判別関数を用いた鱗相形質によるシロザケ系群の識別

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ま え が き

Doc. 2675, 2796 で、Cook（1982）の方法を用いた鱗相形質によるシロザケ系群の識別について報告した。その結果、標識再捕などの従来の知見と一番大きく矛盾する点として、アメリカ地域および日本地域と判別される個体が北太平洋西部水域さらにはオホーツク海に出現することを指摘した。一方、米国ではいくつかの理由により、鱗相分析の方法としてCook方法にかわり線形判別関数法が見直されてきた（Myers et al. 1984）。また、ソ連の調査船に乗船した米国科学者よりソ連科学者による採鱗部位がINPFCの推奨する部位とは異なることが報告され（Harris 1983）、ソ連から提供されている鱗標本についても、その採鱗部位の異なる可能性が懸念されてきた。

本報告では、まずDoc. 2796において採用した5形質によるCookの方法および線形判別関数法による基準群の判別精度を比較した。つぎに、日本のサケ・マス調査船によって採集され、従来の標識再捕の知見よりソ連系と判断される5月および6月の160°E以西の沖合鱗標本とソ連から提供されている沿岸・河川の鱗標本とを比較し、系群識別に有効と判断される鱗相形質を選択した。最後に、これらの形質による判別結果と先の5形質による沖合標本の判別結果とを比較・検討した。

材 料 と 方 法

本報告に用いた鱗標本は、Doc. 2796において用いた1981年の0.3年、成熟魚である。線形判別関数の算出には、農林水産研究計算センターの多変量解析用プログラムパッケージ（Multivariate Analysis Program; MAP）を用いた。

この文書を引用する場合は下記による：
石田行正・伊藤外夫・高木健治. 1985. 判別関数を用いた鱗相形質によるシロザケ系群の識別. 水産庁遠洋水産研究所

結　　果

Cookの方法と線形判別関数法との比較

5形質（Ca, Cb, C2, L1, L2）を用いた、Cookの方法による基準群の判別結果を表1に示した（Doc. 2796より引用）。基準群の判別精度は日本85.6％、ソ連72.8％、アメリカ77.0％、カナダ95.0％、平均82.6％であった。

5形質を採用し、ほぼ同様の基準群を用いて求めた線形判別関数は次のとうりである。

$$Z_{1,2} = -14.916 + 1.115\,Ca - 0.259\,Cb - 0.139\,C2 + 0.088\,L1 - 0.072\,L2$$

$$Z_{1,3} = 10.758 + 0.737\,Ca + 0.222\,Cb - 0.784\,C2 - 0.069\,L1 - 0.012\,L2$$

$$Z_{1,4} = 43.278 - 0.416\,Ca - 1.905\,Cb - 0.533\,C2 + 0.156\,L1 - 0.169\,L2$$

なお、ここでZの添字1は日本、2はソ連、3はアメリカ、4はカナダを示している。基準群の判別精度は日本90.0％、ソ連80.5％、アメリカ82.0％、カナダ92.5％、平均86.3％ であった（表2）。これらの判別精度はCookの方法よりやや高かった。

160°E以西沖合鱗標本とソ連提供鱗標本との比較

計数形質C1、C2（第1年帯および第2年帯のサーキュリー数）および計量形質L1、L2（第1年帯および第2年帯の幅）について、160°E以西沖合鱗標本とソ連提供鱗標本との平均値の差の検定を行ない表3に示した。ここで160°E以西沖合標本は標識再捕の知見よりソ連起源の個体で占められていると判断されるものである。なお、第1年帯を2等分して求めるCa、Cb形質は計量形質の要素を含むため分析から除いた。

C1では、Amur Liman, Bolshaya Garmanda River, Bolshaya River, Khaylyulya River, Anadyr Riverで有意差が認められた。またC2では、Bolshaya River, Khaylyulya River, Anadyr Riverで有意差が認められた。L1ではすべての標本で、またL2ではKhaylyulya River, Anadyr Riverで有意差が認められた。このように計量形質ではすべての標本でL1あるいはL2に有意差が認められたのに対し、計数形質ではAmur River, Kukhutui River. Ust' Kamchatskの3標本でC1、C2ともに有意差が認められなかった。ソ連提供標本の採鱗部位に関する懸念を考慮すると、標識再捕の知見よりソ連系と判断される160°E以西沖合標本とソ連沿岸の3標本との間で有意差の認められなかった計数形質C1、C2を鱗相分析に採用することがより妥当であると考えられる。

