東部ベーリング海及びアリューシャン水域における
ターボット類の資源評価(1986年)

Stock assessment of turbots in the eastern Bering Sea and Aleutian Islands region in 1986

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1986年　9月
September 1986
水　産　庁
Fisheries Agency of Japan

この文書を引用する場合は下記による：
若林　清・水戸啓一．1986. 東部ベーリング海及びアリューシャン水域におけるターボット類の資源評価（1986年）．12頁．（第33回INPFC定例年次会議提出文書．1986年10月．米国，アンカレッジ市）．水産庁，遠洋水産研究所．日本．〒424 清水市折戸5－7－1.

東部ベーリング海及びアリューシャン水域における ターボット類の資源評価（1986年）

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ターボット類は，カラスガレイ及びアラスカアブラガレイ（アブラガレイを含む）の2種よりなる。

カラスガレイは主として東部ベーリング海に生息し，分布は全アリューシャン列島水域及びアラスカ湾の西部水域に及んでいる。これらのカラスガレイは単一のポピュレーションを構成していると推定された（若林1984）。アラスカアブラガレイは，東部ベーリング海，アリューシャン列島水域及びアラスカ湾全域に広く分布しているが，分布の中心はアラスカ湾にある。しかし，この3水域に分布する魚群の相互関係は不明である。

ターボット類の適正漁獲量（OY）又は総許容漁獲量（TAC）は，合衆国により1980－83年に対して90,000トンに設定されたが，1984年に対しては59,610トンに，1985年には更に42,000トンに削減された。1986年の値は，カラスガレイ33,000トン，アブラガレイ20,000トン合計53,000トンに設定されている。

漁　獲　量

ベーリング海におけるターボット類の関係漁業国の報告漁獲量（表1）は，1962年の58千トンから減少して1965年に10千トンの最低を記録した後増加に転じ，1974年には103千トンに達した。しかし，この高水準の漁獲量は維持されず，1977－83年には半減して平均52千トンの水準にある。1983年以降漁獲量は急減し，1985年には21.7千トンの低水準となった。魚種別に漁獲量が推定されている1970年以降の，ターボット類に占めるカラスガレイとアラブガレイの割合は，それぞれ76％と24％であった。

1977年以降の合衆国オブザーバー資料に基づく漁獲量推定値は次表に示すとおりで（Nelson et al. 1978－1983；Berger et al. 1984，1985 and 1986），1984年及び1985年を除き表1に示した各国報告漁獲量より多い。

year	Greenland turbot	Arrowtooth flounder	Turbots total
1977	48,508	17,016	65,524
1978	67,935	16,107	84,042
1979	53,003	17,219	70,222
1980	52,553	18,365	70,918
1981	57,321	17,113	74,434
1982	52,112	11,518	63,640
1983	47,552	14,021	61,573
1984	23,120	9,449	32,569
1985			21,778

カラスガレイ資源

バイオマス推定値

日本調査及び米国調査による東部ベーリング海の大陸棚上とその縁辺部における，主に40*cm*以下の小型魚のバイオマス推定値は，1974年から1980年までの期間比較的安定していたが，1981年以降連続して急激に低下し，1985年には1979年のわずか5％（7,700トン）となった（表2）。1979－85年の体長組成（図1）と1979年の日米共同トロール調査で得られたAge－length－keyから，このバイオマス推定値の減少は，主に1979－84年に発生した年級群の豊度が連続して低かったことによって起っていると推定される。しかし，小型魚の分布はソ連水域にも広く及んでおり，バイオマスが得られた比較調査水域は，分布域の一部にすぎないから，バイオマス推定値が示す程資源量が急激に低下したか疑問がある。米－ソ境界をはさんで両水域に分布する魚群の分布パターンの変化等今後詳細に検討する必要がある。

日米共同トロール調査の日本側資料に基づく東部ベーリング海大陸斜面における主として40*cm*以上の中・大型カラスガレイのバイオマス推定値は，1979年の124,600トンから徐々に低下し，1985年には79.200トンとなった（表2）。同時に得られた体長組成によれば（図1），1985年には1981年及び1982年に比較して体長40－55*cm*の個体の割合が著しく低下しており，豊度の低い年級群の影響が大陸斜面上部水域に分布する魚群に既に現われていることを示している。発生年級群の豊度が調査データに示されるように連続して悪かったとすれば，大陸斜面上部水域に生息する中・大型魚群の資源量は今後低下するものと予想される。

アリューシャン列島水域における1980年の日米共同トロール調査によるバイオマス推定値は，ベーリング海南部水域（Area 1の一部）に対して15,900トン，アリューシャン水域（Area 5）に対して32,800トンであった（Wilderbuer et al. 1985）。また，1983年の調査による推定値はそれぞれ14,000トン及び49,800トンであった。漁撈技術を考慮に入れた相対的な漁獲性能は，

1983年の方が良いと推定されている（若林1984）。したがって，1980年の推定値は1983年に比較して相対的に過少となっていよう。また，トロール調査に基づくバイオマス推定値は，漁具効率（vulnerability）を1.0と仮定して得られているから，真の値に対して一般的に過少である。特にアリューシャン列島水域は海底が荒いためトロール網の着底性が悪く，過少の割合も大きいと考えられる。

