Synopsis of biological informations on the pelagic pollock in the Aleutian Basin

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1987年8－9月にベーリング海で海洋水産資源開発センターが実施した計数魚探と中層トロール網による調査によれば（水産庁, 1988），公海における魚群分布は南東水域で比較的高く，北西水域で低い傾向が見られた（図4，5）。

冬季における分布は，海盆全体についてはまだ明らかにされていないが，180度以東のアリューシャン列島東側の海盆南部東部では，1983年の1－3月に開洋丸による調査が実施され，スケトウダラの分布が確認されている（岡田, 1984a ; 岡田・中山, 1983 ; 水産庁, 1984）。この調査の大半は米国200海里水域内で実施され，公海水域については中央部（180度線）の南端で1回の中層トロール調査が実施されたに留まった（図6）。スケトウダラの分布は公海上の1点を含め180度以東の水域にみられが，180度以西の水域については中層トロール調査の回数が少なく，分布状況の把握は十分ではなかった（図7）。しかし，同時に実施した計数魚探調査の結果をみると（図8），パワーズ・リッジの西側の海盆における密度は，南東部と比較し著しく低かった（水産庁, 1988）。調査水域内で密度が高かった水域は公海に接する西経176－178度，北緯53度30分から55度付近，西緯173度，北緯53度30分付近，及び西緯172度以東，北緯55度以南の海盆南部東部であった。

ベーリング公海における冬季のスケトウダラ魚群の分布に関する情報は，調査船からはまだ入手されていないが，商業船からは漁獲統計資料として得られている（図9，10）。北方トロール船の漁獲統計資料によれば，1985年までは漁業が主として1－2月に行われ，漁獲量の多くは米国200海里水域に接する公海の南部東部で漁獲されていた（佐々木・吉村，1987）。しかし，1986年の公海における冬季操業では，11月と12月の漁獲が増えるとともに主漁場は180度以西のパワーズ・リッジの北西側にも形成された。1987年にはこの傾向はさらに顕著になり，漁獲量の大部分は180度以西の水域で漁獲されている（日本トロール底魚協会データファイル）。

これらの変化が，漁場に関する知見の蓄積によるものか，あるいは冬季における魚群の分布パターンの年変動を反映したものかは，現時点ではまだはっきりしない。

佐々木・吉村（1987）は，1987年冬に公海で操業した北転船に便乗し観察した結果を報告した。便乗調査は，1月24－25日及び2月27－3月2日の2回実施された。漁場は2回の調査とも180度以西のパワーズ・リッジの北側（北緯55－56度，西経178－179度）であった。同漁場では1月末には極めて濃密な魚群が形成され，便乗した漁船のひき網1時間当たりの漁獲量（CPUE）は31.5トンを記録した。2月末には魚群密度は低下し，CPUEは4.2トンであった。
岡田（1979 a）は商用船の魚探記録から、アリューシャン海盆には4〜5月、10〜12月にもスケトウダラが分布すると報告している。また、漁獲統計資料によれば、1985年以降我が国漁船の一部は公海水域で夏季も操業し、量的にはわずかであるがスケトウダラを漁獲している（遠洋水研データファイル）。

以上の情報から、スケトウダラはアリューシャン海盆に広く分布しているが、夏季には広い範囲に分散して分布し、冬季には集群して極めて濃密な群れを形成することがわかる。

2）魚探分布

夏季（6〜8月）における調査船の資料によれば、アリューシャン海盆におけるスケトウダラの魚探反応は、水深30〜150 mに認められた（岡田, 1979 a）。反応は点状で、主な分布層は年によってやや異った。また、この反応は日中は比較的深く、夜間には浅くなることから、日周の垂直移動の存在が観察されている。水深30 m以浅の表層における分布密度が比較的低いうち、調査船の魚探反応によるスケトウダラの集中が、海盆上では1調査点あたり5尾以下であることからも明らかである（山口, 他, 1979）。また、1971年6月に海盆で実施された立網用を用いた調査によれば、漁具が設置された5〜100 mの水深範囲の全層でスケトウダラが漁獲された（菊池・辻田, 1977）。さらに、鈴木（1976）は海盆上で魚探反応にみられるスケトウダラの分布は、主として60〜80 m以浅にみられるが、ときには100 m以深に及ぶと報告している。

これらの報告に対し、1987年8〜9月にベーリング公海で実施された調査結果では（水産庁, 1988），スケトウダラの密度分布は150〜200 mの水深で最も高かった（図11, 12）。この調査では、200 m以深では調査が実施されなかったが、魚探反応に密度は極めて薄かったと判断されている。計量魚探調査結果からは、140 m以浅における分布密度は、北西水域の方が南東水域より相対的に高い傾向がうかがえる（図11）。

1983年の開洋丸による冬季調査によれば、1〜3月の海盆におけるスケトウダラの魚探反応は75〜600 mの範囲に認められ、出現平均水深は夏季より深かった（岡田, 1984 a, 水産庁, 1984）。1月下旬から2月中・下旬には主として250〜300 mの水深に分布し、3月中旬には100〜200 mと浅くなった。冬季にも夏秋と同様の日周垂直移動が認められた。1982年の北転船の海盆における冬季操業から入手された魚探記録によれば（吉田・上田, 1986），2月20日前後には魚群は主として250〜350 mの水深に分布し、その後3月上旬にかけてやや浅くなる傾向がみられる。著者が入手した北転船の1986年12月から1987年1月下旬までの公海における操業記録では、ひき網水深（海面から網目の天井までの水深）は12月には中旬が160〜200 m、下旬が140〜200 mで比較的浅かったが、1月に入ると中旬が160〜220 m、中旬が200〜300 m、下旬が230〜320 mとなり、この間に分布水深が深くなる傾向が認められた。また、1月下旬の資料によれば、魚探反応の下限は水深420 mであった。
以上要約すると、海盆に生息するスケトウダラの鉛直分布は季節的に変動し、夏季には30 - 150 mの水深に分布するが、冬季の1月下旬から2月中旬には分布の中心は230 - 320 mとなり、3月上旬には再び浅くなって100 - 200 mの水深に分布する。これらの分布様式は、同じ季節でも年や場所によって異なり、海洋環境条件の変化と密接に関係しているものと考えられる。

3）移動

アリューション海盆全域を網羅する魚群の移動についてはほとんどわかっていないが、公海水域に限って、漁場形成が魚群移動と連動したものと仮定すれば、月別漁獲量の変化から魚群の移動を推定することができる。図13は、1986年10月から1987年10月までの我々が国北方トロール船の月別漁獲量を示したものである（日本トロール漁協会データ・ファイル）。魚群は10月にソ連200海里水域に接する公海の西側に出現し、月を追って東側に移動する傾向がみられる。2月に入ると公海には少なくなり、3月には大きな魚群は公海から姿を消すように見受けられる。公海における2月末の魚獲が1月末に比較して大きく低下することは、佐々木・吉村（1987）によっても観察されている。4 - 5月になると経度180度線の西側で魚群がみられるようになるが、6 - 9月は夏型の分散した分布になるため操業がほとんど行われなくなることから、魚群の移動に関する情報は入手できない。10月には再び公海の西側に魚群が出現する。

図14は、ベーリング海のソ連200海里水域内で1987年実施された我々が国とソ連とのスケトウダラを対象とした合弁漁業から、水産庁が入手した標本の採取位置を示している。これをみると、海盆のソ連水域にもスケトウダラの密集が分布することがわかる。これらの魚群の回遊経路や産卵場所についても調査を進める必要があるろう。

4）魚群構造

魚探反応にみられる海盆のスケトウダラの魚群構造は、夏季と冬季では全く異なっており（岡田、1977、1978、1979a、1984a；Okada and Yamaguchi、1985；水産庁、1984；鈴木、1976），夏季には点状に分散して分布するが（図15）、冬季には集群して帯状あるいはバッチ状の分布構造を示す。1983年の開洋丸による冬季調査の結果によれば（水産庁、1984）、帯状の分布を示す魚群は最も出現頻度が高く（図16）、ときには100海里以上にまたがる大きな魚群がみられた。バッチ状に分布する魚群の一つを観測した例では（水産庁、1984）、平均280 mの水深に長径22 Km、短径5.5 Km、平均の厚さが65 mの魚群が形成されていた（図17、18）。

1987年1月下旬に、著者が北航船に乗船して公海水域で観察した結果では、魚群は帯状に分布しており、魚群の厚さはおよそ100 m、最大で200 m近くに達していた。カラー魚探でみると、特に濃密な魚群は魚群層のなかの上層部分に形成されていた。吉田・上田（1986）によれば、2月下旬になると、集群した魚群層を離れた上層に飛雲状の反応が多くみられるようになるが、これは性的や活発な繁殖群が濃密な産卵予備群から離れ、大きな群れを形成せずに基本的には雌雄一対一の中層遊泳型の繁殖行動を行っていることによるものと推定されている。このことから、産卵期前に形成された濃密な集団構造は、産卵期間中に徐々に崩れ、やがて夏季にみられる点状
分布へと移行すると考えられる。

2. 系 統 群

ベーリング海に分布するスケトウダラの系統群については、東部ベーリング海の陸棚資源について単一系群説（高橋・山口，1972）とブリピロフ諸島を境界に北西群と南東群が存在すると考えられる2系群説（前田，1971，1972）がある（図19，20）。さらに、ナウリン岬周辺海域にも独立した系群が存在するとされている（前田，1979）。前田（1979）は、ベーリング海のスケトウダラの系統群を再検討し、2系群説の可能性を支持しているが結論を得るには至らなかった。しかし、西緯170度以西の水域では表層におけるスケトウダラの稚魚の分布が、大陸棚上では少なく外洋域で多いこと（前田・平川，1977）、及び同水域の大陸棚とその周辺域には、越冬群と産卵群は大量に生息しているにもかかわらず、大きな産卵群がみられないことから、北西群の産卵群は越冬期〜産卵期の間、大陸斜面から外洋域に分布し、産卵期には大陸棚上に移動すると推察した。

一方、Lynde et al.（1986）は水域別に採集したスケトウダラの標本について年齢と成長を水域別季節別に比較検討し、東部ベーリング海とアリューシャン海盆には再生産の過程が異なる2つの"ユニット"が存在すると想定した。一つはブリピロフ諸島南東域を主産卵場とする群で、生涯を通じて大陸棚及び大陸斜面に生息するが、4歳以上になるとブリピロフ諸島以北の水域にも分布する。この群は成長が遅い。もう一つは、海盆を主産卵場とする群で成長が遅い。卵・稚仔は反時計回りの環流系によって東部ベーリング海の大陸棚に移送され、ブリピロフ諸島以北の水域で3〜4歳まで過ごし、その後成熟すると共に陸棚を離れ海盆に移動する。この仮説は、ブリピロフ諸島北西に生息する群の主産卵群は冬季には外洋域に分布し、そこで産卵すると考えた前田の2系群説と類似している。前田の説では夏季に海盆上に分布するスケトウダラの起源については説明できないが、山口（1984）は、夏季と冬季の海盆のスケトウダラの年齢と成長に差があり、冬季の魚群は夏季のものと比較して年齢別平均体長が大きい傾向がうかがえることから、越冬または産卵のために陸棚を離れできた未成熟な若鰭魚（4歳主体）の大部分と、高齢魚（5歳以上）のうち成長の良い（栄養状態の良い）ものは、夏季には陸棚へ帰るが、高齢魚の大部分はそのまま海盆にとどまるのではないかと考えた。

また、Hinckley（1987）は、アリューシャン海盆を含めた東部ベーリング海の産卵群から採集した標本に基づき、年齢別体長、抱卵数及び産卵期などについて比較検討し、少なくとも3つの分離された産卵群が存在すると報告した。それらは、アリューシャン海盆群、南東水域の大陸棚と大陸斜面及び北西水域の大陸棚群、及び北西水域の大陸斜面群である。Lynde et al.（1987）が海盆のスケトウダラの起源ではないかと想定した北西水域の大陸斜面の魚群については、産卵群としては分離したものであると指摘している。

1983年1〜3月に水産庁調査船観洋丸がアリューシャン海盆の南東部で採集したスケトウダラの年齢別体長組成を詳しく検討した結果によれば（佐々木・吉村，1988）、山口（1984）も指摘
ているように冬季の海盆のスケトウダラは同じ年齢群でも成長が異なるいくつかの異なった群で構成されている（図21）。 特に、満年齢で5歳と6歳の魚群は、年齢形質にみられる成長帯の形成量が異なるそれぞれ4+，4++，5−群及び5+，5++，6−群の3群で構成されている。このことは、山口（1984）及びLynde et al.（1986）が想定したブリピロフ諸島北西水域の大隆斜面に生息する魚群が、海盆群の起源であるとする单一起源説では説明できず、いくつかの異なった水域で成長した群れが混合していると考えられる。