形質C1、C2による判別関数

計数形質C1、C2を用いて次の判別関数を得た。

$$Z_{1,2} = -11.624 + 0.618\,C1 - 0.348\,C2$$

$$Z_{1,3} = \quad 7.269 + 0.263\,C1 - 0.817\,C2$$

$$Z_{1,4} = \quad 46.872 - 0.770\,C1 - 1.059\,C2$$

基準群の判別精度は日本88.5%、ソ連67.5%、アメリカ68.5%、カナダ93.0%、平均79.4%であった（表4）。

沖合標本の判別

表5－7に、5形質を用いたCookの方法および判別関数法、さらに2形質を用いた判別関数法による沖合標本の判別結果を示した。なお、Cookの方法による判別結果はDoc.2796より引用した。これら3つの方法は、それぞれ異なる判別結果をもたらし、要約すると次の2点が指摘できる。

1) 5形質を用いた場合、Cookの方法に比べて判別関数法では、ソ連地域と判別される個体が減少し、日本地域と判別される個体が増加する。アメリカ地域と判別される個体は増加する海区が多いものの、減少する海区もある。カナダ地域もやや増加している。

2) 判別関数法で、使用形質を5形質（Ca、Cb、C2、L1、L2）から2形質（C1、C2）に変えると、アメリカ地域と判別される個体はさらに減少し、ソ連および日本地域と判別される個体は多くの海区で増加している。

考　　察

Cookの方法と線形判別関数法による基準群の判別精度は、それぞれ平均で82.6%および86.3%と大差ない。しかし、沖合標本では海区により、これら2つの方法による判別結果はかなり異なっている。このような相違は比較的標本数の多い海区でも見られ、単に沖合標本数の少なさに起因するものではない。これらのことは、沖合標本の判別に際して、基準群で判別精度の高い分析方法が必ずしも安定した推定値を与えないことを示している。

計数形質であるC1およびC2で、Amur River, Kukhutui RiverおよびUst'Kamchatskの標本と160°E以西沖合標本との間に有意差は認められなかった。このことは、これらの標本が同一母集団より採集されている可能性を示唆している。またこの推測は従来の標識再捕による知見とも矛盾しない（Neave et al. 1976）。しかし、計量形質L1では、すべてのソ連沿岸標本と160°E以西沖合標本との間に有意差が認められた。先の計数形質に基づく推測が正しいとすれば、この計量形質での有意な差は問題点として残る。この原因として、ソ連沿岸標本の採鱗部位が異なり、しかもその影響が計量形質に大きい場合、あるいは鱗標本の取り扱いの違いが計量形質に大き

く影響する場合（沖合標本は採鱗後ただちにガムカードで固定するが、ソ連沿岸標本は採鱗約1年後に固定する）などの可能性が考えられる。

2つの計数形質C1およびC2を用いた判別関数による基準群の判別精度（平均79.4％）は、計量形質を含む5形質（Ca、Cb、C2、L1、L2）を用いた判別関数による精度（86.3％）より低い。しかし、先に論じたように、基準群の判別精度だけでは沖合標本の判別結果の妥当性は判断できない。一方、分散分析では計数形質が計量形質より大きい分散比を示しており、群間の判別に有効な形質であることが示唆されている（未発表資料）。これらのことと先の一部のソ連沿岸標本と160°E以西標本との一致性とを考慮すると、C1およびC2形質による沖合標本の判別結果はより妥当性のあるものといえよう。

以上述べたように、採用する分析方法および形質により沖合標本の判別結果はかなり変動する。判別結果の解釈に際しては、このような推定値の不安定さを考慮しておく必要がある。今後、鱗相分析によって得られた結果を妥当なものと判断するには、他の異なる分析手法による裏付けが必要である。

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Table 1. Decision array for chum salmon based on 5 characters (Ca,Cb,C2,L1,L2) by Cook's method. Source:Ishida et al.1984.