はえなわ調査資料

日米共同はえなわ調査による水深401－800 *m*の水域における相対資源尾数（RPN），相対資源重量（RPW）及び平均尾叉長を表4に示した（佐々木・手島1986；佐々木1986）。RPN及びRPWは水域別，水深帯別のcatch rateに水域面積を乗じて得られている。漁獲されたカラスガレイの95％以上は，尾叉長60 *cm*以上の個体が占めており（Sasaki et al. 1983；Sasaki and Mizogoshi 1986），これらの値は親魚資源に対するものと言える。

東部ベーリング海では，揚縄途中に漁獲物がシャチに食害され，その程度が年々変化したため，RPNやRPWから資源の動向を判断することは困難である。アリューシャン水域におけるRPN及びRPWは特定の経年変化を示していないが，1985年には1982年同様低い値であった。

平均尾叉長は，東部ベーリング海及びアリューシャン水域とも1985年には他の年度より大きい値であった。

最大持続生産量（MSY）

1976－80年におけるCPUEは，最も高かった1972年の1／2より若干高い水準にあったことから，近年の資源量がMSYを与える水準にあると仮定し，1979年のバイオマス推定値348,600トンと自然死亡係数0.19とを用い，収量方程式（Alverson and Pereyra 1969）から，東部ベーリング海におけるMSYとして66,200トンが得られる（若林1983）。

アリューシャン列島水域のカラスガレイは，東部ベーリング海のポピュレーションの一部と考えられるから，1979年の東部ベーリング海と1980年のアリューシャン列島水域におけるバイオマス合計値397,300トンを用いて前記と同様の方法から東部ベーリング海とアリューシャン列島水域を併せたMSYを再計算すれば75,500トンが得られる。しかしながら，これまで75,500トンを越える漁獲量は1972年及び1974年の2年間のみであること，1972－78年の期間の平均66,700トンの漁獲量が資源量を低下させたと推定されることから，Bakkala et al.（1985a）も指摘するように，75,500トンのMSY推定値は過大である可能性がある。

平衡漁獲量（EY）

1972－78年の年間平均66,700トンの漁獲量で資源量は低下し，1979－83年の52,500トンの漁獲量で資源が安定ないしは若干増加したことから，52,500－66,700トンが近年におけるEYの目安を与えよう。しかし，1981－85年には，主に発生年級群豊度が低かったことによるバイオマ

ス推定値の低下が観測されており，ＥＹも低下したものと推定される。ただ，経年的なバイオマス推定値が得られた米国の比較調査水域（ comparative area ）はカラスガレイの分布を充分カバーしておらず，推定値が豊度を正しく示しているか疑問がある。北緯63度以南の米国水域をほぼカバーして実施した日米共同調査のバイオマス推定値は，1982年には1979年の21.5％に低下している。1985年のバイオマスは更に低下したと推定された。この連続して弱勢な年級群の資源に与える影響を予測するため，以下のような外挿計算を行った。弱勢とみなされる1979－1981年級群が，それ以前の年級群の平均的な豊度に対して21.5％に，1982－84年級群が10％に低下し，1985年級以降は通常の水準と仮定した。Bakkala et al.（1985a）によれば，SRA分析結果に基づく東部ベーリング海の近年における5歳以上のバイオマスは，M＝0.18として305,000－356,000トンと推定された。トロール調査に基づくアリューシャン水域のバイオマスは，東部ベーリング海の約31.3％であった。このことから両水域を併せた1984年のバイオマスを434,000トン（平均330,500×1.313）とした。このバイオマスに対する1984年以前の平均漁獲量 55,000トンの割合（開発率）0.127とM＝0.18から生残率0.719（Ｆ＝0.15）を求め，1984年における5歳を1,000尾とした相対年齢組成を計算した。次いで，1984年の漁獲量23,120トン（開発率0.0533）から計算した生残率0.787（Ｆ＝0.06）を用いて1985年における1歳高齢の年齢別相対尾数を求め，次に示す体重の成長式で得た平均重量を乗じて相対バイオマスを求めた。

$$BW_t = 16.633\left(1 - e^{-0.084\left(t + 0.715\right)}\right)^{3.2387}$$

ここで，BWtはt歳の平均個体重（g）である。但し，tは7月を年初としている。1985年の漁獲量は不明のため，1984年と同一の生残率を用いて1986年の相対尾数を得た。1985年及び1986年のバイオマスは，1984年の相対バイオマスとバイオマスの関係から求めた。1986年以降は，1986年の計算バイオマスとOY 33,000トンに対する開発率0.0802で漁獲を行うものとし，生残率0.762を用いて相対尾数を求め，各年のバイオマスを計算した。得られた結果を以下に示す。

年	バイオマス（t）
1984	434,000
1985	420,800
1986	411,400
1987	374,200
1988	334,800
1989	296,700
1990	307,900
1991	325,900
1992	352,900

弱勢な年級群の影響は1989年に最大となって，資源量は最も低い水準となり，以後増加すると予測された。もし1985年及びそれ以降に発生した年級群が弱勢の場合でも1989年以前の結果には影響しない。EYは，上記バイオマスの8.02％であり，1987年に対しては30,000トンとなる。