また、東部ベーリング海の大陸棚上の南東水域における年齢別体長組成は、5月と6月には全年齢群について北西水域の魚群と比較して明らかに大型である。しかし、7月から9月にかけて5歳以上の年齢群の体長組成が不自然に小型化し、北西群の年齢別体長組成と類似するようになる（佐々木・吉村、1988）。このような現象から、南東水域では夏の期間にかなり大きな魚群の構成の変化があるものと考えられる。

アジア側の大陸棚上の資源と海盆上の資源との関係は、これまでほとんど論じられていない。しかし、ブリピルフ群島とオリュートル群島の中間の陸棚上で放流したスケトウダラが2尾海盆上で再捕されており（吉田、1979；遠洋水研データファイル）、ゴーベナ群島沖合で放流したスケトウダラが2尾北部59度付近の東部ベーリング海の大陆棚で再捕されている（吉田、1979）。また、1979年4月、日本の北海道太平洋岸で解凍放流したスケトウダラが、1981年10月に54°35'N，176°05'Wの海盆上で韓国トロール船により再捕されている（北水研データファイル）。これらのことから、アジア側の資源と海盆及び東部ベーリング海の資源とは、無関係ではないことは明らかである。

ベーリング海を含めたスケトウダラの系統群については、生化学的研究（Grant and Utter，1980；Iwata，1975），計数形質と外部形態の地理的変異から分析した研究（橋本・小谷地，1977；小谷地・橋本，1977；Serobaba，1975）などがある。生化学的研究からは、日本近海とベーリング海との間には魚群の交流はないが、ベーリング海のなかでは遺伝的に分離できるような複数の個体群の存在は認められなかった（Iwata，1975）。東部ベーリング海とアラスカ湾のstandardを比較した結果でも、両水域間には若干の遺伝的差異が認められたが、東部ベーリング海の北西群と南東群との間では遺伝的差異は検出されなかった（Grant and Utter，1980）。これに対して、計数形質と外部形態の比較研究では、ベーリング海のスケトウダラは東部、北部、西部及び南部（アリューシャン列島群）の4地方群に分離できるとされている（Serobaba，1975）。

また、オルヤートール群島でのベーリング海東部群とでは、脊椎骨数には差がみられなかったが、眼径の大きさに有意差がみられた（橋本・小谷地，1977；小谷地・橋本，1977）。

以上述べたように、系統群に関する解釈はいろいろ出されているが、標識放流の結果あるいは生化学的研究で明瞭な遺伝的差異が検出された場合を除けば、いずれも決定的な証拠に基づいたものではなく仮説の域を出ない。しかし、海盆に生息するスケトウダラの大部分は5歳以上の高齢魚で（Lynde et al.，1986；Okada and Yamaguchi，1985；Traynor and Nelson，1985；

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Yamaguchi, 1984；吉田・上田, 1986), 産卵は海盆で行われ, 後述するように卵・稚仔魚が
海盆に存在することは確認されているものの, 0 - 4 歳魚が大量に存在することはまだ確認されて
いない。この期間の未成魚は大形層に分布している可能性が考えられるが, はっきりとした証拠は得
られていない。したがって, 海盆のスケトウダラの起源を明らかにするためには, ベーリング海全
体のスケトウダラ個体群の構造を総合的に究明しなければならない。

3. 年齢と成長

1979 年夏季及び 1983 年の冬季に海盆上に調査船により入手された標本から推定されたスケトウ
ダラの成長は（図 23, 24, 25）、ブリビロフ諸島南部の東部ベーリング海大形層上の魚と比較
するとかなり遅が, 同諸島以北の陸棚上の魚とはかなり類似していた (Okada and Yamaguchi, 1985；山口, 1984；Traynor and Nelson, 1985)。しかし, 4 歳魚だけは特異的に東南群の
4 歳魚に近似していた。出現した年齢の範囲は 3 - 12 歳であった。海盆のスケトウダラの成長が遅
いことは, Lynde et al. (1986) 及び Hinckley (1987) によっても報告されている。Lynde
et al. (1986) は, 4 歳以上の海盆スケトウダラの遅い成長は, ブリビロフ諸島以北の大陸斜面
に分布する成長の遅い群の 4 歳までの成長に連続していると指摘した。この結果は, 4 歳魚につい
ては先の山口（1984）の結果と一致していない。

スケトウダラの寿命は陸棚上では一般に 15 歳程度とされているが (Smith, 1981), 海盆の
スケトウダラの最高年齢は Lynde et al. (1986) によれば 13 歳である。1973 年にシベリア沿
岸で標識放流した魚から再捕された 2 尾のうち, バワーズ・リッジ付近で再捕された魚は（図 22）,
1981 年の冬に再捕された（遠洋水研データ・ファイル）。放流時の体長から 4 - 5 歳魚とすれば,
再捕時の年齢は 12 - 13 歳として推定される。このことから, 海盆にも陸棚と同様に高齢な魚が分布し
ていることは確かである。

4. 体長・年齢組成

1) 体長組成

1977 - 79 年の夏季にアリューシャン海盆で調査船によって採集されたスケトウダラの体長組
成は（図 26）, 尾叉長が 38 - 56 cm の範囲にあり, 46 - 48 cm にモードを持つ単峰型の分布を
で調査船が漁獲したスケトウダラの体長組成は（図 27）, 尾叉長の範囲が 36 - 58 cm, モード
が 46 - 48 cm であった（水産庁, 1988）。これらの分布形は, これまでに報告された魚種ご
の漁獲された海盆のスケトウダラの体長組成とはほぼ一致していた（遠洋水研, 1979; 菊地・辻田,
1977; 鈴木, 1976; 吉田・尹, 1981）。大きな特徴は, 尾叉長 42 cm 以下及び 52 cm 以上の魚
が極めて少ないとであることである。

一方, 1983 年の冬季調査から得られた海盆のスケトウダラの体長組成は（図 28）, 全体では

—7—
44 - 46 cmにモードを持つ单峰型の分布を示しており、夏季のモードと比較して2 cm小さかった（山口，1984；水産庁，1984）。また，38 - 40 cmあるいは40 - 42 cmにモードを持つ小型群がみられたことが，大きな特徴といえる。年齢別体長組成をみると（佐々木・吉村，1988），これらの小型群は4歳魚と5歳魚で夏の調査ではみられなかったことから，海盆における出現は冬季における越冬を目的とした一時的なものと考えられる（図29）。小型群は調査水域の全域にみられたが（図30），西経170 - 175度の水域には少なく，その両側の水域で比較的多かった。時期的には，西経170度以東では2月，西経175 - 180度では3月に多かった。


ベーリング公海における1987年冬季の組成（図31）と同年の夏季の組成（図27）を比較するとほとんど変らず，公海海域には周年同じ体長組成の魚群が分布していることを示している。


2）年齢組成

1979年の夏に調査船が採集した海盆のスケトウダラの年齢組成は（図33），3 - 9歳魚で構成されていたが，組成の94％は5 - 7歳魚が占め，雌雄間で組成の違いはみられなかった（Okada and Yamaguchi, 1985）。この報告では年齢形質として鰭が用いられているため，高齢魚は若干過少に推定されている可能性がある。

1983年の冬季調査の結果では（山口，1984），出現した年齢の範囲は4 - 12歳で，全体としてみれば夏と同様に5 - 7歳魚が大部分を占めた（図34）。しかし，夏と異なり6歳魚が特に多いということはなく，5歳魚の割合も高かった（図35）。体長組成にみられた38 - 42 cmにモードを持つ小型群は（図30），主として5歳魚で構成されていた（図36）。また，図30で体長組成に二峰型の分布がみられたところでも，図36の年齢組成では単峰型を示していることから，
体長組成のモードが必ずしも年齢に対応しておらず、成長の異なるいくつかの群れが混在している（山口，1984）。この点については、先に報告したように図21に示した冬季の年齢別体長組成をみるとよく理解される。

5. 再 生 産

1）性的成熟度と性比

夏季にアリューシャン海盆域に出現するスケトウダラは、大部分が産卵魚で産卵後2〜3ヶ月を経過したものであった（吉田・尹，1981）。雄が鰭よりも成熟体長が小さい。一方、1983年の冬季調査の結果によれば（図37），尾叉長42cm以上，雌では44cmの魚がほとんどが成熟魚であった（水産庁，1984；山口，1984）。また，雌雄とも42cm以下の場合にはかなりの未成年魚がいたが，雄の1/2，雌の1/3が成熟していたと判断された。

生殖腺の性的成熟度からみて海盆のスケトウダラは雄先熟で，精巣の成熟は比較的ゆるやかに進行するが，卵巣の成熟速度は比較的速く短時間で完熟状態に達し，放卵すると推定されている（水産庁，1984）。

1987年1月末と3月初めにペーリング公海で採集したスケトウダラの生殖腺に関する観察から，1月末の卵巣内卵の卵径頻度分布は単峰型を示すが，3月初めの卵巣内卵の卵径分布は明瞭な2峰型を示すことが明らかにされた（Teshima et al.，1988）。すなわち，1月末の卵巣内には，成熟段階が主として卵黄期にかかっていることと卵巣細胞がみられるが，3月初めの卵巣内には，水分と吸水で大型化した成熟卵群と成熟段階が卵黄期の後期から前成熟期にある成育前卵群がみられた。精巣の組織学的な観察は，1月末の雄は主として放精の中で，3月初めの雄は主として放精を終えていたことを示している。このことから，公海においても産卵が行われている可能性がある。雌の成熟が，卵巣の成熟期と時期的に一致していないようにみられるが，これが標本の偏りによるものか一般的な現象なのかは，今後さらに多くの標本について検討してみないとはっきりしない。

海盆のスケトウダラの雌の割合は，夏の調査では37〜41％の範囲にあって雌の比率が雄より低い（岡田，1984 b）。しかし，1983年の冬季調査及び1987年の冬に公海で行った調査では，雌の割合はそれぞれ48％及び51％で，性比はほぼ1：1であった（岡田，1984 a；佐々木・吉村，1987）。

2）抱卵数

される。抱卵数と尾叉長との間には図38に示すような関係がみられ、以下の関係式が適合した：

\[ F = 1.3350 \times 3^{1.1470} \quad (r = 0.91) \]

\( F: \) 抱卵数
\( L: \) 尾叉長（cm）

ここで得られた結果は、Hinckley（1987）が報告したアリューシャン海盆のスケトウダラの抱卵数と尾叉長との関係とはかなり異なっており、同じ体長の魚の抱卵数はHinckley（1987）の報告したものよりもかなり多い（図39）。Hinckley（1987）は、海盆のスケトウダラの低い抱卵数は、環境の餌生物が不十分なことによるものと考えている。2つのでった結果が、同じ海盆であっても公海と米国200海里水深域の海盆南東部では魚群が異なることを意味しているのか、あるいは標本の採集時期や卵数の計数方法等による違いによるものかはわからず、今後さらに多くの標本による詳細な分析が必要である。

3）産卵期・産卵場

Hinckley（1987）は、アリューシャン海盆のスケトウダラの産卵期は1月から3月と報告しているが（図40）。1983年の冬季調査から得られた海盆のスケトウダラの生殖腺成熟度組成の月別変化によれば（図41）、1月下旬は雄の一部は完熟状態となっているが、雌の大部分はまだ半熟で産卵は行われていない（山口、1984）。2月中・下旬になると雌雄ともに産卵中の個体の割合が多くなり、一部は既に産卵活動を終えている。3月中旬には、産卵中の個体もみられるが、大部分は産卵を終えている。また、吉田・上田（1986）は、1982年の冬季に海盆で採集した標本に基づき、水産卵（完熟状態）を持つ個体は2月下旬に現われ、3月初めには半数を占めるようになったと報告している。さらに、Teshima et al.（1988）によっても、3月初めの卵巣内には完熟卵がみられることが報告されている。

以上の観察から、海盆のスケトウダラの産卵は2月上旬から3月下旬にかけて行われるが、盛期は2月中旬から3月上旬までのおよそ1ヶ月間であると推定される。東部ベーリング海の陸棚上では、ブリリボフ諸島南東の主産卵場における産卵盛期が4～5月であり（Hinckley, 1987），海盆のスケトウダラの産卵期はこれよりかなり早い。

先に報告したように、産卵期には海盆のスケトウダラは海盆の南東部に極めて濃密な密集群を形成する。公海域のスケトウダラは、1987年1月下旬には180度以西の南端に濃密群が形成され、生殖腺は完熟に半熟状態であった（佐々木・吉村、1987）。卵巣内の卵の一部が完熟状態になるのは2月中旬以降と考えられるが、先に述べたように魚群はこの時期東へ移動する傾向がみられることから、産卵海域は180度以東の水域と考えられる。

海盆を取り囲む周辺の大陸棚における産卵期と産卵場については、東部ベーリング海についてはHinckley（1987）によってかなり詳細に明らかにされている。それによれば、産卵期は南東水域では3～6月、ブリリボフ諸島の北西水域では6～8月で、産卵場は100～200mの水深帯に形成される。量的な比較はできないが、主要な産卵場所はウニマック島の北側、ブリリボフ
諸島周辺、及び北緯 58° - 59 度、西経 173 - 176 度付近の 3 ヶ所と推定される。西部ベーリング
海については限られた情報しかないが、1961 年に我が国が実施した調査では、オリュートル岬
東方及びオリュートル湾で 5 月下旬に産卵密集聚群を発見したと報告されている（三河、1961）。