Overall accuracy 82.6%

Calculated decision	Correct decision			
	Japan	USSR	USA	Canada
Japan	173 (0.856)	22 (0.109)	5 (0.025)	2 (0.010)
USSR	21 (0.104)	147 (0.728)	34 (0.167)	0 (0.000)
USA	6 (0.030)	33 (0.163)	157 (0.770)	8 (0.040)
Canada	2 (0.010)	0 (0.000)	8 (0.039)	192 (0.950)
Total	202	202	204	202

Table 2. Decision array for chum salmon based on 5 characters (Ca,Cb,C2,L1,L2) by linear discriminant function method.

Overall accuracy 86.3%

Calculated decision	Correct decision			
	Japan	USSR	USA	Canada
Japan	180 (0.900)	20 (0.100)	15 (0.075)	7 (0.035)
USSR	15 (0.075)	161 (0.805)	16 (0.080)	1 (0.005)
USA	5 (0.025)	18 (0.090)	164 (0.820)	7 (0.035)
Canada	0 (0.000)	1 (0.005)	5 (0.025)	185 (0.925)
Total	200	200	200	200

Table 3. Comparison of mean values of scale character of chum salmon between offshore sample in the west of 160°E and coastal samples in USSR.
*Significant difference at the 5% level.

Sampling area	Sample size	Scale Character			
		C1	C2	L1	L2
West of 160° E	270	27.53	17.50	132.60	69.87
USSR					
Amur River	75	27.67	17.03	121.00*	67.93
Amur Liman	103	29.02*	17.88	124.31*	71.18
Kukhtui River	50	26.96	17.88	126.44*	71.94
Bolshaya Garmanda River	51	24.22*	17.16	110.20*	69.53
Bolshaya River	74	24.28*	16.73*	105.68*	70.47
Ust' Kamchatsk	60	27.25	17.90	109.70*	71.18
Khaylyulya River	74	24.92*	18.91*	111.07*	75.32*
Anadyr River	55	20.11*	19.73*	99.56*	80.44*

Table 4. Decision array for chum salmon based on 2 characters (C1,C2) by linear discriminant function method.

Overall accuracy 79.4%

Calculated decision	Correct decision			
	Japan	USSR	USA	Canada
Japan	177 (0.885)	38 (0.190)	17 (0.085)	7 (0.035)
USSR	11 (0.055)	135 (0.675)	37 (0.185)	0 (0.000)
USA	10 (0.050)	27 (0.135)	137 (0.685)	7 (0.035)
Canada	2 (0.010)	0 (0.000)	9 (0.045)	186 (0.930)
Total	200	200	200	200

Table 5. Mixing proportion estimates for age 0.3 maturing chum salmon by INPFC area in May, 1981.

Table 5. Mixing proportion estimates for age 0.3 maturing chum salmon by INPFC area in May, 1981.

1) 1st row indicate the estimates by Cook's method based on 5 characters (Ca,Cb,C2,L1,L2). Source:Ishida et al. 1984.
2) 2nd row indicate the estimates by linear discriminant function based on 5 characters (Ca,Cb,C2,L1,L2).
3) 3rd row indicate the estimates by linear discriminant function based on 2 characters (C1,C2).

Area	Sample Size	Japan	USSR	USA	Canada
E5042	18	4.7	48.8	46.5	0
		27.8	44.4	27.8	0
		33.3	50.0	11.1	5.6
E5540	7	8.8	46.5	44.8	0
		14.3	42.9	42.9	0
		28.6	57.1	14.3	0
E5542	26	23.4	54.5	22.1	0
		34.6	34.6	30.8	0
		42.3	34.6	23.1	0
E5544	47	0	83.2	16.8	0
		8.5	53.2	36.2	2.1
		14.9	70.2	12.8	2.1
E6042	2	42.8	57.3	0	0
		50.0	50.0	0	0
		50.0	50.0	0	0
E6044	21	2.3	54.3	43.4	0
		23.8	38.1	38.1	0
		33.3	47.6	19.0	0
E6046	41	0	100	0	0
		12.2	58.5	29.3	0
		22.0	63.4	14.6	0
E6048	32	0	100	0	0
		3.1	75.0	21.9	0
		6.2	84.4	9.4	0
E6540	17	3.2	74.9	21.8	0
		17.6	52.9	29.4	0
		23.5	64.7	11.8	0
E6542	31	0	100	0	0
		16.1	77.4	6.5	0
		9.7	77.4	12.9	0

Table 5. Continued.