アラスカアブラガレイ資源

アラスカアブラガレイについては，漁獲量の大部分が他の魚種に付随して漁獲されており，混獲の割合も年々変化しているため，商業船のCPUEから資源状態を判断することは困難である。

バイオマス推定値

東部ベーリング海大陸棚上の比較調査水域におけるトロール調査によるバイオマス推定値は，1974年から1981年の期間40,800－54,300トンの範囲で比較的安定していたが（1975年の米調査を除く），1982年以降年々増大し，1984年には182,900トンとなった（表3）。その後1985年には159,900トンに低下している。体長組成（Bakkala et al. 1985a）から判断して，1983－85年の高いバイオマスは，主に1981年に発生したと推定される年級群が著しく卓越したこと，また，1979及び1980年級群も相対的に高い豊度であったことに起因している。大陸斜面におけるバイオマス推定値も1982年と1985年の間で著しく増加した。この増加についても，大陸棚上同様1979－81年級群が貢献している。

アリューシャン列島水域における日米共同トロール調査によるバイオマス推定値は，1980年にはベーリング海南部水域（INPFC Area 1の一部）で8,300トン，アリューシャン列島水域（Area 5）32,100トン，合計40,400トンであった（Wilderbuer et al. 1985）。また，1983年にはそれぞれ8,700トンと36,400トン，合計45,100トンであった。これらのバイオマス推定値は，漁獲効率を1と仮定して得られた値であるので，過少であろう。

はえなわ調査資料

日米共同はえなわ調査による200－600 mの水域におけるRPN，RPW及び平均尾叉長を表4に示した（佐々木・手島1986；佐々木1986）。それぞれの値は，東部ベーリング海及びアリューシャン列島とも一定した年変化傾向を示していない。東部ベーリング海におけるRPWは，1985年には1982－84年の値から大幅に増加した，アリューシャン水域における1985年のRPWは1984年の値から増加しているが，1980年以降で最も高い値を示した1982－83年の66－68％と低い値であった。

Sasaki et al.（1983），Sasaki and Mizogoshi（1986）及びBakkala et al.（1985a）に示される体長組成は，比較的大きな年変動を示している。これは，本種の成長が速く，かつ年級群豊度の変動が大きいことに起因していると考えられる。このことが，RPNやRPWの年変動が大きい原因にもなっていると推定される。

最大持続生産量（ＭＳＹ）

アラスカアブラガレイの近年の資源量がカラスガレイと同様MSYを与える水準にあるとすれば，自然死亡係数0.2と収量方程式から得られるMSYは，東部ベーリング海については1979－82年のバイオマス推定値平均83,100トンを用いて16,600トン，アリューシャン列島水域（アリューシャン列島に隣接するArea 1の一部を含む）について1980年の値40,400トンを用いて8,100トン，合計24,700トンとなる。

平衡漁獲量（ＥＹ）

アラスカアブラガレイは他の魚種に付随して漁獲されており，その漁獲量は1974－81年の期間平均18,900トンで安定しており（表1，及びカラスガレイ文中表），また，バイオマス推定値も1974－80年の期間ほぼ一定の水準を示した後1981－84年には増加している。MSYは24,700トンと推定されたから，近年のEYは18,900－24,700トンの範囲にあると推定される。

ターボット類のＥＹ

カラスガレイは近年加入量が連続して低水準にあり，EYも低下して，1987年に対して30,000トンと推定された。アラスカアブラガレイについては，近年卓越年級群の加入によってバイオマスが上昇しているから，EYとして上記EY推定範囲の上限値24,700トンをとれば，東部ベーリング海及びアリューシャン列島水域におけるターボット類のEYは，1987年に対して54,700トンとなる。

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Table 1. All nation catches of arrowtooth flounder and Greenland turbot in the Bering Sea, by area and by nation, in metric tons.