4）産卵行動

スケトウダラが産卵期に形成する濃密な密集群は、雌が上層海域が下層という二層構造になって
いると報告されている（北野、1970；高倉、1954）。ここのような構造は、集団体外受精を行う
ためのものと理解されていった（北野、1970）。しかし、水槽内におけるスケトウダラの繁殖行動
を観察した結果によれば（桜井、1983）、産卵に至るまでに雄間に威嚇・攻撃行動がみられ、さら
に雌に対する求愛行動がみられた後、産卵は雌雄一対の遊泳型で行われた。そして、このような
繁殖行動は自然環境においても普遍的な行動特性であると想定している。海域で 2 月下旬に得
られた魚探記録では、濃密な反応の上層に小さな反応が多数みられ、雄的に活発な繁殖群が濃密
な産卵予備群から離れ、大きな群れを形成せずに基本的には雌雄一対の産卵行動を行っていると
推定された（吉田・上田、1986）。

一方、1983 年の冬季調査中 2 月中・下旬に濃密な魚群を対象に上層部と下層部をトロール漁
具によって水平ひさしの結果では、雌雄による二層構造が報告されたが（岡田、1994 a），北野
（1970）及び高倉（1954）の報告とは逆に、上層には雌下層には雄が多かった。1987 年の 1
月下旬に北転船で観察した結果では、魚群層のなかでも特に密度の濃い上層部からの漁獲物の性
比はほぼ 1:1 で、二層構造はみられなかった（佐々木・吉村、1987）。

水槽内における観察及卵期の組織学的観察から、スケトウダラは卵果内の完熟卵を 1 回に出
出すのではなく、数日間隔で産卵を繰り返すことが明らかにされた（桜井、1983；Hinckley、
1987）。水槽内における観察例の一つによれば、一尾の雌は 18 日間に 4 回の産卵を行った。産
卵時刻は萌芽時から萌明にかけての夜間に集中していたが、水深 100 m 以深の低照度の自然環
境下では、日中に産卵する可能性は十分あると考えられた。

5）卵・稚魚

スケトウダラの卵は分離浮遊卵で、産卵水深を含めた中層から表層に分布する。1983年の冬季
調査で実施された NORPAC ネットの垂直採取の採集結果によれば（図 42）、スケトウダラの発
生卵は発卵水域の広い範囲にわたって出現した（岡田、1984 a，1986）。西経 171 度以東の水
域で、発卵卵の密度が特に高い採集点がみられた。発卵卵の鉛直分布に関しては情報はないが、
3 月中旬に水深 100 - 200 m 層で採集されたスケトウダラの胃内容物中高密度で発卵卵が出
現したことから（水産庁、1984），この時期には少なくとも 100 m 以深には分布していること
は明らかである。なお、東部ベーリング海の陸棚上ではスケトウダラの受精卵から孵化直後の
稚魚に至るまでの鉛直分布が、発生段階別に明らかにされており（図 43）、発卵卵は主として海
面近くに分布すると報告されている（Nishiyama et al.，1986）。

6 - 8 月にベーリング海で北大おしろ丸が実施した稚魚ネット調査の結果から、スケトウダ
ラの稚魚が海盆上の広い範囲の表層付近に分布することが明らかにされている（Haryu, 1980；前田・平川, 1977）。稚魚の分布は 6 ～ 7 月には 180 度以東の水域に限られていたが、8 月には180 度以西の水域でもみられた（図 44）。180 度以東の海盆における稚魚の分布密度は、アリューシャン列島の北側では比較的低く、ブリビロフ諸島南西水域及び北部中央水域で高かった（図 45）。前田・平川（1977）は、これら海盆に分布していた稚魚は、東部ベーリング海の大陸棚上から移動されたものではなく、海盆で産卵されたものであろうと推定している。

6 ～ 8 月の調査からみる限り、海盆では 40 %以上に成長した幼魚は採集されていないが、40 %以上の幼魚は遊泳力がかなり発達するため、タッカー・トロールやマリンヴィッチ・トロールのような中層を速い速度で曳網できる比較的大型の採集用具を用いれば、採集できると思われる。

6. 摂 餌

1977 ～ 79 年の夏季調査から、海盆のスケットウダラの主要な飼料生物が明らかにされた（岡田, 1984b, 1986）。出現頻度からみるとコペボーダが最も多く、次いでオキアミ類、端脚類及び尾虫類（オタマヨ類）が次であった（表 1）。魚類、イカ類は極めて少なく、エビ類は捕食されていなかった。摂摂量では、コペボーダが圧倒的に多く全体の 80 ～ 85 %を占め、次いでオキアミ類が 7 ～ 8 %を占めた。空胃個体の出現率は 2 ～ 3 群と極めて低く、平均胃内容物重量は 4 ～ 11 g であった。

飼生物の組成に関する結果は、夏季海盆で採集したスケットウダラの胃内容物を調べた菊池・辻田（1977）及び吉田（1985）らの結果とはほぼ一致し、このような組成が海盆に分布するスケットウダラの一般的な食性とみられる。しかし、菊池・辻田（1977）の報告では、尾虫類の摂量はコペボーダよりもむしろ多く、場によっては尾虫類が飼料生物として重要な役割を果たしていることがうかがえる。また、吉田（1985）の結果は、飼生物の組成が時期や場所によって異なることを示している。

1983 年の冬季調査の結果によると（岡田, 1984 a, 1986；水産庁, 1984）、出現頻度では魚卵（スケットウダラがほとんど）を含めた魚類が最も多く、オキアミ類、コペボーダから順で、エビ類、イカ類も出現した（表 1）。摂摂量からみると、オキアミが最も多く全体の 40 %を占め、次いでイカ類（22 %）、コペボーダ（18 %）が順であった。空胃率は 58 %と高くなり、平均摂餌量は 0.3 g であった。上の結果から、出現頻度が最も高かったという魚類の中身はほとんどが魚卵であり、組成組成では大いな比重を占めていないことから、実質的な空胃率はもっと高かったと考えられる。1982 年の冬季に海盆で採集された標本によれば、空胃率は 85 %に達し、摂餌量も 1 g 以下の個体が多かった（吉田・上田, 1986）。飼料生物としては、魚類、コペボーダ、イカ類などが出現した。

夏の栄養期に主としてブリビロフ諸島以北の陸棚上で採集された 40 cm 以上の大型スケットウダラの平均胃内容物重量は、体重の 1.19 %と報告されている（Dwyer et al., 1986）。すなわち、
体長47 cm。体重720 gのステトウダラの摂餌量は平均約9 gと推定される。夏季に海盆に生息するステトウダラの平均摂餌量は先に報告したように4～11 gであり、夏季に関する限りブリピロフ諸島以北の陸棚上の魚は大きくは変わらないといえる。海盆のステトウダラは6月には陸棚群より肥満度が低くやややせているが、その後摂餌が活発になり、肝臓重量指数、肥満度とともに増加して、7月以降は少なくとも西縁170度以西の大陸棚上の魚群とはほとんど差がなくなる（山口他，1979）。

海盆のステトウダラの摂餌は日没前後に最も活発になると推定されているが、胃中の飼生物は消化段階の異なる層状を呈したものが観察され、飼生物が通常の捕食されていることがうかがえる（吉田，1985）。ステトウダラの飼育実験による体推定のための日間摂餌量は経験値で体重の0.61％と推定されているが、海盆のステトウダラの雄は胃内容物重量指数が0.6％以上で、量的に多くはないが、十分に生存、成長が可能な量の飼料を摂取していると考えられた（吉田，1985）。

また、飼育実験結果とステトウダラ成魚の成長量から求められた食糧要求量は1日当たり体重の1.1％で、海盆ステトウダラの成長量から求められた値とはほぼ等しかった（吉田，1985）。

7. 現存量


これらの現存量は、漁船が装備している通常の魚探を使用し、魚探反射記録と中層トロール漁具によるステトウダラの漁獲尾数を用いて、調査水域を階層化し、魚探反射の階層別単位長度当たりの魚群密度から推定されている（岡田，1979b）。したがって、中層トロール漁具の漁獲効率が不明であることなど、この推定方法にはいくつかの基本的な問題が含まれている（岡田，1984b）。

1983年の冬季調査では、計量魚探を用いた音響資源調査が実施された。その結果、図45に示した調査水域における海盆のステトウダラの現存量は、114.2万トンと推定された（Okada and Nakayama，1984）。平均魚群密度は4.13～4.53トン/km2であった。調査水域は、主として海盆南東部の米国200海里水域であり、上層水域はほとんど調査されていない。先に述べたように、1987年の公海における冬季操業では、1983年の冬季調査で魚群密度が低かった180度以西のパワーズ・リッジの北側に極めて濃密な魚群が分布していた。したがって、未調査水域に濃密な魚群が分布していた可能性も考えられる。

水産庁は、1985年にブリピロフ諸島に夏季生息するオットセイの主要な飼料であるステトウダラについて音響資源調査を実施した。その結果、7月にブリピロフ諸島沖合の比較的狭い海盆域

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（14万㌧）に生息していた表・中層型スケトウダラの現在量は524万トンと推定された（小野田・他，1986）。

1987年8－9月には海洋水産資源開発センターが，公海海域で2隻の調査船でスケトウダラを対象とした計量魚探調査を実施した。その結果，公海の78%に相当する調査実施水域における夏季のスケトウダラ現存量は910万トンと推定された（水産庁，1988）。この結果は，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，水深の深くなるに従って資源量が増大すること，及び南東水域の方が北西水域より資源量が多いことなどでおおよかな傾向は一致する。しかし，詳細に検討してみるといくつかの不自然な点が見出される。主な問題点は，1）中層トロール調査から得られたCPUE分布と比較し，水平的にも鉛直的にも変化がかなり大きい。例えば，水深150－200mにおける中層トロール網のCPUEは，100－150m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）調査実施水域の8.4%しか占めていない4つの区画（1区画は緯度1度緯度30’）の160－200m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ーのうち，スレッショルド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，吉澤昌彦氏からの私信）。調査に用いたタイプの計量魚探機の場合，一定のスレッショルドを与えるとエコーレベルが浅深度で過小，深深度で過大になる傾向がある（吉澤・他，1988）。調査では雑音が大きかったことから－55dBとかなり高いスレッショルド値を与えており，スレッショルド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，その妥当性に問題があることを判断されることから注意して用いる必要がある。水産庁は，1988年夏に米国と共同でアリューシャン海盆のスケトウダラを対象とした計量魚探調査を実施する予定である。この調査で用いる計量魚探システムは，本調査のために新たに開発されたもので，米国で最高水準のものであり，1987年の調査で生じたような問題を起こさせないようシステム自体に対策が講じられている。さらに，調査の実施に当たっては，雑音特性の把握を行い最適なスレッショルドパラメーターを導入するなどの対応を考えており，精度の高い現存量推定値が得られるものと期待される。

8．海洋環境との関係

夏季海盆上に生息するスケトウダラは広く分散して分布しており，水平分布，鉛直分布ともに環境条件との関係は不明瞭である（菊池・辻田，1977）。スケトウダラの分布は主に水深30－150m層にみられるが，夏季における動物プランクトンの分布密度は150m以浅で高いので（Minoda，1971），スケトウダラの鉛直分布は飼料生物の分布と一致している。

1983年の冬季調査の結果によれば（木谷，1983；岡田・中山，1983；水産庁，1984），水温の鉛直分布は2.5－4.2℃の範囲にあった。水深150－200m層に顕著な水温躍層があり，上層が

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3.5℃以下の冬季表層冷却水で相対的に低温、下層には3.7℃以上のアラスカ暖流系水で相対的に高温となっている（図46）。表層の水温は3.0～3.5℃の範囲にあり、900m以深では3℃以下を示している。スケトウダラ魚群は、1月下旬から2月上旬・下旬は水温躍層下の250～300m層、水温が3.5～4.0℃の水塊に主に分布していた（図46、47）。塩分濃度の範囲は32.8～34.3％であったが、魚群は主として33.6～33.8%の層にみられた（図48）。また、溶存酸素量は0.4～7.4ml/lの範囲内であり、水深が深くなるにしたがって酸素量は低下する。魚群の分布は酸素量が1.0～3.0ml/lの比較的少ない層であった（図48）。3月中旬には、産卵を終えた魚が水温躍層上の表層冷却水中に分布するようになるが、生殖期が完熟状態の個体は水温躍層下にしか分布していないようである。

1987年8～9月に我が国が公海で実施した調査の結果から0～200m間の平均水温の水平分布をみると（図49）、東側で高く西側で低い傾向を示している（水産庁、1988）。これは、アリーヤン列島の南東側から北上していくアラスカ暖流の影響により、東側が西側に比較して相対的に高温となっていることによるものと考えられる。