Area	Sample Size	Japan	USSR	USA	Canada
E6544	45	0	86.7	13.3	0
		8.9	57.8	33.3	0
		13.3	71.1	15.6	0
E6546	67	0	80.6	19.4	0
		10.4	52.2	37.3	0
		7.5	76.1	16.4	0
E6548	46	0	100	0	0
		0	80.4	19.6	0
		10.9	80.4	8.7	0
E6550	20	0	99.4	0.6	0
		5.0	65.0	30.0	0
		10.0	80.0	10.0	0
E7042	36	17.5	62.0	18.6	2.0
		30.6	36.1	27.8	5.6
		33.3	41.7	19.4	5.6
E7044	31	6.2	56.3	37.5	0
		22.6	32.3	45.2	0
		38.7	41.9	19.4	0
E7046	37	7.2	91.5	1.3	0
		35.1	48.6	16.2	0
		35.1	62.2	2.7	0
E7048	40	0	100	0	0
		15.0	60.0	25.0	0
		10.0	77.5	10.0	2.5
E7050	13	0	100	0	0
		7.7	92.3	0	0
		0	100	0	0
E7542	10	0	52.3	47.7	0
		30.0	50.0	20.0	0
		40.0	40.0	20.0	0
E7544	32	12.0	71.4	16.6	0
		18.8	53.1	28.1	0
		18.8	65.6	15.6	0
E7546	50	14.5	60.3	25.2	0
		34.0	40.0	24.0	2.0
		28.0	64.0	6.0	2.0

Table 5. Continued.

Area	Sample Size	Japan	USSR	USA	Canada
E7548	37	0	100	0	0
		8.1	86.5	5.4	0
		16.2	81.1	2.7	0
E7550	35	0	66.9	33.1	0
		5.7	62.9	28.6	2.9
		2.9	80.0	17.1	0
8042	29	28.1	59.0	13.0	0
		48.3	27.6	24.1	0
		41.4	55.2	3.4	0
8044	60	29.6	50.1	20.3	0
		46.7	36.7	16.7	0
		41.7	51.7	6.7	0
8046	67	28.2	64.2	6.6	1.0
		50.7	35.8	13.4	0
		43.3	52.2	4.5	0
8048	70	5.4	85.2	9.4	0
		21.4	52.9	25.7	0
		24.3	67.1	8.6	0
8050	25	9.4	63.3	27.3	0
		20.0	52.0	28.0	0
		24.0	64.0	12.0	0

Table 6. Mixing proportion estimates for age 0.3 maturing chum salmon by INPFC area in June, 1981.
1) 1st row indicate the estimates by Cook's method based on 5 characters (Ca,Cb,C2,L1,L2). Source:Ishida et al. 1984.
2) 2nd row indicate the estimates by linear discriminant function based on 5 characters (Ca,Cb,C2,L1,L2).
3) 3rd row indicate the estimate by linear discriminant function based on 2 characters (C1,C2).

Area	Sample Size	Japan	USSR	USA	Canada
E5040	46	9.8	47.8	42.5	0
		34.8	23.9	41.3	0
		39.1	43.5	17.4	0
E5042	25	31.1	36.9	31.9	0
		40.0	20.0	40.0	0
		48.0	28.0	24.0	0
E5542	35	14.7	57.7	27.5	0
		31.4	31.4	37.1	0
		28.6	51.4	20.0	0
E5544	50	0	75.7	24.3	0
		20.0	44.0	36.0	0
		30.0	54.0	16.0	0
E5546	16	0	67.9	32.1	0
		0	62.5	37.5	0
		18.8	62.5	18.8	0
E6048	17	26.3	56.5	17.2	0
		35.3	35.3	29.4	0
		41.2	47.1	11.8	0
E6542	17	14.9	22.7	62.4	0
		23.5	41.2	35.3	0
		29.4	58.8	11.8	0
E6544	12	0	73.1	26.9	0
		16.7	50.0	33.3	0
		33.3	66.7	0	0
E6546	9	3.0	68.9	28.1	0
		33.3	44.4	27.2	0
		22.2	66.7	11.1	0
E6548	36	15.1	45.2	39.7	0
		30.6	36.1	33.3	0
		33.3	58.3	8.3	0

Table 6. Continued.

