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最尤法による1975年のギンザケの鱗相分析

Scale pattern analysis of 1975 coho salmon by maximum likelihood method

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最尤法による1975年のギンザケの鱗相分析

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加藤・石田（1985，1986）は北太平洋北西部に分布するギンザケについて，1975年及び1976年にさけ・ます調査船により得られた資料を用いて，判別関数による鱗相分析を行い，その大陸起源の検討を行った。その結果，50°N以南，175°E以西に分布するギンザケ60～80％及び50°N以南，175°E～175°Wに分布するギンザケの50～70％がアジア起源であることが示された。一方，長年の標識放流結果は，175°E以西に分布するギンザケは全て，また，50°N以南，175°E～175°Wに分布するギンザケでも87％がアジアが起源であることを示し，鱗相分析結果と大きく相違した。長年の資料による標識放流結果と単年における鱗相分析結果は単純には比較できないが，直接的証拠である標識放流結果と鱗相分析結果との間に矛盾があることが明らかとなった。筆者等は分析手法に問題があると考え，最尤法を用いて1975年の資料を再分析したので，その結果を述べる。

材料と方法

(1) 北米起源群として，1975年にアラスカのYukon河採捕のギンザケ成魚95尾，Kuskokwim河採捕の成魚133尾，及びCook Inlet採捕の成魚80尾（図1），合計308尾の鱗標本と生物資料を用いた。

(2) 日本のさけ・ます調査船が1975年6月～8月に175°W以西の北太平洋，ベーリング海及びオホーツク海（図1）で採捕したギンザケ成魚3,356尾の鱗標本と生物資料を用いた。

(3) 鱗相分析には2.1年魚を用いた。年齢査定法は加藤（1984）と同様である。

(4) 基準標本として以下のA～F群（図1）をとり，このうちA～Cをアジア（ASI）基準群，D～F群を北米（USA）基準群とした。

A：調査船が7月に160°E以西の北西太平洋で採捕の成魚（436尾）

B：調査船が7月～9月に東カムチャッカ沖合で採捕の成魚（182尾）

C：調査船が7月～9月にオホーツク海で採捕の成魚（439尾）

D：西部アラスカのYukon河採捕の成魚（34尾）

E：西部アラスカのKuskokwim河採捕の成魚（118尾）

F：中部アラスカのCook Inlet採捕の成魚（55尾）

(5) 鱗相分析には表1に示す9形質を用いた（表1）。

(6) 6月に42°N，155°E－175°Wの海域で採捕された287尾及び7月に42°N～52°N，160°E

— 175°Wの海域で採捕された1,109尾合計1,369尾のギンザケ成魚を起源未知の標本とした（図2）。

(7) 最尤法のプログラムはワシントン大学漁業研究所より提供されたFORTRANプログラム（プログラム名HISEA）である。系群識別の推定はプログラムHISEAのオプションの1つであるANALYSISにより実施した。

結　　果

海域を経度5°間隔で155°E～160°E，160°E～165°E，165°E～170°E，170°E～175°E，175°E～180°及び180°～175°Wの区間に分け，各区間におけるアジア系（ASI）及び北米（USA）系の出現割合を月別に計算した。その結果を図3及び図4に示した。月別のアジア系と北米系の出現割合は下記のとおりである。

6月：160°E～165°Eにおいてアジア系が92％出現し，その他の区画ではアジア系が100％であった（図3）。

7月：160°E～170°E及び180°～175°Wではアジア系が96％～100％と非常に高かったが，170°E～175°Eではアジア系が73％及び175°E～180°では57％とやや低い値を示した。

考　　察

最尤法による鱗相分析結果は1975年の北西太平洋のギンザケの大部分はアジア系であることを示した。特に，6月の175°W以西の海域では96～100％がアジア系であった。これに対し，判別関数による鱗相分析結果（加藤・石田，1985）では6，7月の175°E以西の海域に北米系が10～30％出現した。また，7月の180°～175°Wの海域におけるアジア系の割合は最尤法では100％に対し，判別関数では50～73％であった。7月の170°E～180°の海域におけるアジア系の割合は前者では57～73％に対し，後者では40～83％であった。以上のように，最尤法による鱗相分析結果は判別関数によるそれと比べアジア系の割合が20～50％高くなっている（7月の170°E～175°Eを除く）。

