Scale pattern analysis of coho salmon in the northwest North Pacific Ocean using materials obtained by salmon research vessels in 1976.

Mamoru Kato and Yukimasa Ishida

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1976年にさけ・ます調査船により得られた
資料による北西北太平洋のギンザケの
鱗相分析

Scale pattern analysis of coho salmon in the northwest North Pacific
Ocean using materials obtained by salmon research vessels in 1976.

加藤守・石田行正

加藤・石田（1985）は北西北太平洋の神合に分布するギンザケについて、1975年にさけ・ます調査船により得られた資料を用いて、鱗相分析によりその大陸起源の検討を行った。その結果によれば、50°N以南、175°E以西に分布するギンザケの70％以上はアジア起源群であるが、10～30％の割合で北米起源群が含まれていることが示された。しかし、長年の観察結果は、この海域から1尾の北米起源魚も出現しないことから、その鱗相分析結果に大きな疑問点を与えた。合衆国の報告によると、42°～52°N、160°E～175°Wの北西北太平洋において1979年ではカムチャック群が卓越し（Myers et al., 1981）、1980年ではカムチャック群、西部及び中部アラスカ群が同じ割合であり（Walker and Harris, 1982）及び1981年では中部アラスカ群がカムチャック群を卓越し（Walker and Davis, 1983）等、毎年卓越群が変化した。筆者等も単年度の分析結果では十分でないと考え、1976年に得られたギンザケ資料を用いて、さらに検討を試みた。

アジア側の起源群としては、前報告と同様、ソ連の河川で採捕されたギンザケの資料は用いてなかった。その理由は、採捕部位に問題があるとみられた（加藤, 1984）からであり、また、ギンザケのように多くの小さい河川に産卵場をもつ種では1～2河川だけでは代表性が低いと考えたからである。標本の代表性の問題は、北米側の起源群にもあってはまると考えられるが、北米近海の調査船資料がないので、前報告と同様、アラスカの3河川ものを基準群とした。

材料と方法

(1) 北米起源群として、1976年にアラスカのYukon河採捕の成魚13尾、Kuskokwim河採捕の成魚233尾及びCook Inlet採捕の成魚161尾、合計407尾の鱗標本と生物資料を用いた。これらの資料はアラスカ州漁業局（ADFG）が採集し、合衆国政府から日本側に提供されたものである。

(2) 日本のさけ・ます調査船が1976年5月～9月に、175°W以西の北西北太平洋、ベーリング海及びオホーツク海で採捕した成魚2,481尾の鱗標本と生物資料を用いた。

(3) 鱗はINPFCが望ましいとした部位から採取された。鱗標本はプラスチック・カードに刻印
されたものを用い、投影機で100倍に拡大して観察、計測を行った。
(4) 年齢査定は加藤（1984）の方法で行い、鱗相分析には2.1年魚のみを用いた。
(5) 基準標本として以下のA～F（図1）をとり、このうちA～C群をアジア（USSR）基準群、D～Fを北米（USA）基準群とした。下記に各基準群の採捕位置と2.1年魚の尾数を示す。(1)は2.1年魚の割合（％）を示す。
A群：さけ・ます調査船が7月に44°～48°N、160°E以西の海域で採捕した491尾（73.9％）。千島沖群と呼ぶ。
B群：さけ・ます調査船が8月9月に東カムチャッカ沖合の50°～56°N、160°E～170°Eの海域で採捕した65尾（69.7％）。東カムチャッカ沖合群と呼ぶ。
C群：さけ・ます調査船が7月9月にオホーツク海で採捕した849尾（85.8％）。オホーツク海群と呼ぶ。ただし、7月採捕のものをC1群、8月9月採捕のものをC2群とする。
D群：西部アラスカのYukon河で採捕した13尾（24.1％）。
E群：中部アラスカのKuskokwim河で採捕した233尾（74.2％）。
F群：中部アラスカのCook Inletに注ぐ、Sustina河及びDeshka河で採捕した161尾（62.4％）。
(6) 鱗相分析には表1に示す9形質を用いた。
(7) 起源未知の沖合標本の採捕海域は図2に示される。以下に月別の海域と尾数（2.1年魚の割合）を示す。
5月：42°～44°N、165°E～180°Nの海域。68尾（76.4％）。
6月：42°48°N、155°E～175°Wの海域。506尾（86.2％）。
7月：44°～54°N、160°E～175°Wの海域。502尾（70.1％）。
(8) 起源未知の標本の判別には農林水産省の多変量プログラム（MAP）を用いた。
各群の鱗相の類似度
A～F群の鱗相の類似度を図3に示す。B群（東カムチャッカ沖合群）とC1群（7月のオホーツク海群）、C2群（8～9月のオホーツク海群）とF群（Cook Inlet群）が最も類似し、次にこのB・C1群とA群（千島沖群）が類似した。D群（Yukon河群）は他のどの群とも類似度が低かった。C2群とF群の類似度が高いことは、地理的に離れた群が必ずしも類似度が低くならないことを示した。鱗相分析による大陸起源の解明が難しいことを暗示している。1975年の場合は、B群とF群が最も類似し、また、D群とA群が類似する等、1976年のものと多少類似度に相違がみられた。D群の標本が少な過ぎて、代表性が十分でないのかも知れないと。
\[
Z = 8.591 - 0.061F_L^2 - 0.073F_N^2 - 0.073F_L + 0.331F_N - 0.157W_0 + 0.036O_A - 0.019O_N
\]

