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はえなわ操業調査によるさけ・ます釣獲分布と餌料の脱落原因

Horizontal distribution of salmonids caught by longline operation and falling factors of bait from the hook

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はえなわ操業調査によるさけ・ます釣獲分布と餌料の脱落原因

Horizontal distribution of salmonids caught by longline operation and falling factors of bait from the hook

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＜要　　約＞

本報告は1987年北光丸1次航海（6月，北太平洋），1986年および1987年若竹丸2次航海(6～7月，ベーリング海）の，はえなわを用いた北洋さけ・ます調査で得られたデータをもとに，さけ・ますの釣獲水平分布および餌イワシの脱落原因を考察したものである。解析の結果，以下の点が示された。

1. さけ・ます類はまとまって釣獲されやすい。
2. 餌イワシの脱落率はCPUEと風速に依存する。

＜緒　　言＞

魚群空間分布の把握は漁業上重要であるが，その把握は経験的解釈に基づいている場合が多い。しかし分布状態を科学的に分析し数量的に捉えることは，その資源をより正しく把握・予測しまた健全な利用に役立てる上で，極めて重要であると考えられる。海洋生活期さけ・ます魚群の空間分布の研究はこれまでにも黒木（1965），三島・上野・川島（1965），三島・上野・川島（1966 a），三島・上野・川島（1966 b），三島・島崎（1969）らによって報告されている。黒木（1965）は時空間系列のスペクトル解析法を適用して魚群団間隔および魚群の移動方向を推定し，三島・上野・川島（1965）は魚群の空間分布は密度，漁期，海域により異なり，その周期性が数100m以上に及ぶ例がみられること，また三島・上野・川島（1966 a，b）はこういった空間的分布特性は網目の選択性，さらには時間帯によっても異なることを報告している。これらはいずれも流網操業における反別漁獲尾数の変動をもとに解析した結果であって考察している魚群のスケールは極めて大きい。一方，三島・島崎（1969）により報告された群性に関する研究は，同じく流網操業の結果から考察したものであるが“群れ”を「魚体間相互の距離として魚体長範囲内に同一方向から羅網している複数尾」と定義した上で，これらの尺度で捉えた“魚群”の出現状況を報告している。群れをどのような尺度でみるのが最も妥当であるかはそれぞれの目的に応じて異なるであろうが，黒木（1965）らの考察したマクロスケールでの魚群もその基本構造としては魚相互で認知・干渉しあうレベルでの群れ特性並びに行動が根底にあるものと考えられる。

本研究では，はえなわ操業による釣獲分布を1鉤ごとに自己相関法などを用いて解析し，三島・島崎（1969）の定義した“群れ”とほぼ同じスケールでその遊泳実態の一側面を推察した。また

漁具能率に関与すると考えられる餌の脱落原因についても考察を行なった。

<操業条件および調査項目>

それぞれの調査航海におけるはえなわ操業時の詳細な記録をTable 1に，調査定点をFig. 1に示した。なお，北光丸での操業時間帯は半数の調査定点において朝方（日出時間帯）と夕方（日没時間帯）に，残りの半数の定点では朝方にのみ設定され，若竹丸の操業では全て朝方にのみ設定された。また1回の操業に，30鉢あるいは20鉢のはえなわが用いられた。投縄に要した時間は10鉢平均9.3分（1986年若竹丸分は除く），揚縄に要した時間は同じく10鉢平均30.2分であった。投縄終了から揚縄開始までの時間（縄待ち時間）は，北光丸で24～34分，平均29.4分，1987年若竹丸で19～47分，平均33.7分であった。本調査では1鉤ごとに，漁獲がある場合には魚種を，ない場合には餌の有無を記録した。ただし北光丸調査では作業の都合上1鉤ごとの魚種判別精度に問題があったので，本報告では北光丸による魚種別検討を省いた。

今回の調査で使用したはえなわは1鉢の長さが148.5 m，これに桐浮子が10個および長さ1 mの天蚕糸付鉤（枝縄）が49本付属している。餌には塩蔵のカタクチイワシを用いた。

<結　　果>

1. さけ・ます釣獲水平分布

それぞれの操業の各調査定点における調査尾数をTable 2に示した。調査定点によっては，漁獲尾数がかなり少ないところがあったが，調査されたさけ・ます類の合計尾数が50以上みられた定点を対象に，各操業別に1鉤を1単位としたさけ・ます類漁獲のコレログラムを作成した。Fig.2には各航海の中からそれぞれ2操業分のコレログラムを取り出して示した。また各航海別に調査尾数50以上の調査点における操業結果のコレログラムを単純平均したものをFig.3に図示した。ただし，北光丸の朝縄操業のうち揚縄時刻をはえなわによる漁獲の最大有効時間帯（日出を挟む時間帯，高木 1971）に設定して行なった定点は，他の操業との条件が異なるためこれらのデータはFig.3を求めるための計算には含めなかった。

Fig.2およびここには示さなかった結果の多くの場合において，すぐ近くの鉤との相関がやや高い，即ち釣獲のあった鉤の近くの鉤にも魚がかかっている割合が高いという傾向がみられるが，偶然変動も大きい。しかしそれぞれの操業別に平均化したコレログラムを見ると（Fig.3），遠くの鉤とは相関がほとんど無くなり，ごく隣り合った部分でのみ相関が認められた。

Table 3には隣り合った鉤間での釣獲状況の相関の有意性検定結果を示した。この表の中でpおよびqは，それぞれさけ・ます類がかかった鉤の隣の鉤にも連続してかかった割合，およびさけ・ます類がかからなかった鉤の隣の鉤にかかった割合を示している。なおここにはさけ・ます調査尾数が50以上の操業について，かつ統計処理上，正規分布に近似できる条件（$p \leqq 0.5$のとき，$np \geqq 5$であるか，または$p > 0.5$のとき，$n(1-p) \geqq 5$　ただしnは1回操業における総調査尾数を表わす。）を満たすものについてのみ示した。Table 3によればこの条件を満たす操業のうち，過半数の操業において有意な差がみられた。従って，さけ・ます類は連続して釣獲される可能

性が高いことが示唆された。

以上においては，さけ・ます類を一括込みにして扱ってきたが，これを魚種別にみた場合，漁獲尾数が比較的多かったシロザケ（８例）およびカラフトマス（１例）について調べた（Table 4）。なおここで用いたｐおよびｑは，同一種類のさけ・ますがある鉤にかかった場合とかからなかった場合のそれぞれについて，その隣の鉤にかかった割合を示している。この結果をTable 3と比べて見ると，№45と№50（いずれも1987年若竹丸）ではさけ・ます類を込みにした場合，差は有意でなかったものが，単一魚種として扱った場合，それぞれ危険率５％で有意となった。

次に，隣り合った鉤に連続してかかった場合の魚種の組み合わせ数を調べた。なお，ここでは釣獲が３連続以上の鉤にみられた場合もすべてペアに分解してその組数を数えた。Table 5には，同一ステーション内において複数魚種にわたり漁獲尾数が比較的多かった№45，46，48の各操業（いずれも1987年若竹丸）結果について示した。これによれば同一魚種の方がペアをつくりやすいことが推察される。

2. 餌の脱落原因

Table 6は，ある鉤に漁獲があった場合および漁獲がなかった場合のそれぞれについてその両隣の鉤の餌の有無，餌の無くなっていた割合（それぞれｐ，ｑとする。）およびｐとｑの差の有意性検定結果を示したものである。ただし，ここでもTable 3と同様に $np \geqq 5$ の条件を満たすものに限っている。これによれば漁獲尾数が比較的多かった操業では有意な差がみられた。即ち，魚がかかった隣では他のところよりも餌がなくなっていた割合が高い傾向がみられた。

