Preliminary Report of a Squid Subsurface Driftnet Experiment in the North Pacific During 1991

by

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I. ABSTRACT

An experiment utilizing six Japanese commercial squid driftnet vessels was conducted in the North Pacific during June- August 1991 to test for differences in catch and bycatch rates (CPUEs) of surface and subsurface driftnets (set 2 m below the sea surface). The ratio of subsurface CPUE to surface CPUE by vessel indicated that the subsurface net substantially reduced CPUEs for flying squid, Pacific pomfret and seabirds; but the ratio varied considerably among vessels for northern fur seal, small cetaceans and sea turtles. Result of the Wilcoxon two-sided signed rank tests indicated that 1) the subsurface driftnet reduced CPUEs for flying squid, Pacific pomfret and seabirds (dark shearwaters) significantly ($P < 0.01$), but 2) no differences in CPUE for northern fur seal, small cetaceans and sea turtles ($P > 0.05$).

II. INTRODUCTION

The Japanese driftnet fishery for flying squid, *Ommastrephes bartrami*, operating in the North Pacific since 1978, has made recent annual catches fluctuating between 123,719 and 215,788 metric tons (Yatsu 1990). High seas driftnet fisheries have created international controversy, mainly because of the incidental takes (bycatch) of salmonids, marine mammals, seabirds, turtles and non-target fish species. A rational management of this fishery requires evaluating the impact of driftnets on bycatch animals and avoiding the adverse effects on non-target species without substantially reducing the catch of target species.

According to some past experiments, the use of subsurface driftnets was effective in reducing the incidental takes of small cetaceans and seabirds (Hembree and Harwood 1987; Todd and Nelson 1990; Hayase 1990). The Fisheries Agency of Japan (FAJ) conducted fishing experiments using subsurface nets since 1989. Although experiments during 1989-90 indicated a reduction in CPUE of seabirds, results were inconclusive for small cetaceans due to the lack of sufficient data.

During May-August 1991, FAJ organized a subsurface driftnet fishing experiment using commercial squid driftnet vessels with scientific observers on board to collect data based on the experimental design developed from the prior understandings among scientists of Canada, Japan and the United States (Simon 1991). The experiment in 1991 was designed to test for differences in CPUEs in the commercial squid driftnet fishery between surface and subsurface driftnets. In this report we present results based on the data from the 1991 observation program. Further analyses will be done by scientists of the three countries using the data to be finalized in the near future.

III. MATERIALS AND METHODS

1. Driftnets Used

Table 1 and Fig. 1 show the specifications of driftnets used in the study. Details of these nets differed by vessel, but the surface and subsurface nets had exactly the same design within a vessel except 1) subsurface driftnet was set 2 m below the sea surface and 2) 1 m difference in net depth for *Keiryou maru No. 25*.

In an experiment in 1990 (Hayase 1990), the number and diameter of hanging lines varied among vessels but the interval between hanging lines was about 1 m. According to the observers who engaged in the 1990 experiment, the numerous hanging lines frequently caused entanglements of lines with the netting when setting the net. We believe, however, these troubles did not affect the catch rates of animals. The fishermen found that handling of the subsurface net was more difficult than that of the surface net. To mitigate the difficulty, the distance between hanging lines was increased to 10 m during the 1990 *Shoyo maru* survey and this was found effective in reducing entanglement of the hanging lines with the netting (Yatsu *et al.* 1991b).

Table 1. Design specifications of surface and subsurface driftnets used by six squid driftnet vessels in the North Pacific during 1991. Major value in each specification is shown in parenthesis.

NAME OF VESSEL		*Keiryou #25*	*Ryoukai #55*	*Ryuhou #25*	*Ibaragi*	*Eihou #61*	*Tatsumi #1*
Area	Latitude	38°-43°N	38°-43°N	39°-45°N	39d-43°N	39°-45°N	39°-45°N
	Longitude	153°-165°W	153°-165°W	151°-166°W	149°-158°W	174°E-147°W	155°-176°W
Period		1 June-25 July	1 June-28 July	1 June-3 Aug.	6 June-4 July	31 May-13 Aug.[1]	13 June-17 Aug.
No. of operations		50	55	52	25	50	48
Tan length (m)							
	Surface	52	48	50	49	42	47
	Subsurface	52	48	50	49	42	47
Mesh size (mm)							
	Surface	115	115	114	115	115	114
	Subsurface	115	115	114	115	115	114
Net depth (m)							
	Surface	11	11	11	12	10	11
	Subsurface	10	11	11	12	10	11
No. of tans per section (raw)							
	Surface	135	140	100	100	160-170(170)[2]	100-170(130)
	Subsurface	135	140	90-100(90)	100	35-165[3]	100-170(130)
No. of tans per section (50m)							
	Surface	140.4	134.4	100	98	134-143(143)	94-160(122)
	Subsurface	140.4	134.4	90-100(90)	98	29-139	94-160(122)
Observed sections							
	Surface	2-3(3)	3	2-4(4)	4	2-4(3)	2-3(3)
	Subsurface	2-3(3)	3	2-4(4)	4	2-4(3)	2-3(3)
Total observed tans (50m)							
	Surface	19,375	22,176	19,800	9,702	19,887	16,904
	Subsurface	19,375	22,176	18,320	9,702	16,463	17,127
No. of floats on mid-line							
	Subsurface	10	0	0	0	0	18

[1] Data from one operation conducted by *Eihou # 61* on 31 May are included in this table.
[2] Six to 70 tans of surface nets were linked with subsurface nets in some net sections, and these additional surface nets were included in this table.
[3] Usually, 110 to 160 tans of subsurface net were used alternately in a section.