Area	Sample Size	Japan	USSR	USA	Canada
E7544	32	16.3	66.3	17.5	0
		43.8	34.4	21.9	0
		25.0	56.2	15.6	3.1
E7546	30	23.6	49.3	27.1	0
		33.3	43.3	23.3	0
		23.3	70.0	6.7	0
E7548	36	25.6	41.5	32.9	0
		36.1	47.2	16.7	0
		27.8	66.7	5.6	0
E7550	16	11.1	82.7	6.2	0
		18.8	68.8	12.5	0
		31.2	68.8	0	0
8050	50	21.7	61.3	17.0	0
		28.0	44.0	28.0	0
		30.0	62.0	8.0	0

Table 7. Mixing proportion estimates for age 0.3 maturing chum salmon by INPFC area in July, 1981.
1) 1st row indicate the estimates by Cook's method based on 5 characters (Ca,Cb,C2,L1,L2). Source:Ishida et al. 1984.
2) 2nd row indicate the estimates by linear discriminant function based on 5 characters (Ca,Cb,C2,L1,L2).
3) 3rd row indicate the estimates by linear discriminant function based on 2 characters (C1,C2).

Area	Sample Size	Japan	USSR	USA	Canada
E6042	3	0	81.1	18.9	0
		0	100	0	0
		0	66.7	33.3	0
E6044	16	13.0	60.1	26.9	0
		25.0	31.2	43.8	0
		25.0	68.8	6.2	0
E6046	27	0	61.2	38.8	0
		18.5	48.1	33.3	0
		25.9	59.3	14.8	0
E6048	52	4.3	59.0	36.7	0
		19.2	57.7	23.1	0
		13.5	80.8	5.8	0
E6544	2	0	52.3	47.7	0
		0	50.0	50.0	0
		0	50.0	50.0	0
E6546	12	9.2	74.8	16.0	0
		50.0	50.0	0	0
		25.0	75.0	0	0
E6548	3	67.2	0	32.8	0
		66.7	33.3	0	0
		66.7	33.3	0	0
E6550	12	0.9	99.1	0	0
		25.0	66.7	8.3	0
		16.7	83.3	0	0
E7044	3	33.1	32.3	34.5	0
		33.3	33.3	33.3	0
		33.3	66.7	0	0
E7046	46	8.1	67.4	24.5	0
		28.3	43.5	26.1	2.2
		17.4	73.9	8.7	0

Table 7. Continued.

Area	Sampple Size	Japan	USSR	USA	Canada
E7048	32	34.7	28.7	36.5	0
		40.6	31.2	28.1	0
		46.9	37.5	15.6	0
E7050	43	17.5	71.3	11.1	0
		27.9	51.2	20.9	0
		30.2	65.1	2.3	0
E7546	7	28.2	23.0	48.9	0
		57.1	14.3	28.6	0
		14.3	57.1	28.6	0
E7550	87	15.9	73.0	9.2	1.9
		29.9	57.5	12.6	0
		25.3	67.8	5.7	1.1
E7556	115	51.3	32.6	13.6	2.6
		58.3	25.2	13.9	2.6
		52.2	31.3	13.0	3.5
E7558	9	86.9	0	8.4	4.7
		77.8	11.1	0	11.1
		77.8	11.1	0	11.1
8044	11	0	100	0	0
		27.3	63.6	9.1	0
		18.2	81.8	0	0
8046	21	0.8	71.5	27.7	0
		28.6	52.4	19.0	0
		23.8	57.1	19.0	0
8048	20	6.9	77.6	15.5	0
		15.0	65.0	20.0	0
		15.0	80.0	5.0	0
8050	76	3.8	87.7	8.4	0
		25.0	59.2	15.8	0
		25.0	68.4	6.6	0
8056	83	58.8	29.9	11.3	0
		56.6	26.5	14.5	2.4
		65.1	21.7	13.3	0

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TRANSLATION

STOCK IDENTIFICATION OF CHUM SALMON BASED ON SCALE PATTERNS BY DISCRIMINANT FUNCTION

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Introduction

Stock identifications of chum salmon based on scale characters using Cook's (1982) method were reported in Docs. 2675 and 2796. Those results pointed out that the most notable contradiction between the results of the scale pattern analysis and previous knowledge obtained from tagging etc. was that chums classified as of United States or Japanese origin appeared in the western North Pacific and even in the Sea of Okhotsk. On the other hand, U.S. scientists came to use the linear discriminant function method instead of Cook's method for several reasons (Myers et al. 1984). Furthermore, a U.S. scientist who boarded a U.S.S.R. research vessel reported that the fish body location from which U.S.S.R. scientists sampled scales was different from that preferred by the INPFC (Harris 1983), and there has been concern that the scale samples provided by the U.S.S.R. might be collected from body locations differing from the INPFC preferred one.