次に餌の脱落の要因をみるために

R：餌なしの鉤数／（餌残りの鉤数＋餌なしの鉤数）

とおき，Rに関与すると考えられる要因としてCPUE（１鉢当りの釣獲数），漁具の海中敷設時間および風速（または風力）に着目し，Rとそれぞれの要因との相関を調べた（Figs. 4～6，Table 7）。それによればRとCPUEおよびRと風速（または風力）との間にはそれぞれ相関がみられたが，Rと海中敷設時間との間には明確な相関はみられなかった。

そこで次にRとCPUE，風速（風力）との重回帰を調べた（Table 8）。その結果それぞれの操業別に計算した相関係数で比較してみると，CPUEと風速（風力）とを分けてRとの１次回帰をとった場合（Table 7）よりも，重回帰をとった場合（Table 8）の方が高い値となり，脱落の原因はこの２要素が50～80％（r^2）寄与していると考えられる。

＜考　　察＞

さけ・ます類は比較的まとまって漁獲されやすいといわれるが，本研究でも１鉤を単位として相関（コレログラム）をみることにより（Figs. 2，3）その傾向が認められ，統計的にも確かめられた（Tables 3，4）。本研究結果ははえなわ操業を通して得られたため，釣獲魚の遊泳方向を推定することはできないが，漁具の海中敷設時間が短いことから考えて２尾の魚が全く別々に遊泳してきて偶然，隣合って釣獲される可能性は少ないであろう。また遊泳方向を推定可能な流網操業

で得られた結果からも同様にまとまってかかる傾向がみられる（三島・島崎 1969 ）ことから，さけます類はある程度群泳習性を持ち合わせているのではないかと推察される。しかし同時に流網操業では漁具の海中敷設時間が長いので，たとえ1尾が羅網しその部分を中心に網目の展開が不良となり後続の魚の羅網を困難ならしめる（三島・島崎 1969 ）としても後続の魚がその部位近くに羅網しないとは言い切れない。また三島・島崎（ 1969 ）も述べているように，先に羅網したあるいは釣獲された個体と，後続の個体との間に誘引作用が働く可能性があることも否定できない。今後ここで言うような誘引作用の存在をさらに詳しく確かめる必要があろう。

次にまとまってかかった場合の魚種の組み合わせ数（ここでは，前述のようにすべてペアに分解している）をみると（ Table 5 ），異なる魚種から成る場合よりも同一魚種から構成されるケースが多く，ある程度魚自身が同種の他個体を認識している可能性が示唆される。この点に関してはさらに同一魚種のペアを作っている魚の生物特性の把握を通して詳しく考察していきたい。

餌の脱落率にはCPUEおよび風速が大きく関与していることが示されたが（ Figs.4〜6，Tables 7，8 ），このことから餌の脱落の原因のかなりの部分は捕食と海況条件によるものと考えることができるであろう。しかしその詳細は不明である。たとえばTable 6で示されたように，隣の鉤に魚がかかった場合に餌がなくなっているケースが多いが，この原因としては魚が鉤にかかる前にその近くの鉤の餌をいくつか食い逃げしていた可能性，および釣獲された後に暴れて隣の餌をおとした可能性の両方が考えられる。

餌の脱落率がCPUEと風速に依存するということは，資源量推定上注意を要する。一般に現存量はCPUEに比例とするものと考えられているが，その比例定数（漁具能率）は餌の脱落が多ければ低下することになる。脱落率はCPUEと風速の関数であるから（ Table 8 ），現存量とCPUEには線形の関係はなくなり，CPUEによる資源量評価は現存量が大きいほど，また海況条件が悪いほど過小評価となるであろう。

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Table 1 Salmon longline operations conducted by Hokko-maru and Wakatake-maru in 1986 and 1987.

Op. No.	Cruise	Date	Station		SR or SS	Setting time Start	Setting time End	Hauling time Start	Hauling time End	Wind [m/s]	WT [°C]	Gear [Hachi]
1	Hokko-maru	1987.06.05	42°30'N	164°30'E	0326	0155	0226	0255	0408	4[‡]	6.0	30
2			42°35'N	166°43'E	1827[#]	1755	1826	1856	2007	3[‡]	5.4	30
3		06.06	42°35'N	166°46'E	0317	0245	0317	0345	0525	4[‡]	5.4	30
4		06.07	42°40'N	168°45'E	0308	0140	0212	0238	0359	4[‡]	6.0	30
5			42°45'N	170°38'E	1814[#]	1745	1818	1845	1955	4[‡]	10.3	30
6		06.08	42°46'N	170°29'E	0259	0230	0305	0329	0443	3[‡]	10.3	30
7		06.09	42°52'N	172°28'E	0252	0120	0154	0220	0336	4[‡]	7.9	30
8			42°54'N	174°46'E	1801[#]	1730	1801	1830	1944	4[‡]	11.0	30
9		06.10	42°53'N	174°45'E	0244	0215	0245	0313	0502	4[‡]	11.0	30
10		06.11	42°30'N	176°34'E	0233	0105	0132	0205	0325	5[‡]	10.9	30
11			44°37'N	176°45'E	1758[#]	1730	1759	1829	1944	4[‡]	6.7	30
12		06.12	44°38'N	176°46'E	0228	0200	0230	0300	0430	2[‡]	6.7	30
13		06.13	44°50'N	174°14'E	0238	0110	0140	0209	0335	4[‡]	7.0	30
14			44°50'N	172°10'E	1819[#]	1750	1821	1849	2009	3[‡]	6.9	30
15		06.14	44°50'N	172°10'E	0244	0215	0244	0316	0440		6.9	30
16		06.15	44°50'N	170°09'E	0253	0125	0153	0225	0400	5[‡]	6.1	30
17			44°45'N	168°11'E	1833[#]	1805	1835	1904	2019	4[‡]	5.8	30
18		06.16	44°49'N	168°10'E	0300	0230	0259	0329	0501	4[‡]	5.8	30
19		06.17	44°51'N	166°51'E	0305	0135	0203	0237	0416	5[‡]	6.9	30
20			44°50'N	164°49'E	1849[#]	1820	1847	1919	2045	5[‡]	7.6	30
21		06.18	44°51'N	164°50'E	0313	0245	0312	0344	0501	6[‡]	7.6	30
22	Wakatake-maru	1986.06.23	55°26'N	174°34'E		2326		0006	0122	6.5	5.2	30
23		06.27	57°31'N	178°23'E		2332		0016	0120	7.0	6.7	20
24		06.28	56°32'N	178°26'E		2340		0032		3.0	6.3	10
25		06.29	55°27'N	178°23'E		2332		0030	0133	5.0	6.7	20
26		07.01	56°28'N	179°26'W		2326		0025	0125	7.0	6.9	20
27		07.03	57°30'N	177°39'W		2325		0027	0134	6.0	7.5	20
28		07.05	55°28'N	177°36'W		2330		0028	0118	9.0	6.4	20
29		07.07	56°31'N	175°36'W		2326		0030	0159	2.5	7.3	30
30		07.09	58°33'N	175°36'W		2326		0026	0209	5.0	8.2	30
31		07.14	58°29'N	177°31'W		2329		0031	0203	10.0	8.5	30
32		07.15	58°35'N	179°35'W		2332		0036	0225	8.1	8.0	30
33		07.16	58°29'N	178°32'E		2327		0031	0202	6.0	7.4	30
34		07.17	58°35'N	176°39'E		2328		0031	0206	9.0	8.3	30
35		07.18	55°30'N	174°30'E		2332		0047	0154		8.6	30

Table 1 (continued)