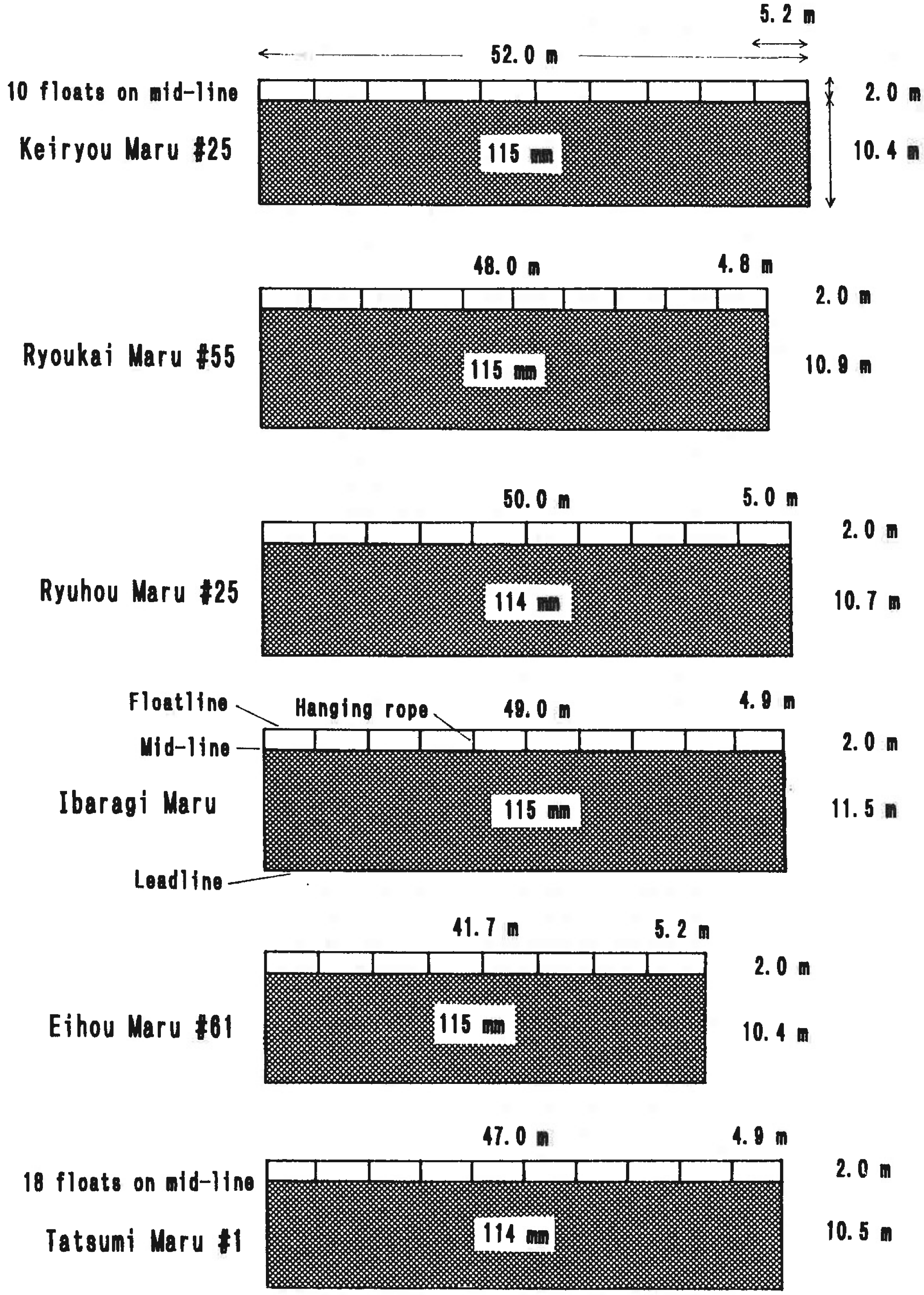

Fig. 1. Design criteria for one tan of subsurface driftnet fished from six Japanese squid driftnet vessels in 1991.

In the present experiment, the interval between hanging lines was set at 5 m complying with the wishes of six fishing masters. This enabled keeping the subsurface net more evenly suspended in the water and handling the subsurface net more smoothly. Ten and 18 floats per tan were attached to the line running along the top of the netting (mid-line) in *Keiryou maru No. 25* and *Tatsumi maru No. 1*), respectively.

2. Vessels and Data Collection

The experiment was carried out by six Japanese commercial squid driftnet vessels. Two Japanese, two U.S. and two Canadian scientific observers were on board the vessels and collected data on fishing effort, catch (number of animals decked for fishes and squids or number of animals entangled for cetaceans, seabirds and turtles), fishing methods and environmental factors according to common procedures (cf. INPFC 1991).

We planned to collect data from 250 fishing operations consisting of 400 tans each (standardized at 50 m in length) of surface and subsurface nets deployed simultaneously per operation (Simon 1991). Usually each vessel divided about 400 tans of each type of net into 3 or 4 net sections, and deployed them alternately to avoid differences in soaking time. This procedure was fully performed by five vessels, but in the case of the *Eihou maru No. 61*, the number of tans in each section changed in later fishing operations due to damage of the subsurface net (see Table 1).

3. Research Area and Time Period

The experimental fishing operations were conducted in the Japanese squid driftnet fishing grounds from May to August, 1991 (Fig. 2). Each fishing location was determined by the fishing master as on a commercial driftnet vessel operation. Most of the operations in May were intended to familiarize the fishermen with the handling of subsurface nets by using only one or two net sections per operation, i.e., not a part of the designed experiment. Thus, we did not use the data collected in May for the analysis except for an operation conducted by the *Eihou maru No. 61* on May 31, which followed the designed procedures.

4. Data Analysis

Catch-per-unit-effort (CPUE, number per 1,000 tans where a tan was standardized at 50 m in length) was calculated for major groups of animals for each fishing operation for the two types of net. Wilcoxon two-sided signed rank tests (Campbell 1967) were applied to detect the differences in CPUEs for major species between the two types of net under a null hypothesis (H_0): no difference in CPUE.

IV. RESULTS

Table 2 shows fishing effort, catch, and CPUEs for the six major groups of animals by vessel and by type of net. Flying squid dominated in the catch followed by Pacific pomfret, *Brama japonica*, for both the surface and subsurface nets. For most fishing operations, CPUEs of flying squid and Pacific pomfret were higher in the surface net than in the subsurface net (Table 2 and Figs. 3 and 4). The overall CPUE of flying squid by vessel for subsurface net was 53-82% (64% on average) of that for surface net and the CPUE of Pacific pomfret was 30-70% (49% on average).

A total of 535 seabirds was entangled by the surface net, whereas 136 individuals were entangled by the subsurface net during 280 operations observed. The overall ratio of subsurface CPUE to surface CPUE by vessel for seabirds was 17-36% (27% on average) (Table 2). The overall CPUE of seabirds by vessel and by type of net is shown in Fig. 5. Dead individuals comprised more than 90% of total seabird entanglements by both nets. Although species identifications have not been verified, unidentified dark shearwaters (Sooty Shearwater, *Puffinus griseus*, and Short-tailed Shearwater, *Puffinus tenuirostris*) comprised about 91% for surface net and 84% for subsurface net of the total seabird entanglements, followed by Black-footed Albatross, *Diomedea nigripes*, and Laysan Albatross, *Diomedea immutabilis* (Table 3). The CPUE of three major species of seabirds by vessel and by type of net is shown in Fig. 6.

A total of 14 northern fur seals, *Callorhinus ursinus* (including 8 alive) was entangled by the surface net, whereas 17 individuals (including 5 alive) were entangled by the subsurface net during the 280 operations observed (Table 2). The CPUE of northern fur seals by vessel and by type of net is shown in Fig. 5.

A total of 79 small cetaceans was entangled by the surface net, whereas 61 individuals were entangled by the subsurface net during the 280 operations observed (Table 2). Dead individuals comprised more than 95% of small cetacean entanglements by both nets. The species included Dall's porpoise, *Phocoenoides dalli*, northern right whale dolphin, *Lissodelphis borealis*, Pacific white-sided dolphin, *Lagenorhynchus obliquidens*, and others (common dolphin *Delphinus delphis*; *Kogia* sp.; Cuvier's beaked whale, *Ziphius cavirostris*; *Mesoplodon* spp., and unidentified small whale) (Table 4).