北緯57度線沿いた東西方向の水温鉛直分布をみると（図50）、水深50m付近に季節躍層が発達している（水産庁、1988）。この躍層は、西側ではシャープな鉛直勾配を示すが、東側の海域に向うにつれて緩やかな勾配となる。躍層の下層には4℃以下の冷水層がみられるが、この冷水層は西側で良好に発達し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は上昇し、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度線沿いた南北断面では、北側の150m層に2.5℃以下の水温極層がみられ、南に向くにつれ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50）。

中層トロール調査及び計量魚探調査の結果と対比させてみると、スケトウダラの鉛直分布は、50～200m間の冷水層と対応して高い密度を示していることがわかる（水産庁、1988）。密度分布が特に高い水域は、第2水温躍層の下層に暖水塊が強く張り出している水域とよく一致する（図11、50）。

海盆の冬季における動物プランクトンの鉛直分布は（図51）、主として水温躍層より下層で密度が高いことを示している（木谷・小牧、1984；水産庁、1984）。現存量も比較的大きく考えられ、冬季のスケトウダラがほとんど採餌していないのは、生息水深中に利用できる飼がないことによるものではなく、繁殖に伴う生理的要因によるものではないかと考えられる。

海洋環境との関係では、海盆で産卵された卵・稚仔の移動の問題が最も大きな課題である。ベーリング海の暖流系の影響を受けると（図52）、アリーハン海盆には反時計回りの暖流系が存在し、中央部は暖流域になっていると考えられて（オホタニ、1973）。近年における研究から、この暖流系が実際に存在することが明らかにされた（木谷、1983；Royer and Emery、1984）。海盆中層を流れる暖流は、アリーハン列島北側沿いに東向き、ウミマック水道北西の陸棚縁辺付近で等深線に沿って北西方向に反転する。冬季における暖流の流速と流量は夏季と比べて著しく

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大きく、300m層で平均0.2〜0.3海里/時間の流速が記録されている（木谷，1983）。

1983年の冬季調査中に船上で観察した結果によれば、スケトウダラの受精卵は水深3〜40mで
約25日で孵化したことから、海盆中央部の産卵場で産卵されたスケトウダラの受精卵は、孵化まで
におよそ150海里北東へ移動されると推定された（Okada, 1986）。産卵期と産卵場の違い、稚
魚の成長速度及び漁獲率についてさらに詳細に明らかにし、主要な産卵場からの稚仔魚の移送経路
を解明する必要がある。

9. 今後の調査研究

以上レビューしたように、アリューシャン海盆に生息するスケトウダラ資源に関する生物学的情
報は、まだ断片的にしか蓄積されていない。当該資源の研究は、大陸棚上の資源を含むベーリング
海全体のスケトウダラ資源による生物生産機構を明らかにするという大きな研究目標の一部と位置
づけられる。

ベーリング海のスケトウダラ資源は、日本、韓国、ポーランド、中国の漁船によって開発され
ており、さらに漁獲を抑制したと伝えられている。公海資源を対象とした各国の独自の調査も
必要であるが、基本的には漁業国と沿岸国が共同してベーリング海全体のスケトウダラ資
源に関する統合的な調査研究を行っていくことが重要であり、そのための協力体制を確立する必要
がある。今後、上記の研究目標を達成するには、以下の研究課題を設定する必要がある。

1）資源構造の解明

ベーリング海にはアリューシャン海盆東方域を含むいくつかの産卵場（産卵群）が知られてい
るが、産卵群が系統的に互いに独立したものかどうかを明らかにする。

(1) 産卵場の確認、特にアジア側。

(2) 各産卵群の生物学的パラメータ（巻度、年齢組成、成長、肥満度、抱卵数、成熟年齢、加入、
死亡率など）の比較。

(3) 各産卵群の外部形態及び計数形質の比較。

(4) 各産卵群の年齢形質（おもに耳石や鱗）の形態及び輪紋のパターンの比較。

(5) 生化学的手法により遺伝子の変異を産卵群ごとに比較する。

(6) 標識放流実験による移動・回遊の解明。特に産卵場から索餌場への移動と索餌場から産卵場への
への回帰、及び陸棚上から海盆あるいは海盆から陸棚への移動を明らかにする。

(7) 各産卵場からの卵稚魚の移送。

(8) 上記(2)〜(5)の項目に関する調査から、系群の存在とそれを識別する有効な形質が明らかにさ
れた場合には、夏季の索餌期に広い範囲から標本を採集し、各群の地理的混合について定量的
に明らかにする。

2）資源量の把握

資源量は、生物生産の規模を決定する基本的な要因の一つであり、年齢別資源量やその年変化
を明らかにすることは、資源から利用可能な生産量を評価するうえで欠くことのできない情報である。なかでも、加入前の若鰹魚や成熟魚の資源量の動向は、資源の将来予測を行ううえで重要である。

(1) 商業船の漁獲資料から、コホート分析のような資源解析モデルを用いて推定する。基礎資料として漁獲物の年齢別漁獲尾数の情報が必要なので、漁獲が行なわれていない未開発水域や漁獲データが利用できない漁業がある場合には、推定は不完全なものとなる。

(2) 調査船による直接推定、計量船探と中層及び着定トロールを組み合わせた音響資源調査から、資源量を直接推定する。資源量推定の基礎となる後方散乱強度や対象魚種の標的強度の測定値により推定値は大きく変わるのので、音響計量システムを統一し、この分野の専門家が参加して調査を実施することが望ましい。特に盛漁期である冬期に行う必要がある。

3) 漁業の実態の解明

漁業からの情報は、モデルによる資源量の推定や漁獲が資源に与える影響を評価するうえで極めて重要である。

(1) 漁獲効率と漁獲量。どちらも正確に報告されなければ、資源研究上意味がない。したがって、各漁業国は正確なデータを入手するシステムを確立するとともに、その詳細な分析を行った上、関係国間でデータを交換すべきである。

(2) 漁獲物体長組成データの収集。

(3) 年齢形質の採取。

(4) 冷凍標本の採取。
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Table 1. Frequency of occurrence and weight of food organisms in pelagic pollock stomachs from the Aleutian Basin in the summer of 1978 and 1979, and the winter of 1983 (Okada, 1986).

<table>
<thead>
<tr>
<th></th>
<th>1978</th>
<th>1979</th>
<th>1983</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Occurrence</td>
<td>Weight (g)</td>
<td>Occurrence</td>
</tr>
<tr>
<td>Euphausiacea</td>
<td>541 1,475.7</td>
<td>252 474.8</td>
<td>365 312.4</td>
</tr>
<tr>
<td>Copepoda</td>
<td>2,069 15,969.4</td>
<td>1,477 5,390.7</td>
<td>245 139.4</td>
</tr>
<tr>
<td>Amphipoda</td>
<td>206 248.1</td>
<td>140 135.1</td>
<td>9 6.8</td>
</tr>
<tr>
<td>Gastropoda</td>
<td>34.8 72</td>
<td>223.7 -</td>
<td>- -</td>
</tr>
<tr>
<td>Oikopleura</td>
<td>146 537.6</td>
<td>202 399.0</td>
<td>- -</td>
</tr>
<tr>
<td>Pisces</td>
<td>42 199.0</td>
<td>9 85.6</td>
<td>408 135.1</td>
</tr>
<tr>
<td>Shrimps</td>
<td>- -</td>
<td>- -</td>
<td>15 20.5</td>
</tr>
<tr>
<td>Squids</td>
<td>- -</td>
<td>6 54.1</td>
<td>78 173.3</td>
</tr>
<tr>
<td>Others</td>
<td>21 58.8</td>
<td>3 3.8</td>
<td>- -</td>
</tr>
<tr>
<td>Unknown</td>
<td>11 12.1</td>
<td>- -</td>
<td>- -</td>
</tr>
<tr>
<td>Total</td>
<td>3,122 18,835.5</td>
<td>2,161 6,766.8</td>
<td>1,120 707.5</td>
</tr>
</tbody>
</table>

Empty Number of specimens

54 66 1,515

Number of specimens 2,353 1,739 2,630
Fig. 1. Survey stations (•) and occurrences (○) of pelagic pollock incidentally caught from Japanese salmon driftnet surveys, 1965-1973 (Yamaguchi et al., 1979).
Fig. 2. Track line and positions of handline (△) and midwater trawl (○) operations in Japanese pelagic pollock surveys in the Aleutian Basin in the summer of 1977-1979 (Okada, 1986).
Fig. 3. CPUE distribution of pelagic pollock from Japanese midwater trawl surveys in the Aleutian Basin in the summer of 1978 and 1979 (Okada, 1986).
Fig. 4. Density distribution of pelagic pollock from Japanese acoustic survey in the international waters in the summer of 1987 (Fisheries Agency of Japan, 1988).
Fig. 5. 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. 6. Track line and positions of handline (▲) and midwater trawl (●) operations in Japanese pelagic pollock survey in the Aleutian Basin in the winter of 1983 (Okada, 1986).

Fig. 7. CPUE distribution of pelagic pollock from Japanese midwater trawl survey in the Aleutian Basin in the winter of 1983 (Okada, 1986).
Fig. 8. Density distribution of pelagic pollock from Japanese acoustic survey in the Aleutian Basin in the winter of 1983 (Okada and Yamanaka, 1984).
Fig. 9. Catch distribution of pelagic pollock by Japanese North Pacific Trawl Fishery in the international waters of the Bering Sea in 1985 (data file in Far Seas Fish. Res. Lab., Shimizu).
Fig. 10. Catch distribution of pelagic pollock by Japanese North Pacific Trawl Fishery in the international waters of the Bering Sea in 1987 (data file in Japan Deep Sea Trawlers Ass., Tokyo).
Fig. 11. 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. 12. 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. 13-1. Catch distribution of pelagic pollock by Japanese North Pacific Trawl Fishery in the international waters of the Bering Sea in October 1986.
Fig. 13-2. Continued (November 1986).
Fig. 13-3. Continued (December 1986).
Fig. 13-4. Continued (January 1987).
Fig. 13-5. Continued (February 1987).
Fig. 13-6. Continued (March 1987).
Fig. 13-7. Continued (April 1987).
Fig. 13-8. Continued (May 1987).
Fig. 13-9. Continued (June 1987).
Fig. 13-10. Continued (July 1987).
Fig. 13-11. Continued (August 1987).
Fig. 13-12. Continued (September 1987).
Fig. 13-13. Continued (October 1987).
Fig. 14. Sampling positions of pollock from the western Bering Sea obtained from Japan-U.S.S.R. joint venture fishery in 1987.
Fig. 15. Spotted echo observed during Japanese acoustic survey of pelagic pollock in the Aleutian Basin in the summer of 1978 (Okada, 1985).
Fig. 16. Belt shape echo observed during Japanese acoustic survey of pelagic pollock in the Aleutian Basin in the winter of 1983 (Fisheries Agency of Japan, 1984).
Fig. 17. Horizontal density distribution of pelagic pollock showing patch shape echo observed during Japanese acoustic survey in the Aleutian Basin in the winter of 1983 (Fisheries Agency of Japan, 1984).

Fig. 18. Vertical density distribution of pelagic pollock showing patch shape echo observed during Japanese acoustic survey in the Aleutian Basin in the winter of 1983 (Fisheries Agency of Japan, 1983).
Fig. 19. Estimated seasonal migration and the fishing grounds of pollock in the eastern Bering Sea (Takahashi and Yamaguchi, 1972).

Fig. 20. Migration of mature pollock in the eastern Bering Sea (Maeda, 1972). W.G.: Wintering grounds
S.G.: Spawning grounds
F.G.: Feeding grounds
W.F.: Water front

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Fig. 21. Size composition at age of pelagic pollock in the Aleutian Basin in the winter of 1983 (Sasaki and Yoshimura, 1988)
Fig. 22. Locations of recoveries of tagged pollock released in the western Bering Sea (Hokkaido Regional Fish. Res. Lab., 1974; Far Seas Fish. Res. Lab., 1977; and data file in Hokkaido Regional Fish. Res. Lab., Kushiro and in Far Seas Fish. Res. Lab., Shimizu).

