東部ベーリング海及びアリューシャン水域における小型カレイ類の資源評価(1987年)

Stock assessment of small-sized flounders in the eastern Bering Sea and Aleutian Islands Region in 1987

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1　東部ベーリング海のコガネガレイ

漁　獲　量

小規模の断続的な漁獲と10年以上にわたる操業中断の後，漁業が再開された1954年以降の国別漁獲量を表1に示した。漁獲量は，1954－58年の年間平均22千トンから1959－62年の345千トンへと急増後，低下し，1963－71年には年間54－167千トンの範囲で変動していた。漁獲量は，1972－77年及び1978－83年の期間には，それぞれ年間平均58千トン及び103千トンで安定していたが，1985年には，漁業最盛期の362－467千トンに次いで高い228千トンへと増加している。

ベーリング海におけるコガネガレイの最適漁獲量（ＯＹ）又は総許容漁獲量（ＴＡＣ）は，合衆国により1977年には106,000トン，1978－79年には126,000トン，1980－83年には117,000トンに設定されたが，1984年には近年の良好な資源状態を反映して230,000トンに引き上げられた。それ以降のＯＹは，1985年226,900トン，1986年209,500トン，そして1987年187,000トンと年々引下げられてきている。

資源量指標の経年変化

商業船のＣＰＵＥ

コガネガレイを主対象に操業する日本のカレイ母船に附属する２そうびき底びき船のＣＰＵＥは，1974年から1979年ないし1980年まで上昇したが1981年－84年には，いずれの漁期についても連続して低下している（表２，図１）。ＣＰＵＥは，1984年と1985年にはほぼ同一の値を示したが，1986年には再び低下した。

トロール調査によるバイオマス推定値

コガネガレイの分布域を広くカバーして実施された合衆国トロール調査による，東部ベーリング海のコガネガレイのバイオマス推定値を下表及び図１に示した（ Bakkla and Wespestad 1985, 1986 ）。

Year	Mean estimate (t)		Sampling Error (% of Mean Estimate)	
	All Area	Comparative Area	All Area	Comparatime Area
1975	1,038,400	972,500	16.2	16.5
1976	1,192,600	—	44.5	—
1978	1,523,400	—	27.6	—
1979	1,932,600	1,866,500	13.6	15.0
1980	1,965,900	1,842,400	12.7	15.7
1981	2,039,900	2,394,700	12.2	13.4
1982	3,322,500	3,275,400	19.5	16.5
1983	3,951,500	3,910,600	12.5	11.8
1984	3,365,900	3,320,300	11.7	11.8
1985	2,308,300	2,277,400	12.2	12.1
1986		1,868,100		15.1

バイオマス推定値は，1975年から1983年にかけて急激に増加し，その後急減している。資源の動向については後述するが，1981年から1982年への増加は，主に調査漁具の着底性の向上に帰せられる（ Bakkla and Westpestad 1984 ）。また，1984年から1985年への低下には，調査実施上の問題が大きく影響していると考えられている（ Bakkala and Wespestad 1985 ）。

コホート解析によるバイオマス推定値

1979年のトロール調査で得た年齢別資源尾数を用いて端末年（ 1979年)の漁獲死亡係数を求め，0.12，0.20，及び0.25の自然死亡係数についてコホート解析を行なった（ Wakabayashi 1984)。得られた年齢別資源尾数と漁業による平均的な依存選択率（ Age — specific selectivity ）とから求めた漁獲対象資源重量Baを図1に示した。

1979年以降のバイオマスの動向

1979年までの資源動向については，トロール調査に基づくバイオマス推定値，商業船のCPUE値及びコホート解析によるバイオマス推定値とも一致して急激な上昇を示した。しかし，それ以降では，トロール調査バイオマスと商業船ＣＰＵＥでは逆の結果を示している。

そこで，次に示すPope(1972)の生存式を用いて1979年以降の資源動向を推定した(Wakabayasi 1985)。

$$N_{t+1} = N_t \cdot e^{-M} - C \cdot e^{-\frac{M}{2}}$$

ここで，N_tはある年級群のｔ歳時における年度当初の資源尾数，C_tは漁獲尾数である。得られた漁獲対象重量Ba(10^3 トン単位)を次表に示す。

Year / M	1979	1980	1981	1982	1983
0.12	1,900	2,132	2,403	2,703	3,013
0.20	1,899	1,999	2,123	2,267	2,466
0.25	1,887	1,893	1,949	2,036	2,178