Year	By Area: Eastern Bering	By Area: Aleutian	By Nation: Japan[a] MS-LG-NPT[b]	By Nation: Japan[a] LBD[b]	By Nation: USSR[b]	By Nation: ROK[b]	By Nation: OT[b]	Total
Arrotooth flounder and Greenland turbot combined								
1960	36,843	0	36,848	0		0		36,843
1961	57,348	0	57,348	0		0		57,348
1962	58,226	0	58,226	0		0		58,226
1963	31,565	7	31,565	7		0		31,572
1964	33,729	504	34,201	32		0		34,233
1965	9,747	300	7,947	300	1,800	0		10,047
1966	13,042	63	10,815	90	2,200	0		13,105
1967	23,869	394	20,741	883	2,639	0		24,263
1968	35,232	213	17,808	2,385	15,252	-		35,445
1969	36,029	228	13,576	5,883	16,798	0		36,257
1970	32,289	559	14,490	10,138	8,220	-		32,848
1971	59,256	2,331	30,642	13,485	17,460	-		61,587
1972	77,634	14,197	26,849	40,717	24,265	-		91,831
1973	64,497	12,371	31,560	27,732	16,576	-		76,868
1974	91,127	11,983	41,105	32,496	29,509	-		103,110
1975	85,651	3,754	33,308	24,169	31,928	-		89,405
1976	78,349	3,437	35,174	21,501	25,111	-		81,786
1977	37,162	4,488	17,015	19,278	5,357	-		41,650
1978	45,781	6,548	22,481	25,607	4,121	120		52,329
1979	42,702	12,829	25,533	26,456	1,574	1,948	20	55,531
1980	48,607	7,546	27,991	20,548	0	7,126	488	56,153
1981	52,204	4,812	29,486	21,882	0	5,235	1,007	57,610
1982	42,932	5,050	23,945	24,037	0	2,161	1,575	51,718
1983	38,784	4,954	19,322	24,416	0	2,761	38	46,537
1984			11,592	20,436	2	993	271	33,294
1985			5,842	14,485[c]	0	894	459	21,680
Arrowtooth flounder								
1970	12,598	274	9,321	307	3,244	-		12,872
1971	18,792	581	6,279	5,905	7,189	-		19,373
1972	13,124	1,323	1,455	3,585	9,407	-		14,447
1973	9,217	3,705	2,398	6,213	4,311	-		12,922
1974	21,473	3,195	2,599	3,419	18,650	-		24,668
1975	20,832	784	445	1,437	19,734	-		21,616
1976	17,826	1,370	255	2,809	16,132	-		19,196
1977	9,454	2,035	4,158	4,017	3,314	-		11,489
1978	8,358	1,782	5,122	2,349	2,578	91		10,140
1979	7,907	6,426	4,492	7,208	948	1,680	5	14,333
1980	13,241	2,236	6,677	2,778	0	5,849	173	15,477
1981			8,485	3,231				
1982			7,215	2,870				
1983			3,918	4,689				
1984			1,259	3,980				
1985			995					
Greenland turbot								
1970	19,691	285	5,169	9,831	4,976	-		19,976
1971	40,464	1,750	24,363	7,580	10,271	-		42,214
1972	64,510	12,874	25,394	37,132	14,858	-		77,384
1973	55,280	8,666	30,162	21,519	12,265	-		63,946
1974	69,654	8,788	38,506	29,077	10,859	-		78,442
1975	64,819	2,970	32,863	22,732	12,194	-		67,789
1976	60,523	2,067	34,919	18,692	8,979	-		62,590
1977	27,708	2,453	12,857	15,261	2,043	-		30,161
1978	37,423	4,766	17,359	23,258	1,543	29		42,189
1979	34,795	6,403	21,041	19,248	626	268	15	41,198
1980	35,364	5,310	21,314	17,770	0	1,277	313	40,674
1981			21,001	18,661				
1982			16,730	21,190				
1983			15,404	19,727				
1984			10,333	16,456				
1985			4,847					

a Japanese catches through 1976 may include small amount of unidentified flounders.

b MS-LG-NPT: Mothership-longline-gillnet-north Pacific trawl fishery
LBD: Landbased dragnet fishery(Hokuten), ROK: Republic of Korea
OT: Taiwan, Poland, West Germany, and Joint venture fishery

c Preliminary

Data sources: 1960-76; Wakabayashi & Bakkala 1978
1977-80 except Japanese catches; Bakkala et al. 1981
1977-85 Japanese catches; Data files of Far Seas Fish. Res. Lab., Shimizu
1981-83 except Japan: PMT 1984
1984-85 except Japan: Berger et al. (1985 & 1986)

Table 2. Biomass estimates for Greenland turbot in the eastern Bering Sea obtained from trawl surveys.

Year	Japanese survey[a] (on the shelf)	U.S. survey[b]	U.S.-Japan cooperative surveys[c]		
			U.S. vessels (on the shelf)	Japanese vessels (on the slope)[d]	U.S.-Japan joint analysis (all area)
1974	90,200[e]				
1975	114,200	126,700			
1976	98,100				
1977	-				
1978	122,500				
1979	105,300[f]	225,600	152,400	124,600	277,000
1980		172,200			
1981		86,800	86,800[g]	99,600	186,400
1982		48,600	36,700	90,600	127,300
1983		35,100			
1984		17,900			
1985		7,700	7,800	79,200	87,100

a Far Seas Fish. Res. Lab. surveys using the R/V Shunyo maru except in 1979, when the Yakushi maru No. 21 and Shotoku maru No. 35 were used. The survey area is shown in Wakabayashi (1983)
b for comparative area (Bakkala et al. 1985a)
c Bakkala et al.(1985b)
d Fishing power correction factors were not applied.
e Survey area was smaller than of the other years.
f Preliminary estimate
g Survey area was smaller than of 1979.

Table 3. Biomass estimates for arrowtooth flounder in the eastern Bering Sea obtained from trawl surveys

Year	Japanese survey[a] (on the shelf)	U.S. survey[b]	U.S.-Japan cooperative surveys[c]		
			U.S. vessels (on the shelf)	Japanese vessels (on the slope)[d]	U.S.-Japan joint analysis (all area)
1974	41,600[e]				
1975	52,800	28,000			
1976	50,300				
1977	-				
1978	54,300				
1979	40,800[f]	35,000	36,600	36,400	73,000
1980		47,800			
1981		49,500	49,500[g]	34,900	84,400
1982		67,400	67,400	24,700	92,200
1983		149,300			
1984		182,900			
1985		159,900	148,200	74,400	222,600

See Table 2 for footnotes.

