the western side, it became a gentle slope as it headed toward the eastern side.
A cold water layer of 4°C and lower was observed in the layer below this thermocline, and this cold water layer was well developed in the western side, but scarcely developed in the eastern side. Water temperature rose in the lower cold water layer, and in particular, warm water of 4°C and higher developed in depths of 200 m and deeper.

In the south to north section along a line of 180°, a cryogenic layer of water temperature of 2.5°C and lower was observed in depth of 150 m layer in the northern side, it became gradually warmer, as it headed toward the south, and warm water of 4°C and higher expanded in depths of 200 m and deeper (Fig. 13-B).

In comparison with the results of XBT observation and the results of quantitative echo sounder and midwater trawl surveys, the vertical distribution of pollock appeared to show a high density which corresponded to a cold water mass developed in depths of 50 m to 200 m layer. The area in which density distribution was particularly high corresponded with the area in which warm water mass strongly extended in the lower layer of the second thermocline.

5) Norpac Net Survey

A total of 52 samplings with the Norpac nets was conducted in almost the same point in which the XBT observations were made. As the results of work to sort eggs and larvae of fishes and zooplankton, larvae of pollock were not caught. This indicated the possibility that larvae of pollock of catchable size with the Norpac net were not distributed in the international waters of the eastern Bering Sea in this season. On the other hand, in order to know whether juvenile pollock which have fairly well developed swimming powers are distributed in this area or not, it is necessary to conduct surveys using relatively large-sized sampling gear which are able to tow at a high speed in the surface and midwater.
4. **SOME CONSIDERATION OF THE ESTIMATED BIOMASS**

As reported before, the biomass of pollock in the survey area which corresponds to 78% of the international waters of the Bering Sea was estimated to be 9.1 million t from the results of quantitative echo sounder survey. In comparison of the results obtained from the quantitative echo sounder survey with that from midwater trawl net surveys which were conducted at the same time, the general tendencies were agreed such as an increase of the biomass of pollock as depth becomes deeper and a larger biomass of pollock in the southeastern area than that in the northwestern area. However, when we consider in detail, there are several problems. The major problems are as follows: 1) The horizontal and vertical changes of population density of pollock obtained from the quantitative echo sounder survey were fairly larger than the distributions of CPUE obtained from the midwater trawl survey. For instance, in the case of vertical distribution, CPUEs of pollock obtained from the midwater trawl net in depths of 150 m to 200 m were 1.5 to 2.2 times larger than those in depths of 100 m to 150 m layer, but the results obtained from quantitative echo sounder survey were 14.6 to 22.2 times larger; 2) The biomass of pollock in depths of 160 m to 200 m of four survey blocks (one block is 1° longitude and 30' latitude) where accounted for only 8.4% of the survey areas were extremely large, and accounted for 51% of the whole estimated value.

From the hydro-acoustic point of view, this survey results indicated that there were some problems concerning the establishment of thresholds out of the parameters of quantitative echo sounders used for this survey (private letter from Mr. Masahiko Furusawa, National Research Institute of Fisheries Engineering). In the case of the quantitative echo sounder system which was used for the survey, given a constant value of threshold, that system had a tendency for the echo level to become less in the shallower layers and to become more in the deeper layers (Furusawa et al., 1988).
In the survey, a fairly high threshold value such as -55 dB was established because of a larger noise, it is considered that threshold effect and noise had quite an effect on the results of the survey.

From the above points of view, it is necessary to carefully use the estimated biomass of pollock in the international waters of the Bering Sea in the summer of 1987, because there are some unsolved problems.

Reference, Tables 1 to 3 and Figs. 1 to 4, 5-1 to 5-4 and 6 to 13 are in English in the Japanese document.