Baの値は，いずれのMについても1983年まで上昇しており，トロール調査バイオマスと類似した年変化傾向を示した。

以上のことから，1983年までは，卓越した1966－70年級及び1973－77年級群によって，資源量は増加したものと推定できる。1980年から1983年における商業船によるCPUEの急激な低下は，漁獲対象主群であった1960－70年級群が年齢とともにその年級群重量を減じ，また，漁業による選択率も低下した結果であると考えられる。

1983年以降は，トロール調査バイオマス，商業船CPUEともに資源量の低下を示唆している。Bakkala and Wespestad（1986）が示した年齢組成は，1978年以降に発生した年級群の豊度が，卓越した1966－70年及び1973－77年級群より低いことを示している。また,1973－77年級群が，1966－70年級群ほど強勢でなかった可能性もある。今後の資源動向を注意深く見守っていく必要がある。

平衡漁獲量（ＥＹ）

Wakabayashi（1985）は,漁業による年齢依存選択率を考慮に入れた加入当り収量（Y／R）解析とコホート解析から得た加入量からＥＹを以下のように推定した。

自然死亡係数 M	最適漁獲死亡係数 F_{opt}	最適加入当り収量 Y／R (gr.／Indiv.)	加入尾数 Recruit（$\times 10^9$）	平衡漁獲量 E Y (ton)
0.12	0.14	64.0	(L)[a] 1.11	71,000
			(H) 4.16	266,000
0.20	0.16	35.3	(L) 2.30	81,000
			(H) 6.81	240,000
0.25	0.17	24.7	(L) 3.84	105,000
			(H) 9.30	230,000

a　加入尾数水準　（L）：低水準　（H）：高水準

Recruit level　（L）：Low　（H）：High

資源量は，1984年以降年々低下してきていると推定されている。この低下には，加入尾数の減少が影響していると考えられ，最早高水準の加入尾数に対応するＥＹは達成できないかもしれない。

Bakkala and Wespestad（1986）によれば，1979及び1980年級群の豊度は中位水準である。1978，1981，及び1982年級群の豊度を低水準と仮定し，1972－77年級群の豊度を高水準

として，資源への貢献度の高い6～16歳魚の3歳時における平均加入尾数を求めた。平均加入尾数と最適Y／Rの値がEYとなる。

EYは0.12，0.20，及び0.25のMに対して，それぞれ195,300トン，182,500トン，180,700トンとなる。低水準と仮定した1981及び1982年級群の豊度は今のところ不明であるので，3水準のMに対するEYの平均186,200トンを1988年に対するEYとした。

2　ベーリング・アリューシャン水域のコガネガレイ以外の小型カレイ類

本魚種群には，前項で扱ったコガネガレイ，別の文書で扱う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），そしてオヒョウを除くカレイ類を全て含む。

バイオマス及び漁獲量の多い主要魚種は，シュムシュガレイ，ウマガレイ及びツノガレイである。この3魚種のバイオマス推定値は全体の90％以上に達する。

この魚種群の最適漁獲量（OY）又は総許容漁獲量（TAC）は，合衆国により以下のように設定されてきた。

Year	OY／Tac（トン）
1981－83	61,000
1984	111,490
1985	109,900
1986	124,200
1987	148,300

漁　獲　量

主要3種及びその他のカレイ類の経年漁獲量を表3に示した。総漁獲量は，1970－72年及び1985年に高い値（65－92千トン）それ以外の年は12－44千トンの水準にある。

漁獲量に占める主要魚種の割合は，1966－77年については，ウマガレイ52％，シュムシュガレイ40％及びツノガレイ7％であった。しかし，1978年以降では，シュムシュガレイの割合は41％と変化なかったが，ツノガレイが40％へと著しく増加し，また，ウマガレイが16％へと低下している。

バイオマス推定値

日米共同調査又は米国調査に基づく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トロール調査で得られたバイオマス推定値を表4に示した。東部ベーリング海については，どの魚種についても1982年以降の値が1981年以前の値より著しく大きくなっている。この推定値の増大は，主に，相対的に豊度の高い年級群が連続して発生したこと及び調査漁具の着底性が改良されて，漁獲効率（vulnerability）が著しく向上したことによっている（Bakkala 1984）。しかし，dandy