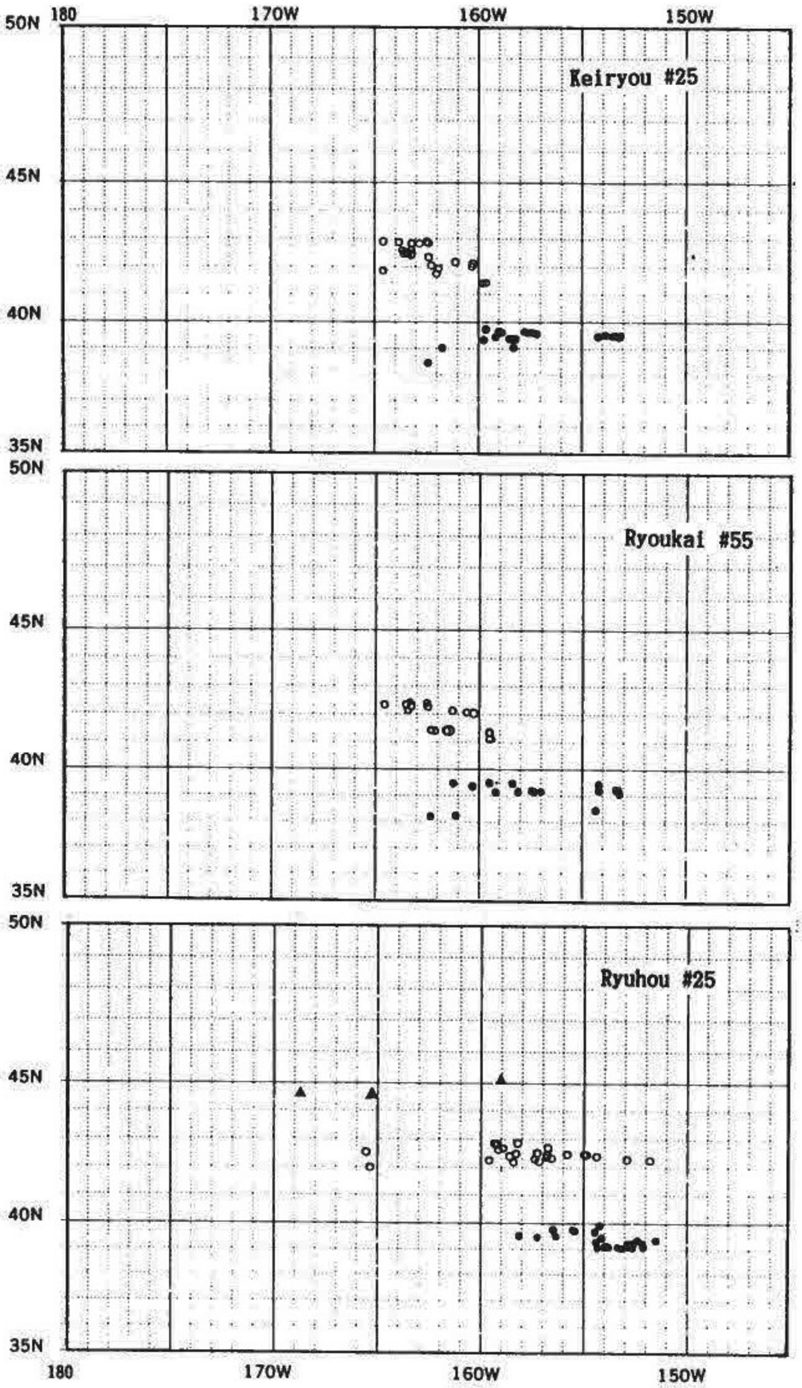

Fig. 2. Locations of fishing operations by six Japanese squid driftnet vessels in 1991, practice operations excluded.
△: May, ●: June, ○: July, ▲: August

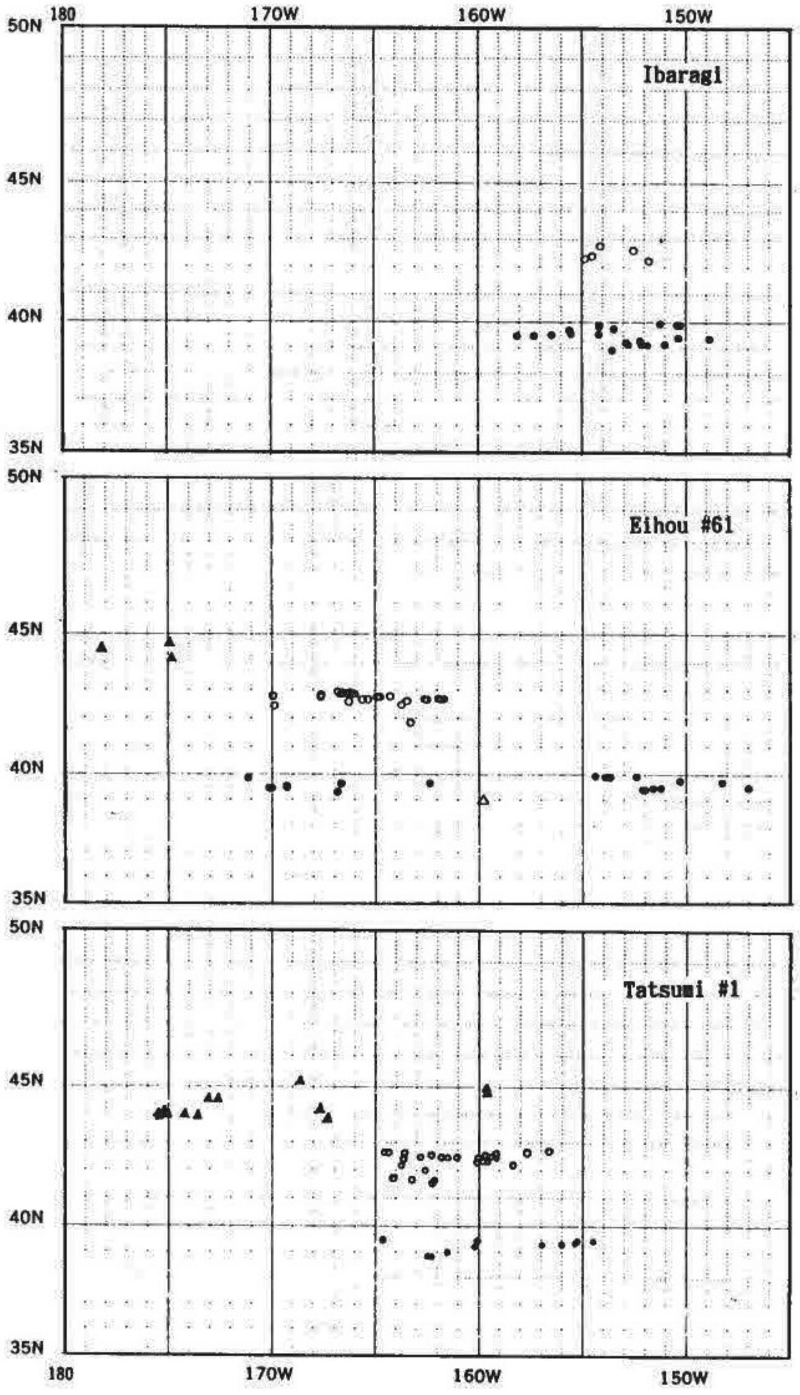

Fig. 2. Continued.
▵: May, ●: June, ○: July, ▴: August

Table 2. Comparison of observed tans (standardized at 50 m in length), catch in numbers and CPUE (No./1000 tans) of six major groups of animals taken in the subsurface driftnet experiment in the North Pacific during 1991.

NAME OF VESSEL	*Keiryou #25*	*Ryoukai #55*	*Ryuhou #25*	*Ibaragi*	*Eihou #61*	*Tatsumi #1*	*Pooled*
Observed tans (Surface)	19,375	22,176	19,800	9,702	19,887	16,904	107,844
Observed tans (Subsurface)	19,375	22,176	18,320	9,702	16,463	17,127	103,163
Subsurface/Surface Ratio in tan (%)	100	100	93	100	83	101	96
Flying squid							
Catch (Surface)	33,837	46,046	39,290	15,923	52,522	48,061	235,679
Catch (Subsurface)	19,671	26,992	22,937	12,371	22,900	39,917	144,788
CPUE (Surface)	1,746.4	2,076.4	1,984.3	1,641.2	2,641.0	2,843.2	2,185.4
CPUE (Subsurface)	1,015.3	1,217.2	1,252.0	1,275.1	1,391.0	2,330.6	1,403.5
Subsurface/Surface Ratio in CPUE (%)	58	59	63	78	53	82	64
Pacific pomfret							
Catch (Surface)	8,146	7,755	4,113	422	10,822	10,394	41,652
Catch (Subsurface)	4,234	3,093	1,126	154	3,584	7,410	19,601
CPUE (Surface)	420.4	349.7	207.7	43.5	544.2	614.9	386.2
CPUE (Subsurface)	218.5	139.5	61.5	15.9	217.7	432.7	190.0
Subsurface/Surface Ratio in CPUE (%)	52	40	30	36	40	70	49
Seabirds							
Catch (Surface)	132	96	33	22	140	112	535
Catch (Subsurface)	47	25	10	8	20	26	136
CPUE (Surface)	6.81	4.33	1.67	2.27	7.04	6.63	4.96
CPUE (Subsurface)	2.43	1.13	0.55	0.82	1.21	1.52	1.32
Subsurface/Surface Ratio in CPUE (%)	36	26	33	36	17	23	27
Northern fur seal							
Catch (Surface)	4	1	1	0	3	5	14
Catch (Subsurface)	8	2	0	0	5	2	17
CPUE (Surface)	0.21	0.05	0.05	0.00	0.15	0.30	0.13
CPUE (Subsurface)	0.41	0.09	0.00	0.00	0.30	0.12	0.16
Subsurface/Surface Ratio in CPUE (%)	200	200	0	n.a.	201	39	127
Small cetaceans							
Catch (Surface)	12	9	16	4	21	17	79
Catch (Subsurface)	5	13	19	2	5	17	61
CPUE (Surface)	0.62	0.41	0.81	0.41	1.06	1.01	0.73
CPUE (Subsurface)	0.26	0.59	1.04	0.21	0.30	0.99	0.59
Subsurface/Surface Ratio in CPUE (%)	42	144	128	50	29	99	81
Sea turtles							
Catch (Surface)	0	1	5	6	3	0	15
Catch (Subsurface)	0	0	0	3	2	0	5
CPUE (Surface)	0.00	0.05	0.25	0.62	0.15	0.00	0.14
CPUE (Subsurface)	0.00	0.00	0.00	0.31	0.12	0.00	0.05
Subsurface/Surface Ratio in CPUE (%)	n.a.	0	0	50	81	n.a.	35