In this report, the classification accuracies for standard groups obtained from Cook's method based on the five characters which were adopted in Doc. 2796 and from the linear discriminant function method are compared. Then, based on the comparison between scale samples of chum salmon caught in the area west of 160°E during May to June by the Japanese salmon research vessels and inferred to be of U.S.S.R. origin according to the results from taggings ("offshore samples west of 160°E"), and those collected from U.S.S.R. rivers and coastal areas and provided by the U.S.S.R. ("coastal samples from the U.S.S.R."[1]), the scale characters judged to be effective for stock identification were selected. Finally the results of classifications of offshore scale samples of unknown origin obtained based on these characters and those based on the previously mentioned five characters are compared and examined.

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[1]Coastal samples from the U.S.S.R. consist of eight groups (U.S.S.R. coastal sample groups).

Materials and Methods

Scale samples used in this report were obtained from maturing 0.3 fish caught in 1981, as used in Doc. 2796. A program package of the Computing Center for Research in Agriculture, Forestry and Fishery (Multi-Variate Analysis Program; MAP) was used for calculation of the linear discriminant functions.

Results

Comparison between Cook's method and linear discriminant function method

The decision array for standard groups based on five characters (Ca, Cb, C2, L1, L2) by Cook's method is shown in Table 1 (cited from Doc. 2796). The classification accuracy of the standard groups was 85.6% for Japan, 72.8% for the U.S.S.R., 77.0% for the United States, and 95.0% for Canada. Overall accuracy was 82.6%.

The linear discriminant functions obtained based on these five characters and almost the same standard groups are as follows--

$$Z1,2 = -14.916 + 1.115 \times Ca - 0.259 \times Cb - 0.139 \times C2 + 0.088 \times L1 - 0.072 \times L2$$

$$Z1,3 = 10.758 + 0.737 \times Ca + 0.222 \times Cb - 0.784 \times C2 - 0.069 \times L1 - 0.012 \times L2$$

$$Z1,4 = 43.278 - 0.416 \times Ca - 1.905 \times Cb - 0.533 \times C2 + 0.156 \times L1 - 0.169 \times L2$$

Where the notation 1 implies Japanese, 2 the U.S.S.R., 3 the United States and 4 Canada. The classification accuracy of the standard groups was 90.0% for Japan, 80.5% for the U.S.S.R., 82.0% for the

United States, and 92.5% for Canada. Overall accuracy was 86.3% (Table 2). Generally these values of classification accuracy were somewhat higher than for those obtained from Cook's method.

Comparison between the offshore samples west of 160°E and coastal samples from the U.S.S.R.

Based on counts for characters C1 and C2 (the number of circuli of the first year band and that of the second year band, respectively) and measurements for characters L1 and L2 (the width of the first year band and that of the second year band, respectively), the difference between the mean value of each character of offshore samples west of 160°E and that of each U.S.S.R. coastal sample group was tested and results are shown in Table 3.

The offshore samples from west of 160°E were judged to be obtained from fish of U.S.S.R. origin according to the results from taggings. Characters Ca and Cb obtained by dividing the first year band equally were not used for this analysis because Ca and Cb include factors of the measured characters.

A significant difference was observed between the offshore samples west of 160°E and the following U.S.S.R. coastal sample groups: Amur Liman, Bolshaya Garmanda River, Bolshaya River, Khaylyulya River and Anadyr River for C1, Bolshaya River, Khaylyulya River and Anadyr River for C2, all coastal sample groups for L1 and Khaylyulya River and Anadyr River for L2. Thus, while based on the measured characters (L1 or L2), significant differences were observed between those samples, based on the count characters they were not observed between offshore samples west of 160°E and three coastal sample groups (Amur River, Kukhtui River, and Ust' Kamchatka) for either C1 or C2. Taking into account the concern over the body location from which the coastal samples in the U.S.S.R. were collected, it was considered more

appropriate to use the count characters for which significant differences were not observed between the offshore samples west of 160°E (inferred to be of U.S.S.R. origin according to the results from taggings) and the three coastal sample groups for analysis.

