日本さけ・ます調査船による1987年の海産哺乳動物目視調査の概要と北太平洋のイシイルカの豊度推定

Outline of Sighting Survey for Marine Mammals by Japanese Salmon Research Vessels in 1987 and Estimation of Dall's Porpoise Abundance in the North Pacific Ocean

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要　　約

日本は、1987年6月1日から9月26日まで北太平洋北部及びベーリング海（21°〜60°N、141°E〜125°W）において10隻の調査船によりイシイルカを中心とした海産哺乳動物の目視調査を実施した。さけ・ます調査船9隻及び照洋丸は航走距離35,775海里とおいてイシイルカ644群2,243頭、カマイルカ34群、セミイルカ7群、シャチ10群、マイルカ14群、オットセイ166群等の目視を行った。

さけ・ます調査船及び照洋丸が1980〜1987年の6月〜8月に集収した目視資料中ビューフォート階級で0〜3の海況条件から得た資料を基に、Fourier series と negative exponential を estimatorとしてイシイルカの豊度を推定した。リクゼンイルカの豊度は133〜135 × 10^3頭、北西北太平洋のイシイルカ型のそれは826〜874 × 10^3頭、北東北太平洋のイシイルカ型のそれは992〜1,175 × 10^3頭及びベーリング海のイシイルカ型のそれは367〜437 × 10^3頭と推定された。

は し が き

1978年以来10年間、日本はさけ・ます調査船及びイシイルカ専門調査船は、北太平洋において海産哺乳動物の目視調査を行っている。この調査の目的は海産哺乳動物、特にイシイルカ豊度を推定し、それをモニタリングすることにある。本報告では1987年行われた目視調査の概要を述べると共に、1987年以前に得られた目視資料をも含めて、イシイルカの豊度推定を行った。また、イシイルカの捕獲調査を主目的とした、イシイルカ専門調査船、第12宝洋丸航海の資料は用いなかった。その報告については吉岡その他（1988）を参照されたい。

1987年の目視調査の概要

1987年に9隻のさけ・ます調査船及び照洋丸は6月1日から8月23日まで北太平洋北西部、ベーリング海及びアラスカ湾を含む北太平洋北東部で海産哺乳動物の目視調査を行った。海域別調査隻数は、北太平洋北西部で10隻、ベーリング海で2隻及び北太平洋北東部で2隻であった。その調査海域は21°N～60°N、141°E～125°Wに及んだ（表1）。

目視調査の項目は加藤（1983）と全く同じものであった。さけ・ます調査船及び照洋丸においては乗組員が目視業務に従事した。

さけ・ます調査船及び照洋丸による目視調査は6月1日から8月23日まで行われ、延べ目視日数は416日、航走距離は35,775海里であった。航走距離の内訳けは165°W以西の北太平洋北西部で30,044海里、165°W以東の北太平洋北東部で7,475海里及びベーリング海で2,809海里であった。目視されたイシイルカは644群、2,243頭であった。内訳けは、イシイルカ型が479群1,705頭（76.0％）、リクゼンイルカ型が21群66頭（2.9％）及び型不明イシイルカが144群472頭（21.1％）であった。その他、カマイルカ34群、セミイルカ7群、シャチ10群、マイルカ14群、オットセイ166群等が目視された。

図1－1－3に1987年にさけ・ます調査船及び照洋丸によって行われた。航走1,000海里当りのイシイルカの目視群数を月別（6月～8月）、20×50区画別に示した（図1－1～3）。

6月：目視群数はベーリング海中央部及び50°N以北のアリューシャン列島付近で最も高く（11～105）、次いで38°～42°N、170°E以西の北太平洋北西部で比較的高(8～96)、及び42°N～50°N、175°W以西の北太平洋北西部で低かった（0～19）。

7月：目視群数は40°N～46°N、170°E以西の北太平洋北西部で比較的高（0～49）、46°N～52°N、180°以西の北太平洋北西部で低く0～29を示した。ベーリング海及び北太平洋北東部では一部高い値を示す海域がみられた。

8月：目視群数は42°N～46°Nの北太平洋でかなり高い値（0～201）を示した。40°N、175°W～165°Wにも21～27の値がみられた。

目視調査の努力量が海域の広さに対し十分ではなく、イシイルカの時空間的な回遊を把握することは難しかった。7月～8月の北太平洋北東部海域でイシイルカが38°N～40°Nで170°W～160°W発見された。このことはイシイルカが7月～8月でも比較的低緯度に分布していることを示している。

イシイルカの豊度測定

イシイルカはイシイルカ型、リクゼンイルカ型及び型不明イシイルカの3型に分けて記録されたが、この3型全てが豊度推定の資料として用いられた。精度の高い豊度推定を行うためには、広い空間を短時間で調査した資料を使うことが望ましい。しかしながら、従来さけ・ます調査船の調査

期間は4〜8月と長く、しかも各月では調査海域が限定されている。また、年により調査海域が変化する場合もある。このような欠点を補なうため、従来より長年をプールした資料により豊度推定を行ってきた。この報告では1980〜1987年の6月〜8月をプールした資料を用いることとした。イシイルカ専門調査船から得られた資料は観測場所やイシイルカの追跡の有無を含む調査方法が異なるため、さけ・ます調査船による目視調査と同一視できないと判断し、この資料から除外した。