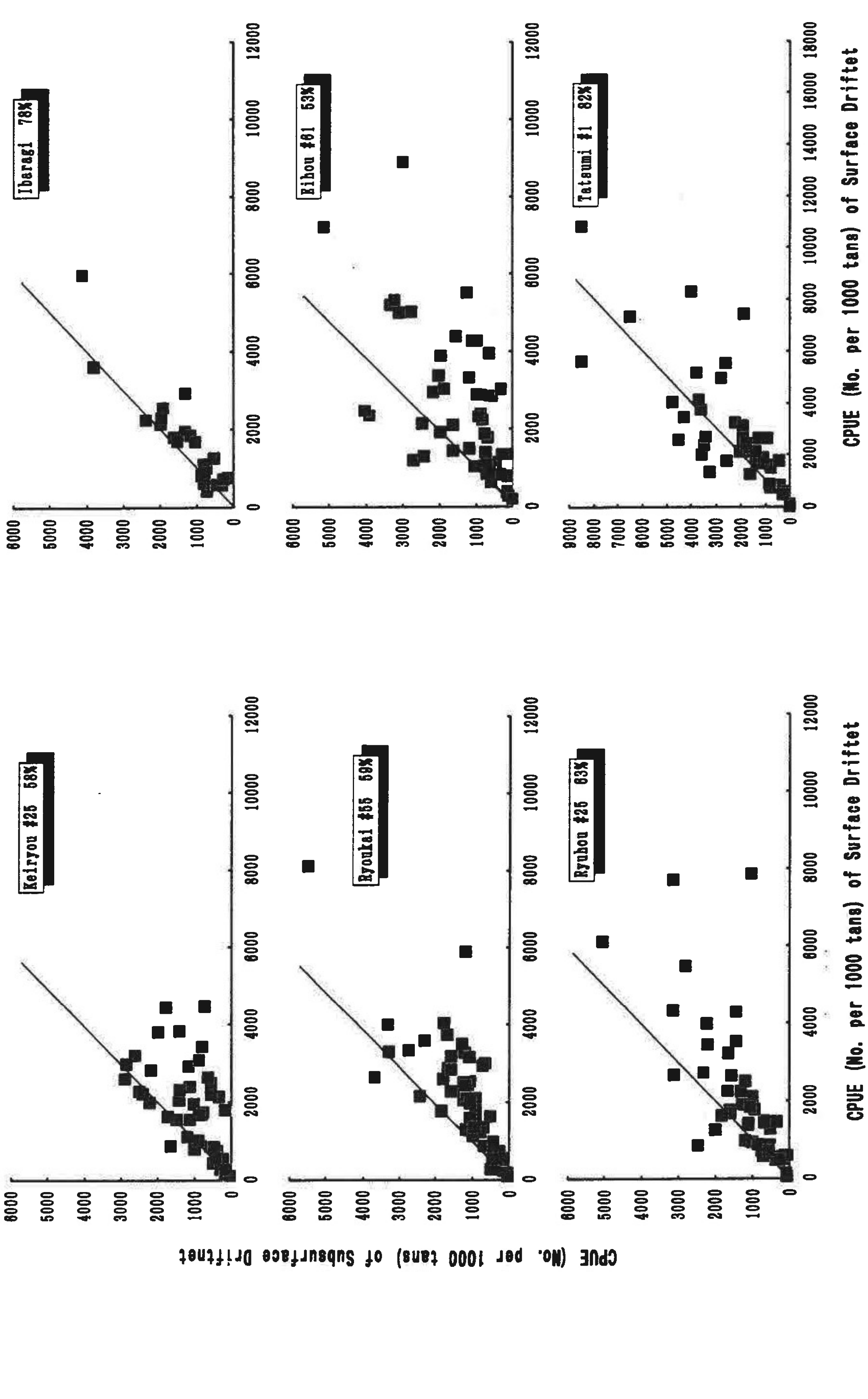

Fig. 3. Flying squid CPUE (No./1000 tans) per operation by surface and subsurface driftnets for six Japanese squid driftnet vessels. Pooled subsurface/surface ratio of CPUE is shown for each vessel.