— lines による駆集効果も高くなったと考えられ，1982年以降の推定値が過大となった可能性が生じている。

最大持続生産量（MSY）

1982年以降のバイオマスが過大である可能性があることから，収量推定の基礎資料として,1981年（アリューシャンは1980年）のバイオマス推定値を用いる。バイオマスに対して漁獲量水準は低い。しかし，ツノガレイ及びその他のカレイ類についても，開発が徐々に進んできているので，全て魚種について現在の資源水準が処女資源水準の $3/4$ にあると仮定する。自然死亡係数Mは,前報(Wakabayashi;1985)同様シュムシュガレイとウマガレイについて0.23，ツノガレイ及びその他のカレイ類について0.20とする。MSYは，処女資源推定値B。（現在のバイオマス× $4/3$）と次に示すAlverson and Pereyra（1969）の収量方程式を用いて求める。

$$MSY = Bo \times \frac{1}{2} \times M$$

得られた魚種別MSY（アリューシャン水域を含む）は，以下のとおりである。

シュムシュガレイ

48,700トン（$= 317,800 \times \frac{4}{3} \times \frac{1}{2} \times 0.23$）

ウマガレイ

26,100トン（$= 169,900 \times \frac{4}{3} \times \frac{1}{2} \times 0.23$）

ツノガレイ

62,100トン（$= 465,600 \times \frac{4}{3} \times \frac{1}{2} \times 0.20$）

その他のカレイ類

9,900トン（$= 74,500 \times \frac{4}{3} \times \frac{1}{2} \times 0.20$）

総　　計

146,800トン

用いたバイオマスは過小に推定されているから，得られたMSYも過小と考えられる。

平衡漁獲量（EY）

この魚種群を構成する各魚種は，現在の資源水準がMSYを与える資源水準より高く，資源状態は良好と考えられる。したがって，MSY水準の漁獲量は達成可能であり，EYはMSYに等しいと判断される。以上のことから魚種別のEY推定値の下限値は，シュムシュガレイ48,700トン，ウマガレイ26,100トン，ツノガレイ62,100トン及びその他カレイ類9,900トン，合計146,800トンとなる。

東部ベーリング海及びアリューシャン列島水域に生息するコガネガレイ以外の小型カレイ類から，少なくとも合計146,800トンの漁獲量が得られる。

REFERENCES CITED

Alverson, D. L. and W. T. Pereyra. 1969. Demersal fish exploitations in the northeastern Pacific Ocean - an evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts. J. Fish. Res. Bd. Can., 26: 1985-2001.

Bakkala, R. G. 1984. Other flatfish. In R. G. Bakkala and L. L. Low (editors), Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1983. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-53: 77-89.

———— and G. E. Walters. 1985. Other flatfish. In R. G. Bakkala and L. L. Low (editors), Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1985. Unpubl. rep.: 97-109. Northwest and Alaska Fish. Center, NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115 (submitted to INPFC in October 1985).

————, J. J. Traynor, K. Teshima, A. M. Shimada, and H. Yamaguchi. 1985b. Results of cooperative U.S.-Japan groundfish investigations in the eastern Bering Sea during June-November 1982. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-87. 448p.

————, K. Wakabayashi, and T. M. Sample. 1985a. Results of the demersal trawl surveys. In R. G. Bakkala and K. Wakabayashi (editors), Results of cooperative U.S.-Japan groundfish investigations in the Bering Sea during May-August 1979. Int. Nor. Pac. Fish. Comm. Bull., 44: 39-191.

———— and V. G. Wespestad. 1984. Yellowfin sole. In R. G. Bakkala and L. L. Low (editors), Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1983. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-53: 37-60.

————, ————. 1985. Yellowfin sole. In R. G. Bakkala and L. L. Low (editors), Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1985. Unpubl. rep.: 61-77. Northwest and Alaska Fish. Center., NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115 (submitted to INPFC in October 1985).

————, ————. 1986. Yellowfin sole. In R. G. Bakkala and J. W. Balsiger (editors), Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1986. Unpubl. rep., 182p. Northwest and Alaska Fish. Center., NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115 (submitted to INPFC in October 1986).

Pope, J. G. 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. ICNAF Res. Bull., 9: 65-74.

Sample, T. M., K. Wakabayashi, R. G. Bakkala, and H. Yamaguchi. 1985. Report of the 1981 cooperative U.S.-Japan bottom trawl survey of the eastern Bering Sea continental shelf and slope. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-88. 338p.

Wakabayashi, K. 1983. Condition of flounder stocks in the Bering Sea and Aleutian Islands region. (Document submitted to INPFC) 24p. Fish. Agency Japan.

———. 1984. Estimation of biomass and yield for yellowfin sole in the eastern Bering Sea. Int. Nor. Pac. Fish. Comm. Bull., 42: 65-72.

———. 1985. Stock assessment of flounders in the Bering Sea and Aleutian Islands region (1985). (Document submitted to INPFC) 22 p. Fish. Agency Japan.

——— and R. Bakkala. 1978. Estimated catches of flounders by species in the Bering Sea - updated through 1976. Unpubl. rep. 14p. Northwest and Alaska Fish. Center, NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112. (Document submitted to INPFC by the Japanese and U.S. National Sections).