1956～1987年に170°W以西で放流され，沿岸及び河川に回帰したギンザケの標識放流魚の再捕結果を表2に示した。これらによると，170°W以西で放流されたギンザケの沿岸再捕の大部分はアジア起源である。特に，175°E以西の放流魚は全てアジア起源であった。北米起源魚は175°以東で比較的多くみられ，特に50°N以南よりむしろ50°N以北においてその傾向が強い（表2）。

最尤法による鱗相分析結果は標識放流・再捕による各起源群の出現割合と6月の全海域，7月の170°E以西及び180°～175°Wの海域ではよく一致している。しかし，7月の170°E～180°の海域の鱗相分析結果では北米系が比較的多く出現し，標識放流結果と若干異なっている。標識放流結果では50°N以北に北米起源魚が比較的多く出現することから，さらに50°N線で南北に分けて分析するならば，両者の矛盾は小さくなるであろうと考えられる。

標識放流結果は各年毎の分布を示しているわけではないので，単年における鱗相分析結果と比較

することは問題があるかも知れない。しかし，標識放流結果は直接的証拠であることを考えれば，どんな分析方法を用いるにせよ，標識放流結果と大きく矛盾する結果がもたらされる場合には，その分析方法に何らかの欠陥があると考えるべきである。最尤法によるギンザケの鱗相分析結果は判別関数によるそれと比べ標識放流結果とかなりよく一致したと考えられる。さらに他の年の資料を分析することにより，この方法の信頼性を確かめる必要があろう。

LITERATURE

Kato, M. 1984. Preliminary examination related scale pattern analysis of coho salmon. (Document submitted to 1984 annual meeting of the INPFC, October 1984, Vancouver, Canada). 13p. FAJ, FSFRL, Japan, 424 Shimizu.

Kato, M. and Y. Ishida 1985. Scale pattern analysis of coho salmon in the northwest North Pacific Ocean by materials obtained in 1975. (Document submitted to the 1985 annual meeting of the INPFC, October 1985, Tokyo, Japan). 18p. FAJ, FSFRL, Japan, 424 Shimizu.

Kato, M. and Y. Ishida 1986. Scale pattern analysis of coho salmon in the northwest North Pacific Ocean using materials obtained by salmon research vessels in 1976, (Document submitted to the 1986 annual meeting of the INPFC, October 1986, Anchorage, USA). 17p. FAJ, FSFRL, Japan, 424 Shimizu.

Table 1. Scale characters used in the scale pattern analyses.

Character number	Description
1	Size of zone 1 (FL1)
2	Size of zone 2 (FL2)
3	Size of zone 3 (OCL)
4	No. of circuli zone 1 (FN1)
5	No. of circuli zone 2 (FN2)
6	No. of circuli zone 3 (OCN)
7	Distance end of zone to 5th circulus in zone 3 (WO5)
8	Size of ocean annulus (OAL)
9	No. of circuli in ocean annulus (ANN)

Zone 1: The area of the scale from the center of focus to the outer edge of the last circulus in the first freshwater annulus.

Zone 2: The area of the scale from outer edge of the last circulus in the first freshwater annulus to the outer edge of the last cieculus in the second freshwater annulus.

Zone 3: The area of the scale from the outer edge of the last circulus in the second freshwater annulus to the outer edge of last circulus in the ocean annulus.

Table 2. Relation between release and recovery areas shown by number of tagged coho salmon, 1956-1987.

Release area		Recovery area				
Longitude	Latitude	Asia		North America		Total
		Number	%	Number	%	
West of 175°E	South of 50°N	23	100.0	0	0.0	23
	North of 50°N	32	100.0	0	0.0	32
	S. total	55	100.0	0	0.0	55
175°E-170°W	South of 50°N	27	87.1	4	12.9	31
	North of 50°N	34	69.4	15	30.6	49
	S. total	61	76.2	19	23.8	80
	Total	116	85.9	19	14.1	135