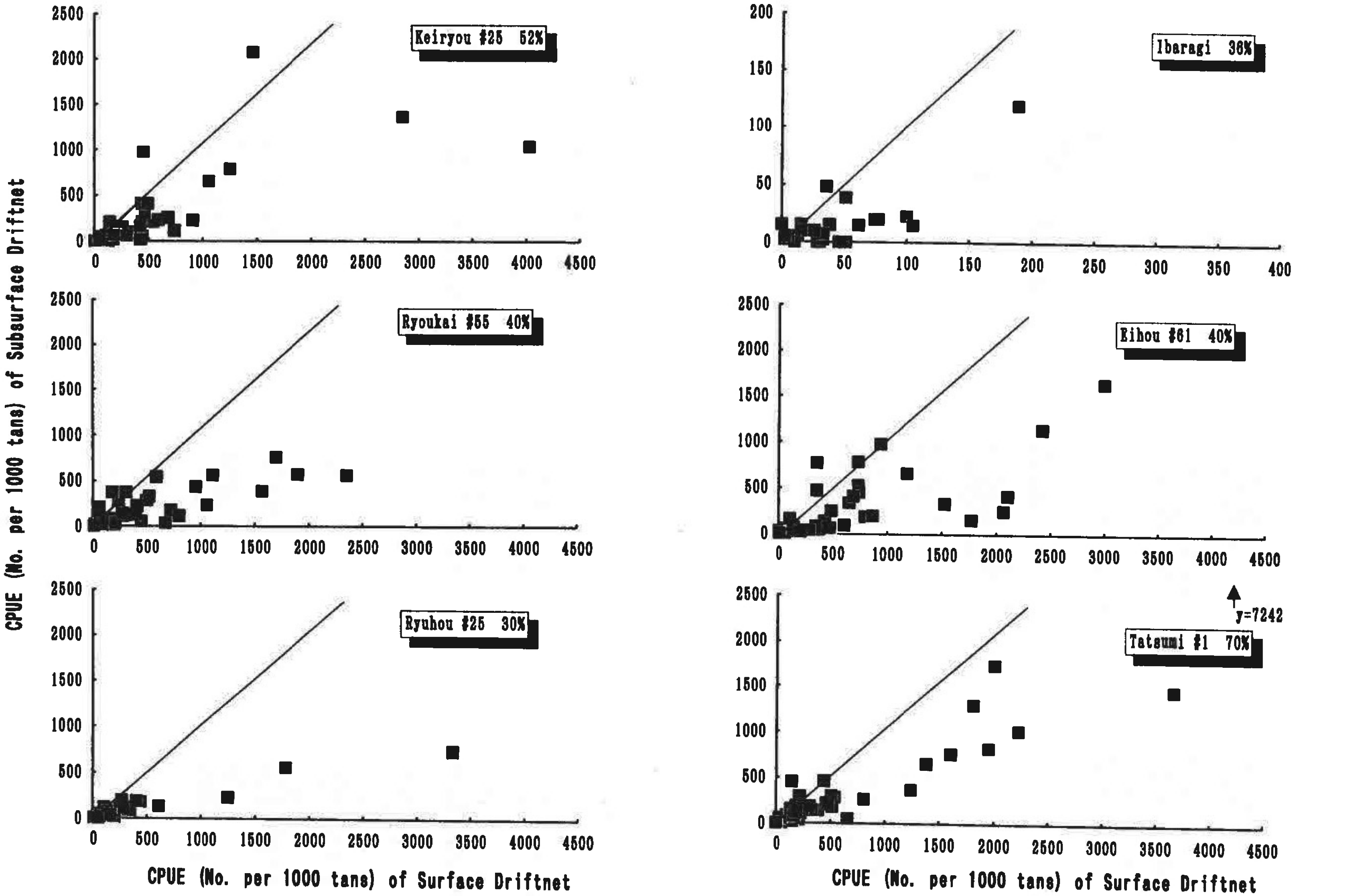

Fig. 4. Pacific pomfret CPUE (No./1000 tans) per operation by surface and subsurface driftnets for six Japanese squid driftnet vessels. Pooled subsurface/surface ratio of CPUE is shown for each vessel.

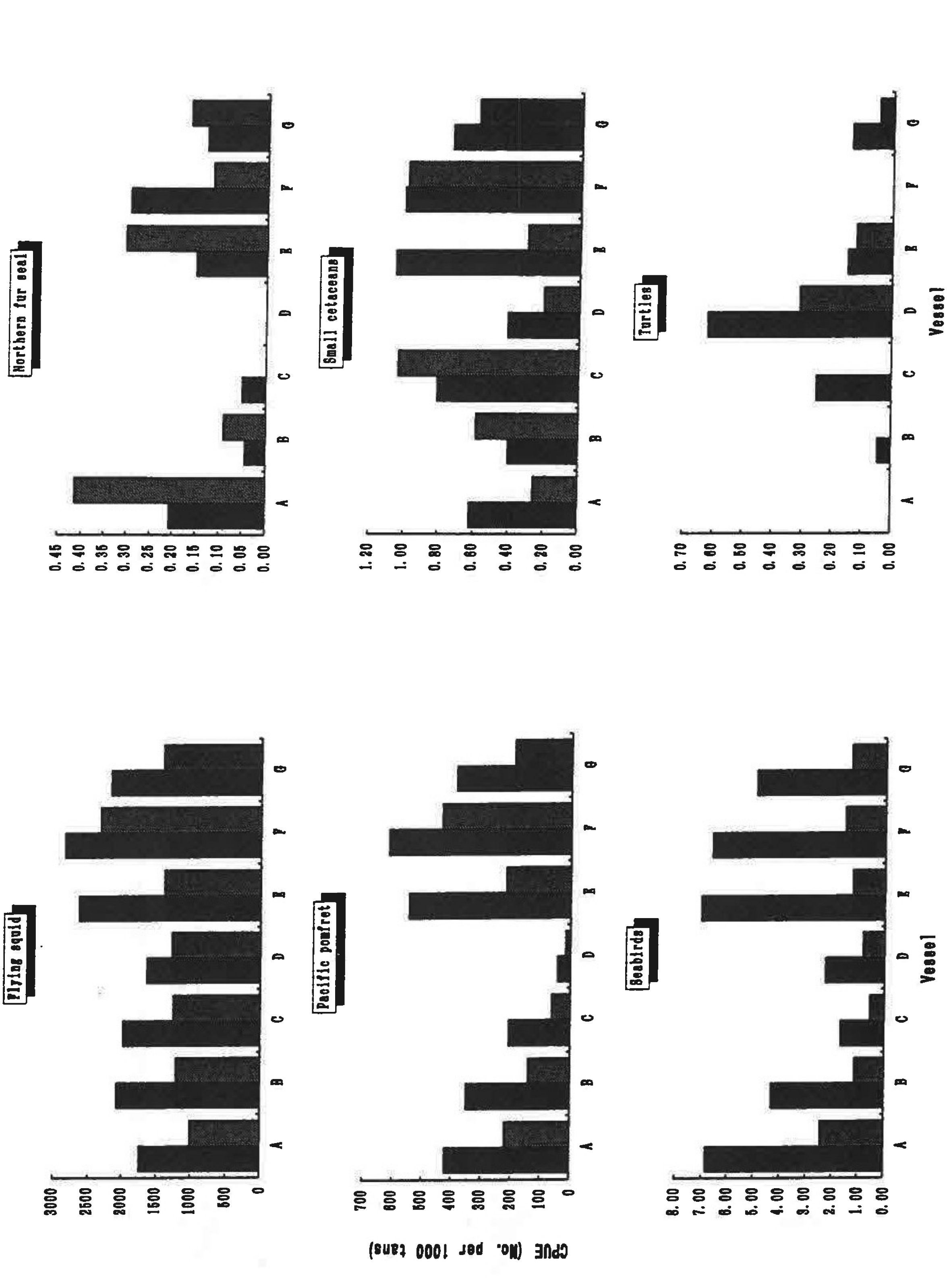

Fig. 5. Six animal group CPUEs (No./1000 tans) caught by surface (left) and subsurface (right) driftnets by vessel. A: *Keiryou #25*, B: *Ryoukai #55*, C: *Ryuhou #25*, D: *Ibaragi*, E: *Eihou #61*, F: *Tatsumi #1*, G: Six vessels pooled.

Table 3. Comparison of catch in numbers and CPUE (No./1000 tans) of three major species of seabirds taken in the subsurface driftnet experiment in the North Pacific during 1991.

NAME OF VESSEL	*Keiryou #25*	*Ryoukai #55*	*Ryuhou #25*	*Ibaragi*	*Eihou #61*	*Tatsumi #1*	*Pooled*	%
Dark shearwaters								
Catch (Surface)	123	90	26	14	130	105	488	91
Catch (Subsurface)	36	24	8	6	18	22	114	84
CPUE (Surface)	6.35	4.06	1.31	1.44	6.54	6.21	4.53	
CPUE (Subsurface)	1.86	1.08	0.44	0.62	1.09	1.28	1.11	
Subsurface/Surface Ratio in CPUE (%)	29	27	33	43	17	21	24	
Black-footed Albatross								
Catch (Surface)	5	2	5	8	1	0	21	4
Catch (Subsurface)	9	0	2	2	1	0	14	10
CPUE (Surface)	0.26	0.09	0.25	0.82	0.05	0.00	0.19	
CPUE (Subsurface)	0.46	0.00	0.11	0.21	0.06	0.00	0.14	
Subsurface/Surface Ratio in CPUE (%)	180	0	43	25	121	n.a.	70	
Laysan Albatross								
Catch (Surface)	3	4	1	0	7	2	17	3
Catch (Subsurface)	2	1	0	0	1	3	7	5
CPUE (Surface)	0.15	0.18	0.05	0.00	0.35	0.12	0.16	
CPUE (Subsurface)	0.10	0.05	0.00	0.00	0.06	0.18	0.07	
Subsurface/Surface Ratio in CPUE (%)	67	25	0	n.a.	17	148	43	
Others								
Catch (Surface)	1	0	1	0	2	5	9	2
Catch (Subsurface)	0	0	0	0	0	1	1	1
CPUE (Surface)	0.05	0.00	0.05	0.00	0.10	0.30	0.08	
CPUE (Subsurface)	0.00	0.00	0.00	0.00	0.00	0.06	0.01	
Subsurface/Surface Ratio in CPUE (%)	0	n.a.	0	n.a.	0	20	12	