Op. No.	Cruise	Date	Station		SR or SS	Setting time Start	Setting time End	Hauling time Start	Hauling time End	Wind [m/s]	WT [°C]	Gear [Hachi]
36	Wakatake-maru	1987.06.14	54°30'N	179°30'W	0022	2358	0018	0050	0220	0.0	4.5	30
37		06.15	54°30'N	178°30'E	0030	0007	0032	0102	0240	2.0	5.6	30
38		06.16	55°30'N	178°30'E	0021	0001	0023	0056	0226	4.0	4.6	30
39		06.19	57°30'N	178°30'E	0008	0000	0025	0055	0212	10.0	5.6	30
40		06.21	58°30'N	178°30'E	2356	2357	0026	0045	0217	4.0	4.7	30
41		06.22	58°30'N	179°30'W	2349	2355	0017	0046	0259	3.0	6.7	30
42		06.23	57°30'N	179°30'W	2359	2354	0009	0049	0140	7.0	5.7	20
43		06.27	55°30'N	179°30'W	0016	2357	0017	0104	0309	4.6	5.6	30
44		06.28	55°30'N	177°30'W	0009	0000	0016	0055	0205	5.5	5.7	20
45		06.29	55°30'N	175°30'W	0001	2356	0035	0059	0253	3.5	6.5	30
46		07.01	56°30'N	175°30'W	2355	0000	0016	0057	0203	4.0	7.4	20
47		07.04	56°30'N	177°30'W	0006	2354	0021	0058	0249	2.0	6.9	30
48		07.05	57°30'N	177°30'W	0000	2356	0015	0057	0235	3.0	7.5	30
49		07.06	57°30'N	175°30'W	2353	0000	0022	0058	0231	0.0	7.9	30
50		07.07	58°30'N	175°30'W	2345	0000	0028	0055	0248	2.0	7.6	30
51		07.10	60°30'N	175°30'W	2329	0000	0030	0057	0226		7.5	30
52		07.11	60°30'N	177°30'W	2339	2358	0032	0059	0236	6.0	7.5	30
53		07.14	58°30'N	177°30'W	0003	2356	0022	0102	0237	7.0	7.8	30
54		07.15	57°30'N	179°30'W	0021	2356	0020	0100	0227	4.0	7.5	30

SR: Sunrise, SS: Sunset, WT: Water temperature, "*" indicates the time of sunset. "+" indicates the degree of the wind force. All the times are shown in Japanese Standard Time.

Table 2 The number of salmonids examined and the ratio of hooks without a bait in each operation.

Op. No.	No. of salmonid fish examined S	Cm	P	Ck	O	T	Ratio of no bait	Op. No.	No. of salmonid fish examined S	Cm	P	Ck	O	T	Ratio of no bait
1						75	0.21	28	0	4	1	0	0	5	0.41
2						110	0.31	29	1	50	1	8	0	60	0.71
3						232	0.73	30	0	104	2	1	5	112	0.68
4						114	0.40	31	2	102	0	1	0	105	0.70
5						36	0.51	32	2	183	0	13	3	201	0.68
6						226	0.88	33	2	156	0	3	5	166	0.78
7						157	0.35	34	0	148	0	4	9	161	0.75
8						54	0.41	35	5	25	0	1	1	32	0.47
9						212	0.86	36	1	3	1	0	0	5	0.21
10						41	0.65	37	11	5	0	5	0	21	0.17
11						42	0.22	38	3	3	0	1	0	7	0.59
12						209	0.75	39	4	2	0	4	2	12	0.67
13						131	0.39	40	1	3	0	0	1	5	0.14
14						94	0.25	41	3	4	0	9	5	21	0.23
15						237	0.57	42	0	7	0	3	1	11	0.20
16						148	0.74	43	1	9	17	1	0	28	0.49
17						26	0.43	44	10	7	25	2	0	44	0.51
18						261	0.64	45	11	34	61	1	0	107	0.64
19						163	0.68	46	17	34	26	4	0	81	0.43
20						96	0.50	47	5	12	27	0	0	44	0.29
21						87	0.95	48	4	63	28	0	0	95	0.35
22	0	7	0	0	0	7	0.30	49	7	13	22	3	0	45	0.30
23	0	7	2	0	0	9	0.37	50	7	105	9	2	0	123	0.57
24	0	1	0	0	0	1	0.43	51	0	12	2	1	6	21	0.44
25	0	17	0	0	0	17	0.44	52	0	20	2	0	10	32	0.56
26	0	43	0	4	0	47	0.51	53	1	30	19	0	0	50	0.50
27	4	10	1	4	1	20	0.43	54	1	42	23	1	0	67	0.43

S: Sockeye salmon, Cm: Chum salmon, P; Pink salmon, Ck: Chinook salmon, O: Other salmons, T: Total. Ratio of no bait is calculated by the following formula; $R = Nb / (Nb + B)$, R: Ratio of no bait, Nb: the number of hooks without a bait, B: the number of hooks with a bait.

Table 3 The number of occurrences of longline catch of salmonids in four cases# (combination of a hook and adjacent one).

Op.No.	(1,1)	(1,0)	(0,1)	(0,0)#	p	q	u
2	32	73	72	999	0.30	0.07	8.00**
3	49	170	171	766	0.22	0.18	1.30
6	42	158	167	672	0.21	0.20	0.25
8	6	46	44	1046	0.12	0.04	2.24*
9	64	137	143	692	0.32	0.17	4.59**
12	46	154	155	759	0.23	0.17	1.91
14	18	70	70	953	0.20	0.07	4.33**
15	56	154	168	695	0.27	0.19	2.21*
18	70	172	170	648	0.29	0.21	2.57*
20	21	68	66	926	0.24	0.07	5.42**
21	14	70	68	926	0.17	0.07	3.05**
29	10	46	36	852	0.18	0.04	4.33**
30	23	85	84	820	0.21	0.09	3.67**
31	21	77	75	436	0.21	0.15	1.53
32	46	150	138	689	0.23	0.17	2.12*
33	29	134	125	661	0.18	0.16	0.48
34	46	111	100	611	0.29	0.14	4.50**
45	14	93	86	928	0.13	0.08	1.41
46	22	56	54	583	0.28	0.08	5.14**
48	20	72	60	860	0.22	0.07	4.96**
50	18	101	100	820	0.15	0.11	1.22

#"1" and "0" indicate the hook with and without any salmonid respectively. "p": (1,1)/{(1,1)+(1,0)}, "q": (0,1)/{(0,1)+(0,0)}. "u": u value in normal distribution, *: significant at 5% level, **: significant at 1% level.

Table 4 The number of occurrences of longline catch of a same salmonid species in four cases# (combination of a hook and adjacent one). Every example except operation No.45 which shows pink salmon is chum salmon.

Op.No.	(1,1)	(1,0)	(0,1)	(0,0)#	p	q	u
29	8	39	31	852	0.17	0.04	4.13**
30	20	78	78	820	0.20	0.09	3.52**
31	21	75	72	436	0.22	0.14	1.76
32	39	134	128	689	0.23	0.16	2.08*
33	27	124	117	661	0.18	0.15	0.76
34	39	102	93	611	0.28	0.13	4.19**
45	7	53	47	928	0.12	0.05	2.02*
48	10	47	38	860	0.18	0.04	4.15**
50	18	83	83	820	0.18	0.09	2.56*

"1" and "0" indicate the hook with and without a same salmonid species respectively. Other symbols are same as in Table 3.

Table 5 The number of pairs in each combinations caught in three operations.

Op.No.	Chum - Chum	Chum - Pink	Pink - Pink
45	4	1	7
46	5	4	4
48	10	5	3

Table 6 The number of occurrences in four cases# as for a catch and a bait at any hook and the adjacent one, the ratios "p" and "q" indicating the situations of no bait at any hook in cases accompanied with and without a catch of salmonids at the adjacent hook respectively, and the "u" value indicating the deviation between "p" and "q" in each longline operation.