Release data:
A: June 26, 27, 1973; 61°18'N, 174°52'E; Handline
B: October 17, 1972; 59°18'N, 166°20'E; Handline
C: April 27, 1979; 42°48'N, 145°05'E; Handline

Recovery data:
1: Jan. 24, 1974; 59°30'N, 177°50'W; Bottom trawl (Japan)
2: Apr. 15, 1975; 59°19'N, 178°26'W; Bottom trawl (Japan)
3: Jul. 19, 1977; 57°15'N, 179°10'E; Surface driftnet (Japan)
4: Feb. 10, 1981; 55°10'N, 177°55'E; Midwater trawl (Japan)
5: Oct. 7, 1981; 54°35'N, 176°05'W; Midwater trawl (Republic of Korea)
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Area E: Southeastern area
Area M: Middle area
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SYNOPSIS OF BIOLOGICAL INFORMATION ON THE
PELAGIC POLLOCK IN THE ALEUTIAN BASIN

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THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:
Synopsis of biological information on pelagic pollock  
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Introduction

Pollock (Theragra chalcogramma (Pallas)) is widely distributed in the North Pacific Ocean, and is generally known as a groundfish living on the continental shelf and slope. However, it is distributed in the upper and middle layers on the high seas, and it also has a characteristic of pelagic fish. In the Bering Sea, this species is also widely distributed in the midwaters on the Aleutian Basin. The density distribution of pelagic pollock is considerably low in summer as compared with on the continental shelf; consequently the large scale fisheries had not targeted on this stock. However, it is identified that pelagic pollock forms extremely high density of the school in winter, which is widely distributed in summer. Consequently, recently the midwater trawl fishery targeting on this stock has been rapidly developed (Sasaki and Yoshimura 1987). Following the large reductions of the allocations in the U.S. and U.S.S.R. 200 miles zones, the international waters located in the center of the Basin has become most valuable fishing ground for the traditional far sea fisheries nations. Those nations are Japan, South Korea, Poland, and newly the People's Republic of China. It is estimated that the total harvest of pelagic pollock from those nations exceeded 1.0 million in 1986, and exceeded previous year in 1987.
Pelagic pollack which forms the concentrated school in winter, spawns on the Basin in February to March (Fisheries Agency of Japan (FAJ), 1984; Okada, 1986; Hinckley, 1987). Only part of the biological characteristics of this stock is known at present, however it is estimated that the biomass is considerably large, and it seems that this stock contribute greatly to the reproduction of the pollock resources in the Bering Sea. Consequently, it is urgently required to accumulate the biological informations in order to rationally manage and effectively utilize this stock.

On this report, the informations available which are inevitable to promote further surveys and studies, were reviewed as detailed as possible.

1. Distribution and Migration

(1) Geographical Distribution

It has been known since long time ago that pelagic pollock is widely distributed in the upper layer on the Aleutian Basin, because this species were incidentally caught in the surface driftnets (Okada and Kobayashi, 1968; Suzuki, 1976).

Based on the report which analysed the bycatch data from the surface driftnet survey conducted from 1965 to 1973 (Yamaguchi et al., 1979), pelagic pollock was widely distributed and observed on the Aleutian Basin at least for three months from June to August when the surveys were conducted (Fig. 1). However, the survey stations on where the amount of bycatch was exceeded 100 fish, were limited nearby continental shelf and on the center of the Basin. And in general the amounts of bycatch were 5 fish or less and primarily 1 fish on the each station. And also based on the vertical longline survey conducted in June 1971, pelagic pollack was widely observed on the Aleutian Basin (Kikuchi and Tsujita, 1977).
The distribution in summer (June to August) was also observed by the survey for pelagic pollock conducted from 1977 to 1979 (Okada, 1977, 1978, 1979a, 1979b, 1986; Okada and Yamaguchi, 1985). The survey area was east of the US-USSR boundary (Fig. 2) and pelagic pollock was widely distributed in the survey area. The density distributions were relatively high on the Bowers Ridge and northwest of the Bowers Ridge and southeast of the Basin from 174°W to 178°W where is contiguous to the Aleutian Islands (Fig. 3).

Based on the acoustic/midwater trawl survey conducted by the Japan Marine Fishery Resource Research Center (JAMARC) in the international waters in August to September 1987 (FAJ, 1988), it was observed that the density of the school was high in the southeast area and low in the northwest area (Fig. 4, 5).

The distribution of pelagic pollock on the Basin in winter was not totally analysed yet. However, the research vessel KAIYO MARU conducted the survey from January to March in 1983 in the southeast area of the Basin east of 180° and north of the Aleutian Islands, and the distribution of pelagic pollock was observed (Okada, 1984, 1986; Okada and Nakayama, 1983; FAJ, 1984). This survey was primarily conducted within the US 200 miles zone and only one midwater trawling operation was conducted in the south end of the center (180°) of the international waters (Fig. 6). The distribution of pelagic pollock was observed in the region east of 180° including one survey station in the international waters. Because the trawling operations were quite limited, it was not clear in the region west of 180° (Fig. 7). However, the results of acoustic survey conducted at the same time shows the density in the waters west of the Bowers Ridge was considerably lower than one in the southeast region of the Basin (Fig. 8).
The density in the survey area was high in the southeast area of 176°-178°W, 53°30' -55°N adjacent to the boundary of the international waters, in the area of 173°W, 53°-30°N and the southeast area east of 172°W, south of 55°N.

The information in connection with the distribution of winter pelagic pollock in the international waters of the Bering Sea was not available from the research vessel. However, the catch statistic data from the commercial fleet are available. According to the statistics till 1985 from the North Pacific Trawl Fishery, fishing were conducted primarily in January through February (Sasaki and Yoshimura, 1987). Pollock was widely harvested in the international waters, however, most of the harvests were recorded in the area southeast of the international waters adjacent to the US 200 miles zone (Fig.9). However, the catches in November and December increased and the main fishing ground was formed on the north side of Bowers Ridge northwest of 180° in the international waters in winter 1986. This trend became conspicuous in 1987 (Fig.10), large part of catches was taken in the waters west of 180° (data file in Japan Deep Sea Trawlers Ass.). It is not yet distinct whether this change is due to the learning effect on the fishing grounds and movement of school of fish, or reflects the annual fluctuation of the distribution pattern of school.

Two scientists from the Far Seas Fisheries Research Laboratory were on board two land-based trawlers in winter 1987, for the purpose of collecting samples of fish and observing the actual situation of the Japanese pelagic pollock fishery on the international waters (Sasaki and Yoshimura, 1987). Two observations were conducted in January 24-25, and in February 27 to March 2, respectively.
The fishing ground was located in the international waters on the north side of the Bowers Ridge area between 55° and 56° N, 178° and 179° E for both times. The extremely dense fish school was observed in late January, and the vessel recorded 31.5 t of the average catch per hour of trawling. However, the density decreased in late February and the CPUE was 4.2 t.

Okada (1979a) reported that pelagic pollck was distributed in the Aleutian Basin from April to May and from October to December based on the records of fish finders from the commercial fleet. And also according to the catch statistic data, the part of Japanese commercial vessels have engaged in fishing and havested a small amount of pollock in summer in the international waters since 1985 (data file in Far Seas Fisheries Rsearch Laboratory).

Based on the informations described above, pelagic pollock is widely distributed all year in the Aleutian Basin, and in summer the school is spread out and distributed in the broad area, and in winter, it is concentrated and forms extremely dense school.

(2) Vertical Distribution.

Based on the data from the research vessel in summer (June-August), the echograms from fish finder of pellagic pollock were observed from the depth zone of 30m-150m (Okada, 1979a). The echograms were spotted and the primary distribution layers were varied by year. And, the daily vertical migrations were observed due to the echograms came from relatively deep range in the day time and shallow range in the night time. It is obvious that the density distribution was relatively low on the shallower than 30m.
Because the surface driftnet research vessel used the driftnet with 7m net depth from the surface and the pollock bycatch was 5 fish or less on each station on the Basin (Yamaguchi et al., 1979). And also based on the vertical longline survey conducted in June 1971, pelagic pollock was caught in the depth zone of 5-100m on where the gears were set (Kikuchi and Tsujita, 1977). Furthermore, Suzuki (1976) reported that the distribution of pelagic pollock was observed primarily on the shallower than 60m or 80m and occasionally observed deeper than 100m based on the echograms obtained on the Basin.

In contrast to these observations, based on the survey conducted in the international waters of the Bering Sea from August to September in 1987 (FAJ, 1988), the density distribution was highest on the depth zone of 150-200m (Fig.11,12). Though this survey was not conducted deeper than 200m, it is estimated that the density deeper than 200m was extremely low based on the echograms. Based on the result of the survey by the quantitative echo sounder, the density distribution of pelagic pollock shallower than 140m was higher in the northwest region than in the southeast region (Fig.11).

Based on the winter survey conducted by KAIYO MARU in 1983, the echograms of pelagic pollock were observed on the depth range from 75m to 600m from January to February. The mean depth of the observation was deeper than one in summer (Okada, 1984;FAJ, 1984). Pelagic pollock was primarily distributed on the layer of 250-300m from late January to mid or late February and the distribution zone became shallow to 100-200m depth on the mid March. In winter the daily vertical migration was also observed as well as in summer. Based on the fish finder records available from
the land-based trawlers operated on the Basin in winter 1982 (Yoshida and Ueda, 1986), the school of pelagic pollock had been distributed on the layer of 250-350m till around February 20, and then the distribution gradually became shallow around early March. Based on the fishing logs of the land-based trawlers operated from December 1986 to late January 1987, the trawling depth (the depth from the surface to the baitsings of the net opening) was relatively shallow on 160-200m in mid December and 140-200m in late December, however it became gradually deeper to 160-220m in early January and 200-300m, in mid January and 230-320m in late January, respectively. And also based on the data in late January, the deepest echogram was observed from the 420m depth.

In brief, the vertical distribution of pelagic pollock on the Basin is seasonally fluctuated, and it is distributed on the relatively shallow depth from the surface to 200m in summer and the primary depth zone of the distribution moves to 230-320m from late January to mid February in winter and moves again to shallow depth on 100-200m in early March. The patterns of these distributions are varied by year and area in the same season. It seems that these fluctuations are closely related to the changes of the oceanic environmental conditions.

(3) Migration.

Though the migration of the school covered all of the Aleutian Basin is still unknown, on the limited the international waters, it is able to estimate the migration of the school based on the changes of the monthly catch distribution on the assumption that the formation of fishing
grounds are in connection with the movement of fish school. The Figure 13 shows the monthly catch distributions of the Japanese North Pacific Trawlers from October 1986 to October 1987 (data file in Japan Deep Sea Trawlers Ass.). The school appeared on the west end of the international waters nearby the boundary of the USSR 200 miles zone in October, and then the school tended to move eastward month by month. It seems that the school was gradually disappearing in February and the large school disappeared from the international waters in March. This phenomenon was also reported by Sasaki and Yoshimura (1987). The school was observed in the west of 180° in April and May, and it was spread out and widely distributed from June to September. As there were a few fishing activities during summer season, the information regarding the migration of the school was not available in summer. In October the school appeared again in the west of the international waters.

The Figure-14 shows the sampling locations where FAJ (Fisheries Agency of Japan) obtained the pollock samples from the joint venture between Japan and USSR targeting on pollock in the USSR 200 miles zone of the Bering Sea in 1987. This figure shows that the school was also formed in the USSR waters of the Basin. It is necessary to promote the extensive surveys to make clear the migration pattern and apawning ground of these fish.

(4) Structure of school.

The structure of the pollock school which appeared on the echograms, has completely different shapes between summer and winter season (Okada, 1977, 1978, 1979, 1984; Okada and Yamaguchi, 1985; FAJ, 1984; Suzuki, 1976). It was spread out
and spotted in summer (Fig.15), and it was concentrated and formed belt shape or patch shape in winter. Based on the result of the winter survey by KAIYO MARU in 1983 (FAJ, 1984), the school primarily appeared with the belt shape (Fig.16) and occasionally the large school extending over 100 miles was observed. As an example of the school formed patch shape (FAJ, 1984), the school with 22km long, 5.5km wide and the mean thickness of 65m was formed on the mean depth of 280m (Fig.17,18).

The author was on board a land-based trawler in late January 1987 and observed the school which was distributed with the belt shape and its thickness was approximately 100m and 200m at the maximum. The particular dense school was formed on the upper range in the school zone, which was observed by the color fish finder. According to Yoshida and Ueda (1986), in late February a lot of the echograms shaped fleeting cloud were observed above the concentrated school. It seems that this school which consisted of the sexually matured fish and separated from the dense prematurely school, formed small school and spawned in the mid waters basically with a pair of male and female. Given this observation, it seems that the dense concentration of the school which is formed before spawning season, would be gradually collapsed during the spawning season and then move to the spotted distribution observed in summer.

2. Stock Structure

In connection with the stock structure of pollock being distributed in the eastern Bering Sea, there are two different theories. One is single population theory
(Takahashi and Yamaguchi, 1972), which advocates that the pollock stock on the continental shelf in the eastern Bering Sea is the single unit (Fig.19). The other is two subpopulations theory (Maeda, 1971, 1972), which advocates that there are northwest subpopulation and southeast subpopulation across the Pribilof Islands (Fig.20). Furthermore, it is estimated that the another independent subpopulation exists around the Cape Navarin (Maeda, 1979). Maeda (1979) reviewed the stock structure of pollock in the Bering Sea, and supported the likelihood of the two subpopulation theory, but the final conclusion was not made. However, it is estimated that the main spawning school of the northwest subpopulation is distributed in the region from the continental slope through the Aleutian Basin during the period between the wintering and spawning season, and moves into the continental shelf during the feeding season. Because pollock larvae on the surface layer is distributed in relatively small on the continental shelf and in abundance on the Aleutian Basin west of 170°W (Maeda and Hirakawa, 1977), and though the wintering and feeding schools exist in abundance on or around the continental shelf in the region, the large spawning school is not observed.