この判別関数を起源未知の標本に用いた場合の判別精度は全体で70.3％、アジア基準群のそれは72.8％、北米基準群のそれは67.8％であった（表2）。1975年の結果と比較して、判別精度は全体で5％、特に北米基準群で8％低かった。

起源未知標本の判別

判別関数を用いて起源未知標本の判別結果を月別、2°×5°区画別に示した（図4、5、6）。アジア（USSR）起源と判別された群は5月では170°E以東で63～76％と卓越した。6月ではアジア群は大部分の海域では57～72％と卓越したが、46°～48°N、175°E～175°Wの海域でのみ40.0～47.4％と北米群より低い割合を示した。7月ではアジア系は大部分の海域で53～82％と卓越したが、50°～54°N、165°E～175°Eの海域で22～33％と非常に低い値を示した。

考察

鱗相分析の結果、1976年の北西北太平洋に分布するギンザケの多くはアジア起源群であり、特に50°N以南、175°E以西の大部分の海域ではアジア系が卓越（56～100％）した。一方、北米起源群は6月の48°N以北、175°E以東の海域で53～60％、7月の50°N以北、165°E～175°Eの海域で67～78％と卓越した。

1975年の分析結果と比較すると、アジア起源群の割合がやや少なくなっている。特に、7月に50°N以北、165°E～170°Eの海域で北米起源群が卓越したことが特徴的であった。

1976年では、C群（8～9月のオホーツク海群）とF群（Cook Inlet群）の鱗相の類似度が高く、また、1975年ではB群（カムチャッカ群）とF群の類似度が最も高かった。このように、F群は常にアジア起源群と類似度が高く、鱗相分析による大陸起源の識別に混乱を起こす原因の一つとなっているのではないかと推測される。

次に、海域別の鱗相分析判別結果とその海域において標識放流され、大陸に回帰したギンザケの再捕結果と比較してみる。

加藤・石田（1985）は1975年の資料の鱗相分析を行い、50°N以南、175°E以西に分布するギンザケのうち、北米起源群が10～30％出現するとの結果を得た。今回の分析結果も同様に、1976年の同海域に北米起源群が20～50％出現することを示した。

また、合衆国の鱗相分析結果（Myers et al., 1981; Walker and Harris, 1982; Walker and Davis, 1983）をみると、同海域における北米起源群の割合は、1979年に10～50％、1980年に40～60％及び1981年には50～100％となっている。

また、50°N以北、175°E以西の海域では、日本の鱗相分析結果によると、1975年に30～60％、1976年に30～80％が北米起源との結果となった。合衆国の鱗相分析結果によると、同海域
で1979年に0〜70％、1980年に40〜70％及び1981年に30〜80％の北米起源群が出現した。