Table 4. Abundance indices[a] and average fork-length[b] of turbots in the eastern Bering Sea and Aleutian region, based on the Japan-U.S. joint longline surveys, 1979-85.

Greenland turbot

Year	Eastern Bering[c] RPN[d]	(Index[e])	RPW[f]	(Index)	Average length(cm)[g]	Aleutian region RPN	(Index)	RPW	(Index)	Average length(cm)
1979	-	(-)	-	(-)	-	-	(-)	-	(-)	-
1980	-	(-)	-	(-)	-	1,397	(100)	6,902	(100)	77.0
1981	-	(-)	-	(-)	-	1,998	(143)	10,367	(150)	77.7
1982	3,113	(223)	13,999	(203)	77.2	1,000	(72)	5,061	(73)	77.5
1983	2,229	(160)	11,517	(167)	77.4	1,317	(94)	6,653	(96)	77.8
1984	1,556	(111)	7,039	(102)	75.7	1,215	(87)	6,367	(92)	78.4
1985	2,491	(178)	12,348	(179)	78.0	917	(66)	5,289	(77)	80.3

Arrowtooth flounder

Year	Eastern Bering[c] RPN[d]	(Index[e])	RPW[f]	(Index)	Average length(cm)[g]	Aleutian region RPN	(Index)	RPW	(Index)	Average length(cm)
1979	-	(-)	-	(-)	-	-	(-)	-	(-)	-
1980	-	(-)	-	(-)	-	1,591	(100)	4,866	(100)	60.0
1981	-	(-)	-	(-)	-	1,199	(75)	3,405	(70)	57.8
1982	1,601	(101)	2,913	(60)	52.2	1,458	(92)	5,169	(106)	61.8
1983	1,783	(112)	2,978	(61)	51.0	1,552	(98)	5,017	(103)	59.9
1984	1,272	(80)	2,238	(46)	51.8	995	(63)	3,105	(64)	58.6
1985	2,490	(157)	4,324	(89)	51.1	1,000	(63)	3,414	(71)	60.7

a Sasaki and Teshima (1986)
b Sasaki (1986)
c RPNs, RPWs and their indices were underestimated because of predation by killer whales.
d Relative population number, sum of (catch rate x area size) by sampling stratum.
e Values relative to the 1980 value for Aleutian region
f Relative population weight
g Fork-length

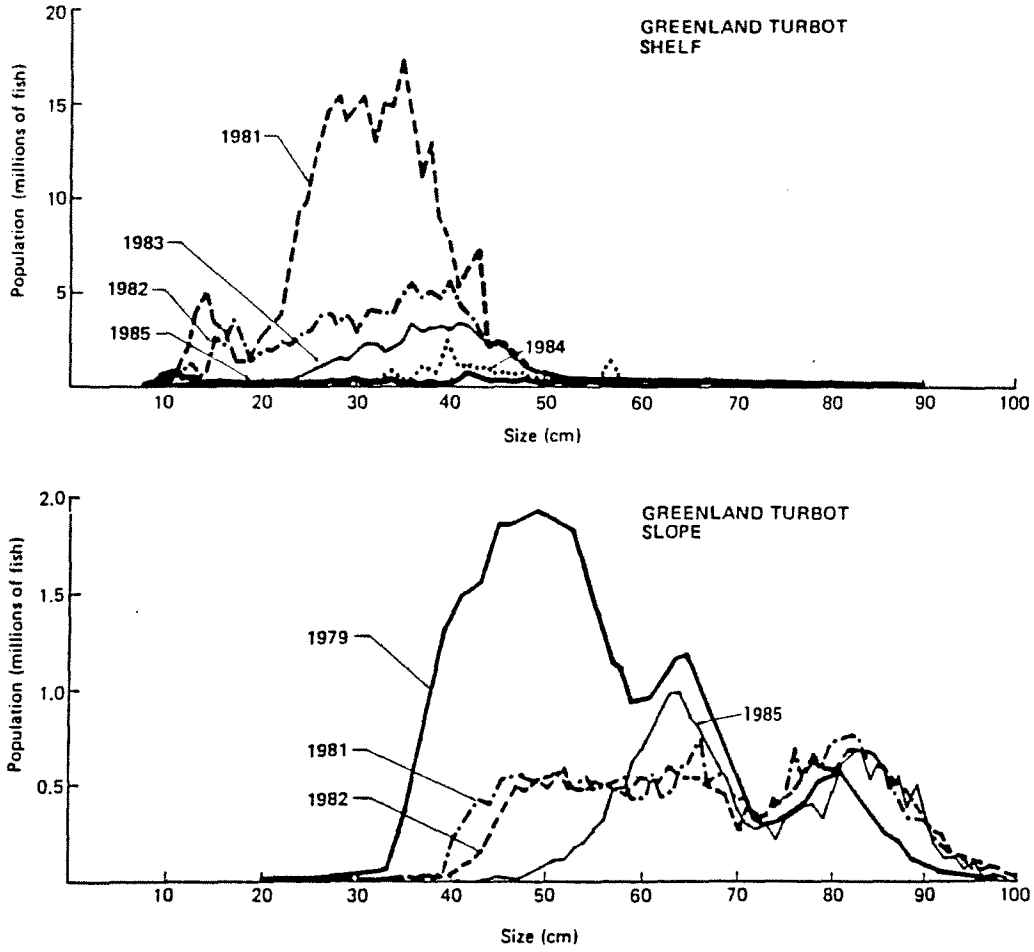

Figure 1.--Size composition of Greenland turbot on the eastern Bering Sea continental shelf and slope during research vessel surveys, 1979-85. (Bakkala et al. 1985a, revised by adding the 1985 slope data)