海域区分はKato（1987 a）と同様に行った。

海域1. 38°〜44°N、155°E以西の北太平洋北西部（197 × 10^3平方海里）

海域2. 38°N以北で165°W以西の海域1を除いた北太平洋（1,521 × 10^3平方海里）

海域3. 42°N以北で165°W以東の北太平洋（1,561 × 10^3平方海里）

海域4. 62°N以南のベーリング海（567 × 10^3平方海里）

Kato（1986）は海況をビューフォート階級0〜3(A)と4〜7(B)の2つに区分し、海況Bでは豊度が過少に評価されることを示した。当然ながら、全階級（0〜7）を混合して用いれば、豊度の過少評価となる。したがって、この報告では海況Aの時の目視資料のみを用いて豊度推定を行った。図3には海域2における船からの垂直距離と1海里当り発見群数の関係を示した。500 m以上では群の発見割合が非常に小さくなることを示した。

豊度推定に際し、目視資料によく適合するestimatorを用いることが重要である。各海域別に目視資料を用い、Fourier series と negative exponential の適合度の検定を行ったところ、有意水準95％でこの目視資料は両estimatorによく適合すると判定された。豊度推定に当り、両estimator（Kato、1987 b）を用いることにした。

豊度推定値

豊度推定結果を表2に示した。豊度推定に用いた航走距離と発見群数は、海域1で30,199海里、786群、海域2で87,263海里、1,829群、海域3で8,657海里、246群及び海域4で13,227海里、296群であった。

Fourier series による豊度推定

1平方海里当りの個体密度は海域1で0.69、海域2で0.54、海域3で0.64及び海域4で0.65であった。

豊度は海域1で135 × 10^3頭（95％の信頼区間で103〜167 × 10^3頭）、海域2で826（662〜990）× 10^3頭、海域3で992（190〜1,794）× 10^3頭、及び海域4で367（275〜459）× 10^3頭、計2,319（1,230〜3,410）× 10^3頭と推定された。

negative exponential による豊度推定

1平方海里当りの個体密度は海域1で0.68、海域2で0.57、海域3で0.75及び海域4で0.77

であった。

豊度は海域1で133（ 100〜167 ）× 10^3 頭、海域2で874（ 759〜990 ）× 10^3 頭、海域3で1,175（ 221〜2,129 ）× 10^3 頭、及び海域4で437（80〜793）× 10^3 頭、計2,619（ 1,160〜4,079 ）× 10^3 頭と推定された。

海域1の豊度は主にリクゼンイルカ型のそれを示し、133〜135 × 10^3 頭と推定された。海域2の豊度は北太平洋北西部のイシイルカ型のそれを示し、826〜874 × 10^3 頭と推定された。海域3の豊度は北太平洋北東部のイシイルカ型のそれを示し、992〜1,175 × 10^3 頭と推定された。海域4のそれはベーリング海のイシイルカ型のそれを示し、367〜437 × 10^3 頭と推定された。

同一海域における両 estimator による推定豊度は海域1及び2においてはほとんど相異せず、海域3及び4で若干相異した（ negatins expanential の値を1として、Fourier series のそれは0.84 ）。この相異は複合した原因によると考えられるが、その一つとして資料数の相異があげられる。海域1及び2では786群及び1,829群とかなり大きい資料数を用いているのに対し、海域3及び4では246群及び296群と比較的少ない。今後海域3及び4の資料数を増加させることが、両 estimator の推定値の相異を減少させることに役立ち、したがってより精度の高い豊度推定につながると考える。

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Table 1. Japanese research vessels engaged i the sighting surveys of marine mammals in 1987.

Name	Tonnage	Horse power	Cruise	Dates surveyed	Area covered	Distance sighted (nautical miles)	Days sighted
Hokushin	219.5	1,000	1	June 10 - July 24	41-51°N, 148°E-177°W	2,083	37
Oshoro	1,779	3,000	1	June 7 - Aug. 16	37-59°N, 145°E-126°W	4,581	51
Hokusei	892.5	2,100	1	June 6 - June 17	34-44°N, 145°E-155°E	1,001	11
			2	June 25 - July 6	34-43°N, 144°E-155°E	939	10
			3	July 14 - Aug. 10	38-49°N, 145°E-175°E	2,009	25
Hokko	466.5	1,800	1	June 1 - June 21	42-44°N, 144°E-177°E	2,339	21
			2	June 30 - July 20	43-49°N, 147°E-170°E	1,582	17
Iwaki	200.0	1,300	1	June 1 - July 9	36-49°N, 141°E-162°E	1,339	21
Hokuho	414.4	1,300	1	June 2 - July 30	40-47°N, 144°E-175°E	4.324	55
Wakatake	424.0	1,500	1	June 6 - July 21	40-60°N, 144°E-175°W	3,381	38
Kaiun	299.6	770	1	June 5 - July 11	41-53°N, 145°E-172°E	2,033	32
Shin-riasu	471.0	1,400	1	June 1 - July 30	39-51°N, 142°E-173°W	3,761	44
Shoyo	1,362	4,000	1	June 26 - Aug. 23	21-47°N, 141°E-149°W	6,403	54
					Total	35,775	416

Table 2. Abundance and density of Dall's porpoise from the sighting survey of salmonresearch vessels in 1980-1987 pooled data collected in sea condition of Beaufort 0-3. Estimates based on Fourier series estimator and negative exponential model.