Discriminant functions based on characters C1 and C2

The following discriminant functions were obtained based on the count characters C1 and C2:

$$Z1,2 = -11.624 + 0.618 \times C1 - 0.348 \times C2$$
$$Z1,3 = 7.269 + 0.263 \times C1 - 0.817 \times C2$$
$$Z1,4 = 46.872 - 0.770 \times C1 - 1.059 \times C2$$

Classification accuracy of the standard groups was 88.5% for Japan, 67.5% for the U.S.S.R., 68.5% for the United States, and 93.0% for Canada. The overall accuracy was 79.4% (Table 4).

Classification of offshore samples of unknown origin

Results of classification of the offshore samples of unknown origin by Cook's method and the linear discriminant function method based on the five characters and by the latter method based on two characters, are shown in Tables 5, 6, and 7. The results from Cook's method are from Doc. 2796. These three different methods produced different results of classification which are summarized as follows--

(1) When five characters were used, comparing the results for the linear discriminant function method with those for Cook's method, the number of individuals classified as U.S.S.R. origin was smaller as Japan was larger, in many areas as United States was larger, and as Canada was larger (Table 5).

(2) When the two characters (C1, C2) were used in the linear discriminant function instead of the five characters (Ca, Cb, C2, L1, L2), the numbers of individuals classified as United States origin further decreased, and those classified as of U.S.S.R. and Japanese origin increased in many areas.

Discussion

Overall accuracies of classification of standard groups are 82.6% and 86.3% from Cook's method and the linear discriminant function method, respectively, and did not show great difference. However, when the offshore samples of unknown origin were examined by these two methods, considerable differences between the results of classification are observed in some areas. Since these differences occur in the areas where the numbers in samples are relatively large, they are not attributable only to the small amount of the data used. This indicates that the analyses which provide higher classification accuracies for the standard groups do not necessarily produce consistent stable estimates for the offshore samples of unknown origin.

Based on count characters C1 and C2, significant differences were not observed between the coastal groups Amur River, Kukhtui River, and Ust' Kamchatka, and the offshore samples west of 160°E. This suggests that these samples might be collected from the same population. This assumption is consistent with information obtained from taggings (Neave et al. 1976). However, based on measure character L1, a significant difference between each U.S.S.R. coastal sample group and the offshore samples west of 160°E was shown. If the assumption based on count character mentioned earlier is true, the significant difference for this measure character should be questioned.

This difference might be caused by the following--the body locations from which U.S.S.R. coastal samples were collected differed from the INPFC preferred location and this greatly influenced the measure

characters; or differences in the handling of scale samples may also have greatly affected the measure characters (while scales from offshore samples were placed on gummed cards immediately after sampling, the U.S.S.R. coastal samples were affixed one year after sampling).

The classification accuracies for the standard groups by the discriminant functions based on the two count character C1 and C2 (average of 79.4%) are lower than those by the discriminant functions based on the five characters (Ca, Cb, C2, L1, and L2) including the measure characters (average of 86.3%). However, as discussed earlier, the validity of the results of classification of the offshore samples may not be determined only according to the classification accuracies for the standard groups. On the other hand, according to the analysis of variance, count characters show higher variance ratio than measure characters and it is suggested the count characters are effective for discriminating between groups (unpublished data). Considering these views and the good agreement between some U.S.S.R. coastal sample groups and the offshore samples west of 160° noted above, the results of classification of the offshore samples based on the characters C1 and C2 are considered to be more valid.

As explained thus far, the results of classification of the offshore sample vary with the method of analysis and/or characters employed. In interpreting the results of classification it is necessary to take into account the instability of estimates. In order to judge results from scale pattern analysis as adequate, validation by the different methods of analysis will be required.

REFERENCES AND TABLES 1 TO 7 ARE IN ENGLISH IN THE JAPANESE DOCUMENT