——— and K. Mito. 1987. Estimation of groundfish biomasses in the Aleutian Islands waters based on Japanese trawl survey in 1986. (Document submitted to the U.S.-Japan bilateral meetings) Far Seas Fish. Res. Lab., Shimizu.

Walters, G. E., and K. L. Halliday. 1986. Other flatfish. In R. G. Bakkala and J. W. Balsiger (editors), Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1986. Unpubl. rep., 182 p. Northwest and Alaska Fish. Cent., NMFS, NOAA, 7600 Sand Point Way NE., Seattle, WA 98115 (submitted to INPFC in Oct. 1986).

Wilderbuer, T. K., K. Wakabayashi, L. L. Ronholt, and H. Yamaguchi. 1985. Survey report: Cooperative U.S.-Japan Aleutian Islands groundfish trawl survey-1980. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-93. 356 p.

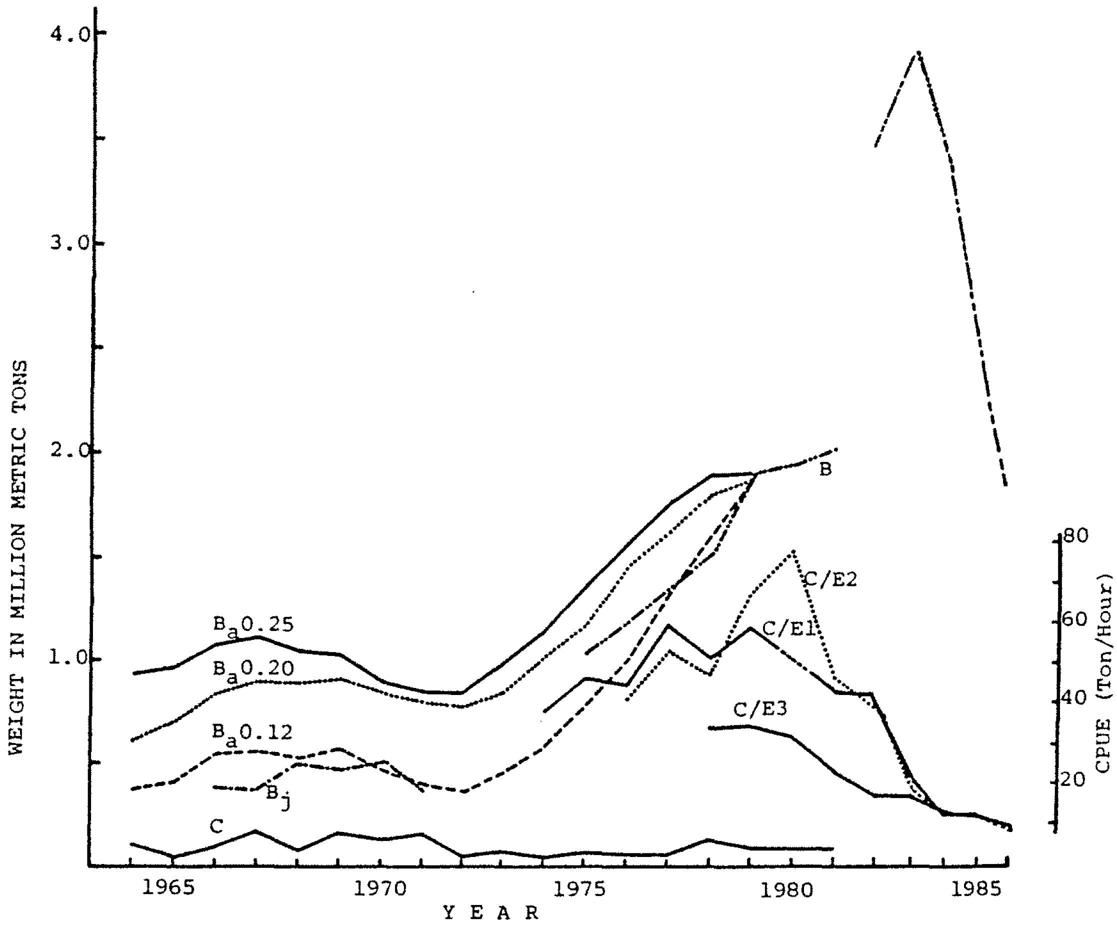

Figure 1. Catch, biomass, and catch per unit effort for yellowfin sole in the eastern Bering Sea.

C: Catch

B_a0.12, B_a0.20, B_a0.25: Exploitable biomass to the fishery from the cohort analysis for respective natural mortality coefficient (Wakabayashi 1984)

B: Biomass from the U.S. or the Japan-U.S. trawl surveys. Fishing efficiencies were changed between 1981 and 1982.