Op.No.	(1,0)	(1,1)	(0,0)	(0,1)#	p	q	u	Op.No.	(1,0)	(1,1)	(0,0)	(0,1)#	p	q	u
1	44	50	94	440	0.47	0.18	6.17**	29	56	24	596	236	0.70	0.72	-0.18
2	77	70	265	682	0.52	0.28	5.84**	30	123	44	504	246	0.74	0.67	1.53
3	245	93	472	174	0.72	0.73	-0.12	31	112	38	268	123	0.75	0.69	1.29
4	86	78	282	474	0.52	0.37	3.50**	32	222	77	362	190	0.74	0.66	2.52*
5	46	18	555	563	0.72	0.50	3.33**	33	249	53	372	118	0.82	0.76	2.08*
6	248	40	502	66	0.88	0.88	-	34	212	53	329	124	0.80	0.73	2.12*
7	114	109	271	581	0.51	0.32	5.28**	35	46	47	423	484	0.49	0.47	0.41
8	48	44	412	611	0.52	0.40	2.11*	36	13	33	225	859	0.28	0.21	1.04
9	226	53	524	72	0.81	0.88	-2.62**	37	17	21	190	991	0.45	0.16	4.41**
10	38	27	596	321	0.58	0.65	-0.93	38	53	34	628	437	0.61	0.59	0.24
11	32	23	242	942	0.58	0.20	6.43**	39	14	13	439	212	0.52	0.67	-1.45
12	257	52	482	189	0.83	0.72	3.75**	41	25	28	249	864	0.47	0.22	3.99**
13	100	76	300	534	0.57	0.36	5.05**	43	25	24	516	548	0.51	0.48	0.20
14	60	82	207	704	0.42	0.22	4.87**	44	46	27	301	310	0.63	0.49	2.10*
15	219	103	317	289	0.68	0.52	4.54**	45	133	46	520	325	0.74	0.62	3.14**
16	154	39	427	160	0.80	0.73	1.85	46	64	45	216	321	0.59	0.40	3.45**
17	24	19	476	648	0.56	0.42	1.59	47	42	33	263	698	0.56	0.27	5.11**
18	252	90	315	221	0.74	0.59	4.43**	48	84	46	245	567	0.65	0.30	7.55**
19	186	42	437	235	0.82	0.65	4.60**	49	36	38	260	660	0.49	0.28	3.56**
20	89	44	431	466	0.67	0.48	3.97**	50	149	54	389	340	0.73	0.53	5.03**
21	132	5	853	46	0.96	0.95	-	51	15	17	419	534	0.47	0.44	0.14
23	17	28	251	424	0.38	0.37	0.24	52	32	14	507	412	0.70	0.55	1.77
25	30	33	300	390	0.48	0.43	0.50	53	55	33	440	452	0.63	0.49	2.25*
26	47	31	259	259	0.60	0.50	1.57	54	84	54	370	541	0.61	0.41	4.38**
27	19	20	299	403	0.49	0.43	0.59								

"1" and "0" of the left side in each parenthesis indicate the situations of a catching and non-catching of salmonids at any hook respectively. Ones of the right side in each parenthesis indicate the situations of being a bait and no bait at the adjacent hook respectively. "p": (1,0)/{(1,1)+(1,0)}, "q": (0,0)/{(0,1)+(0,0)}. Other symbols are same as in Table 3.

Table 7 Correlation coefficients between R and CPUE or wind velocity (or wind force) in each cruise.

	CPUE vs R	wind velocity vs R
1987 Hokko-maru	0.56	0.26*
1986 Wakatake-maru	0.46	0.47
1987 Wakatake-maru	0.85	0.10

The value marked with "*" was calculated using wind force.

Table 8 The results of multiple regression relating R to both CPUE and wind velocity (or wind force) in each cruise.

	n	b_0	b_1	b_2	correlation coefficient	$s[b_1]$	$s[b_2]$	$t_{(n-3,0.05)}$ $t_{(n-3,0.01)}$
1987 Hokko-maru	20	-0.208	6.74×10^{-2} **	0.111 *	0.71	1.75×10^{-2}	4.60×10^{-2}	2.110 2.898
1986 Wakatake-maru	13	0.509	5.89×10^{-2} **	-2.29×10^{-2}	0.89	9.63×10^{-3}	1.18×10^{-2}	2.228 3.169
1987 Wakatake-maru	18	9.29×10^{-2}	7.44×10^{-2} **	3.97×10^{-2} **	0.75	2.20×10^{-2}	1.19×10^{-2}	2.131 2.947

n: the number of samples. b_0, b_1 and b_2: coefficients in the following equation; $R = b_0 + b_1 \times CPUE + b_2 \times W$ (W:wind velocity or wind force.)

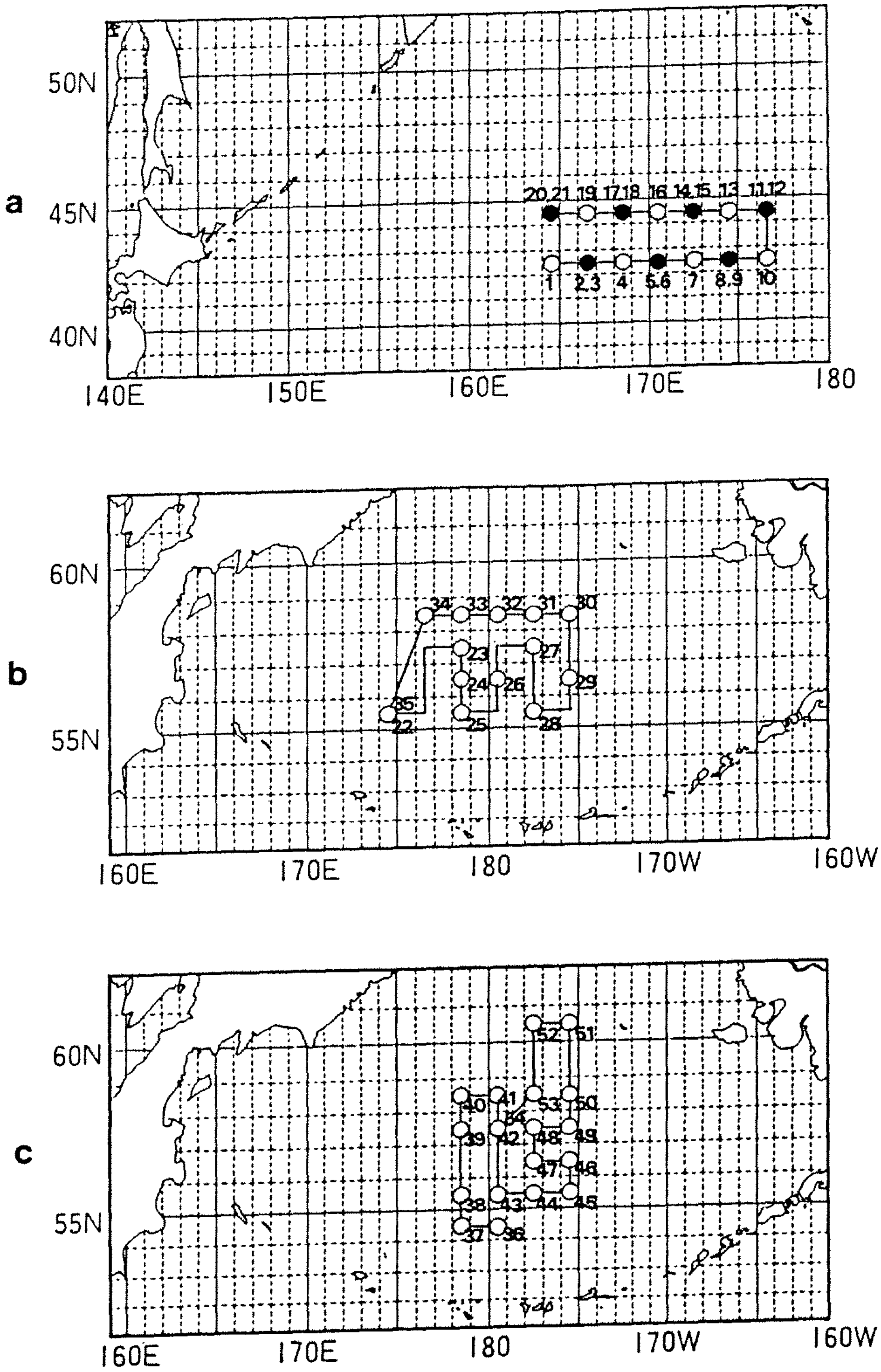
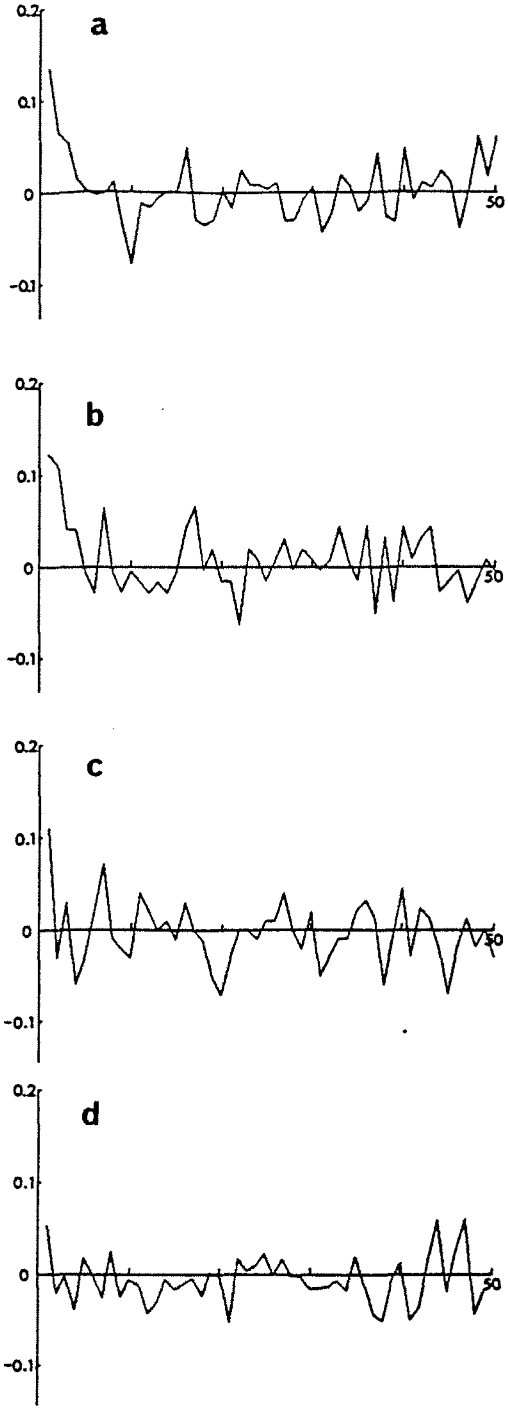