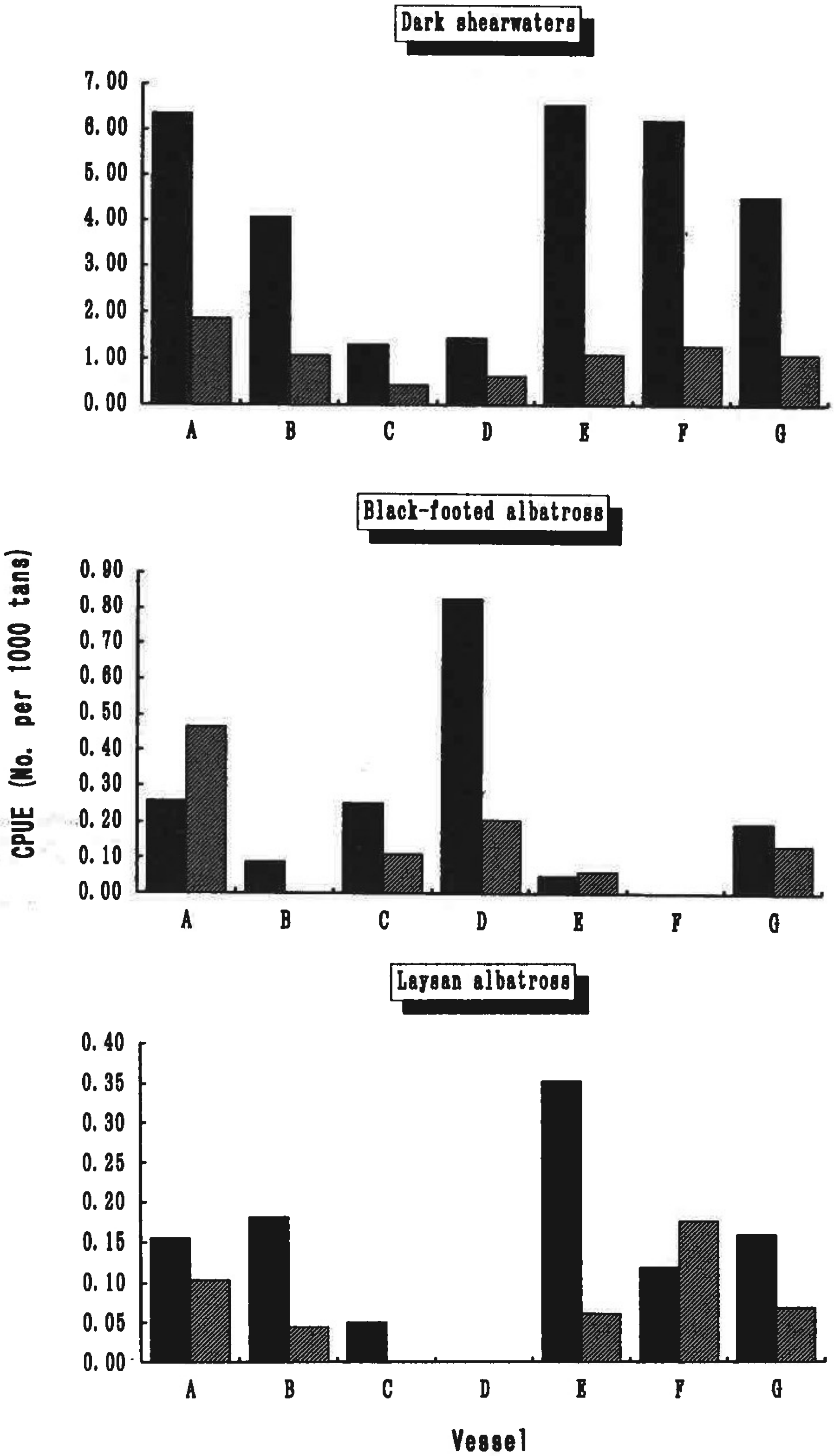

Fig. 6. CPUE (No./1000 tans) for three species of seabirds caught by surface (left) and subsurface (right) driftnets by vessel. Symbols A-G are same as Fig. 5.

Table 4. Comparison of catch in numbers and CPUE (No./1000 tans) of major species of small cetaceans taken in the subsurface driftnet experiment in the North Pacific during 1991.

NAME OF VESSEL	*Keiryou #25*	*Ryoukai #55*	*Ryuhou #25*	*Ibaragi*	*Eihou #61*	*Tatsumi #1*	*Pooled*	*%*
Dall's porpoise								
Catch (Surface)	3	2	1	0	3	3	12	15
Catch (Subsurface)	1	1	1	0	0	4	7	12
CPUE (Surface)	0.15	0.09	0.05	0.00	0.15	0.18	0.11	
CPUE (Subsurface)	0.05	0.05	0.05	0.00	0.00	0.23	0.07	
Subsurface/Surface Ratio in CPUE (%)	33	50	108	n.a.	0	133	62	
Northern right-whale dolphin								
Catch (Surface)	4	4	15	3	14	10	50	63
Catch (Subsurface)	3	12	18	1	3	10	47	77
CPUE (Surface)	0.21	0.18	0.76	0.31	0.70	0.59	0.46	
CPUE (Subsurface)	0.15	0.54	0.98	0.10	0.18	0.58	0.46	
Subsurface/Surface Ratio in CPUE (%)	75	300	130	33	26	99	98	
Pacific white-sided dolphin								
Catch (Surface)	5	2	0	0	3	3	13	17
Catch (Subsurface)	0	0	0	0	1	3	4	7
CPUE (Surface)	0.26	0.09	0.00	0.00	0.15	0.18	0.12	
CPUE (Subsurface)	0.00	0.00	0.00	0.00	0.06	0.18	0.04	
Subsurface/Surface Ratio in CPUE (%)	0	0	n.a.	n.a.	40	99	32	
Others								
Catch (Surface)	0	1	0	1	1	1	4	5
Catch (Subsurface)	1	0	0	1	1	0	3	5
CPUE (Surface)	0.00	0.05	0.00	0.10	0.05	0.06	0.04	
CPUE (Subsurface)	0.05	0.00	0.00	0.10	0.06	0.00	0.03	
Subsurface/Surface Ratio in CPUE (%)	200	0	n.a.	100	121	0	78	

The CPUEs of small cetaceans by vessel and by type of net are shown in Figs. 5 and 7. The ratio of subsurface CPUE to surface CPUE for small cetaceans varied considerably among vessels and among species (Tables 2 and 4, Figs. 5 and 7).

A total of 12 loggerhead turtles (including 10 alive), *Caretta caretta*, and three live leatherback turtles, *Dermochelys coriacea*, were entangled by the surface net; five loggerhead turtles (including three alive) were entangled by the subsurface net. The overall turtle CPUE of sub-surface net was much less than that of surface nets; however, the ratio of subsurface CPUE to surface CPUE varied considerably among vessels (Table 2, Fig. 5).

The null hypothesis was rejected for flying squid, Pacific pomfret and seabirds ($P < 0.01$), but accepted for northern fur seal, small cetaceans and sea turtles ($P > 0.05$) (Table 5).

V. DISCUSSION

To compare with the present experiment, the results of subsurface net experiments conducted using Japanese commercial squid driftnet vessels in 1990 and Japanese research vessels in the North Pacific during 1989-91 are summarized in Tables 6 and 7. The design of the subsurface net used in the 1991 experiment differed from that of the 1990 and the 1989-91 experiments in the distance between hanging lines (0.5-11 m or 600 mm mesh in the 1990 and the 1989-91 experiments, and 5 m in the 1991 experiment) and presence or absence of floats on the mid-line (Tables 1, 6 and 7). The 1989-91 experiments using research vessels deployed a small amount of fishing effort and the 1990 experiment using commercial vessels were mostly carried out in May, prior to the fishing season. Therefore, the 1991 commercial vessel data may be the most reliable.

