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ON THE RELATION BETWEEN THE VARIATION OF THE IMPORTANT FISHERIES CONDITIONS AND THE OCEANOGRAPHICAL CONDITIONS IN THE ADJACENT WATERS OF JAPAN 1.

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It is wellknown that the fluctuation of the oceanographical conditions has the profound influence upon the recruitment, survival and mortality, growth, migration, fishing grounds and the catches of important fishes, and consequently results to their natural fluctuation. However hitherto, owing to the lack of the basic materials and the complexity of the problems, the researches on those interrelationships were very scarce. The author has intended to attack and solve those difficult problems as far as he can at present.

Now, let us consider the yield of a species of fish per unit fishing effort N, the abundance of the fish P, the recruitment of that fish R, and their corresponding environmental factors for P and R as Q and Q_o respectively.

Then $N=f_1\ (P,Q)=f_2(R,Q)=f_3\ (Q,Q_o)$.

Accordingly we may consider that in general the environmental (oceanographical and meteorological) conditions have the dominant influence upon the recruitment of each year and the succeeding yields of those fishes on their migratory routes. It seems that the factors such as water temperature, currents, constituents of the sea water, plankton etc. may give influences on the spawning, development and survival of youngs, migration and ultimately to the fluctuation of the fish abundance.

1. THE SPRING HERRING YIELD OF HOKKAIDO CORRELATED WITH THE SEA CONDITIONS

As for the fluctuation of the spring herring fishery of Hokkaidō the studies by M. Kurakami [1], T. Kawana [2], S. Sato [3] etc. have already shown the relation between the yield of herring and its recruitment (brood) with the sun-spot number and the sea conditions i. e. the rich years correspond to the favourable intensity of the Tsushima Current.

(i) Comparing the fluctuation of the herring yield and its recruitment shown by the above studies to the hydrographical fluctuation, the author found a remarkable correlation between the poor catch years of the Hokkaidō herring and the abnormal cold (abnormal low sea temperature) as shown in the Table 1. (See Fig. 1).

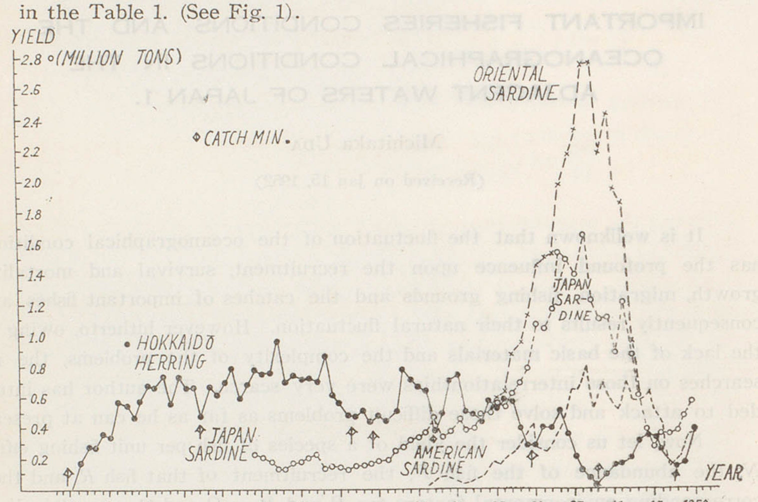


Fig. 1. Yields of herring and sardine in the statistical years.

Table 1.

The abnormal Cold year		Interval Years	The Poor catch year of Hokkaidō Herring
(Bad Harvest)	1866	4	1870
〃	(1869)	4	(1873)
〃	(1884)	3	1887
〃	1902	4	1906, 1907
〃	1905	4	1909
〃	1913	4	1917
〃	1926	4	1930
〃	1934, (1935)	4	1938(1939)
〃	1944, (1945)	4	1948

Therefore, we have the bad years of the Hokkaidō spring herring fishery on every four (or three) years after the abnormal cold year (the year of the bad harvest of rice crop on the land), which means that the bad breeding in the year of the extreme low water temperature (the weak year of warm current) resulted to the scacity of the dominant adults migrated as the fourth (or third) aged herring.

(ii) Corresponding to the anomalous years of Kuroshio (the rich years of skipjack in the seas off the coast of the Wakayama and Mie Prefecture presented westerly coastal current near C. Sionomisaki and the strong onshore current near Sima Penninsula), the spring herring fishery in Hokkaidō has shown the extremely bad years (poor catch in general) as we see in 1937-39, 1917-18, and 1906-07.[4]

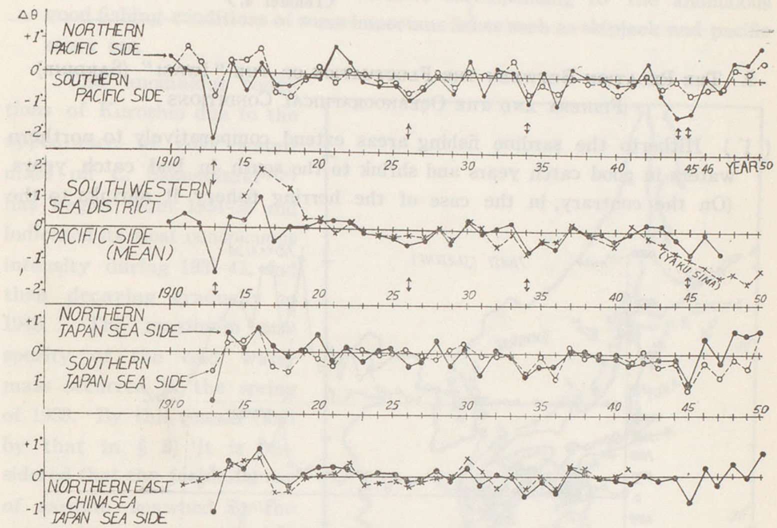


Fig. 2. Anomaly of coastal water temperature (Year Mean) $\Delta\theta$.