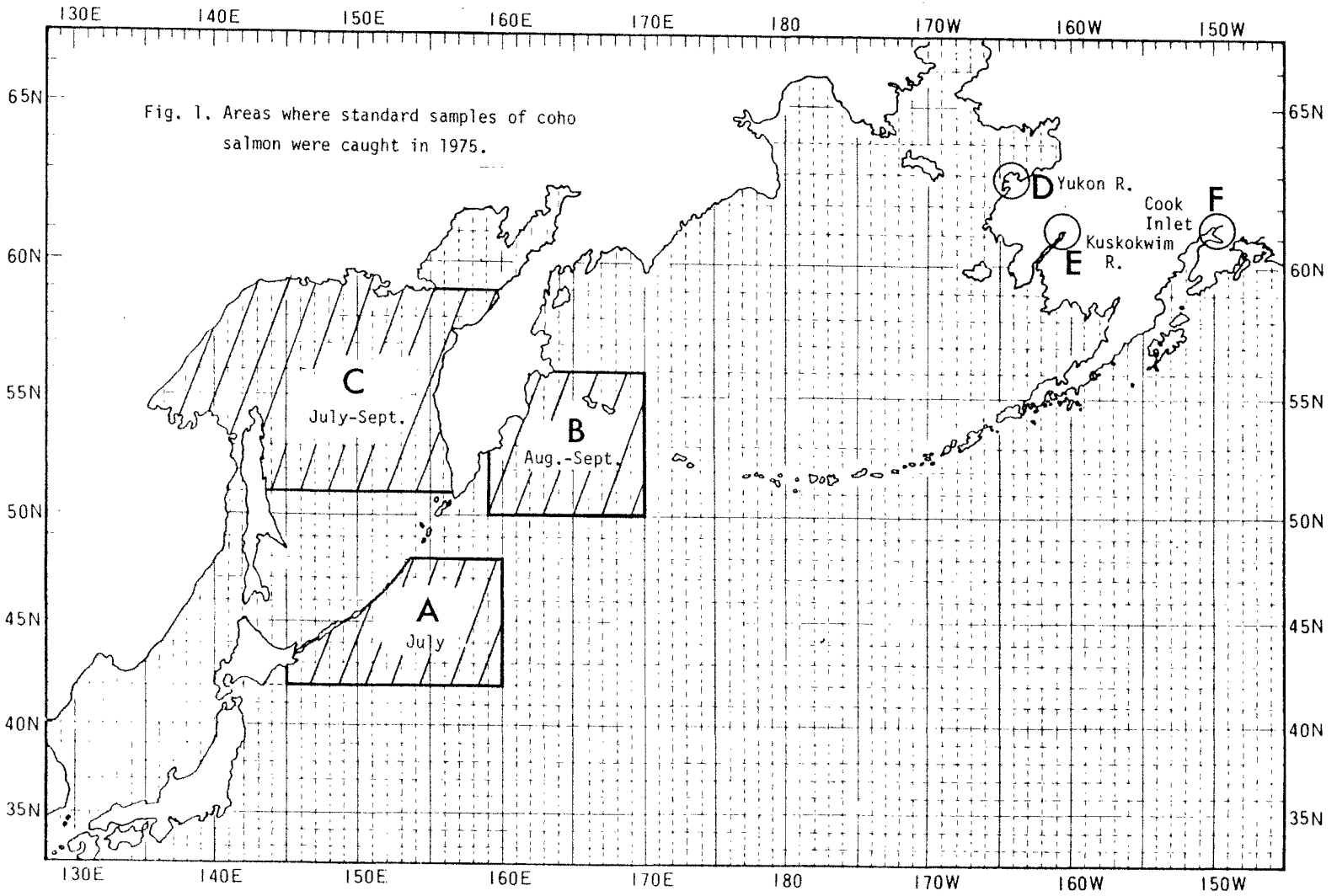

Fig. 1. Areas where standard samples of coho salmon were caught in 1975.