B_j: Biomass from the Japanese trawl survey (Wakabayashi 1983)

C/E1: Catch per unit effort (CPUE) of pair trawlers attached to Japanese flounder mothership in October-December

C/E2: CPUE in September-November

C/E3: CPUE in July-October

Table 1. Historical catch (t) of yellowfin sole in the eastern Bering Sea.

Year	Japan	U.S.S.R.	R.O.K.	Others	Joint venture	Total
1954	11,934					11,934
1955	13,735					13,735
1956	22,721					22,721
1957	22,213					22,213
1958	35,238	4,500				39,738
1959	108,346	54,736				163,082
1960	306,088	81,600				387,688
1961	336,814	129,991				466,805
1962	245,397	116,706				362,103
1963	20,504	65,306				85,810
1964	48,800	62,297				111,177
1965	26,039	27,771				53,810
1966	45,523	56,930				102,353
1967	60,429	101,799				162,228
1968	40,834	43,355	-[a]			84,189
1969	81,449	85,685	-			167,134
1970	59,851	73,228	-			133,079
1971	82,179	78,220	-			160,399
1972	34,846	13,010	-			47,856
1973	75,724	2,516	-			78,240
1974	37,947	4,288	-			42,235
1975	59,714	4,975	-			64,690
1976	52,668	2,908	625			56,201
1977	58,090	283	-			58,373
1978	62,064	76,300	69			138,433
1979	56,724	40,271	1,919	3		98,917
1980	60,505	6	16,198	263	9,623	86,601
1981	62,633	0	17,179	115	16,046	95,973
1982	64,288	0	10,277	45	17,381	91,991
1983	64,844	0	21,050	0	22,511	108,405
1984	85,212	7,951	34,855	47	32,764	160,829
1985	60,348	8,205	33,041	0	126,407	227,995

a: Unknown

Data sources; 1954-63: Wakabayashi (1976)
1964-76: Wakabayashi & Bakkala (1978)
1977-85 for Japan: Data file of the Far Seas Fish. Res. Lab., Shimizu
1977-85 for others than Japan: Bakkala and Wespestad (1986)

Table 2. Catch, effort, and CPUE of yellowfin sole by pair trawlers of the Japanese frozen-fish mothership fishery in the eastern Bering Sea --for 1/2° by 1° statistical blocks and months in which yellowfin sole made up 50% or more of total catch of groundfish.

Year	October-December			September-November			July-October		
	Catch (t)	Effort[a] (hour)	CPUE (t/hr)	Catch (t)	Effort (hour)	CPUE (t/hr)	Catch (t)	Effort (hour)	CPUE (t/hr)
1974	20,911	562	37.21						
1975	25,825	566	45.63						
1976	24,165	553	43.70	16,996	422	40.27			
1977	21,854	371	58.91	21,983	419	52.46			
1978	15,444	304	50.80	18,719	395	47.38	22,373	630	35.51
1979	8,844	150	58.96[b]	16,088	239	67.31	30,619	826	37.07
1980				14,763	192	76.89[c]	31,860	966	32.98
1981	11,236	260	43.22[b]	19,658	440	44.68	30,270	1,162	26.05
1982	13,974	335	41.71	21,993	645	34.10	28,965	1,499	19.32
1983	10,720	484	22.15[b]	17,390	869	20.01	28,936	1,592	18.18
1984	7,562	637	11.87[b]	13,925	1,109	12.56	28,200	2,049	13.76
1985	8,153	597	13.66[b]	14,522	1,137	12.77	25,858	2,034	12.71
1986	-	-	-	9,100	1,102	8.26[c]	25,410	2,552	9.96

a : Average engine horse-power over these years was constant at 1,400 ps.
b : October-November
c : September-October

Table 3. All nation catches of rock sole, flathead sole, Alaska plaice, and miscellaneous flatfish in the eastern Bering Sea and Aleutian Islands region in t, 1963-85[a].