一方、175°E以西で標識放流され、大陸で再捕されたギンザケは、50°N以南で16例、50°N以北で32例あるが、このうち北米で再捕されたものは皆無であり（図7〜9、表3）、麂相分析結果と大きく矛盾している。

50°N以南、175°E〜175°Wの海域に分布するギンザケのうち、北米起源群の割合は日本の分析結果では1975年に15〜50％及び1976年に20〜50％であった。また、合衆国の分析結果では、同海域の北米起源群の割合は1979年に40〜70％、1980年に40〜60％及び1981年に50〜90％であった。

一方、標識放流の再捕結果は、この海域から放流され、大陸で再捕された23例のうち、北米起源魚はわずか3例（13％）にしかすぎない（図7〜9、表3）。この結果も麂相分析結果と大きく相異なる。

標識放流再捕結果は各年毎の分布傾向を示すほどの数の結果を得られていないので、これと麂相分析結果の矛盾が特定の年についてのみのものであれば、年による分布の変動がこの原因であると考えられる可能性もあるかも知れない。しかしながら、1975, 1976, 1979, 1980及び1981年の5年分について、直接的証拠である標識放流結果とこのような矛盾が生じることは、麂相分析の手法そのものに大きな問題点があることに起因すると考えることが合理的である。このような分析法から得られた数値を解釈するためには、標識放流再捕結果、生物学的情報、その他の手法により得られた結果等と比較検討の上で、慎重に行うべきである。
LITERATURE


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Table 1. Scale characters used in the discriminant analyses.

<table>
<thead>
<tr>
<th>Character number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Size of zone 1 (FL1)</td>
</tr>
<tr>
<td>2</td>
<td>Size of zone 2 (FL2)</td>
</tr>
<tr>
<td>3</td>
<td>Size of zone 3 (OL)</td>
</tr>
<tr>
<td>4</td>
<td>No. of circuli zone 1 (FN1)</td>
</tr>
<tr>
<td>5</td>
<td>No. of circuli zone 2 (FN2)</td>
</tr>
<tr>
<td>6</td>
<td>No. of circuli zone 3 (ON)</td>
</tr>
<tr>
<td>7</td>
<td>Distance end of zone 2 to 5th circulus in zone 3 (W05)</td>
</tr>
<tr>
<td>8</td>
<td>Size of ocean annulus (OAL)</td>
</tr>
<tr>
<td>9</td>
<td>No. of circuli in ocean annulus (OAN)</td>
</tr>
</tbody>
</table>

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

Zone 2: The area of the scale from the outer edge of the last circulus in the first freshwater annulus to the outer edge of the last circulus 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. Decision array for 2.1 coho salmon of USSR vs. USA origin in 1976.

<table>
<thead>
<tr>
<th>Calculated decision</th>
<th>Correct decision</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>USSR</td>
<td>USA</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>USSR</td>
<td>1,023 (72.8)</td>
<td>382 (27.2)</td>
<td>1,405</td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>131 (32.2)</td>
<td>276 (67.8)</td>
<td>407</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1,154</td>
<td>658</td>
<td>1,812</td>
<td></td>
</tr>
</tbody>
</table>

Overall accuracy 70.3 %
Table 3. Relation between release and recovery areas shown by number of tagged coho salmon, 1956-1986.