Estimator	Area	10^3NMI^2	Transect length (NMI)	Number of schools of porpoise	Density $(\hat{D}g)$ schools/UMI^2	$\hat{Var}(\hat{D}g)$	Mean school size $(\bar{G})$	Coefficient of variation $\hat{Cv}(\hat{D}g)$	Coefficient of variation $\hat{Cv}(\bar{G})$	Density $(\hat{D}i)$ indi./NMI^2	Abundance $(\hat{T})$ 10^3	95% confidence interval around $(\hat{T})$ 10^3
Fourier series	1	197	30,199	786	0.1733	0.000095	3.96	0.0562	0.1087	0.6855	135.0	102.6- 167.4
	2	1,521	87,263	1,829	0.1410	0.000024	3.85	0.0349	0.0952	0.5429	825.7	661.6- 989.8
	3	1,561	8,657	246	0.1531	0.000231	4.15	0.0992	0.4005	0.6354	991.9	189.9- 1,793.9
	4	567	13,227	296	0.1669	0.000177	3.87	0.0797	0.1002	0.6467	366.7	274.7- 458.7
	Total	3,846	139,346	3,157							2,319.3	
Negative exponential	1	197	30,199	786	0.1709	0.000130	3.96	0.0667	0.1087	0.6760	133.2	99.9- 166.5
	2	1,521	87,263	1,829	0.1493	0.000106	3.85	0.0690	0.0952	0.5748	874.3	758.5- 990.1
	3	1,561	8,657	246	0.1814	0.000383	4.15	0.1078	0.4005	0.7528	1,175.1	220.8- 2,129.4
	4	567	13,346	296	0.1987	0.000288	3.87	0.0854	0.1002	0.7708	436.6	80.4- 792.8
	Total	3,846	139,346	3,157							2,619.2	

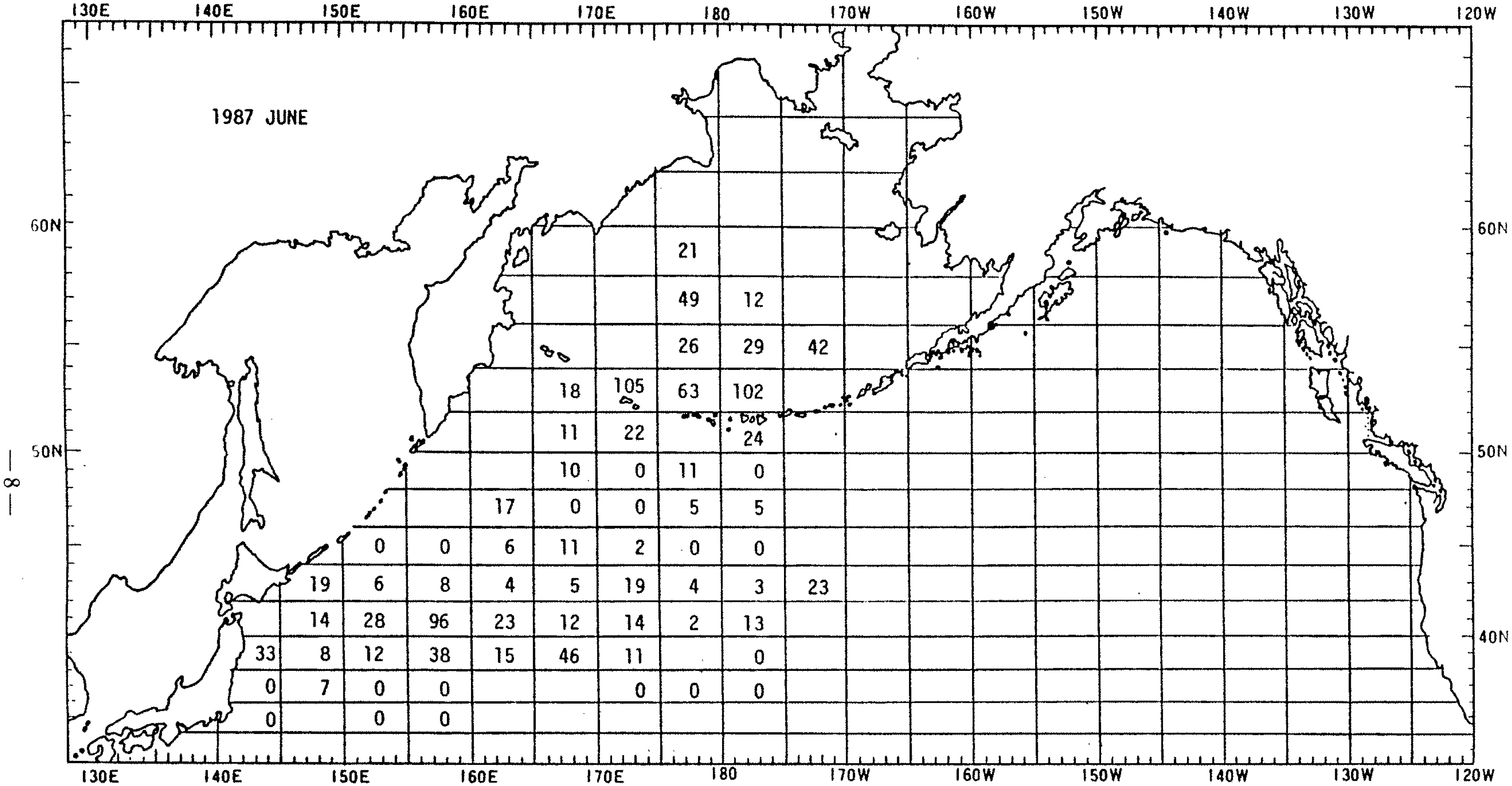

Fig. 1-1. Number of Dall's porpoise schools sighted per 1,000 miles of research vessels in June, 1987.