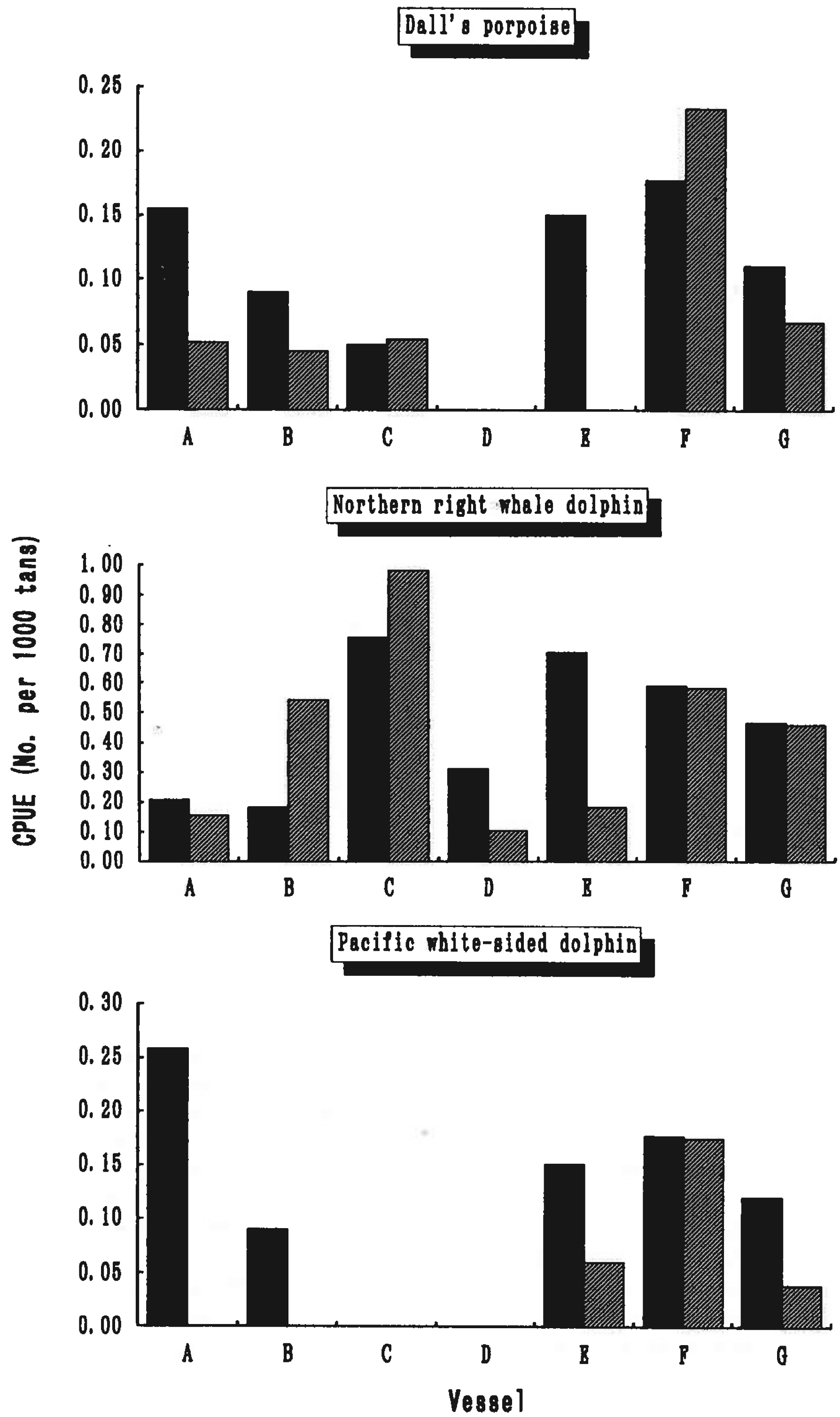

Fig. 7. CPUE (No./1000 tans) for three species of small cetaceans caught by surface (left) and subsurface (right) driftnets by vessel. Symbols A-G are same as Fig. 5.

Table 5. Results of statistical tests of differences in CPUE by species or species group between surface and subsurface driftnets fished during 1991. Wilcoxon two-sided signed rank tests were applied under the null hypothesis, no differences in CPUE.

SPECIES GROUP	FLYING SQUID	PACIFIC POMFRET	TOTAL SEABIRDS	DARK SHEARWATERS	OTHER SEABIRDS	SEA TURTLES
Effective No. for analysis[1]	280	268	140	117	49	15
Table value						
T(0.01)	16,177	14,751	3,697	2,504	355	15
T(0.05)	17,012	15,534	3,993	2,731	415	25
Statistic value (T)	4,987.5	3,060.5	1,805.5	1,202	370.5	38
P value	<0.01	<0.01	<0.01	<0.01	0.01<P<0.05	>0.05

SPECIES GROUP	NORTHERN FUR SEAL	TOTAL SMALL CETACEANS	DALL'S PORPOISE	NORTHERN RIGHT WHALE DOLPHIN	PACIFIC WHITE-SIDED DOLPHIN	OTHER SMALL CETACEANS
Effective No. for analysis[1]	18	60	13	37	14	7
Table value						
T(0.01)	27	565	9	182	12	-
T(0.05)	40	649	17	221	21	2
Statistic value (T)	74	832	37	331	36	9.5
P value	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05

[1] Operations without differences in CPUE between surface and subsurface nets were excluded.

Table 6. Summary of driftnet specifications, effort and catch from the 1990 subsurface net experiment using seven Japanese commercial squid driftnet vessels in the North Pacific. Major value in specification is shown in parenthesis.

NAME OF VESSEL	*Fuji #63*	*Ryuhou #25*	*Akebono #65*	*Daikichi #3*	*Shinsei #51*	*Fuji #11*	*Fuji #11*	*Suwa #18*
Area Latitude	36-38°N	35-38°N	35-38°N	35-39°N	35-39°N	38-39°N	37-43°N	38-39°N
Longitude	175E-166°W	175E-166°W	152-177°W	152-177°W	146-154°W	176-177°E	147-166°W	163-164°W
Period	May,'90	May,'90	May,'90	May,'90	May,'90	May,'90	Jun-Jul,'90	June, '90
No. of operations	12	7	17	18	14	5	14	4
Tan length (m)								
Surface	50	49	42	48	47	49	49	47
Subsurface	50	49	42	48	47	49	49	47
Mesh size (mm)								
Surface	115	114	115	113 or 115	115	115	115	115
Subsurface	103	114	115	115	115	115	115	115
Net depth (m)								
Surface	10	10	9	10	9	10	10	10
Subsurface	10	10	9	10	9	10	10	10
Distance between hanging lines (m)	1	1	1	1	1	1	1	1
Set depth (m)	2	2	2	2	2	2	1	1
No. of tans per section (raw)								
Surface	170	140	150-180(150)	125-140(130)	160	160	160-170(165)	140
Subsurface	95-100	70	80	50-135(100)	80-100(80)	95-100	70-90	100
Observed tans (50m)								
Surface	7,990	5,351	12,550	12,446	7,219	2,352	6,958	1,579
Subsurface	1,185	472	1,142	1,680	1,090	475	1,103	376
Subsurface/Surface Ratio in tan (%)	14.8	8.8	9.1	13.5	15.1	20.2	15.9	23.8

.../cont.

Table 6. Continued.