Year	Rock sole	Flathead sole	Alaska plaice	Miscellaneous flatfish	Total
1963	5,029	29,639	975	–	35,643
1964	3,390	25,331	1,883	–	30,604
1965	3,825	6,841	1,020	–	11,686
1966	9,186	11,045	4,633	–	24,864
1967	4,787	23,469	3,853	–	32,109
1968	5,267	21,761	2,619	–	29,647
1969	9,242	18,565	6,942	–	34,749
1970	20,125	41,163	3,402	–	64,690
1971	40,420	51,040	992	–	92,452
1972	60,829	15,694	290	–	76,813
1973	23,837	18,165	1,917	–	43,919
1974	20,011	14,958	2,388	–	37,347
1975	12,014	5,888	2,491	–	20,393
1976	9,964	8,162	3,620	–	21,746
1977	2,914	7,909	2,589	981	14,393
1978	3,323	6,957	10,420	340	21,040
1979	1,468	4,351	13,672	233	19,724
1980	7,601	5,247	6,908	650	20,406
1981	9,021	5,218	8,653	536	23,428
1982	11,844	4,509	6,811	645	23,809
1983	13,618	5,240	10,766	830	30,454
1984	18,750	4,458	18,982	2,096	44,289
1985	37,678	5,636	24,888	2,977	71,179

a : from Walters and Halliday (1986)

Table 4. Biomass estimates (t) for rock sole, flathead sole, Alaska Plaice, and other small-sized flounders in the eastern Bering Sea and Aleutian region, obtained from trawl surveys.

Year	Rock sole	Flathead sole	Alaska plaice	Others	Total
Eastern Bering Sea					
1979[a]	176,400	128,300	273,200	50,500	628,400
1980[b]	283,000	128,400	348,800	59,000	819,200
1981[c]	289,300	166,600	465,600	71,700	981,400
1982[d]	682,400	342,500	786,600	166,300	1,878,800
1983[b]	869,700	279,200	745,400	69,700	1,964,000
1984[b]	967,500	340,900	726,800	52,000	2,087,200
1985[b]	678,200	293,600	554,300	31,200	1,526,100
1986[h]	1,013,700	369,300	550,600	47,400	1,981,000
Southern Bering[e]					
1980[f]	15,400	1,500	------- 1,500 -------		18,400
1983[g]	4,000	700	------- 4,500 -------		9,200
1986[i]	4,600	2,100	------- 2,500 -------		9,200
Aleutian region					
1980[f]	13,100	1,800	------- 1,300 -------		16,200
1983[g]	19,300	800	------- 2,100 -------		22,200
1986[i]	26,100	3,800	------- 3,800 -------		33,700

a : Bakkala et al. (1985a)
b : Bakkala and Walters (1985)
c : Sample et al. (1985)
d : Bakkala et al. (1985b)
e : Northern Aleutian between 165°-170°w
f : Wilderbuer et al. (1985)
g : U.S.-Japan joint analysis
h : Walters and Halliday (1986)
i : Wakabayashi and Mito (1987)

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TRANSLATION

STOCK ASSESSMENT OF SMALL-SIZED FLOUNDERS IN THE EASTERN BERING SEA AND ALEUTIAN ISLANDS REGION IN 1987

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1. Yellowfin Sole in the Eastern Bering Sea

Catch

The yellowfin sole fishery was resumed in 1954, after small-scale, intermittent fishing which had been followed by discontinuation for more than 10 years. The annual catches by each country since 1954, are shown in Table 1. The catch increased sharply from an annual average of 22,000 t, in the 1954 - 1958 period, to an annual average of 345,000 t in 1959 - 1962. It then decreased, and fluctuated, with annual amounts ranging from 54,000 to 167,000 t in the period from 1963 to 1971. The catch stabilized at an annual average of 58,000 t in 1972 - 1977, and was also stable at 103,000 t in 1978 - 1983. It then increased to 228,000 t, which was second only to the amounts of 362,000 - 467,000 t at the peak of the fishery.

The optimum yield (OY), or the total allowable catch (TAC) of yellowfin sole in the eastern Bering Sea, was established by the United States as 106,000 t for 1977, 126,000 t for 1978 - 1979, and 117,000 t for 1980 - 1983. However, this was raised to 230,000 t for 1984 because of good stock conditions in recent years. The OY was set at 226,900 t for 1985, 209,500 t for 1986, and 187,000 t for 1987.

Annual Trends of Stock Indices

CPUEs of commercial vessels

CPUE (catch per unit effort) values of pair trawlers attached to Japanese flounder motherships, whose target was mainly yellowfin sole, increased from 1974 to around 1979 or 1980, but decreased continuously between 1981 and 1984 in all fishing seasons (Table 2, Fig. 1). The CPUE was almost at the same level in 1984 and 1985, but decreased in 1986.

Biomass estimated by trawl survey

Fig. 1 and the table below, show the estimated biomass of yellowfin sole in the eastern Bering Sea, according to the U.S. trawl surveys, which were conducted over a wide area of yellowfin sole distribution (Bakkala and Wespestad, 1985, 1986).