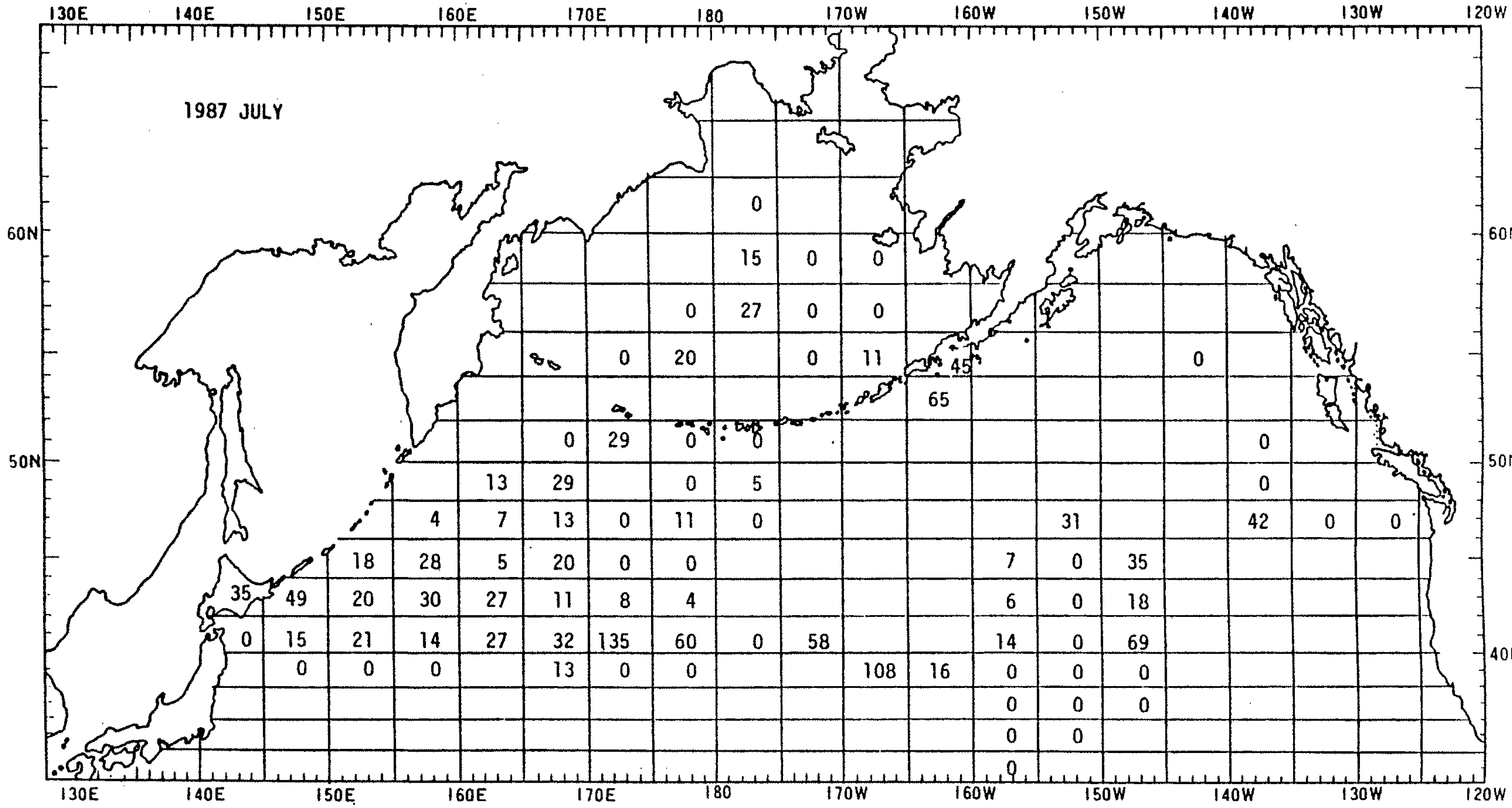

Fig. 1-2. Number of Dall's porpoise schools sighted per 1,000 miles of research vessels in July, 1987.