<table>
<thead>
<tr>
<th>Release area</th>
<th>Recovery area</th>
<th>Asia</th>
<th></th>
<th>North America</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitude</td>
<td>Latitude</td>
<td>Number</td>
<td>%</td>
<td>Number</td>
<td>%</td>
<td>Number</td>
</tr>
<tr>
<td>West of 175°E</td>
<td>South of 50°N</td>
<td>16</td>
<td>100.0</td>
<td>0</td>
<td>0.0</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>North of 50°N</td>
<td>32</td>
<td>100.0</td>
<td>0</td>
<td>0.0</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>S. total</td>
<td>48</td>
<td>100.0</td>
<td>0</td>
<td>0.0</td>
<td>48</td>
</tr>
<tr>
<td>175°E-175°W</td>
<td>South of 50°N</td>
<td>20</td>
<td>87.0</td>
<td>3</td>
<td>13.0</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>North of 50°N</td>
<td>34</td>
<td>69.4</td>
<td>15</td>
<td>30.6</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>S. total</td>
<td>54</td>
<td>75.0</td>
<td>18</td>
<td>25.0</td>
<td>72</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>102</td>
<td>85.0</td>
<td>18</td>
<td>15.0</td>
<td>120</td>
</tr>
</tbody>
</table>
Fig. 1. Areas where standard samples of coho salmon were caught in 1976.
Fig. 2. Area where separation of unknown origin of coho salmon was conducted by scale pattern analysis. Samples were obtained by Japanese salmon research vessels in May to July, 1976.
Fig. 3. Clustering by taxonomic distance of standard groups of coho salmon.
Fig. 5. Mixing proportion estimated by 2° × 5° area for 2.1 coho salmon in June, 1976.
Fig. 6. Mixing proportion estimated by 2\(^\circ\) x 5\(^\circ\) area for 2.1 coho salmon in July, 1976.
Fig. 7. Release and recovery of coho salmon, 1956-1986.
Release area: south of 50°N, west of 170°W
Fig. 8. Release and Recovery (except Kamchatka R.) of coho salmon, 1956-1986.
Release area: north of 50°N, west of 170°W
Fig. 9. Release and recovery (to Kamchatka R.) of coho salmon, 1956-1986.
Release area: north of 50°N, west of 170°W
SCALE PATTERN ANALYSIS OF COHO SALMON IN THE NORTHWEST NORTH PACIFIC OCEAN USING MATERIALS OBTAINED BY SALMON RESEARCH VESSELS IN 1976

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Fisheries Agency of Japan
1986 September

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:
Kato and Ishida (1985) examined the continental origin of coho salmon distributed in the northwest North Pacific using scale pattern analysis of material obtained by the Japanese salmon research vessels in 1975. The results showed that Asian origin group constituted 70% or more of the total coho salmon distributed in waters southwest of 50°N, 175°E and North American groups constituted 10 to 30%. However, findings of tagging experiments conducted over many years had shown that not even one coho salmon of North American origin had occurred in those waters and this posed a major question for the results obtained from the scale pattern analysis. On the other hand, according to reports by the U.S. scientists, in the North Pacific between 42° and 52°N and 160°E and 175°W, coho salmon of Kamchatka origin were dominant in 1979 (Myers et al. 1981), the Kamchatka, western Alaska, and central Alaska groups accounted for almost the same proportion in 1980 (Walker and Harris 1982), and the central Alaska group was dominant over the Kamchatka group in 1981 (Walter and Davis 1983); the dominant group varied by year. The present authors also believe that the results for a single year are inadequate and attempted further examination using coho salmon data obtained in 1976.

The scale samples obtained at U.S.S.R. rivers were not included in the Asian origin group, as in the previous report, because it is considered that the suitability of the body location sampled for scales was questionable (Kato 1984) and the samples obtained from only one or two rivers were lacking in representativeness for such a species as coho salmon which spawns in numerous minor rivers. The question of representativeness of samples was assumed to be also the case for the North American origin group. However, since no scale samples were obtained by research vessels in North American inshore waters, those obtained from three Alaskan rivers were used as the standard samples as in the previous report.
Materials and Methods

(1) For North American origin groups, scale samples and biological data were those obtained in 1976 from 407 adult coho salmon as follows: 13 fish caught at the Yukon River in Alaska, 233 fish from the Kuskokwim River, and 161 fish from Cook Inlet. These samples were collected by the Alaska Department of Fish and Game (ADFG) and provided to Japan through the U.S. government.

(2) Scale samples and biological data from a total of 2,481 adult coho salmon caught by the Japanese salmon research vessels from May to August in 1976 in the northwest North Pacific west of 175°W, the Bering Sea and the Sea of Okhotsk.