Fig. 1 Stations of longline operations in each cruise; a: 1987 Hokko-maru, b: 1986 Wakatake-maru, c: 1987 Wakatake-maru. Closed circles in 1987 Hokko-maru indicate the stations where two operations were carried out, that is around sunrise and sunset.



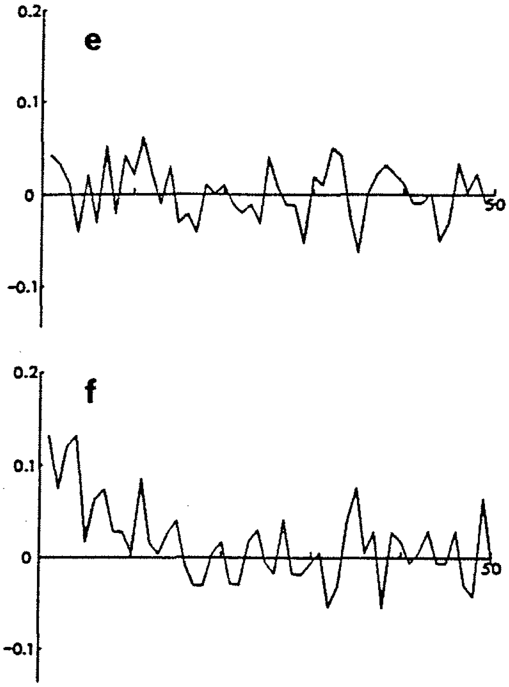


Fig. 2　　Correlogrums showing the fishing results by regarding each hook as one unit. The operation numbers of examples shown here are as follows; a: 9, b: 14, c: 30, d: 32, e: 45, f: 48. All the caught salmonid fish are dealt without distinction as for species The ordinate and the abscissa indicate the correlation coefficient and the distance between any hooks respectively.

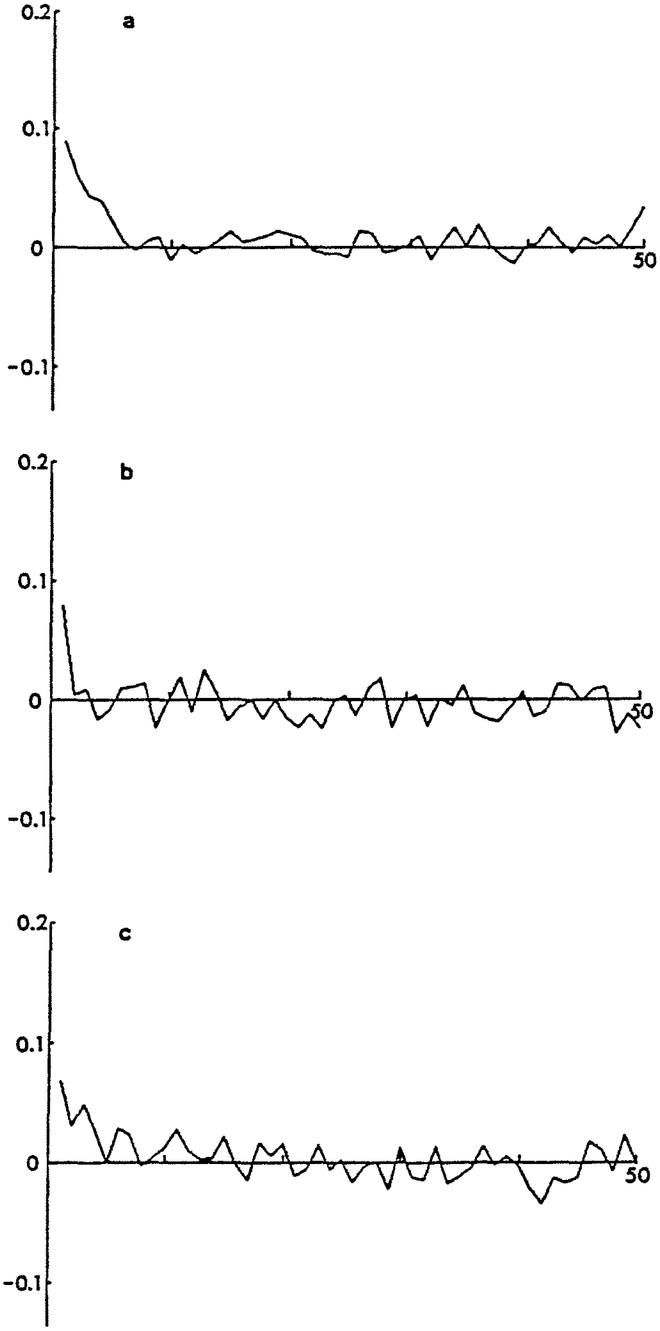


Fig. 3　　Average correlogrums in each cruise; a: 1987 Hokko-maru, b: 1986 Wakatake-maru, c: 1987 Wakatake-maru. Both the ordinate and the abscissa are same as in Fig.2.