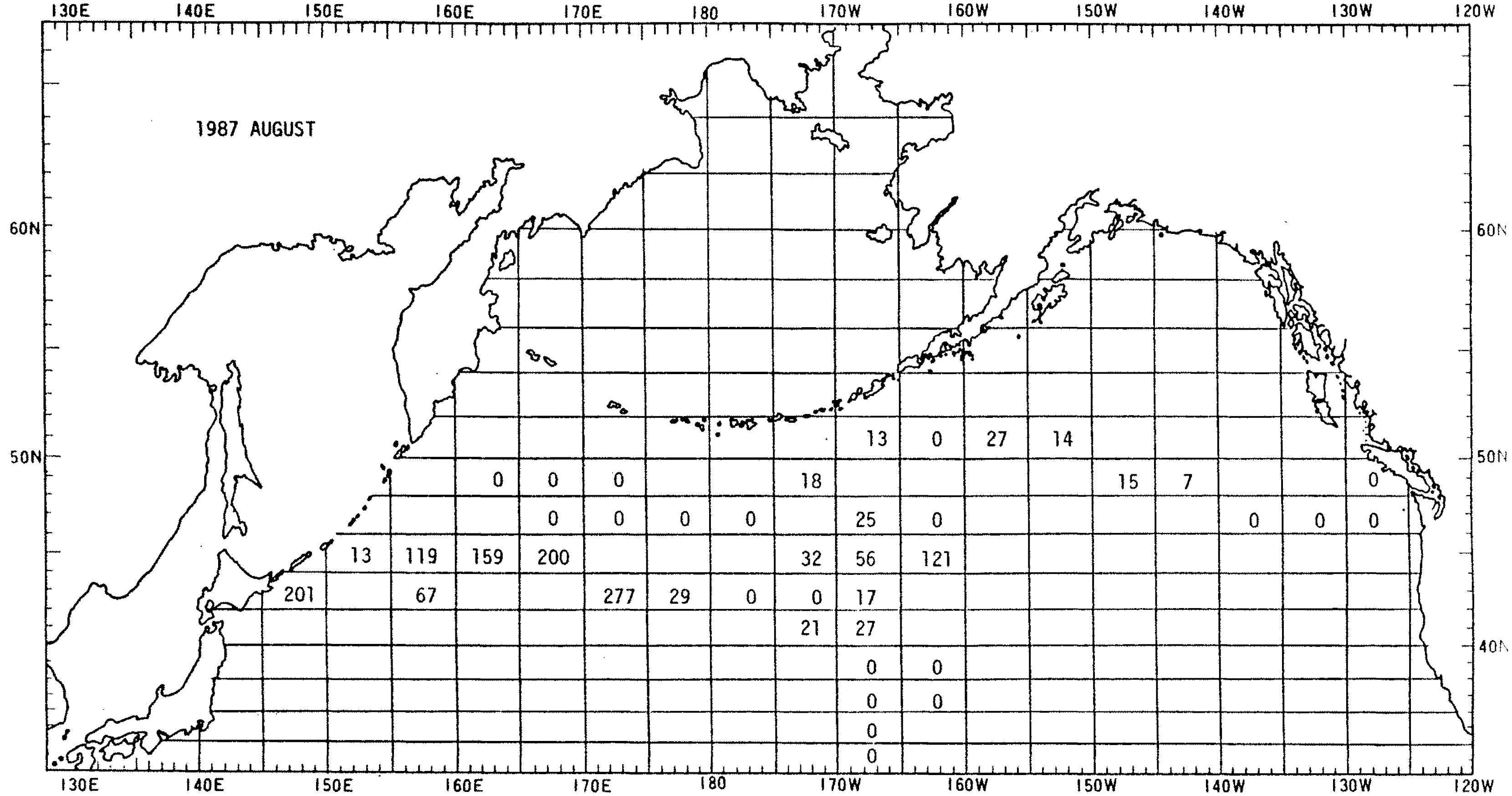

Fig. 1-3. Number of Dall's porpoise schools sighted per 1,000 miles of research vessels in August, 1987.