(3) Scales were sampled from the INPPC preferred location. Scale impressions on plastic cards were used and scales were measured on projected images at 100 times magnification.

(4) Age determinations were carried out according to the method indicated by Kato (1984) and scales from only age 2.1 fish were used for the scale pattern analysis.

(5) The following groups (A to F) were established as standard samples, with groups A, B, and C regarded as Asian (U.S.S.R.) standard groups and groups D, E, and F as North American (U.S.A.) standard groups. Catch location, numbers of 2.1 fish, etc. of each group are as follows (figures in parentheses are the percentage of 2.1 fish in age compositions)--

Group A: 491 fish (73.9%) from salmon research vessels taken in waters west of 160°E between 44° and 48°N in July (referred to as "off-Kuril group")
Group B: 65 fish (69.7%) from salmon research vessels taken in waters off eastern Kamchatka between 50° and 56°N and 160° and 170°E from August to September (referred to as "off-eastern Kamchatka group")

Group C: 849 fish (85.8%) from salmon research vessels taken in the Okhotsk Sea from July to September (referred to as "Okhotsk Sea group"). Further, those caught in July are referred to as "C₁ group" and those from August to September as "C₂ group")

Group D: 13 fish (24.1%) from the Yukon River in Western Alaska

Group E: 233 fish (74.2%) from the Kuskokwim River in Western Alaska

Group F: 161 fish (62.4%) from the Sustina and Deska Rivers both flowing into Cook Inlet of Central Alaska

(6) Nine characters (shown in Table 1) were employed in the scale pattern analysis.

(7) The areas where the offshore samples of unknown origin were obtained are shown in Fig. 2. The areas and number of fish sampled by month are as follows (figures in parentheses are the percentage of 2.1 fish in age composition)--

May: Between 42° and 44°N, and 165°E and 180°
68 fish (76.4%)

June: Between 42° and 48°N, and 155°E and 175°W
506 fish (86.2%)

July: Between 44° and 54°N, and 160°E and 175°W
502 fish (70.1%)

3066--4
(8) The Multi-Variate Analysis Program (MAP) of the Ministry of Agriculture, Forestry and Fisheries was used to classify these samples of unknown origin.

**Similarity in scale pattern of group**

Similarity in scale pattern of the A to F groups is shown in Fig. 3. Highest similarities were observed between group B (off eastern Kamchatka) and group C1 (Okhotsk Sea-July) and group C2 (Okhotsk Sea-August to September) and group F (Cook Inlet). The next highest was among groups B and C1, and group A (off Kurils). Group D (Yukon River) showed little similarity to any other group. The high similarity observed between group C2 and group F indicated that the similarity between scale patterns of groups whose origins are separated by a long geographical distance is not necessarily low and suggested the difficulty in determining the continental origins by scale pattern analysis.

The results obtained for 1976 showed some difference in similarities from those for 1975, i.e. for 1975 the highest similarity was observed between group B and group F and group D and group A showed some similarity. However, the number of samples in group D may have been too small to allow group D to be adequate in representation.

**Discriminant function**

The following discriminant function was used for classification of samples:

\[
Z = 8.591 - 0.061FL2 - 0.073FN2 - 0.073FL1 + 0.331FN1 - 0.157W05 + 0.011OL - 0.207ON + 0.036OAL - 0.019OAN
\]
The results obtained using this discriminant function for samples of known origin showed that overall classification accuracy was 70.3% and classification accuracies for Asian origin and North American standard groups were 72.8% and 67.8%, respectively (Fig. 2). Compared with those obtained for 1975, the overall classification accuracy decreased by 5%. In particular, North American standard groups were lower by 8% in classification accuracy.

Classification of samples of unknown origin

Results of classification of samples of unknown origin using the discriminant function are shown by 2°×5° area by month in Figs. 4 to 6. Groups classified as of Asian (U.S.S.R.) origin were predominant at 63 to 76% in the areas east of 170°E in May. They also dominated in most areas (57 to 72%) in June but showed lower proportions (40.0 to 47.4%) compared to those shown by North American groups in a limited number of areas; i.e. those between 46° and 48°N and 175°E and 175°W. In July, they also dominated in most areas (53 to 82%) but constituted very low proportions (22 to 33%) in the areas between 50° and 54°N and 165°E and 175°E.