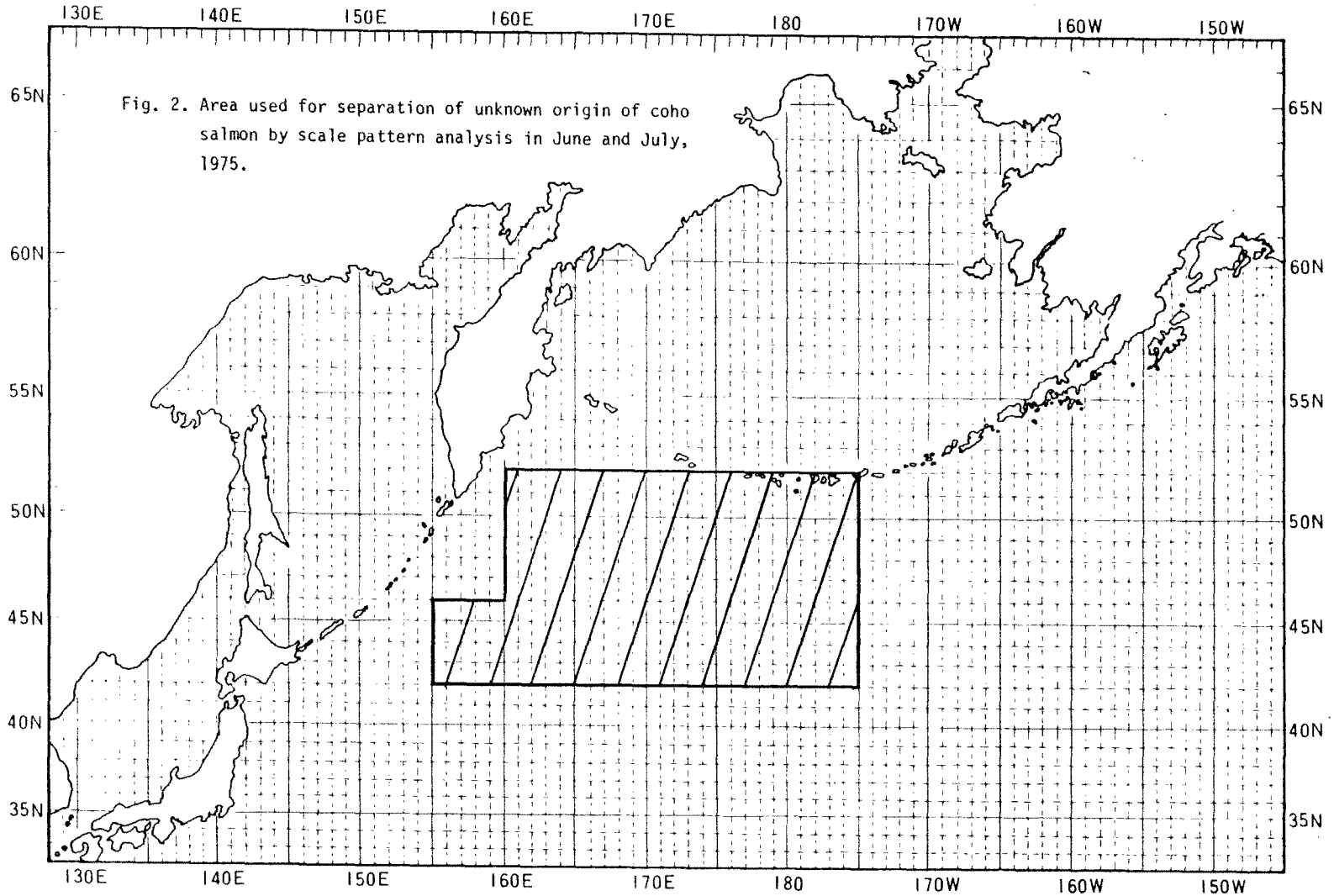

Fig. 2. Area used for separation of unknown origin of coho salmon by scale pattern analysis in June and July, 1975.