Not to be cited by INPFC
Document number

INPFC
Doc. 3044

TRANSLATION

STOCK ASSESSMENT OF TURBOTS IN THE EASTERN BERING SEA AND ALEUTIAN ISLANDS REGION IN 1986

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1986 September

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:
Wakabayashi, Kiyoshi, and Kei-ichi Mito. 1986. Stock assessment of turbots in the eastern Bering Sea and Aleutian Islands region in 1986. (Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, Anchorage, Alaska, 1986 October.) 11 p. Fisheries Agency of Japan, Tokyo, Japan 100.

Turbots consist of two species such as Greenland turbot and arrowtooth flounder (including Kamchatka flounder).

Greenland turbot inhabit mainly the eastern Bering Sea and its distribution extends to whole Aleutian Islands region and the western area of the Gulf of Alaska. It has been assumed that these Greenland turbots consist a single population (Wakabayashi 1984). Arrowtooth flounder is distributed widely in the eastern Bering Sea, Aleutian Islands region, and the whole Gulf of Alaska, and the center of their distribution is in the Gulf of Alaska. However, the interrelationships of groups distributed in these three areas are unknown.

Although the optimum yield (OY) or the total allowable catch (TAC) of turbots was established by the United States as 90,000 t for 1980 to 1983 and 59,610 t for 1984, it decreased further to 42,000 t in 1985. In 1986 it was set at 53,000 t in total; 33,000 t for Greenland turbot and 20,000 t for arrowtooth flounder.

Catch

The catches of turbots reported by the concerned countries in the Bering Sea (Table 1) decreased from 58,000 t in 1962 to 10,000 t (the lowest level of catch) in 1965 but thereafter increased and reached 103,000 t in 1974. However, this high level of catch was not maintained and during the period of 1977 to 1983 the catches decreased to one-half (average 52,000 t) of the highest catch. The catches decreased drastically in 1983 and after and it was as low as 21,700 t in 1985. The proportion of Greenland turbot and arrowtooth flounder in the turbots catch in 1970 and after was 76% and 24%, respectively.

The estimated catches based on data from U.S. observers in 1977 and after were shown in the following table (Nelson et al. 1978-1983; Berger et al. 1984, 1985, and 1986), they were higher than the catches reported by each country, shown in Table 1, except those in 1984 and 1985.

Year	Greenland turbot	Arrowtooth flounder	Turbots total
1977	48,508	17,016	65,524
1978	67,935	16,107	84,042
1979	53,003	17,219	70,222
1980	52,553	18,365	70,918
1981	57,321	17,113	74,434
1982	52,112	11,518	63,640
1983	47,552	14,021	61,573
1984	23,120	9,449	32,569
1985			21,778

Greenland turbot stock

Estimated biomass

Although the estimated biomass of small fish, mainly less than 40 cm, from the Japanese and U.S. surveys in the eastern Bering Sea continental shelf and edge area was relatively stable from 1974 to 1980, it drastically and continuously decreased in 1981 and after and accounted for only 5% (7,700 t) of that of 1979 in 1985 (Table 2). A decrease of the estimated biomass from the length compositions from 1979 to 1985 (Fig. 1) and the age-length key obtained from the Japan-U.S. joint trawl survey in 1979 was estimated to be caused mainly by the continuous low level of abundances of the year classes that occurred from 1979 to 1984. However, it is doubtful whether the

biomass drastically decreased as much as shown by the estimated biomass because the distribution of small-sized fish extended widely to the U.S.S.R. area and the comparative survey area where the biomass was obtained was only a part of the area of distribution. From now on, it is necessary to consider in detail changes in the distribution pattern of fish groups distributed in both areas between the U.S. and U.S.S.R. boundaries.

The estimated biomasses of the middle and large-sized Greenland turbot, chiefly larger than 40 cm, were distributed on the eastern Bering Sea continental slope and, based on the Japanese data of the Japan-U.S. joint trawl survey, decreased gradually from 124,600 t in 1979 to 79,200 t in 1985 (Table 2). According to the length composition obtained at the same time (Fig. 1), the proportion of individuals in the lengths between 40 and 55 cm in 1985 decreased remarkably compared with those in 1981 and 1982, suggesting that influences of the year classes in low abundance already appeared in the fish group distributed on the upper continental slope. If it is assumed that abundances of the year classes that occurred were continuously as low as shown in the survey data, it is anticipated that the biomasses of middle and large-sized fish groups inhabiting the upper continental slope will decrease from now on.