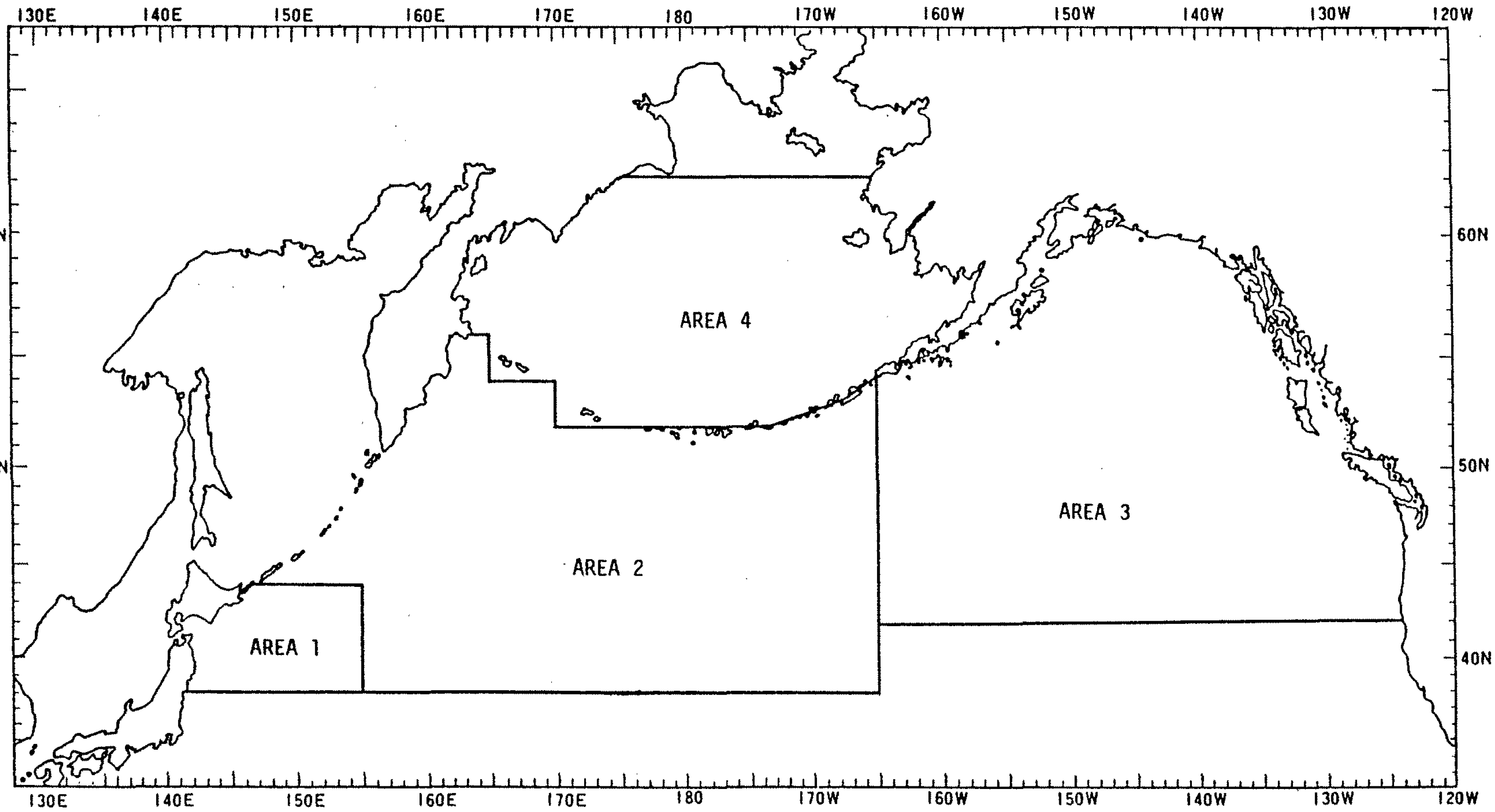

Fig. 2. Areas for abundance estimation of Dall's porpoise.

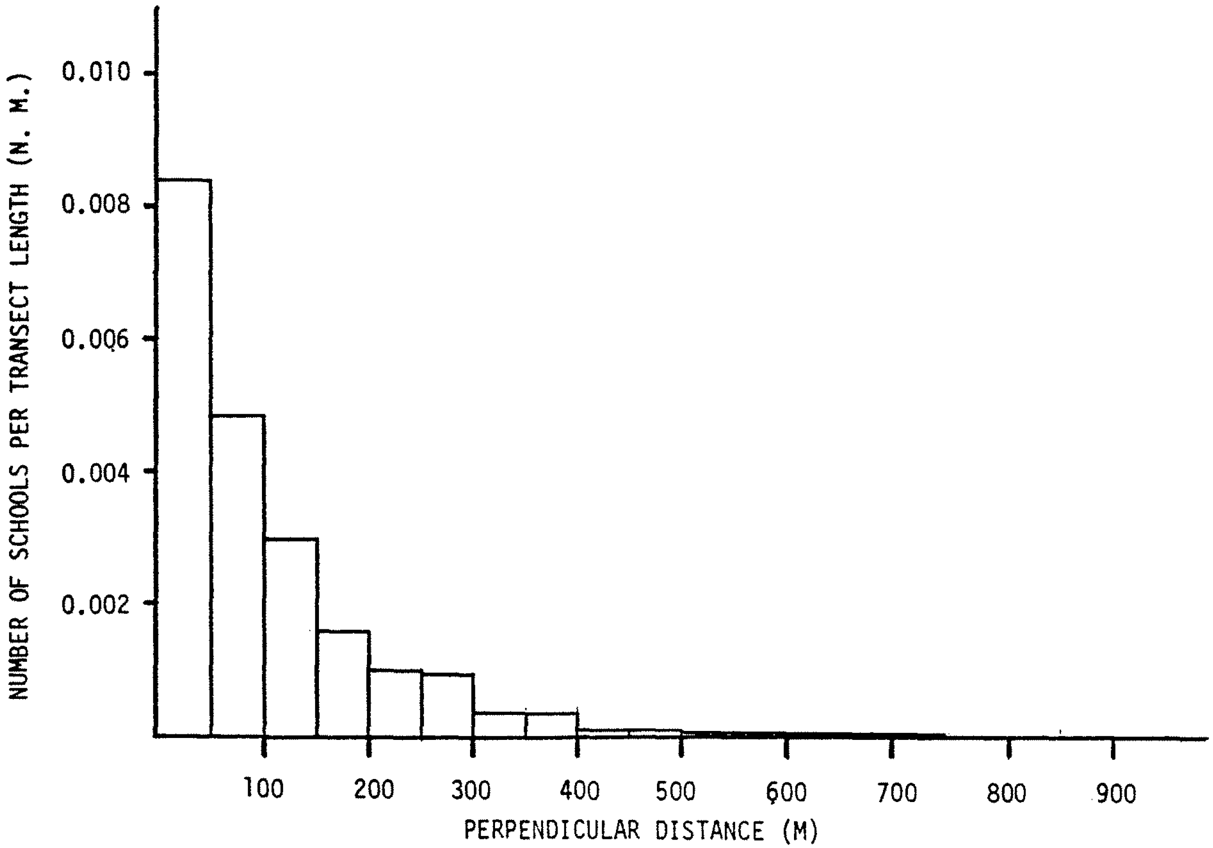

Fig. 3. Relation between number of Dall's porpoise schools per transect length (nautical mile) and perpendicular distance (m) sighted in Area 2 in sea condition of Beaufort 0-3, 1980-1987 pooled data.