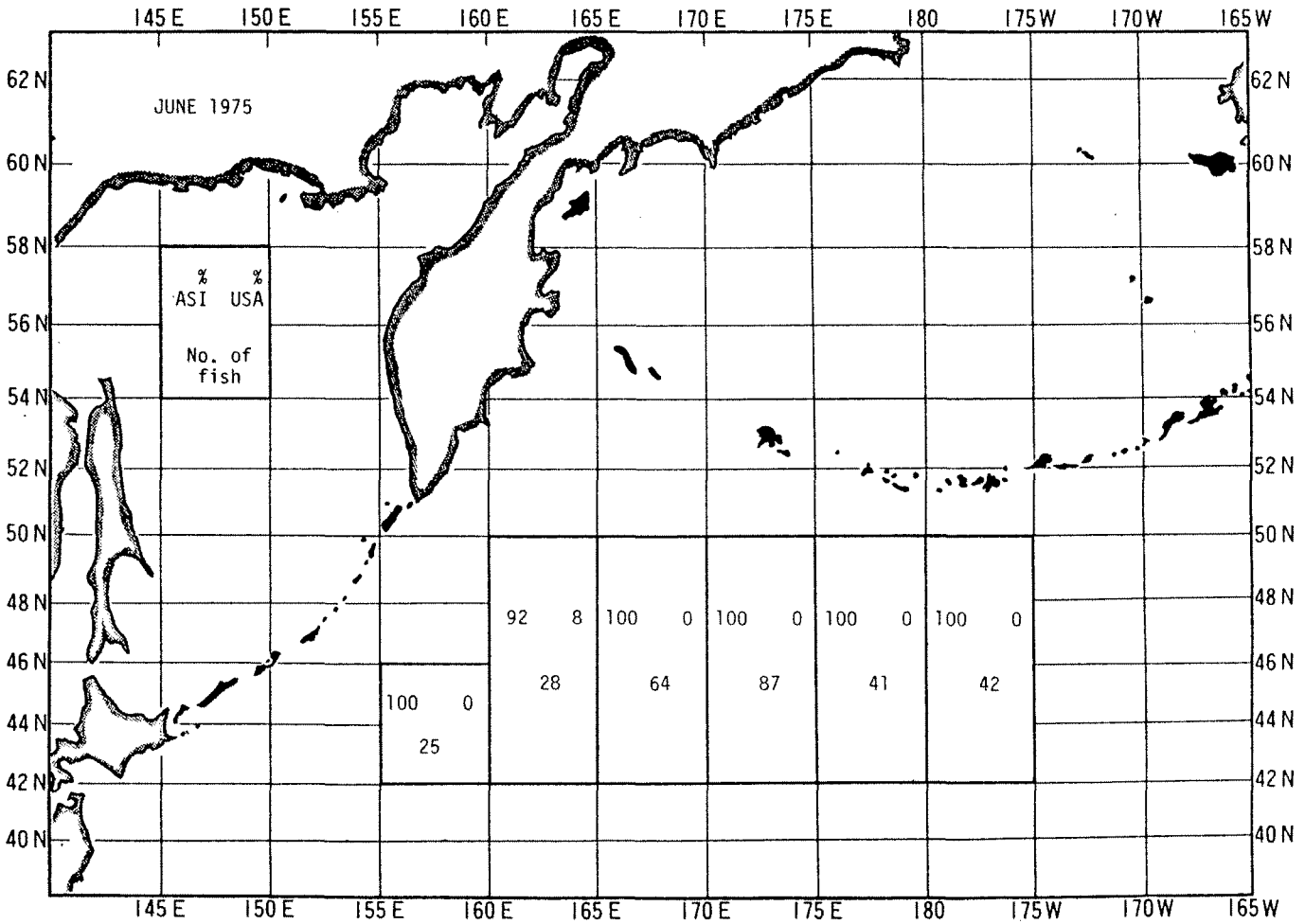

Fig. 3. Estimated mixing proportion of 2.1 coho salmon in June, 1975.