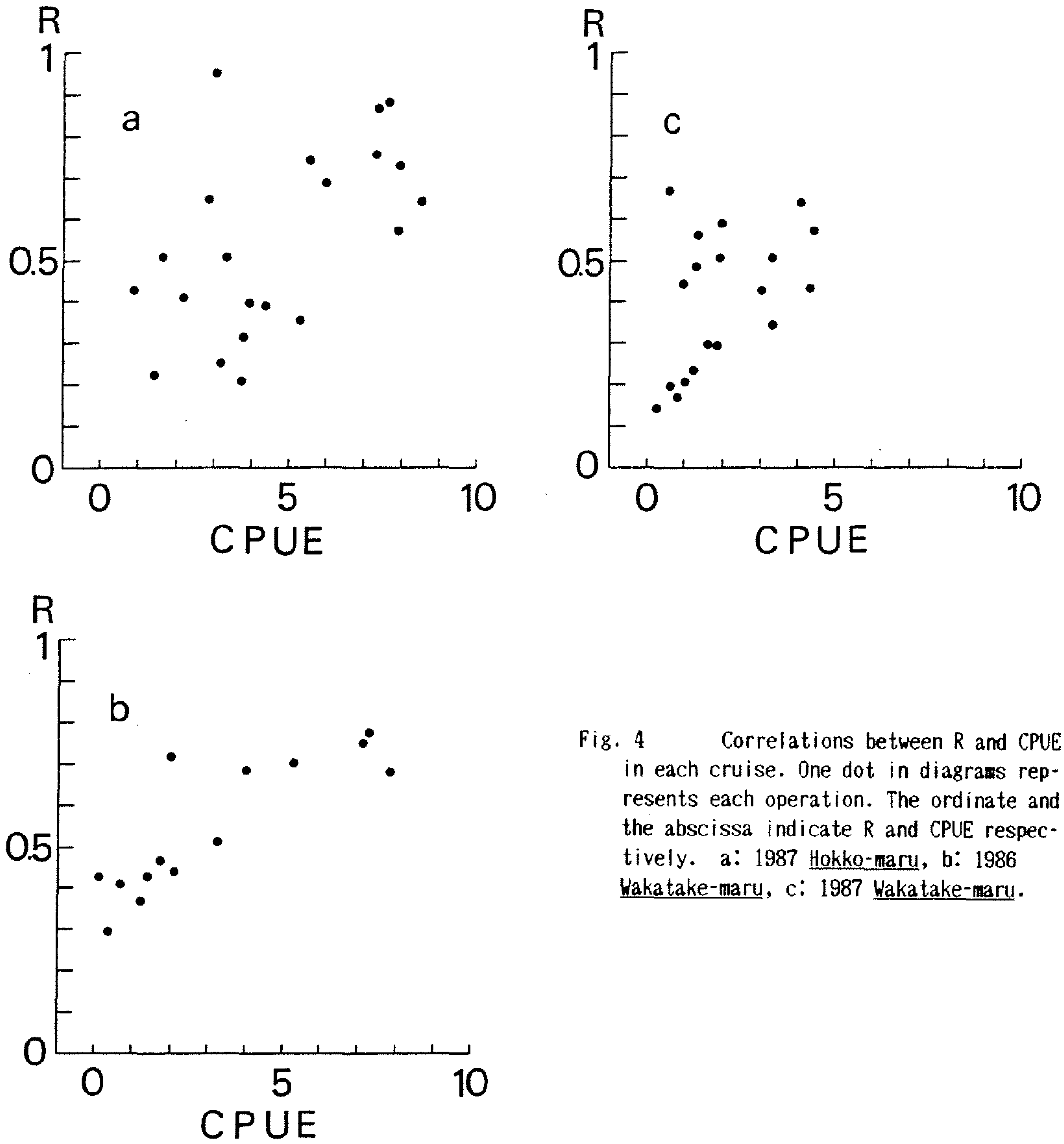
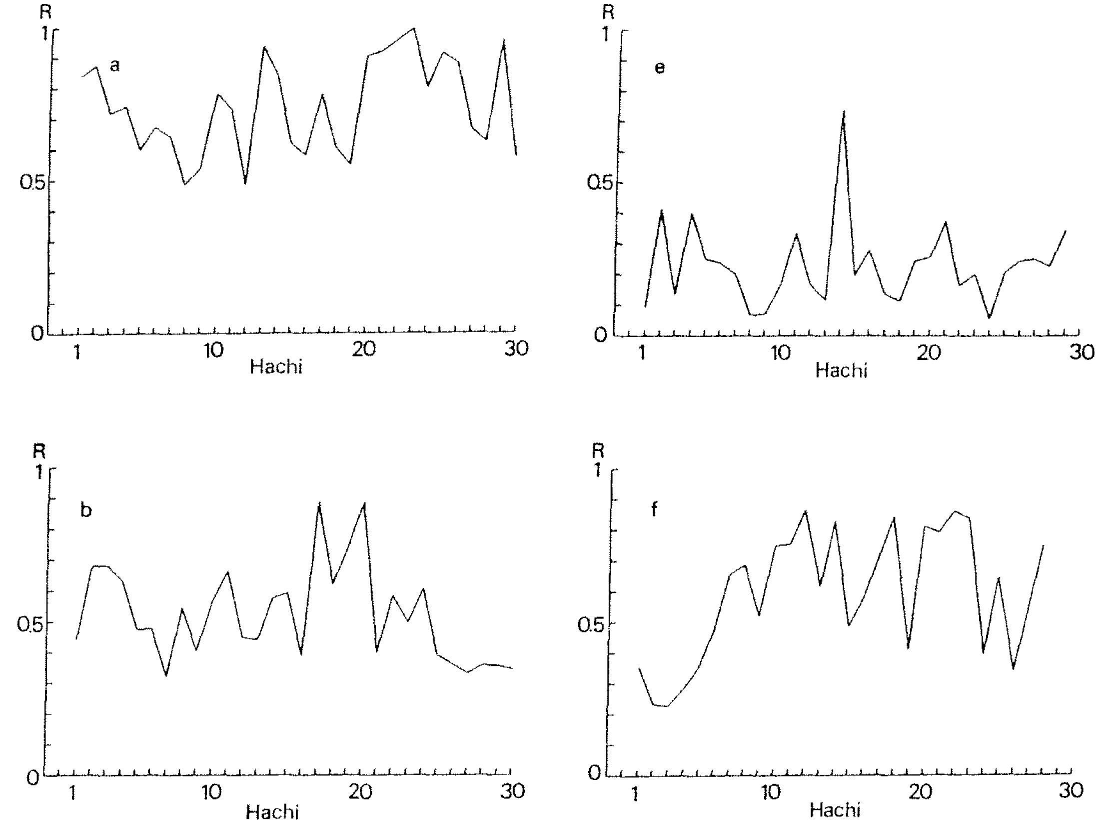


Fig. 4 Correlations between R and CPUE in each cruise. One dot in diagrams represents each operation. The ordinate and the abscissa indicate R and CPUE respectively. a: 1987 Hokko-maru, b: 1986 Wakatake-maru, c: 1987 Wakatake-maru.