On the other hand, Lynde et al. (1986) conducted comparative study on the age and growth by area and season based on the samples of pollock, consequently it is estimated that there are two different units of populations which have own reproduction process in the eastern Bering Sea and the Aleutian Basin respectively. One is the population which has main spawning ground in the southeast region of the Pribilof Islands, lives on the continental shelf and slope throughout the life and the part of over 4 years old is distributed in the north of the Pribilof
Islands. This population is rapidly grown. The other is the population which has the main spawning ground on the Basin is slowly grown. The egges and larvae are transferred into the continental shelf in the eastern Bering Sea by the anticlockwise circulation, and the fish stay untill 3-4 years old in the north region of the Pribilof Islands and the fish moves into the Basin from the continental shelf as they sexually mature.

This assumption is similar to Maeda's two subpopulation theory, which assumes that the main spawning school of the subpopulation which lives in the northwest region of the Pribilof Islands, is distributed and spawns on the Aleutian Basin in winter. The origin of pollock which is distributed on the Basin in summer, is not explained from the Maeda's theory. However, Yamaguchi (1984) assumed that the majority of the premature pollock (primary 4 years old) left from the continental shelf for wintering and spawning, and the ones with rapid growth rate or high condition factor among the old pollock (over 5 years old), return to the continental shelf but the majority of the old pollock remains on the Basin, because there are differences of the age and growth of pollock on the Basin between in summer and in winter, and it seems that the fish in winter is larger than one in summer in terms of the mean size at age.

And also, Hinckley (1987) conducted the comparative study on the mean size at age, the fecundity and spawning season based on the samples of pollock collected during the spawning season in the eastern Bering Sea including the Aleutian Basin, and reported the existence of at least three separated spawning populations. Those populations are on the Aleutian Basin, and on the continental shelf in the southeast and northwest region and the slope in the
southeast region, and on the continental slope of the northwest region. She indicated that the fish in the northwest slope which Lydre et al. (1987) assumed as a origin of pelagic pollock on the Basin, was the separated spawning population from the others.

As a result of the study in detail on the size composition at age of pelagic pollock which the research vessel KAIYO MARU sampled on the southeast part of the Aleutian Basin from January to March 1983 (Sasaki and Yoshimura, 1988), pelagic pollock consists of several different groups in the same age class which have the different growth rates (Fig. 21). Especially, fish of the full 5 years and 6 years old fish consist of the group of 4+, 4++, 5- and the group of 5+, 5++, 6- respectively. As reference, these ideograms mean the differences of the growth zones on the scales. This is hardly explained by the single origin theory in which Yamaguchi (1984) and Lynde et al. (1986) assumed that the fish living on the continental shelf in the northwest region of the Pribilof Islands was the origin of the fish of pelagic pollock on the Basin. It is estimated that the several groups which grow up in the different regions are mixed up.

And also, the size composition at age in the southeast region on the continental shelf of the eastern Bering Sea is obviously larger than the fish in the northwest region through the different age groups in May and June. However, in July through September the size composition over 5 years old unnaturally becomes small and similar to the size structure at age of the fish in the northwest region (Sasaki and Yoshimura, 1988). Based on this, it is estimated that the population structure in the southeast region may considerably change in summer.
The relationship between the stocks on the Basin and the ones on the continental shelf of the Asian side have not been discussed so far. However, according to the result of tagging experiments (Fig.22), the two of pollock tagged and released on the continental shelf between the Cape Navarin and the Cape Olyutorskii were captured on the Basin (FAJ, 1977; data file in Far Seas Fisheries Research Laboratory). And two of pollock tagged and released off the Cape Govena were captured on the continental shelf around 59° N of the eastern Bering Sea (Yoshida, 1979). Furthermore, one tagged fish released off the Pacific coast of the Hokkaido Island in April 1979 recaptured by the Korean trawler in the Aleutian Basin at 54°35' N and 176°05' W in October 1981 (data file in Hokkaido Regional Fisheries Research Laboratory, Kushiro). Based on these data, it is obvious that the stocks of the Asian side is related to the stocks on the Basin and in the eastern Bering Sea.

In connection with the stock structure of pollock in the North Pacific including in the Bering Sea, the results of the biochemical study (Grant and Utter, 1980; Iwata, 1973) and the study based on the geographic variations of the meristics and morphometrics (Hashimoto and Koyachi, 1977; Koyachi and Hashimoto, 1977; Serobaba, 1975) are available. Based on the biochemical study, the regional interchange of the stock was not identified between onshore of Japan and the Bering Sea, however the populations indicated the genetic differences were not identified in the Bering Sea (Iwata, 1973). As a result of the study compared the samples of the eastern Bering Sea and the Gulf of Alaska, there were a few genetic differences between them, but the genetic differences between the northwest and southeast populations were not identified (Grant and Utter, 1980). In contrary, according to the study of comparison
between the meristics and the morphometrics, pollock in the Bering Sea is separated into four regional subpopulations as eastern, northern, western and southern (subpopulation of the Aleutian Islands) subpopulations (Serobaba, 1975). And also, the differences were not identified on the number of vertebrae but were identified on the diameter of eye between the population around the Cape Navarin and the population of the eastern Bering Sea (Hashimoto and Koyachi, 1977; Koyachi and Hashimoto, 1977).

As described above, there are several interpretations on the stock structures. Except the cases indicated distinct differences on the results of the tagging and biochemical study, every study does not provide the conclusive evident on the subpopulations and those interpretations still remain as the assumptions. However, the majority of pelagic pollock living on the Basin is the old fish over five years old (Lynde et al., 1986; Okada and Yamaguchi, 1985; Traynor and Nelson, 1985; Yamaguchi, 1984; Yoshida and Ueda, 1986), and there is not observed in abundance of 0-4 years old fish, though it was identified that the fish spawns on the Basin, and the eggs and larvae are distributed on the Basin. It is likely that the juvenile fish during the period (0-4 years old) is distributed on the continental shelf, however the positive evidence is not yet available. Therefore, in order to clarify the origin of pelagic pollock on the Basin, it is required to comprehensively study the structure of the pollock populations in all of the Bering Sea.

3. Age and Growth

Based on the samples obtained from the research vessel on the Basin in summer 1979 and in winter 1983 respectively, it is estimated that the growth of pelagic pollock
(Fig. 23, 24, 25) was considerably slow as compared with the one on the continental shelf southeast of the Pribilof Islands, however, fairly similar to the one on the continental shelf north of the Pribilof Islands in the eastern Bering Sea (Okada and Yamaguchi, 1985; Traynor and Nelson, 1985; Yamaguchi, 1984). But regarding four years old fish on the Basin, its growth was remarkably similar to the one of the southeast population. The range of the ages observed were from 3-12 years old. Lynde et al. (1986) and Hinckley (1987) also reported that the growth of pelagic pollock was slow on the Basin. Lynde et al. (1986) indicated that the slow growth of pelagic pollock over 4 years old on the Basin was connected with the growth till 4 years old of the slow growth fish which is distributed on the continental slope north of the Pribilof Islands. As a result, regarding the 4 years old fish it is not same as the result of Yamaguchi (1984) described above.

The longevity of pollock is generally believed about fifteen years on the continental shelf (Smith, 1981), and according to Lynde et al. (1986), the oldest pelagic pollock is thirteen years old. The two of pollock tagged and released onshore of Siberia in 1973 were captured (Fig. 22). One of them was captured nearby the Bowers Ridge in winter 1981 (data file in Far Seas Fisheries Research Laboratory). Assuming that the fish was four or five years old based on the size when released, it is estimated that the age of the fish was twelve or thirteen years old when it was captured. Based on this, it is obvious that the aged fish is distributed on the Basin as well as in the continental shelf.
4. Size and Age composition

(1) Size Composition

Based on the samples of pelagic pollock obtained from the research vessel on the Aleutian Basin in summer in 1977 to 1979 respectively, the size composition (Fig. 26) was the range of 38-56cm in fork length and indicated the unimodal frequency distribution, which had the mode of 46-48cm (Okada, 1977, 1978, 1979a, 1986). And also based on the samples of pelagic pollock obtained from the research vessel in the international waters of the Bering Sea in August to September 1987, the size composition (Fig. 27) was the range of 36-58cm in fork length and the mode was 46-48cm (FAJ, 1988). This type of the distribution was almost same as the one of pelagic pollock incidentally caught in the surface driftnet fishery on the Basin (Yamaguchi et al., 1979; Kikuchi and Tsujita, 1977; Suzuki, 1976; Yoshida and Yoon, 1981). The remarkable characteristic is that there were very few fish under 42cm and over 52cm in fork length.

On the other hand, the size composition of pelagic pollock (Fig. 28) obtained from the winter survey on the Basin in 1983 indicated the unimodal frequency distribution, which had the mode of 44-46cm. The mode was 2cm smaller than the one in summer (Yamaguchi, 1984; FAJ, 1984). It was remarkable characteristic that the fish of the small size which had the modes of 38-40cm or 40-42cm, were observed. Based on the size composition at age, the fish of small size were four and five years old (Sasaki and Yoshida, 1988). It seems that the fish temporarily appeared on the Basin in winter for wintering because those fish were not observed in the summer survey (Fig. 29). The fish of small size were observed in all areas covered by the survey.
(Fig. 30), however those fish were observed in small in the area of 170° W to 175° W and relatively in abundance in the areas of the both sides. On seasonalwise, those fish were observed in abundance in February east of 170° W and in March in 175° W to 180°.

The size compositions (Fig. 31) of the catch obtained from the land-based trawlers which operated in the south part of the international waters west of 180° in late January and from the end of February to early March respectively in 1987, were the range of 38-58 cm in fork length and indicated the unimodal frequency distribution which had the mode of 46-48 cm. The mean length of pelagic pollock caught from the end of February to early March was slightly larger than the end of January because the fish over 48 cm was increased in the size composition. As compared with the size composition of pelagic pollock sampled by the research vessel in the southeast region of the Basin from January to March 1983 (FAJ, 1984; Yamaguchi, 1984), there was not difference on the mode between 1983 and 1987. However, the composition of pelagic pollock among the 1983 survey, which were caught in where the land-based trawlers operated in 1987, had the mode of 38-42 cm which was completely different from the one in 1987. The data of 1983 were collected in mid March, when was two weeks later than in 1987. And because the data of 1987 were collected from the extremely limited area, whether the difference of composition between the both years indicated the annual fluctuation on the abundance of the appearance of the small size fish, or the annual changes of the geographic distribution pattern, remains to be studied.

As compared with the size composition of pelagic pollock in the international waters between in winter (Fig. 31) and in summer (Fig. 27) in 1987, there was very few changes.
It indicated that the fish which had the constant size composition, was distributed all year round in the international waters.

According to the past studies, there is difference of the size composition of pelagic pollock on the Basin between the male and female, the size composition of the female is larger than the male in both of summer and winter (Okada and Yamaguchi, 1985; Suzuki, 1976; FAJ, 1984; Yoshida and Yoon, 1981). Based on the size composition of pelagic pollock which land-based trawlers caught in the international waters in winter 1987 (Fig. 32), the female was larger than the male (Sasaki and Yoshimura, 1987).

(2) Age composition

The age composition of pelagic pollock which the research vessel collected on the Basin in summer 1979, comprised of the 3-9 years old fish (Fig. 33). The 5-7 years old fish dominated 94% of the composition, and there was not difference of the composition between male and female (Okada and Yamaguchi, 1985). It may be possible that the older fish were somewhat underesimated because the scales were used as the age material for this report.

Based on the result of the winter survey (Yamaguchi, 1984), the range of the age was 4-12 years old. In general, the 5-7 years old fish dominated the majority as well as in summer (Fig. 34). The percentage of the 6 years old fish was extremely high in summer, however in winter this trend was not observed remarkably and the percentage of 5 years old fish was also high (Fig. 35). The fish of small size which had the mode of 38-42cm in the size composition (Fig. 30), comprised of primarily 5 years old fish (Fig. 36).
And also, it indicated the unimodal frequency distribution in the age composition, at where the bimodal frequency distribution was indicated in the size composition in the Figure 30. In other words, the mode of the size composition was not equivalent to the one of the age composition. It is indicated that there is likelihood of the several groups which have different growth rates being mixed up (Yamaguchi, 1984). On this point, as described above, the size composition at age in winter shown in the Figure 21 could give a good explanation.

5. Reproduction

(1) Sexual Maturity and Sex Ratio

The majority of pelagic pollock appeared on the Aleutian Basin in summer was the postspawn fish two or three month after the spawning (Yoshida and Yoon, 1981). The mature size of the male was smaller than the one of the female. On the other hand, based on the result of the winter survey in 1983 (Fig.37), the most of the male over 42cm and the female over 44cm were mature fish (FAJ, 1984; Yamaguchi, 1984). And also, it is estimated that one half of the male and one third of the female below 42cm were mature, while substantial number of fish below 42cm were premature.