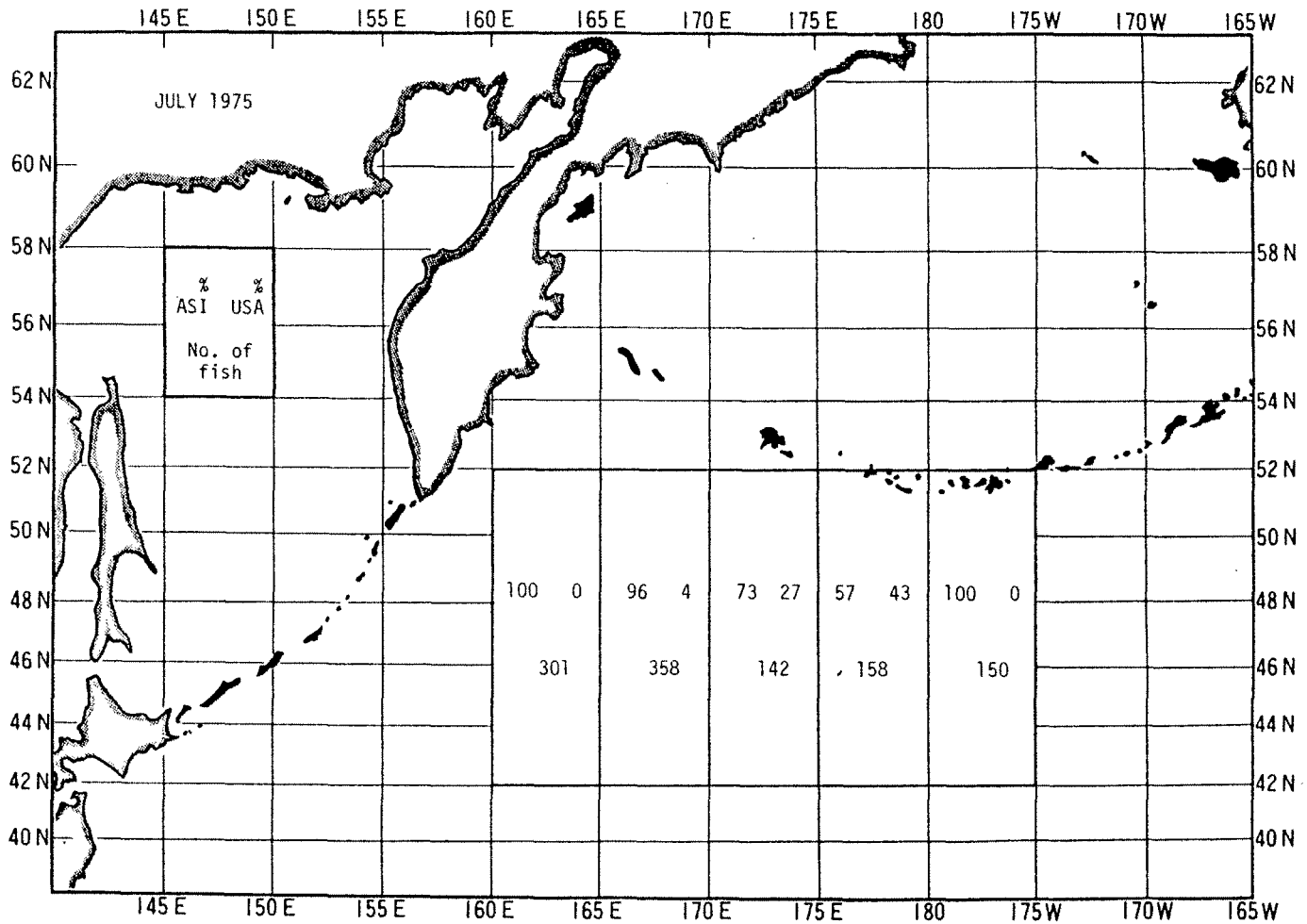

Fig. 4. Estimated mixing proportion of 2.1 coho salmon in July, 1975.

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TRANSLATION

SCALE PATTERN ANALYSIS OF 1975 COHO SALMON BY MAXIMUM LIKELIHOOD METHOD

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Kato and Ishida (1985 and 1986) conducted scale pattern analysis by discriminate function using data obtained by the salmon research vessels in 1975 and 1976 for coho salmon distributed in the northwestern Pacific Ocean and to determine its continent of origin. As a result, 60% to 80% of coho salmon which is distributed in waters south of 50°N and west of 175°E and 50% to 70% of coho salmon distributed in waters south of 50°N and 175°E to 175°W were indicated to be of Asian origin. On the other hand, the results of tagging for many years indicated that all coho salmon distributed in waters west of 175°E and even 87% of coho salmon distributed in waters south of 50°N and 175°E to 175°W are of Asian origin. There was a large difference between the results of tagging for many years and the results of scale pattern analysis. Although we can not simply compare between the results of tagging for many years and the results of scale pattern analysis for a single year, it is obvious that there is a contradiction between the results of tagging, which provides direct evidence, and the results of scale pattern analysis. As the authors thought that there are some problems in the analytical procedures, and re-analized the 1975 data using the maximum likelihood method. The results are as follows:

Data and method

(1) A total of 308 scale samples; 95 adult coho salmon caught in the Yukon River, Alaska in 1975, 133 adult coho salmon recovered in the Kuskokwim River, and 80 adult coho salmon recovered in the Cook Inlet (Fig. 1), and biological data were used.

(2) Scale samples of 3,356 adult coho salmon caught in the North Pacific Ocean, Bering Sea and Okhotsk Sea west of 175°W by the Japanese salmon research vessels from June to August in 1975 and its biological data were used.

(3) Age 2.1 coho salmon were used for scale pattern analysis. Age determination method was the same as the Kato (1984) method.

(4) As the standard sample, the following A to F groups (Fig. 1) were taken, and of those, from A to C were set as the Asian standard samples (ASI) and from D to F groups were set as the North American standard samples (USA).