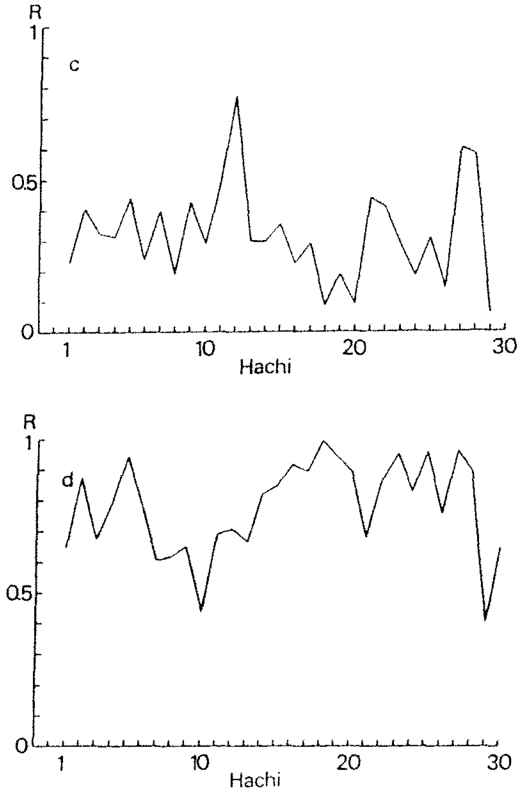
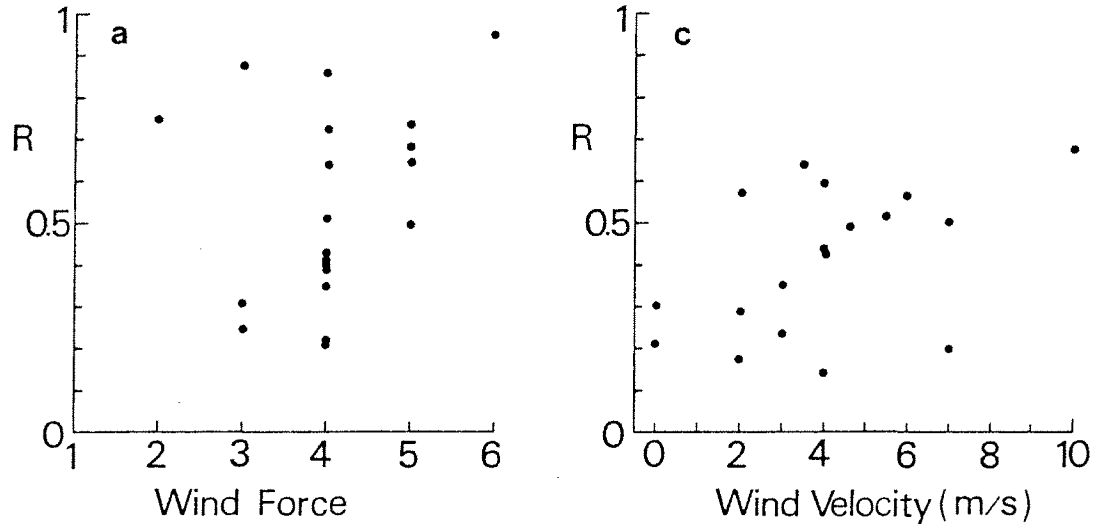


Fig. 5 Relation between R and soaking time. Two examples in each cruise are shown, of which operation numbers are as follows; a: 3, b: 5, c: 22, d: 33, e: 36, f: 38. The ordinate indicates R and the abscissa indicates the hauling order of Hachi which was adopted as relative time.



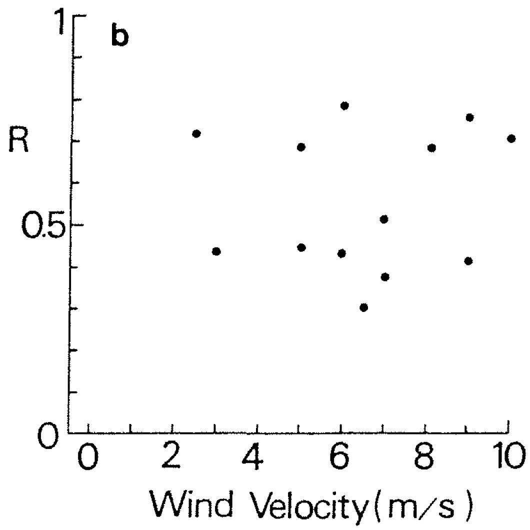


Fig. 6　Correlations between R and wind velocity (or wind force) in each cruise. One dot in diagrams represents each operation. The ordinate and the abscissa indicate R and wind velocity (or wind force) respectively. a: 1987 Hokko-maru, b: 1986 Wakatake-maru, c: 1987 Wakatake-maru. In the diagram of "a", the abscissa indicates wind force in Beaufort's scale.

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TRANSLATION

HORIZONTAL DISTRIBUTION OF SALMONIDS CAUGHT BY LONGLINE OPERATION AND FALLING FACTORS OF BAIT FROM THE HOOK

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Abstract

This report discusses horizontal distribution of salmonid catch by longlines and factors relating to the drop-off from the hook of anchovy used as bait based on data from longline surveys on salmonids in the North Pacific conducted by the Hokko maru during its first cruise in 1987 (June, the North Pacific) and by the Wakatake maru during its second cruises in 1986 and 1987 (June to July, the Bering Sea). The results of the analysis show the following:

1. Salmonids tend to be caught with longline in groups.

2. Rate of drop-off from the hook of anchovy bait is dependent on the CPUE and wind velocity.

Introduction

Determining the spatial distribution of fish schools is important for the fishery and sometimes relies on empirical interpretations. However, scientific analysis and quantitative understanding of state of the distribution is considered extremely important in determining and forecasting the state of the resource and for its sound utilization. Kuroki (1965), Mishima et al. (1965, 1966a and 1966b) and Mishima and Shimazaki (1969) reported research on spatial distribution of salmonid fish schools during their ocean life stage. Kuroki (1965) estimated spaces between groups of fish schools and direction of their migration by applying spectrum analytical method for spatio-temporal series. Mishima et al. (1965) reported that distribution of fish schools varied with density, fishing season and spatial area, and a periodicity was observed over a several-hundred-meter range in some cases. In addition, Mishima et al. (1966a,b) reported that these spatial distribution characteristics varied with differences in the selectivity of the mesh sizes and time of day. These findings were brought about by analyses based on variations in the number of salmon caught by tan in the driftnet operations and the size of fish schools discussed in these analyses was extremely large. On the other hand, the study on the nature of fish schools reported by Mishima and Shimazaki (1969), which was also based on the results of the driftnet operations, defined "fish school" as more than one fish which became entangled in the same direction in the nets and the spaces among entangled individuals were within the range of the body length of the fish entangled and reported the pattern of the "fish school" according to this measure. The most appropriate measure by which a fish school is defined may differ depending on the purposes of the studies, but consideration of the fish schools in macro scale is assumed based on characteristics of the schools and behavior at a level where recognition and interaction occurs among individual fish.

In this study, the distribution of the longline catch was analyzed, with auto-correlogram, etc., by hook and some aspects of swimming pattern were estimated by means almost the same in scale as that defined by Mishima and Shimazaki (1969). In addition, the factor of bait drop-off, which is considered to be related to gear efficiency, was discussed.

Conditions of operations and details recorded during the surveys

Table 1 gives a detailed record of the longline operations during the respective survey cruises and Fig. 1 illustrates the survey stations. Operations took place both in the morning (near sunrise) and evening (near sunset) for half of the total stations for the *Hokko maru*, and only in the morning for the other half of the stations for the *Hokko maru* and all the stations for the *Wakatake maru*. In each operation 20 or 30 hachi of longline were used. Time required for setting the longline averaged 9.3 minutes per 10 hachi (excluding the operations by the *Wakatake maru* in 1986) and time for hauling averaged 30.2 minutes per 10 hachi. Time from the completion of the setting to the commencement of hauling ranged from 24 to 34 minutes, averaging

29.4 minutes for the operations by Hokko maru and from 19 to 47 minutes, averaging 33.7 for the Wakatake maru in 1987. In this study, the following was recorded by hook--the species caught or whether or not the bait remained on the hook when there was no catch. However, data from the Hokko maru was not examined on a species basis since the accuracy of identification of the species by hook was questionable because of the circumstances in the research operation on this vessel.