Discussion

The results of the scale pattern analysis showed that most coho salmon distributed in the northwest North Pacific in 1976 were of Asian origin. In particular, Asian groups were dominant, accounting for 56 to 100% of the total samples in most areas southwest of 50°N, 175°E. On the other hand, North American groups dominated in the areas northeast of 48°N, 175°E in June (53 to 60%) and north of 50°N between 165°E and 175°E in July (67 to 78%).

Compared with the analytical results obtained for 1975, the percentage of Asian groups in the 1976 stock composition became somewhat lower. It was particularly notable that North American groups were dominant in the areas north of 50°N between 165°E and 170°E in July.
In 1976, the highest similarity was observed between group C2 (Okhotsk Sea-August to September) and group F (Cook Inlet) while in 1975 group B (Kamchatka) and group F showed highest similarity. As shown, group F always showed high similarities with the Asian origin groups and this is presumed to be one factor bringing confusion into identification of continental origins by scale pattern analysis.

Next, a comparison by area between the results of classification from the scale pattern analyses and findings from recoveries of tagged coho released in the area and which returned to the continent was made as follows.

Kato and Ishida (1985) reported from the scale pattern analysis using the 1975 materials that of coho salmon distributed southwest of 50°N, 175°E North American groups accounted for 10 to 30%. Similarly, results obtained in this study showed that North American groups occurred at 20 to 50% in the same areas in 1976.

In addition, according to the results of scale pattern analyses conducted by U.S. scientists (Myers et al. 1981; Walker and Harris 1982; Walter and Davis 1983), the proportions of North American groups of the total fish in the above-mentioned areas ranged from 10 to 50% in 1979, 40 to 60% in 1980, and 50 to 100% in 1981.

Further, for areas northwest of 50°N, 175°E, the results of scale pattern analyses by Japan showed that North American groups accounted for 30 to 60% in 1975 and 30 to 80% in 1976 while those by the United States showed that North American groups occurred at 0 to 70% in 1979, 40 to 70% in 1980, and 30 to 80% in 1981.

On the other hand, from releases in areas west of 175°E, a total of 48 tagged coho salmon (16 and 32 recoveries from releases south and north of 50°N, respectively) were recovered on the continents. None of those recoveries were obtained in North America (Figs. 7 to 9; Table 3). These findings are greatly inconsistent with those from the scale pattern analyses.
For coho salmon distributed in areas south of 50°N between 175°E and 175°W, the analyses by Japan showed that North American groups accounted for 15 to 50% in 1975 and 20 to 50% in 1976 while those by the United States showed that those groups accounted for 40 to 70% in 1979, 40 to 60% in 1980, and 50 to 90% in 1981.

On the other hand, according to the results of recoveries of tagged fish, only three (13%) recoveries of coho salmon of North American origin were found in the 23 recoveries obtained on the continent from releases in the above-mentioned areas (Figs. 7 to 9; Table 3). These findings are also greatly inconsistent with those from the scale pattern analyses.

Since the volume of tag recovery data available has not been large enough to indicate any yearly trend in distribution, if a discrepancy between results from tagging and scale pattern analysis is observed only for certain years, this discrepancy might be attributable to yearly fluctuations in the distribution. However, as mentioned previously, inconsistencies exist between the results from the scale pattern analyses and those from tagging experiments which are regarded as direct evidence for the five years of 1975, 1976, 1979, 1980, and 1981 and it is reasonable to consider that these inconsistencies are attributable to the fact that the methodology of the scale pattern analysis has a major fault. Therefore, interpretation of the values obtained from these scale pattern analyses should be made carefully and considered together with findings from tagging studies, biological information, and results obtained from other methodologies.

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REFERENCES, TABLES 1 TO 3, AND FIGS. 1 TO 9
ARE IN ENGLISH IN THE JAPANESE DOCUMENT