Year	Mean estimate (t)		Sampling error (% of mean estimate)	
	All areas	Comparative area(s)	All areas	Comparative area(s)
1975	1,038,400	972,500	16.2	16.5
1976	1,192,600	-	44.5	-
1978	1,523,400	-	27.6	-
1979	1,932,600	1,866,500	13.6	15.0
1980	1,965,900	1,842,400	12.7	15.7
1981	2,039,900	2,394,700	12.2	13.4
1982	3,322,500	3,275,400	19.5	16.5
1983	3,951,500	3,910,600	12.5	11.8
1984	3,365,900	3,320,300	11.7	11.8
1985	2,308,300	2,277,400	12.2	12.1
1986		1,868,100		15.1

The estimated biomass increased sharply from 1975 to 1983. This rise was followed by a rapid decrease. The stock trend will be discussed later. The increase in biomass from 1981 to 1982, is attributable mainly to the improvement of the bottom-contacting properties of the fishing gear used in the surveys (Bakkala and Wespestad, 1984). The apparent increase of biomass, from 1984 to 1985, was also considered to be affected by problems in the operation of the survey (Bakkala and Wespestad, 1985).

Biomass estimated by cohort analysis

The fishing mortality coefficient in the terminal year (1979) was obtained by using the population number for each age, determined from the trawl survey in 1979. Cohort analysis was carried out for the natural mortality coefficients of 0.12, 0.20, and 0.25 (Wakabayashi 1984). Fig. 1 shows the exploitable biomass (Ba), which was obtained from population number estimates for each age and the age-specific selectivity by fishery.

Biomass trend in 1979 and later

All stock indices, that is, the estimated biomass based on trawl surveys, the CPUE values from commercial fishing vessels, and the biomass estimated by cohort analysis, indicated sharp increases of stock until 1979. However, the biomass estimates based on the trawl surveys and the CPUEs from commercial fishing vessels after 1979, showed opposite results.

The biomass trend for 1979 and later was therefore estimated using Pope's survival equation (1972), as shown below (Wakabayashi 1985).

$$N_{t+1} = N_t \cdot e^{-M} - C \cdot e^{\frac{M}{2}}$$

Here, N_t is the population number of age t fish for a particular year class, at the beginning of the year. C_t is the number of fish caught during the year. The exploitable biomass values, Ba, are shown in the following table (Unit : 1,000 t).

Year M	1979	1980	1981	1982	1983
0.12	1,900	2,132	2,403	2,703	3,013
0.20	1,899	1,999	2,123	2,267	2,466
0.25	1,887	1,893	1,949	2,036	2,178

The value of Ba for any value of M, increased continuously until 1983, and showed an annual trend similar to that of the biomass as determined by the trawl survey.

From the above results, the biomass until 1983 can be assumed to have been increased by the dominant year classes of 1966 - 1970 and the 1973 - 1977 year classes. The sharp decrease of the CPUE from commercial fishing vessels in 1980 - 1983, can be considered to have resulted from the decline in biomass of the major exploitable year classes born in 1966 - 1970, as their ages increased. The decreased selectivity by fisheries was also considered to be a reason for this decrease.

After 1983, both the estimated biomass determined from the trawl surveys and the CPUE value from commercial fishing vessels showed decreases in stock size. The age composition shown by Bakkala and Wespestad (1986) indicates that the abundances of year classes which appeared in 1978 and later are lower than those of the dominant year classes of 1966 - 1970 and 1973 - 1977. There is also a possibility that the 1973 - 1977 year classes were not as strong as the year classes of 1966 - 1970. It is necessary to watch the future biomass trend carefully.

Equilibrium Yield (EY)

Wakabayashi (1985) estimated the EY as shown below, using the recruitment obtained from cohort analysis and the analysis of the yield per recruit (Y/R), with consideration of the age-specific selectivity by fishery.

Natural mortality coefficient M	Optimum fishing mortality coefficient F_{opt}	Optimum yield per recruit Y/R (gr./indiv.)	Number of recruits R (x 10^9)	Expected yield EY (t)
0.12	0.14	64.0	(L)[a] 1.11	71,000
			(H) 4.16	266,000
0.20	0.16	35.3	(L) 2.30	81,000
			(H) 6.81	240,000
0.25	0.17	24.7	(L) 3.84	105,000
			(H) 9.30	230,000

a : Recruitment level (L) : Low level (H) : High level

It is estimated that the biomass has decreased annually since 1984. This decrease is considered to be an effect of the decrease of recruitment. Therefore, the EYs corresponding to the high recruitment level may no longer be able to be achieved.