The length of one hachi of longline used in this survey was 148.5 m. To the hachi were attached 10 floats and 49 branch lines of 1 m nylon monofilament with a hook. Salted anchovies (*Engraulis japonica*) were used as bait.

Results

1. Horizontal distribution of salmonids

The number of salmonids examined at each station during the respective cruises is shown in Fig. 2. At some stations fairly small numbers of salmonids were caught. However, correlograms of the salmonid catch were drawn by operation for stations at which the total number of salmonids examined was 50 or more. One hook was regarded as one unit. Figure 2 shows six correlograms extracted from operations of the three cruises (2 operations from each). Averaged correlograms of fishing results for stations at which 50 or more salmonids were caught and examined by cruise are plotted in Fig. 3. Data from the morning operations by the Hokko maru, for the operations where hauling time was at the maximum efficient time (time zone including sunrise (Takagi 1971)) were not included in the calculation for Fig. 3 since the conditions of those operations differed from the others.

In many cases for the fishing results, including those shown in Fig. 2 and those which are not shown in this report, correlations with hooks in the immediate vicinity were fairly high. In other words, salmonids tend to be caught with high probability on hooks in the vicinity of the hook which caught a salmonid. However, the range of contingent fluctuations was large. Averaged correlograms for the respective operations (Fig. 3) showed almost no correlations with the hook away from the hook concerned and correlations were observed with only adjacent hook.

Table 3 shows the result of tests of the significance of correlations of state of catches between a hook and each of the adjacent hooks. In this table, "p" and "q" imply the probabilities of the case where a salmonid was caught on the hook adjacent to the hook on which a salmonid was caught, and where a salmonid was caught on the hook adjacent to the hook on which no salmonid was caught, respectively. The data shown in Table 3 are only those which were from operations where 50 or more salmonids were caught and examined and met the conditions concerning statistical procedure under which the distribution of the data can be approximated by a normal distribution (when $p \leq 0.5$ then $np \geq 5$ or when $p > 0.5$ then $n(1-p) \geq 5$, where n implies the total number of fish caught and examined in a single operation). According to Table 3, significant differences were observed in the majority of operations which met these conditions. Therefore, the possibility is suggested that salmonids are caught on hooks located side-by-side.

All species of salmonids were combined in the above discussion. In order to examine the correlation by species, data on the result of fishing for chum salmon (from eight operations) and pink salmon (from one operation) where numbers caught were relatively high were analyzed (Table 4). Again, "p" and "q" in Table 4 imply the probabilities of the case where any salmonid was caught or not caught on a hook, and the same species of salmonid was caught on the hook adjacent to the hook, respectively. Comparing these results to those shown in Table 3, while the differences were not significant for data of operations Nos. 45 and 50 (both from the 1987 cruise of the Wakatake maru) when all species were combined, the difference turned out to be significant at $p<0.05$ when only a single species was considered. Next considered was the number of pairs by species composition when salmonids were caught on the hooks located side-by-side. For this examination, where catches are made consecutively on three hooks or more, the array was divided into pairs and the numbers of pairs were counted. Table 5 shows the results of fishing at stations 45, 46, and 48, all of which were fished during the 1987 cruise of the Wakatake maru, and where the number of salmonids caught was relatively large for plural number of species. From these findings it is presumed that the same species tended to form pairs.

2. Drop-off factor of bait from the hook

Table 6 shows the following; for either case where (1) catch was made on a hook or (2) not, the presence or absence of the bait and probabilities of the case where the bait was absent (p and q, respectively) on the hook adjacent to the hook concerned, and tests of significance of the difference between p and q. Data used were limited to those which met the conditions: $np \geq 5$, similar to the case for Table 3. According to these findings, significant differences were observed for operations where the number of salmonids caught was relatively large. In other words, bait on the hooks adjacent to a hook on which a fish was caught tended to be missing with higher probabilities.

Next, in order to define the drop-off factor, we proceeded as follows--R=the number of hooks on which the bait was lost/(the number of hooks on which the bait remained plus the number of hooks on which the bait was lost). Considering CPUE (the number of salmonids caught with one hachi of longline), gear soaking time, and wind velocity as factors affecting R, the correlation between R and each of these factors was examined (Figs. 4 to 6, Table 7). The results show a correlation between R and each of CPUE and wind velocity but no clear correlation between R and gear soaking time.

The multiple regression of R to both CPUE and wind velocity was examined (Table 8). Comparison of the correlation coefficients calculated by operation between Tables 7 and 8 showed higher values for the case where the multiple regression equation was applied to the correlation of R to both CPUE and wind velocity (Table 8) compared to the case where linear regressions were calculated between R and each of CPUE and wind velocity (Table 7).

The contribution of these two factors is considered to account for 50 to 80% (r^2) of the incidence of drop-off of bait from the hooks.

Discussion

It is said that relatively speaking salmonids tend to be caught in groups. In this study, this tendency was observed and confirmed statistically based on examination of correlograms (Figs. 2,3) by regarding each hook as a unit (Tables 3, 4). Since the results of this study were obtained from longline operations, the swimming direction of the salmonids caught cannot be determined. However, the possibility of the case where two fish which had been approaching adjacent hooks from different directions and were caught on those hooks by accident would be low in light of the short soaking time. In results from driftnet operations from which swimming directions can be determined, the tendency for salmonids to be caught in groups is also observed (Mishima and Shimazaki 1969). Therefore, it is presumed that schooling behavior is to some extent innate in salmonids. At the same time, soaking time is long in the driftnet operations. As a result, although a fish which became entangled in driftnet caused an undesirable configuration of the meshes around the location of the entangled fish and made it difficult for following fish to get entangled in this area of the net (Mishima and Shimazaki 1969), it cannot be affirmed that following fish will not get entangled in the vicinity of the fish already caught. In addition, as stated by Mishima and Shimazaki (1969), the possibility of attraction of individual fish which have already been caught on a hook or in a net to following fish or fish schools cannot be denied. In the future, existence of the attraction referred to here should be confirmed in more precise manner.

Next, examination of the number of the pairs by species (as mentioned previously, catches on consecutive hooks were separated into pairs) where catches were made in groups (Table 5) shows that the catches were composed of the same species in many cases rather than of different species and this suggests the possibility of fish identifying other individuals of the same species. The authors of the present report would like to examine this possibility by studying biological characteristics of fish forming pairs of the same species.

Since it was shown that CPUE and wind velocity greatly contribute to incidence of drop-off of bait from the hook (Figs. 4 to 6, Table 7, 8), feeding and oceanic conditions could be considered to account for a considerable portion of the causes for the drop-off. However, such details are unknown. For example, in many cases, the bait was missing from the hook adjacent to the hook on which a fish was caught, as shown in Fig. 6. As causes of this phenomenon, the following two cases are considered possibilities: the fish had fed on bait on hooks in the vicinity of the hook on which it was finally caught, without being caught, and the fish which was caught on a hook struggled, resulting in the loss of the bait on adjacent hooks.

Care should be taken in estimating the abundance from longline survey data because of the fact that the incidence of drop-off of bait from the hook is dependent on the CPUE and wind velocity. Generally, biomass is considered proportional to the CPUE but the factor of proportionality (gear efficiency) will decrease if the incidence of drop-off is high. Since the incidence of the drop-off is a function of the CPUE and wind velocity (Table 8), no linear relationship can exist between biomass and CPUE. Therefore, the biomass assessed from CPUE values becomes more underestimated for larger biomass and/or for worse oceanic conditions.

REFERENCES, TABLES 1 TO 8, AND FIGS. 1 TO 6
ARE IN ENGLISH IN THE JAPANESE DOCUMENT