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TRANSLATION

OUTLINE OF SIGHTING SURVEY FOR MARINE MAMMALS BY JAPANESE SALMON RESEARCH VESSELS IN 1987 AND ESTIMATION OF DALL'S PORPOISE ABUNDANCE IN THE NORTH PACIFIC OCEAN

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Summary

A total of 10 Japanese research vessels conducted a marine mammal sighting survey focusing mainly on Dall's porpoise from June 1 to August 23, 1987, in waters of the northern North Pacific and Bering Sea ranging from 21° to 60°N and 141°E to 125°W. Nine salmon research vessels and the _Shoyo maru_ cruised over a distance of 35,775 nmi and 2,243 individual Dall's porpoise in 644 schools, and other marine mammals as follows were sighted (figures in parentheses are numbers of schools sighted for the respective species): Pacific whitesided dolphins (34), northern right whale dolphins (7), killer whales (10), common dolphins (14), northern fur seals (166), etc.

Based on sighting data obtained by salmon research vessels and the _Shoyo maru_ for sea conditions of 0 to 3 on the Beaufort scale during the periods from June to August of 1980 to 1987, the abundance of Dall's porpoise was estimated using the Fourier series estimator and negative exponential estimator. The abundances of _truei_ type Dall's porpoise, _dalli_ type in the northwestern North Pacific, _dalli_ type in the northeastern North Pacific, and _dalli_ type in the Bering Sea were estimated to be 133 to 135 x 10^3, 826 to 874 x 10^3, 992 to 1,175 x 10^3, and 367 to 437 x 10^3 individuals, respectively.

Introduction

During the ten years from 1978, Japanese salmon research vessels and vessels dedicated to research on Dall's porpoise have conducted marine mammal sighting surveys in the North Pacific with the object of estimating and monitoring the abundance of marine mammals, particularly Dall's porpoise. The present report describes the 1987 sighting survey and results of the abundance estimation for Dall's porpoise based on the sighting data obtained from the surveys conducted until 1987. The data collected by the Hoyo maru No. 12 which made the research cruise with the major object of capturing Dall's porpoise were not included in this study. A detailed report for the cruise of the Hoyo maru No. 12, the vessel dedicated for Dall's porpoise research, is given by Yoshioka et al. (1988).

Outline of sighting survey in 1987

In 1987, nine salmon research vessels and the Shoyo maru conducted marine mammal sighting surveys in the northwestern North Pacific, Bering Sea, and northeastern North Pacific including the Gulf of Alaska from June 1 to August 23. Ten vessels conducted surveys in the northwestern North Pacific, two in the Bering Sea, and two in the northeastern North Pacific. The areas in which the surveys were conducted ranged over 21° to 60°N and 141°E to 125°W (Table 1).

The particulars for the 1987 sighting survey were identical to those reported by Kato (1983). Crew members were engaged in the sighting surveys on the salmon research vessels and the Shoyo maru.

The sighting survey in 1987 commenced on June 1 and was completed on August 23. The total distance cruised in which sighting was conducted was 35,775 nmi over a total of 416 days. The distance cruised was 30,044 nmi in the North Pacific west of 165°W, 7,475 nmi in the North Pacific east of 165°W, and 2,809 nmi in the Bering Sea. The total number of Dall's porpoise sighted was 2,243 individuals in 644 schools. Of the Dall's porpoise sighted, dalli type accounted for 1,705 individuals (76.0%) in 479 schools, truei type 66 individuals (2.9%) in 21 schools, and unidentified Dall's porpoise 472 individuals (21.1%) in 144 schools. In addition, 34 schools of Pacific whitesided dolphin, seven schools of northern right whale dolphin, ten schools of killer whales, 14 schools of common dolphin, 166 schools of northern fur seals, etc. were sighted.

The number of schools sighted per 1,000 nmi cruising distance for the 1987 survey conducted by the salmon research vessels and the *Shoyo maru* is shown by month (June to August) by 2°x5° area in Figs. 1-1 to 1-3.

June: The number of schools sighted by 2°x5° area was largest (11 to 105) for the areas in the central Bering Sea and Aleutian Islands regions north of 50°N, relatively large (8 to 96) in the northwestern North Pacific between 38° and 42°N, west of 170°E, and small (0 to 19) in the northwestern North Pacific between 42° and 50°N, west of 175°W.

July: The number of schools sighted by 2°x5° area was relatively large (0 to 49) for the areas in the northwestern North Pacific between 40° and 46°N, west of 170°E and small (0 to 29) in the northwestern North Pacific between 46° and 52°N, west of 180°. Some areas in the Bering Sea and northeastern North Pacific show large numbers of school sighted.

August: The number of schools sighted by 2°x5° area was quite large (0 to 201) for the areas in the North Pacific between 42° and 46°N. In addition, 21 and 27 schools were sighted in two areas between 40° and 42°N, 175° and 165°W.

There was difficulty in determining the spatio-temporal migration of Dall's porpoise because of the inadequacy in sighting effort considering the area of Dall's porpoise distribution. Dall's porpoise were sighted in waters of the northeastern North Pacific between 38° and 40°N, and 170° and 160°W in July and August. This indicates that Dall's porpoise are distributed in areas of relatively low latitudes even in July and August.