According to Bakkala and Wespestad (1986), the abundances of the 1979 and 1980 year classes are at a medium level. When it is assumed that the abundance of each year class, 1978, 1981, and 1982, is at a low level, and it is also assumed that the abundances of the 1972 - 1977 year classes are at high levels, the average recruitment at age 3 years is obtained for the age 6 - 16 fish. These age groups make a major contribution to the stock. The product of the average recruitment and the optimum yield per recruit (Y/R), is EY.

The equilibrium yields (EY) for each of the M values of 0.12, 0.20, and 0.25, are 195,300 t, 182,500 t, and 180,700 t, respectively. The abundances of the 1981 and 1982 year classes, which are assumed to be at low levels, are unknown at present. Therefore, the EY for 1988 is determined as 186,200 t, which is the average of the EY for the three levels of M.

2. Small-sized Flounders, Other than Yellowfin Sole, in the Bering Sea and in the Aleutian Islands Region

This fish group includes all of the flounders, except for yellowfin sole, discussed in the previous section and Greenland turbot, arrowtoothed flounder (including Kamchatka flounder) and Pacific halibut, discussed in a separate document.

The major species, which have large biomasses and large catches, are rock sole, flathead sole, and Alaska plaice. The total of the estimated biomasses of these 3 species, is greater than 90% of the total biomass.

The Optimum yield (OY) or Total allowable catch (TAC) for these species was set as shown below, by the United States.

Year	OY/TAC (t)
1981 - 83	61,000
1984	111,490
1985	109,900
1986	124,200
1987	148,300

Catch

Table 3 shows the annual catches of the 3 major species and of other flounders. The total catch showed high values (65,000 - 92,000 t) in 1970 - 1977 and 1985. The catch in other years varied between levels of 12,000 - 44,000 t.

The share of each major species in the catches from 1966 - 1977 was 52% for flathead sole, 40% for rock sole, and 7% for Alaska plaice. After 1978 there has been no change in the rate for rock sole, which remained at 41%, but Alaska plaice increased remarkably, to 40%, and flathead sole decreased to 16%.

Estimated Biomass

Table 4 shows biomass estimates, obtained by the trawl surveys in the eastern Bering Sea and in the Aleutian Islands region, based on either Japan-U.S. joint surveys or the U.S. surveys. Beginning in 1982, the values of the estimated biomass, for each species in the eastern Bering Sea, became much greater than the values of 1981 and earlier. The increase of these estimated biomasses results mainly from the continuous appearances of year classes of relatively high abundance and remarkable improvements in vulnerability, due to the improvement of the bottom-tendency of the fishing gears used for the survey (Bakkala 1984). However, the herding effect by dandy-lines is also considered to be higher. Therefore, there is a possibility that the estimated biomasses in 1982 and after have been overestimated.

Maximum Sustainable Yield (MSY)

The estimated biomass in 1981 (1980 for the Aleutian Islands region), is used as the basic data for estimation of yield, because there is a possibility that the estimated biomasses were overestimated for 1982 and later. The catch levels are low, compared to the biomass. The exploitation of Alaska plaice and other flounders has been progressing gradually. Therefore, the levels of current biomasses of all species are assumed to be at 3/4 of the level of their virgin biomasses. The natural mortality coefficient (M) was estimated as 0.23 for rock sole and flathead sole and 0.20 for Alaska plaice and other flounders, just as noted in the previous report (Wakabayashi 1985). The MSY can be obtained using the yield equation by Alverson and Pereyra (1969), as shown below, and the estimated virgin biomass (Bo) (present biomass x 4/3).

$$MSY = Bo \times 1/2 \times M$$

The MSY for each species (including the Aleutian Islands region), obtained from this equation, is as shown below.

Rock sole

48,700 t (= 317,800 x 4/3 x 1/2 x 0.23)

Flathead sole

26,100 t (= 169,900 x 4/3 x 1/2 x 0.23)

Alaska plaice

62,100 t (= 465,600 x 4/3 x 1/2 x 0.20)

Other flounders

9,900 t (= 74,500 x 4/3 x 1/2 x 0.20)

Grand total

146,800 t

The biomasses used for this estimation are underestimated. Therefore, the MSY obtained is also considered to be underestimated.

Equilibrium Yield (EY)

The present level of the biomass for each species constituting this fish group, is higher than the level of biomass which gives the MSY, and so the stock can be considered to be in good condition. It is therefore possible that the catch at the MSY level can be achieved and that the EY is equal to the MSY. For the above considerations, the minimum value of the estimated EY for each species is: 48,700 t for rock sole, 26,100 t for flathead sole, 62,100 t for Alaska plaice, and 9,900 t for other flounders, for a total of 146,800 t.

A total catch of at least 146,800 t can be obtained from the small-sized flounders other than yellowfin sole, inhabiting the eastern Bering Sea and the Aleutian Islands region.

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