NAME OF VESSEL	*Fuji #63*	*Ryuhou #25*	*Akebono #65*	*Daikichi #3*	*Shinsei #51*	*Fuji #11*	*Fuji #11*	*Suwa #18*
Flying squid								
Catch (Surface)	11,840	10,748	17,793	14,846	8,832	6,431	18,241	3,271
Catch (Subsurface)	2,022	370	2,268	1,502	1,462	576	1,729	1,062
Subsurface/Surface Ratio in CPUE (%)	115.1	39.0	140.1	75.0	109.6	44.3	59.8	136.3
Pacific pomfret								
Catch (Surface)	1,289	302	890	1,306	897	118	3,065	449
Catch (Subsurface)	946	20	171	76	138	18	55	63
Subsurface/Surface Ratio in CPUE (%)	494.8	174.6	39.6	24.1	101.9	50.7	11.3	58.9
Seabirds								
Catch (Surface)	58	75	14	48	43	23	29	2
Catch (Subsurface)	1	0	0	4	4	0	0	0
Subsurface/Surface Ratio in CPUE (%)	11.6	0.0	0.0	61.7	61.6	0.0	0.0	0.0
Northern fur seal								
Catch (Surface)	0	0	0	0	0	0	2	0
Catch (Subsurface)	0	0	0	0	0	0	0	0
Subsurface/Surface Ratio in CPUE (%)	n.a.	n.a.	n.a.	n.a.	n.a	n.a.	0.0	n.a.
Small cetaceans								
Catch (Surface)	6	4	3	10	3	1	13	3
Catch (Subsurface)	0	1	0	1	0	0	3	1
Subsurface/Surface Ratio in CPUE (%)	0.0	283.4	0.0	74.1	0.0	0.0	145.6	140.0
Sea turtles								
Catch (Surface)	0	0	0	0	3	0	1	0
Catch (Subsurface)	0	0	0	0	0	0	1	0
Subsurface/Surface Ratio in CPUE (%)	n.a.	n.a.	n.a.	n.a.	0.0	n.a.	630.8	n.a.
Source	Hayase 1990	Hayase 1990	Hayase 1990	Hayase 1990	Unpublished Observer data	Hayase 1990	Hayase 1990	Hayase 1990

Table 7. Summary of driftnet specifications, effort and catch from the 1989-91 experiments using Japanese research vessels in the North Pacific.

NAME OF VESSEL	*Kanki #3*	*Oumi*	*Kanki #3*	*Hokuhou*	*Shoyo*	*Kaiun*
Area Latitude	41°-47°N	28°-30°N	32°-39°N	31°-38°N	40°-47°N	42°-45°N
Longitude	162°-177°W	143°-144°E	172°-178°E	162°-172°W	147°-173°W	178°E-177°W
Period	Sep-Oct,'89	March,'90	Apr-May,'90	Apr-May,'90	Jun-Aug,'90	Aug,'91
No. of operations	19	10	11	17	30	13
Tan length (m)						
Surface	53	49	53	53	50	53
Subsurface	53	49	53	53	50	53
Mesh size (mm)						
Surface	115	112	115	115	115	115
Subsurface	115	112	115	115	115	115
Net depth (m)						
Surface	6	6	7	7	8.5	7
Subsurface	6	6	7	7	8.5	7
Distance between hanging line (m)	600mm mesh	0.5	1	1	1 or 10	10.6
No. of floats on mid-line	0	0	0	0	0	6 or "One-line"[1]
Set depth (m)	3	5	3	3	3	2
No. of tans per operation (raw)						
Surface	30	25	30	30	30	200
Subsurface	30	25	30	30	30	200
Observed tans (50m)						
Surface	604	245	342	541	885	2,652
Subsurface	603	214	339	541	869	2,719
Subsurface/Surface Ratio in tan (%)	100	87	99	100	98	103
Flying squid						
Catch (Surface)	380	535	169	353	2,709	7,230
Catch (Subsurface)	387	216	65	72	693	4,787
Subsurface/Surface Ratio in CPUE (%)	102	46	39	20	26	65
Pacific pomfret						
Catch (Surface)	586	5	11	760	5,158	949
Catch (Subsurface)	86	0	1	97	3,784	424
Subsurface/Surface Ratio in CPUE (%)	15	0	9	13	75	44
Seabirds						
Catch (Surface)	22	0	3	1	27	161
Catch (Subsurface)	2	0	0	2	0	3
Subsurface/Surface Ratio in CPUE (%)	9	n.a.	0	200	0	2
Northern fur seal						
Catch (Surface)	0	0	0	0	1	1
Catch (Subsurface)	0	0	0	0	2	0
Subsurface/Surface Ratio in CPUE (%)	n.a.	n.a.	n.a.	n.a.	204	0

.../cont.

Table 7. Continued.

NAME OF VESSEL	*Kanki #3*	*Oumi*	*Kanki #3*	*Hokuhou*	*Shoyo*	*Kaiun*
Small cetaceans						
Catch (Surface)	0	1	0	2	2	2
Catch (Subsurface)	0	0	0	0	0	1
Subsurface/Surface Ratio in CPUE (%)	n.a.	0	n.a.	0	0	49
Sea turtles						
Catch (Surface)	0	2	0	0	0	0
Catch (Subsurface)	0	2	0	0	0	0
Subsurface/Surface Ratio in CPUE (%)	n.a.	114	n.a.	n.a.	n.a.	n.a.
Source	Yatsu *et al.* 1990	Inoue and Watanabe 1990	Hayase and Domon 1990	Kubota and Hayase 1990	Yatsu *et al.* 1991b	Yatsu *et al.* 1991a

[1] "One-line" is a float-contained rope.

The present and the past descriptive statistics (Tables 2, 6 and 7) indicate that the subsurface net may substantially reduce CPUEs of flying squid, Pacific pomfret and seabirds. The statistical tests of 1991 data indicated that the CPUEs were significantly different for these three species or groups. For northern fur seal, small cetaceans and sea turtles, however, the differences in CPUEs between surface and subsurface nets were not detected in the present experiment (Table 5).

The depth distribution of some animals caught by driftnet has been studied. Yatsu *et al.* (1991a) reported that flying squid were caught more frequently from the middle to upper parts of surface nets than the lower part, whereas Pacific pomfret was most frequently caught in the upper part of the net followed by the middle part.

Amano (1990) reported that 33 dark shearwaters out of the 36 taken by the squid driftnet fishery were entangled in the upper part of the net, and the remaining three Laysan Albatrosses were entangled in the middle part of the net. Akamatsu and Hatakeyama (1991) reported that about 50% of the dark shearwaters caught by salmon driftnets were entangled within 0.5 m of the sea surface, whereas most of the tufted puffin, *Lunda cirrhata*, were entangled about 3 m in depth.

Jones *et al.* (1987) reported that 139 Dall's porpoises out of the 202 taken by the salmon driftnet fishery were entangled in the upper part of the net followed by the middle part (47) and the lower part (16). Amano (1990) examined vertical positions of eight small cetaceans taken by the squid driftnet fishery and reported the following results.

SPECIES	LOCATION ENTANGLED IN THE NET		
	UPPER	MIDDLE	LOWER
Dall's porpoise	3	2	0
Northern right whale dolphin	2	0	0
Pacific white-sided dolphin	0	1	0

These depth distributions agree with the present results for flying squid, Pacific pomfret and seabirds. Although Dall's porpoise, one of the major species entangled by the salmon driftnet fishery (Jones *et al.* 1987), tended to be entangled by the squid surface driftnet (Table 4, Fig. 7), no difference in CPUE was detected between the surface and the subsurface driftnets (Table 5).

Hayase *et al.* (1990) reported that in the South Pacific, the large-mesh subsurface net suspended at a depth of 2 m reduced the CPUE of small cetaceans (mostly consisted of common dolphin and striped dolphin, *Stenella coeruleoalba*) to about 8% of that of the surface net. This large-mesh subsurface net was equipped with mid-line floats, and the distance between hanging lines was about 8 m. Hembree and Harwood (1987) reported bycatch rates of small cetaceans (mostly bottlenose dolphin, *Tursiops truncatus* and spinner dolphin, *Stenella longirostris*) in trials using the subsurface gillnet in Australian seas. The small cetacean CPUE of the subsurface gillnet set at a depth of 4.5 m was half that of the surface gillnet.

The striking difference in the results for small cetaceans between the present experiment and these past experiments may be due to the differences in species caught, area, time and gear design.

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