In connection with the maturity stage of the gonad of pelagic pollock on the Basin, it is estimated that the male matures earlier than the female and the maturity of the testis proceeds relatively slowly, however the ovary reaches to the ripe stage relatively in short time and then spawns (FAJ, 1984).
Based on the observation of the gonad of pelagic pollock collected from the international waters of the Bering Sea in late January and early March respectively in 1987, it was disclosed that the frequency distribution of the oocyte diameters in the ovary indicated to be unimodal distribution in late January, however it indicated the distinct bimodal distribution in early March (Teshima et al., 1988). The oocytes with almost same diameter which were primarily at the yolk stage, were observed in late January. However, in early March the hydrated oocytes which became large due to sucking up the waters, and the oocytes from the late yolk stage to the premature stage were observed.

As a result of the histological observation of the testis, the males in late January were primarily in ejaculating and the ones in early March were primarily in spent. This shows the possibility that the fish may spawn in the international waters. This is not equivalent to the spawning season of the female in terms of the timing. Further reviews will be required to clarify whether this is due to the bias of the samples or general condition.

The ratio of the female of pelagic pollock on the Basin was the range of 37-41% in the summer survey, and it was lower than the male (Okada, 1986). However, in the winter survey in 1983 and the winter observation conducted in the international waters in 1987, the ratio of the female was 48% and 51% respectively, and the ratio of male and female was about 1:1 (Okada, 1984; Sasaki and Yoshimura, 1987).

(2) Fecundity

Teshima et al., (1988) clarified the relationship between
the fecundity and the body length based on the samples collected from the international waters of the Bering Sea in late January 1987. The individual female of pelagic pollock spawns several times during the spawning season (Sakurai, 1983; Kitano, 1979; Hinckley, 1987), and the oocytes with the different diameter due to differences of maturing stage are mixed up in the ovary during the period before and in spawning (Teshima et al., 1988). Consequently, it seems that sampling in late January is most appropriate to count the number of oocytes, when the oocytes with almost same diameter are in the ovary. It is identified that there is the relationship between the fecundity and the fork length, which indicated in the Figure 38. And the appropriate formula is as follows:

\[ F = 1.3350L^{0.1470} \quad (r=0.91) \]

F: Number of ova
L: Fork length (cm)

This result is quite different from the relationship between the fecundity and the fork length of pelagic pollock on the Aleutian Basin reported by Hinckley (1987). The fecundity of the same size fish is higher than the ones reported by Hinckley (1987), (Fig.39). Hinckley (1987) indicated that the lower fecundity of pelagic pollock on the Basin was due to the shortage of the food organisms. Further detail analysis based on substantial number of the samples will be required to clarify the differences of the results and whether this means that there are different populations on the Basin within the international waters and the southeast of the Basin in the US 200 miles zone respectively, or this is due to the differences of the time of sampling or the counting method of the fecundity.
(3) Spawning Season and Ground

Hinckley (1987) reported that the spawning season of pelagic pollock was in January through March (Fig. 40). However, based on the monthly changes in the composition of the maturity stage of the gonad of pelagic pollock obtained on the Basin from the winter survey in 1983 (Fig. 41), in late January the part of the males were in the full mature stage but the majority of the females were in the premature stage and did not spawn yet (FAJ, 1984; Okada, 1986; Yamaguchi, 1984). In mid February, many of the both of males and females were in spawning and some of them already finished spawning. In mid March, some of fish were in spawning but the majority already finished spawning. And also, Yoshida and Ueda (1986) reported that pollock with the hydrated oocytes appeared in late February and in early March, which dominated one half of the samples. Furthermore, Teshima et al. (1988) also reported that the hydrated oocytes were observed in the ovary in early March.

Based on the observations described above, pelagic pollock on the Basin spawns in early February through late March, it is estimated that the main spawning season is about one month from mid February to early March. The main spawning season of pollock on the spawning ground in the southeast of the Pribilof Islands on the continental shelf of the eastern Bering Sea is in April through May (Hinckley, 1987), and the spawning season of pelagic pollock on the Basin is considerably earlier than the area.

As reported above, pelagic pollock forms extremely dense school in the southeast region of the Basin during the spawning season. The dense school of pelagic pollock was observed in the south end of the international waters west
of 180° in late January 1987, and the gonad of the female was in the premature stage (Sasaki and Yoshimura, 1987). It is estimated that the part of oocytes in the ovary become mature on and after mid February. As described above, it is estimated that the school tends to move to the direction of the east in this time, so that it seems that the fish spawn on the Basin east of 180°. Hinckley (1987) reported that the spawning of pelagic pollock occurred widely in the observed area, namely the southeast part of the Basin (Fig.40). It is estimated from the winter survey in 1983 that one of the spawning grounds of pelagic pollock in the area close to 60 nautical miles north of Unimak Island (Okada, 1986).

In connection with the spawning season and ground on the continental shelf surrounding the Basin, it is explained in detail by Hinckely (1987) regarding in the eastern Bering Sea. According to the report, the spawning season is in March to June in the southeast region and in June to August in the northwest region of the Pribilof Islands, and the spawning ground is formed at the depth of 100-200m. The quantitative comparison is not available, however it is estimated that the main spawning grounds are in the north side of Unimak Island and around the Pribilof Islands and around 58°-59°N, 173°-176°W. Though the information regarding the western Bering Sea is limited, it is reported that the concentrated spawning schools were observed in the east of the Cape Olyutorskii and in the Bay of Olyutorskii on the survey conducted by Japan in 1961 (Mikawa, 1961). However, it is considered that this spawning population is probably extremely small as compared with the populations in other areas (Kitano, 1979).
(4) Spawning behavior

It is reported that the dense school which pelagic pollock forms during the spawning season, is comprised of two layers in which the male is upper layer and the female is lower layer (Kitano, 1970; Takakura, 1954). This structure was regarded as the behavior for the effective external fertilization (Kitano, 1970). However, based on the observation of the spawning behavior of pollock in the tank (Sakurai, 1983), the action of scare or attack was observed among the males until the spawning, and the courting action for the female was observed, and then the spawning happened with a pair of male and female as they swim. And it is supposed that this spawning behavior is common nature to be displayed in the natural circumstance. On the records of the fish finder obtained from the Basin in late February, a lot of the small echograms were observed above the dense echogram. And it is estimated that the sexually active spawning school separates from the dense premature school, and takes the spawning activity basically with a pair of male and female without forming the large school (Yoshida and Ueda, 1986).

On the other hand, the operation of the horizontal trawling was conducted on the winter survey in 1983, which targeted on the upper and lower layer of the dense school in mid to late February. As a result, the structure of two layers comprised of males and females was observed (Okada, 1984). However, in contrast with the report of Kitano (1970) and Takakura (1954), there were a lot of females on the upper layer and a lot of males on the lower layer respectively. As a result of the observation on the land-based trawler in late January, the sex ratio on the upper layer where the school was particularly dense among the layers of the schools, was 1:1, and the structure of two layers was not observed (Sasaki and Yoshimura, 1987).
Based on the observation in the tank and the histological observation of the ovary, it was observed that pollock did not spawn the whole of the oocytes in the ovary only one time but repeated spawning several times at intervals of several days (Sakurai, 1983; Hinckley, 1987). As an example of the observations in the tank, one female spawned four times in eighteen days. The time of the spawning was concentrated at the twilight through the dawn. However, it is supposed that pollock may spawn in the day time under the natural circumstances where is deeper than 100m and in the low illuminance.

(5) Egg and Larva

The egg of pollock is the separated floating type, and is distributed on the mid layer including the depth of spawning through the surface. Based on the result of the vertical sampling with the NORPAC net operated in the winter survey in 1983 (Fig. 42), the pollock eggs were observed in the broad area covered by the survey (Okada, 1984, 1986).

The density distribution of the eggs was extremely high on the sampling station east of 171° W. The information regarding the vertical distribution of the eggs is not available. However, the eggs at eyed period were frequently observed in the contents of pollock stomach obtained from the depth zone of 100-200m in mid March (FAJ, 1984). Consequently, it is obvious that eggs are distributed at least deeper than 100m during this period. And also, The vertical distributions of the fertilized eggs through the larvae just after the hatching by the different development stages on the continental shelf in the eastern Bering Sea is available (Fig. 43), and it is reported that
the eggs at early eyed period are distributed primarily near the surface (Nishiyama et al., 1986).

Based on the result of the larva net surveys which the research vessel of Hokkaido University (OSHORO MARU) conducted in June through August, it was observed that the pollock larvae were distributed in the broad area on the Basin (Haryu, 1980; Maeda and Hirakawa, 1977). The distribution of the larvae was limited east of 180 in June through July, however it was observed west of 180 in August (Fig.44). On the Basin east of 180°, the density distribution of the larvae was relatively low north of the Aleutian Chains but high in the southwest region of the Pribilof Islands and in the northern central region (Fig.45). Maeda and Hirakawa (1977) estimates that the larvae which were distributed on the Basin, were not transferred from the continental shelf in the eastern Bering Sea but spawned on the Basin.

According to the surveys conducted by the (OSHORO MARU) in June through August, the juvenile fish over 40mm was not collected on the Basin. However, because the juvenile fish over 40mm has moderate swimming ability, it seems to be able to collect those juvenile fish if the relatively large sampling net such as the Tucker trawl or Marinovich mid water trawl is available.

6. Feeding Habit

Based on the summer survey conducted in 1977 to 1979, the main diets of pelagic pollock on the Basin were identified (Okada, 1984, 1986). The rank order of the stomach contents in terms of frequency of appearance was the Copepoda, then
Enphausiacea, Amphipoda, and Oikopleura (Table 1). There were very few of fish and squid and none of shrimp in the stomach. On the stomach contents in weight, the Copepoda was extremely in abundance and dominated 80-85% of the total, and the next was the enphausiacea and dominated 7-8% of the total. Pollock of which stomach was empty, were very little and dominated 2-3% of the total. The mean weight of the stomach contents was 4-11g. The result regarding the composition of the diets was almost equivalent to the result of Kikuchi and Tsujita (1977) and Yoshida (1985) who analysed the stomach contents of pelagic pollock collected from the Basin in summer. However, based on the report of Kikuchi and Tsujita (1977), the feeding quantity of Oikopleura was more than the Copepoda in many cases, it seems that occasionally the Oikopleura acts the important role as the diets. And also, the result of Yoshida (1985) indicated that the composition of the stomach contents was changed by season or area.

Based on the winter survey in 1983 (Okada, 1984a, 1986; FAJ, 1984), the rank order of the stomach contents in terms of frequency of appearance was fish including eggs (mostly pollock egg), then Enphausiacea, Copepoda, and shrimp and squid (Table 1). On the feeding quantity, Enphausiacea was the most in abundance and dominated 40% of the total, and the next was squid (22%), and Copepoda was 18%. Pollock with empty stomach contents dominated 58% of the total, the mean weight of the stomach contents was 0.3g. As a result, fish which appeared in the stomach were observed in abundance, were identified mostly as fish eggs, and dominated fairly in small on the quantity. Consequently, it seems that the percentage of the empty stomach was substantially higher. Based on the samples collected from the Basin in winter 1982, the percentage of the empty stomach reached 85%, and there were a lot of pollock of
which the feeding quantity was less than 1g (Yoshida and Ueda, 1986). As the diets observed in the stomach, there were fish, copepoda and squid.

It is reported that the mean weight of the stomach contents of large pollock over 40cm which were collected from the continental shelf in the summer feeding season primarily north of the Pribilof Islands, was 1.19% of the body weight (Dwyer et al., 1986). That is, it is estimated that the mean feeding quantity of pollock with the length of 47cm and the weight of 720g which is equivalent to the mean size of pollock on the Basin is approximately 9g. As reported above, the mean weight of the feeding quantity of pelagic pollock living on the Basin in summer is 4-11g, and it seems that this is almost similar to the one of pollock in summer on the continental shelf north of the Pribilof Islands. Pelagic pollock on the basin is a little skinny in June and its condition factors are lower than the ones of the fish on the shelf. However, then the feeding becomes in active and the both of the liver weight index and condition factor gradually increase and since July those are almost similar to the fish on the continental shelf at least west of 170°W (Yamaguchi et al., 1979).

It is estimated that the feeding of pelagic pollock on the Basin becomes the most in active around the sunset, however it is estimated that pelagic pollock feeds constantly the food organisms because a lot of food items which were in the different digested stages were observed (Yoshida, 1985). It is estimated that the daily feeding quantity to maintain the life is 0.61% of the body weight in case of adult pollock based on the experiment of pollock rearing. However, the weight index of the stomach contents of pelagic pollock on the Basin are mostly more than 0.6%, and though the quantity is not in abundance, it seems that
pelagic pollock feeds the sufficient quantity of the foods to survive or expedite its growth (Yoshida, 1985). And also, based on the result of the experiment of pollock rearing and the growth rate of adult pollock, the quantity of foods required per day was estimated 1.1% of the body weight, and almost similar to the one calculated from the growth rate of pelagic pollock on the Basin (Yoshida, 1985).