The estimated biomass from the Japan-U.S. joint trawl survey on the Aleutian Islands region in 1980 was 15,900 t for the southern Bering Sea (a part of Area 1) and 32,800 t for the Aleutian Islands region (Area 5) (Wilderbuer et al. 1985). The estimated values from the survey in 1983 for these areas were 14,000 t and 49,800 t, respectively. For the relative fishing efficiency with due regard to fishing technique, it is estimated that the relative fishing efficiency of 1983 was better than that of 1980 (Wakabayashi 1984). Thus, the estimated value of 1980 was presumably underestimated compared with that of 1983. Because the estimated biomass based on

the trawl survey is obtained using the assumption that gear vulnerability is 1.0, it is generally underestimated from the true value. In particular, because the sea bottom conditions in the Aleutian Islands region are rough and the bottom-tending property of trawl net is poor, it is considered that the magnitude of the underestimate is even larger for this region.

Longline survey data

The relative population number (RPN), relative population weight (RPW), and average fork length of Greenland turbot in the depths of 401 to 800 m obtained from the Japan-U.S. joint longline survey are shown in Table 4 (Sasaki and Teshima 1986; Sasaki 1986). RPN and RPW are obtained by multiplying the area catch rate by depth and size of area surveyed. Ninety-five percent or more of Greenland turbot caught were individuals of 60 cm or more in fork length (Sasaki et al. 1983; Sasaki and Mizogoshi 1986). It is said that these values correspond to those of the parent population.

In the eastern Bering Sea, it is difficult to judge the trend of stock from RPN and RPW because the catches were sometimes intercepted by killer whales during hauling the longlines and its proportion varied each year. Although the RPN and RPW of Greenland turbot in the Aleutian Islands region did not indicate specific yearly trend through 1985, the 1985 values were low similar to those of 1982.

The average fork lengths of Greenland turbot in both the eastern Bering Sea and Aleutian Islands region in 1985 were larger than those in the other years.

Maximum sustainable yield (MSY)

Because CPUE values during 1976 to 1980 were at a level which was somewhat higher than one-half of the value in 1972, when the highest CPUEs were recorded, by assuming the biomass in recent years to be at the level yielding MSY, from the yield equation (Alverson and Pereyra 1969) using the estimated biomass of 348,600 t in 1979 and the natural mortality coefficient of 0.19, MSY of Greenland turbot in the eastern Bering Sea was calculated to be 66,200 t (Wakabayashi 1983).

Because Greenland turbot in the Aleutian Islands region is considered as a part of the population in the eastern Bering Sea, MSY values combined the eastern Bering Sea and Aleutian Islands region were obtained to be 75,500 t from the same method mentioned above using the value (397,300 t), summing the biomasses in the eastern Bering Sea of 1979 and Aleutian Islands region of 1980. However, because catches exceeding 75,500 t were observed in only two years of 1972 and 1974 and it is believed that the annual average catch of 66,700 t from 1972 to 1978 may have decreased the biomass, the estimated MSY of 75,500 t might be an overestimate, as indicated by Bakkala et al. (1985a).

Equilibrium yield (EY)

Because the biomass was decreased by the annual average catch of 66,700 t from 1972 to 1978 and the biomass was stable or somewhat increased by the annual average catches of 52,500 t from 1979 to 1983, the catches of 52,500 t to 66,700 t will be an aim for the recent equilibrium yield. However, a decrease of the estimated biomass was observed from 1981 to 1985 mainly due to the low abundances of the year classes, thus it is estimated that EY also decreased. It is doubtful whether the estimated biomass indicated correctly the abundance because the U.S. comparative survey area from which the yearly estimated biomass was obtained did not cover fully the distribution of Greenland turbot. The estimated biomass from the

Japan-U.S. joint survey covered almost all the U.S. areas south of 63°N in 1982 decreased to 21.5% of the estimated biomass in 1979. It was estimated that the biomass in 1985 further decreased. The following extrapolated calculation was conducted in order to anticipate the effect of the continuous weak year classes on the Greenland turbot stock. It was assumed that the 1979 to 1981 year classes which were regarded as weak decreased to 21.5% and the 1982 to 1984 year classes decreased to 10% of the average abundances of the year classes before 1979 and the abundances of the 1985 and later year classes were at ordinary levels. According to Bakkala et al. (1985a), the current biomasses of Greenland turbot of 5-year-old and over in the eastern Bering Sea, based on the SRA analytical results, were estimated using M = 0.18 to be 305,000 to 356,000 t. The biomass in the Aleutian Islands region, based on the trawl survey, was about 31.3% of that in the eastern Bering Sea. From this, the biomass in both areas combined in 1984 was established as 434,000 t (average 330,500 (for the eastern Bering Sea) x 1.313). The survival rate of 0.719 (F = 0.15) was obtained from the exploitation rate (0.127) of the average catch of 55,000 t in and prior to 1984 from this biomass and M = 0.18, and the relative age composition with 1,000 fish of age 5 in 1984 was calculated. Subsequently, the relative population number by age of the 1-year-older fish in 1985 was obtained using the survival rate of 0.787 (F = 0.06) calculated from the catch of 23,120 t in 1984 (exploitation rate of 0.0533) and the relative biomass was obtained by multiplying the relative population numbers by age and by the average weight obtained from the following growth equation of body weight:

$$BW_t = 16{,}633\ (1 - e^{-0.084\ (t + 0.715)})^{3.2387}$$

where, BW_t is the average individual body weight (g) at t year old. However for t, July is regarded as the beginning of the year. Because the catch of 1985 was unknown, the relative population number in 1986 was obtained using the same survival rate as that in 1984. The 1985 and 1986 biomasses were obtained from the relationship between the

relative biomass of 1984 and the biomass. In 1986 and after, it is assumed that fishing will be conducted at the calculated biomass of 1986 and the exploitation rate of 0.0802 for the optimum yield of 33,000 t, and the relative population number was obtained using the survival rate of 0.762 and the biomass of each year was calculated. The results obtained are as follows:

Year	Biomass
1984	434,000
1985	420,800
1986	411,400
1987	374,200
1988	334,800
1989	296,700
1990	307,900
1991	325,900
1992	352,900

It was anticipated that the influence of the weak year classes will be greatest in 1989 and the biomass will be the lowest and thereafter increase. Even though the year classes occurred in 1985 and after were weak, they will not effect the results obtained in and prior to 1989. EY is 8.02% of the above biomass and is 30,000 t for 1987.

Arrowtooth flounder stock

For arrowtooth flounder, most of the catch is taken incidentally with the other species and the proportion of incidental catch varies by year. Therefore, it is difficult to judge the stock condition of arrowtooth flounder from CPUE value of the commercial vessels.

Estimated biomass

The estimated biomasses from the trawl surveys in the comparative survey areas on the eastern Bering Sea continental shelf ranged from 40,800 t to 54,300 t during 1974 to 1981 and were in relatively stable condition (except the U.S. survey in 1975) but it had increased year by year in 1982 and after and reached 182,900 t in 1984 (Table 3). Thereafter it decreased to 159,900 t in 1985. Judging from the size composition (Bakkala et al. 1985a), the high biomasses during the period of 1983 to 1985 resulted from the remarkably dominant year class of 1981 and from the relatively high abundances of the 1979 and 1980 year classes. The estimated biomass on the continental slope increased remarkably from 1982 to 1985. The 1979 to 1981 year classes also contributed to this increase, similar to the case on the continental shelf.

The estimated biomass from the Japan-U.S. joint trawl survey in the Aleutian Islands region in 1980 was 40,400 t in total; 8,300 t for the southern area of the Bering Sea (a part of INPFC Area 1) and 32,100 t for the Aleutian Islands region (Area 5) (Wilderbuer et al. 1985). The estimated biomass in 1983 was 8,700 t and 36,400 t, respectively, and 45,100 t in total. Because these estimated biomasses were the values which were obtained by assuming the fishing efficiency = 1, they appeared to be underestimates.

Longline survey data

The RPN, RPW, and average fork length from the Japan-U.S. joint longline surveys in the depths of 200 to 600 m are shown in Table 4 (Teshima and Sasaki 1986; Sasaki 1986). Value did not show any specific yearly trend in the eastern Bering Sea or Aleutian Islands. RPW in the eastern Bering Sea in 1985 increased extensively from the values from 1982 to 1984. RPW in the Aleutian Islands region in 1985

increased from the value of 1984 but was still as low as 66% to 68% of the value for 1982 and 1983 when the highest values since 1980 were recorded.

The body length compositions in Sasaki et al. (1983), Sasaki and Mizogoshi (1986), and Bakkala et al. (1985a), show relatively large yearly fluctuations and it is assumed that this phenomenon is attributable to the fast growth rate of this species and the large fluctuation of year class abundances. It is also considered that this phenomenon results in the large yearly fluctuations of RPN and RPW.

Maximum sustainable yield (MSY)

If the biomass of arrowtooth flounder in recent years is assumed to be at a level which gives the MSY, similar to the case of Greenland turbot, MSY for the eastern Bering Sea is estimated to be 16,600 t from the natural mortality coefficient of 0.2 and yield equation using the average estimated biomass in 1979 to 1982 of 83,100 t. For the Aleutian Islands region (including a part of Area I adjacent to the Aleutian Islands), similarly the estimated 1980 biomass of 40,400 t yields the MSY of 8,100 t at the natural mortality coefficient of 0.2. Thus, a total of 24,700 t.

Equilibrium yield (EY)

Arrowtooth flounder is caught incidentally with the other species and its catch averaged 18,900 t during the period of 1974 to 1981 and was in stable condition (Table 1 and the table in the text on Greenland turbot). The estimated biomass showed almost uniform level during the period of 1974 to 1980 and thereafter increased in 1981 to 1984. Because MSY was estimated to be 24,700 t, it is considered that the current EY ranges from 18,900 t to 24,700 t.

EY of turbots

The recruitment of Greenland turbot in recent years has been at a low level and EY also decreased to a value estimated to be no more than 30,000 t for 1987. Because the biomass of arrowtooth flounder is rising with the recent strong year classes, by taking the upper value of 24,700 t of the estimated EY range for arrowtooth flounder mentioned above, future EYs of turbots in the eastern Bering Sea and Aleutian Islands region are estimated to be 54,700 t.

REFERENCES, TABLES 1 TO 4, AND FIG. 1
ARE IN ENGLISH IN THE JAPANESE DOCUMENT