Estimation of abundance of Dall's porpoise

The number of Dall's porpoise sighted was recorded by each of three categories: *dalli* type, *truei* type, and unidentified Dall's porpoise. The data for all the three categories were used in the estimation of abundance.

For estimation of abundance of high accuracy it is desirable to use sighting data which are obtained from surveys conducted over large areas for a short period. However, the periods of surveys by the salmon research vessels were rather long, extending from April to August and areas in which the surveys were conducted were limited according to month in some years. In addition, survey areas varied between years. In order to offset these deficiencies, the estimations of abundance have been based on data which were pooled for a number of years. In the present report, the sighting data collected from June to August of 1980 to 1987 were pooled and used for the abundance estimation. Sighting data obtained by the dedicated vessel were excluded from the estimation since these data were judged not to be in the same category as those from salmon research vessels because of differences in the survey mode including positions on the vessels from which sightings were made and whether or not the Dall's porpoise sighted were chased by the vessel.

Area divisions are identical to those noted by Kato (1987a).

Area 1	Northwestern North Pacific Ocean, 38° to 44°N, west of 155°E (197 x 10^3 nmi^2)
Area 2	North Pacific Ocean north of 38°N west of 165°W, excluding Area 1 (1,521 x 10^3 nmi^2)
Area 3	North Pacific Ocean north of 42°N, east of 165°W (1,561 x 10^3 nmi^2)

Area 4 Bering Sea south of 62°N (567 x 10^3 nmi^2)

Kato (1986) divided sea conditions into two categories: Category A (Beaufort scale 0 to 3) and B (4 to 7), and indicated that the abundance was underestimated from data obtained under sea condition Category B.

As a matter of course, the abundance will also be an underestimate when based on data collected under all sea conditions combined (Beaufort scale 0 to 7). Therefore, in the present report, estimation of abundance was made using only sighting data for sea condition Category A. Figure 3 shows the relation between perpendicular distance (m) from the vessel and number of Dall's porpoise schools per 1 nmi of transect length cruising distance. The figure shows that the number of schools sighted at perpendicular distances over 500 m amounted to an extremely small percentage of the total number of schools sighted.

In estimating abundance, it is important to employ an estimator which adequately fits the sighting data. Using the sighting data, the fitness of both the Fourier series estimator and the negative exponential estimator was tested by area. It was determined that the sighting data fit well both estimators at the 95% level of significance. Therefore, both estimators (Kato 1987b) were employed in the estimation of abundance.

Estimates of abundance

The results of estimation of abundance are shown in Table 2. The cruising distance and number of schools sighted which were used in the estimation are 30,199 nmi and 786 schools for Area 1, 87,263 nmi, and 1,829 schools for Area 2, 8,657 nmi and 246 schools for Area 3, and 13,227 nmi and 296 schools for Area 4.

Abundance estimation by Fourier series estimator

Individual density of Dall's porpoise (individuals/nmi^2) was 0.69, 0.54, 0.64, and 0.65 in Areas 1, 2, 3, and 4, respectively.

The abundance was estimated to be 135 x 10^3 individuals (95% confidence interval: 103 to 167 x 10^3 in Area 1, 826 x 10^3 individuals (662 to 990 x 10^3) in Area 2, 992 x 10^3 individuals (190 to 1,794 x 10^3) in Area 3, and 367 x 10^3 individuals (275 to 459 x 10^3) in Area 4, totalling 2,319 x 10^3 individuals (1,230 to 3,410 x 10^3).

Abundance estimation by negative exponential estimator

Individual density of Dall's porpoise was 0.68, 0.57, 0.75, and 0.77 individuals/nmi^2 in Areas 1, 2, 3, and 4, respectively.

The abundance was estimated to be 133 x 10^3 individuals (100 to 167 x 10^3) in Area 1, 874 x 10^3 individuals (759 to 990 x 10^3) in Area 2, 1,175 x 10^3 individuals (221 to 2,129 x 10^3) in Area 3, and 437 x 10^3 individuals (80 to 793 x 10^3) in Area 4, totalling 2,619 x 10^3 (1,160 to 4,079 x 10^3).

The abundance of Dall's porpoise in Area 1 which consists mainly of truei type was estimated to be 133 to 135 x 10^3 individuals. The abundances for Areas 2, 3 and 4 which represent those of dalli type in the northwestern North Pacific, northeastern North Pacific, and Bering Sea, respectively were estimated to be 826 to 874 x 10^3, 992 to 1,175 x 10^3, and 367 to 437 x 10^3 individuals, respectively.

While there were no differences in the estimates of abundance for Areas 1 and 2 between the types of the estimators, there were some differences in Areas 3 and 4 (considering values from the negative exponential estimator as 1, the values from the Fourier series estimator are 0.84 for both areas). It is possible that these differences were caused by a number of factors. One factor is the difference in amount of data among areas: while the estimates of abundance for Areas 1 and 2 employ a fairly large database (786 and 1,829 schools, respectively), those for Areas 3 and 4 are based on relatively small amounts of data (246 and 296 schools, respectively).

It is considered that further accumulation of sighting data for Areas 3 and 4 will be useful in reducing the difference in estimates of abundance between the estimators and thus will enable us to make abundance estimates of still higher accuracy.

REFERENCES, TABLES 1 AND 2, AND FIGS. 1 TO 3
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