7. Biomass

The biomass of pelagic pollock on the Basin east of the US-USSR boundary is estimated 2.688 million mt in 1977, 5.442 million mt in 1978, and 1.269 million mt in 1979 based on the summer survey conducted in 1977 to 1979 (Okada, 1979b; Okada and Yamaguchi, 1985). There is not difference between 1978 and 1979 in terms of the survey areas except the survey was extended to the edge of the continental shelf in 1978, however the big difference of the biomass estimate between the two years has not been discussed so far. Nunnallee (1978) estimates that the biomass is 0.84 million mt based on the same data of the survey conducted by Japan in 1978, however Okada (1979b) indicated that this value was extremely underestimated.

These biomass were calculated and estimated from the density of the fish per unit of volume by each layer based on the stratification of the survey area according to the records of the echograms by using normal fish finder equipped on the fishing vessel and the number of catch of pelagic pollock by the midwater trawling (Okada, 1979b). Therefore, there are some fundamental problems including the uncertainty of the catchability of the midwater trawl gears on these estimates (Okada, 1979b).
On the winter survey in 1983, the quantitative echo sounder system was used, and the hydro-acoustic survey was conducted. As a result, the density distribution in the survey area on the Basin showed in the Figure 8, and the biomass was estimated 1.142 million mt (Okada and Nakayama, 1984). The mean density of the fish was 4.13-4.53 t/km². The survey area was within the US 200 miles zone southeast of the Basin, and the most of international waters was not covered. As mentioned above, on the winter operations in the international waters in 1987, the extremely high dense school was observed in the north side of the Bowers Ridge west of 180°. Therefore, it is likelihood that the dense school was distributed in the area where the survey did not cover in 1983.

The Fisheries Agency of Japan (FAJ) conducted the hydro-acoustic survey of pollock in 1985, which is important diets for the northern fur seal living in the Pribilof Islands in the summer season. As a result, the biomass of pelagic pollock living on the relatively small area on the basin (0.14 million km²) off the Pribilof Islands in July was estimated 5.24 million mt (Onoda et al., 1986).

The Japan Marine Fishery Resource Research Center (JAMARC) conducted the survey of pelagic pollock by the quantitative echo sounder system by the two research vessels in the international waters in August to September in 1987. As a result, the biomass in the area equivalent to 78% of the international waters was estimated 9.10 million mt (FAJ, 1988). As compared with the midwater trawl survey conducted at the same time, the general trends which indicated that the biomass increased in proportion as the depth and the biomass in the southeast region was more than in the northwest region, were consistent with the result of
the midwater trawl survey. However, the result of the acoustic survey was reviewed in detail, consequently, there were several problems as follows; First, the charging rates in the density of fish was considerably higher in verticalwise or horizontalwise as compared with the CPUEs obtained from the midwater trawl survey. For example, on the midwater trawl survey, the CPUE on the depth of 150-200m was 1.5-2.2 times higher than on the depth of 100-150m, however on the result of the acoustic survey, it was 14.6-22.2 times higher. Secondly, the biomass on the depth of 160-200m in the four subsections (each subsection divided by 1 of the longitude and 30 of the latitude) where dominated only 8.4% of the total survey area, was extremely high and dominated 51% of the total biomass estimated.

From the point of view of the hydro-acoustics, it is pointed out that there might be problem on the selection of the threshold level among the parameters of the echo sounder system used in this survey (personal communication with Mr. Furusawa in the National Research Institute of Fisheries Engineering). In case of the type of echo sounder used in this survey, if the constant threshold was given, the echo levels tend to be overly low on the shallow depths and overly high on the deep depths (Furusawa et al., 1988). Since the high noise was observed in this survey, the considerable high threshold value at -55dB was given. It seems that the threshold effect and the noise considerably affected the result of the survey.

Taking into consideration of the informations described above, it seems that the biomass estimate obtained from the survey in the international waters in summer 1987 should be carefully treated. The Fisheries Agency of Japan will conduct the acoustic survey with the United States on the Aleutian Basin in summer 1988. The quantitative echo
sounder system being used in this survey has been newly developed and is the highest level at present in Japan, which is improved to avoid the problems encountered on the survey in 1987. Furthermore, on this survey, the best threshold parameter will be used, which is fit for the characteristic of the noise. It is expected that the accurate biomass estimate will be obtained.

8. Relationship with Oceanographic Circumstances

Pelagic pollock is spread out and widely distributed on the Basin in summer, the relationship between the horizontal or vertical distribution and the oceanographic conditions was not clear (Kikuchi and Tsujita, 1977). The distribution of pelagic pollock is primarily observed on the layer of 30-150m, and the density distribution of the zooplanktons is high shallower than 150m in summer (Minoda, 1971). And the vertical distribution of pelagic pollock is consistent with the one of the diets such as the zooplanktons.

Based on the result of the winter survey in 1983 (Kitani, 1983; Okada, 1986; Okada and Nakayama, 1983; FAJ, 1984), the vertical distribution of the water temperature was the range of 2.5-4.2 °C. The remarkable thermocline was observed on the layer of 150-200m. And the water on the upper layer was the winter surface cooling waters below 3.5 °C and relatively cold water temperature, and the waters on the lower layer was the part of the Alaskan stream over 3.7 °C and relatively warm water temperature (Fig.46). The water temperature on the surface was the range of 3.0-3.5 °C, and the one deeper than 900m was below 3.0 °C. The school of pelagic pollock in late January and in mid to late February was primarily distributed on the layer of
250-300m where the water temperature was 3.5-4.0°C under the thermocline (Fig. 46, 47). The salinity (density) was the range of 32.8-34.3%, and the school was primarily observed on the layer of 33.6-33.8% (Fig. 48). And the resolved oxygen was the range of 0.4-7.4ml/l, and decreased in proportion to the depth. The school was observed on the layer on where the resolved oxygen was relatively low at 1.0-3.0ml/l (Fig. 48). In mid March, the fish after spawning moves into the layer of the surface cooling waters above the thermocline, however it seems that pelagic pollock which gonad is in the full mature stage, is distributed under the thermocline layer.

Based on the result of the survey conducted by Japan in the international waters in August to September 1987, the horizontal distribution (Fig. 49) of the mean water temperature on the depth of 0-200m was high on the east side and low on the west side (FAJ, 1988). It is considered that the Alaskan stream which goes up northward from the southeast side of the Aleutian Islands, affects the water temperature in the international waters, and the one on the east side is relatively higher than on the west side.

On the vertical distribution of the water temperature along the line of 57°N (Fig. 50), the thermocline prevails around the depth of 50m (FAJ, 1988). This thermocline indicates the sharp gradient in vertical wise on the west side but indicates the slow gradient towards east side. The cold water layer below 4°C is observed under the thermocline, and this cold water layer develops well on the west side but it does not develop on the east side. On the layer under the cold water layer, the water temperature goes up, and particularly on the east side the warm waters over 4°C prevails on the depth zone deeper than 200m.
On the vertical section along with the line of 180 longitude, the coldest layer below 2.5°C is observed on the layer of 150m on the north side, and it becomes warm towards south side and the warm waters over 4°C develop in the layer deeper than 200m (Fig.50).

As compared with the results of the midwater trawl survey and hydro-acoustic survey, the vertical distribution of pelagic pollock indicates the high density on the cold water layer of 50-200m (FAJ,1988). The area on where the density distribution is high in particular, is consistent with the area on where the warm waters prevails remarkably under the second thermocline (Fig.11,50).

The vertical distribution of the zooplanktons on the Basin in winter (Fig.51) indicates that the density is high on the layer under the thermocline (Kitani and Komaki,1984; FAJ,1984). It seems that the biomass of the zooplanktons on the Basin is relatively in abundance. And it is assumed that the reason why pelagic pollock in winter feeds a few of foods is not due to the lack of the foods available in the living layer but the physiological factors in connection with the reproduction.

On the relationship with the oceanographic circumstances, the transfer of the eggs and larvae spawned on the Basin is the most important subject. Based on the simulation of the current system in the Bering Sea (Fig.52), it was estimated that there was the anticlockwise circulation system on the Aleutian Basin, and the eddying current on the central region (Ohtani,1973). Based on the recent study, the circulation was identified (Kitani,1983; Royer and Emery,1984). The circulation which flows on the mid layer on the Basin, moves eastward along with the north side of the Aleutian Islands and changes the direction to the
northwest around the edge of the continental shelf northwest of the Unimak Pass. The speed and flow of the current is remarkably large in winter as compared with in summer, and the mean speed of 0.2-0.3 nautical miles per hour was recorded on the depth of 300m (Kitani, 1983).

Based on the observation on board during the winter survey in 1983, the fertilized eggs of pelagic pollock hatched in about 25 days with 3-4°C. Consequently, it is estimated that the fertilized eggs which are spawned on the southeast region of the Basin, are transferred to the point about 150 nautical miles away on the northeast direction (Okada, 1986). Further studies on the difference in the spawning season and period for the major spawning populations, the growth rate of larvae, and the current system is necessary to make clear the route of the transportation of eggs and larvae to the nursery grounds from the major spawning grounds.

9. Further Research

Based on the review described above, the biological informations regarding pelagic pollock which lives in the Aleutian Basin, has been partially accumulated so far. The study on this stock concerned is deemed as a part of large scale study to clarify the biological production mechanism of pollock resource in the whole Bering Sea including the stock on the continental shelf.

Pelagic Pollock in the international waters has been exploited by the fishing vessels from Japan, South Korea, Poland, and People's Republic of China. And it is reported that USSR has started fishing there. The survey conducted
by the each nation on the stock in the international waters is necessary, however it is important that the comprehensive survey and study on the pollock stocks in the whole Bering Sea should be conducted in cooperation with the fisheries nations and coastal nations concerned. For this reason, it is necessary to establish the cooperative regime. In the future, in order to achieve the objective of the study described above, it is necessary to establish the subjects of the study as follows:

(1) Analysis of Stock Structure

It is generally known that there are several spawning grounds (spawning populations) of pollock including on the Aleutian Basin, however it is necessary to clarify that those spawning populations are independent each other in terms of lineage.

i. Confirmation of the spawning grounds and the scale of spawning populations, in particular in the Asian side.

ii. Comparison of the biological parameters of the each spawning populations. (abundance, age composition, growth, condition factor, fecundity, mature at age, recruitment, mortality, etc.).

iii. Comparison of the meristics and morphometrics of the each spawning populations.

iv. Comparison of the shape or the formation patterns of the growth ring on the age materials (in general otolith or scale) of the spawning populations.

v. Comparison of the variations of the gene by the biochemical method in each spawning populations.
vi. Explication of the movement and migration, in particular the movement from the spawning ground to the feeding ground, and the migration from the feeding ground to the spawning ground, and the movement from the continental shelf to the Basin or from the Basin to the continental shelf.

vii. The transfer of larva from the each spawning ground.

viii. Based on the surveys regarding the items of ii to v, if the existence of the subpopulations and the valid characteristics to identify those were disclosed, the geographical mixture of the individual subpopulations will be explicated quantitatively by the samples collected from the broad area in the summer feeding season.

(2) Biomass estimate

The biomass is one of basic factors to determine the scale of the biological production of living resource. The informations regarding the biomass by age and its annual fluctuation are inevitable to estimate the harvest level available from the resource. Among those informations, the abundance trend of juvenile fish before recruitment and the mature fish are the most important to predict the future trend of the resource.

i. Direct estimation by the research vessel; The biomass is estimated by the survey in combination of the quantitative echo sounder system and the midwater or onbottom trawl nets. The biomass estimate is varied by the values of the back scattering strength and the target strength as a base of the biomass estimate. Therefore, the acoustic survey
should be carefully conducted, and hopefully the experts concerned participate in the survey. And it is appropriate to conduct the survey in summer and winter.

ii. Based on the catch data of the commercial fishing vessels, the biomass is estimated with the resource analysis models such as the Cohort model. As the basic informations, the number of fish by age is necessary. In case that there is no data or the data are not available from the certain fishery, the biomass estimate will be incomplete.

(3) Explication of commercial fishing

The informations from the commercial fishing vessels are extremely important to evaluate the biomass estimates from the models and surveys and the impacts of accuracy of the commercial catch on the resource.

i. Fishing efforts and catch; If the both of them are not reported accurately, it is meaningless on the study of the resource. Therefore, the individual nations should establish the system to obtain the accurate data from their commercial fishing vessels, and exchange those data after completion of the analysis in detail.

ii. Collection of the catch data of the size composition.

iii. Collection of the age materials.

iv. Collection of the frozen samples.

References and Fig. 1 to 52 and Table 1 are in English in the Japanese document.