A: Adult fish (436) caught by the research vessels in the northwestern Pacific Ocean west of 160°E in July

B: Adult fish (182) caught by the research vessels in offshore of east Kamchatka during July to September

C: Adult fish (439) caught by the research vessels in Okhotsk Sea during July to September

D: Adult fish (34) caught in the Yukon River of western Alaska

E: Adult fish (118) caught in the Kuskokwim River of western Alaska

F: Adult fish (55) caught in the Cook Inlet of central Alaska

(5) Nine characters shown in Table 1 were used for scale pattern analysis (Table 1).

(6) A total of 1,396 adult coho salmon; 287 fish recovered in waters of 42° to 50°N and 155°E to 175°W in June and 1,109 fish recovered in waters of 42° to 52°N, 160°E to 175°W in July were set as unknown origin (Fig. 2).

(7) The maximum likelihood program is the FORTRAN program provided by the Fisheries Research Institute, University of Washington (name of program is HISEA). Estimation of stock identification was conducted by ANALYSIS which is one of the options of the program HISEA.

Results

The area was divided into the following sub-areas in intervals of 5° longitude; 155°E to 160°E, 160°E to 165°E, 165°E to 170°E, 170°E to 175°E, 175°E to 180°E and 180°E to 175°W. Occurence proportion of salmon of Asian origin and North American origin in each sub-area was calculated by month. The results were shown in Fig. 3 and 4. Occurence proportion by month of salmon of Asian and North American origin is as follows:

June: 92% of the Asian origin salmon occurred in sub-area 160°E to 165°E and 100% of the Asian origin salmon occurred in other sub-areas (Fig. 3)

July: Although the Asian origin salmon showed a very high proportion such as 96% to 100% in sub-areas 160°E to 170°E and 180° to 175°E, the Asian origin salmon showed 73% in sub-area 170°E to 175°E and showed a somewhat low proportion such as 57% in sub-area 175°E to 180° (Fig. 4)

Consideration

The results of scale pattern analysis by the maximum likelihood method indicated that most coho salmon distributed in the northwestern Pacific Ocean in 1975 were of Asian origin. In particular, 96% to 100% of coho salmon distributed in waters west of 175°W in June were of Asian origin. In contrast, in the results of scale pattern analysis by discriminant function (Kato and Ishida 1985), 10% to 30% of coho salmon originating in North America occurred in waters west of 175°E in June and July. Also, occurrence proportion of Asian coho salmon in waters of 180° to 175°W in July was 100% by the maximum likelihood method and was 50% to 73% by the discriminant function.

The proportion of occurence of Asian coho salmon in waters of 170°E to 180° in July by the maximum likelihood method was 57% to 73%, and 40° to 83% by the discriminant function. As the above mentioned, proportion of Asian coho salmon obtained from the scale pattern analysis by the maximum likelihood method was higher by 20% to 50% than the results by discriminant function (except sub-area 170°E to 175°E in July).

Table 2 shows the results of recovery for tagged coho salmon released in waters west of 170°W from 1956 to 1987 and returned to the coastal areas and rivers. According to these results, most of the coho salmon released in waters west of 170°W and recovered in the coastal areas were of Asian origin. In particular, fish released in waters west of 175°E were all of Asian origin. Fish originating in North America were relatively more abundant in waters east of 175°E and the tendency is particularly strong in waters north of 50°N than that south of 50°N (Table 2).

The results of scale pattern analysis by the maximum likelihood method coincided well with occurrence proportions of each originating group by the tagging and recovery in all sub-areas in June, and waters west of 170°E and 180° to 175°W in July. However, according to the results of scale pattern analysis in waters of 170°E to 180° in July, the North American fish occurred fairly abundantly, and were somewhat different from the results of tagging. In the results of tagging, as the North American fish appeared fairly often in waters north of 50°N, it is considered that if we further divided on the line of 50°N and conducted an analysis, that the contradictions between analyses would be smaller.

Since the results of tagging do not always indicate the distribution of fish every year, there may be some problems to compare with the results of scale pattern analysis in a single year. However, if we consider that the results of tagging provide direct evidence, even if we use any kind of analytical method, when the results contradict the results of tagging, we should think that there are some kind of defects in its analytical method.

It is considered that the results of scale pattern analysis by the maximum likelihood method were coincided more closely with the results by tagging than with the results by discriminant function. Furthermore, it is necessary to analyze data obtained in other years to make sure of the reliability of this method.

Tables 1 to 2 and Figs. 1 to 4 in English are in the Japanese document.