(iii) The trends of the yield variation of herring are appeared to run conversely to that of sardine (see Fig. 1)* In the years 1937 and 1938 (the strongly north-going warm current period) against the richest yield of Hokkaidō sardine the herring yields were the poorest.

In the years 1944 and 1945 (of the lowest water temperature) the complete decline of the sardine catch corresponds to the somewhat restoration of the herring fishery.

(iv) The historical fluctuation of the European herring fishery as explained by Otto Pettersson[5] coincides well with the phase of the fluctuation of the oriental herring fishery.[2][6] (See Table 2).

* Also the california sardine yield (abundant in 1934-44) shows nearly inverse trend to that of the oriental herring.

Table 2.

European herring rich period	1660–80,	1752–1810,	1876–97.
Hokkaidō herring rich period	(no record),	1748–76,	
		Hōen, Hōreki An'ei	1877–1905,
		Max, Meiwa 1764–71	Meidi 10–38
Hokkaidō herring poor period	(〃)	1777–83–91 (Min.1784, Tenmei 4,)	1906–43

2. The Relation Between the Fluctuation of the "Iwasi" (Sardine) Fishery and the Oceanographical Conditions

(i) Hitherto the sardine fishing areas extend comparatively to northern waters in good catch years and shrink to the south in bad catch years. (On the contrary, in the case of the herring fishery it shrinks to the

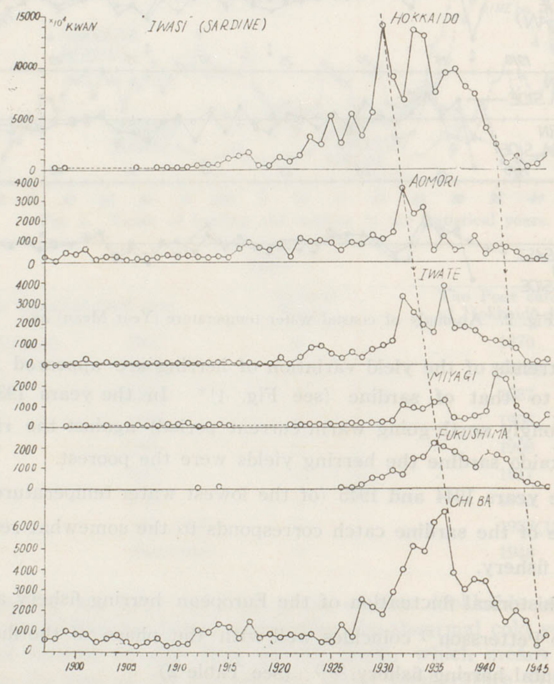


Fig. 3. The yeald of sardine from North (Hokkaidō) to South (Chiba Pref.) in the NE-Japan sea region and the Lags of Its Max, and Min.

north in bad years and extends to the south in good years.) (See Fig. 3).

(ii) Inspecting in the secular variation of the coastal water temperature along the Japan Is. (Fig. 2 & Tab. 3) it shows a general trend of decrease from the beginning of the Taishō era (1914–15) to the years 1944–45 (at its minimum) and then increase year by year from 1946 to 1950, especially in 1949 and 1950 considerably warmer, corresponding to the anomalous good fishing conditions of some important fishes such as skipjack and pacific saury etc.

The anomalous conditions of Kuroshio due to the appearance of cold water-mass off C. Sionomisaki[4)7)8)] has begun from 1934–35 and indicated its most conspicuous intensity during 1937–41, and then decaying gradually to 1945. The maximum prosperity of the cold water mass occurred in the spring of 1938. By this reason (and by that in § 3) it is considered that the feeble larvae of sardine spawned in the southern coastal water-mass off Kyūshū drift in the Kuroshio Current, and on its journey carrying out to the southern warm (saline) water area off C. Sionomisaki, most of them should be destroyed as suggested by Z. Nakai[9)].

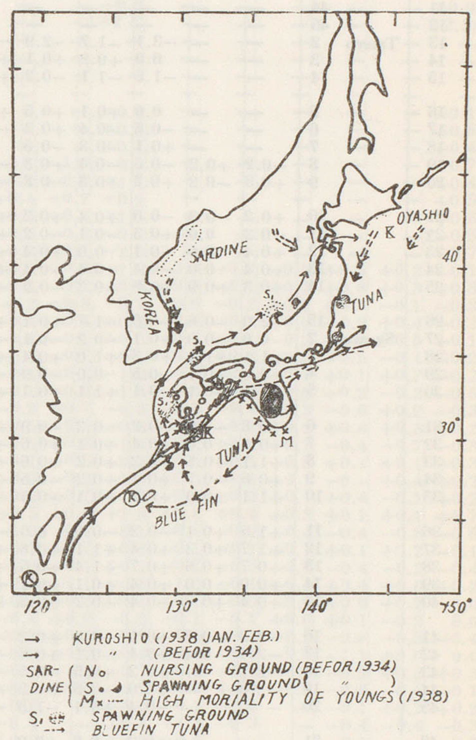


Fig. 4. Some illustrations for sardine and bluefin tuna fishing grounds.

As its consequence the important cause of the succeeding decline of the oriental sardine yield may be found in the above-mentioned hydrographical variation. The effect of the anomalous Kuroshio upon the sardine resource caused by conspicuous cold water mainly in the years 1937–45 (and along the pacific coast to 1947), toge-

Table 3. (A) Anomaly of annual mean water temp. (°C) on the coast of Northern Pacific side.

Location		Tisima Etorohu Atoiya C.	Hokkaido C. Notori	Hokkaido C. Nosyappu	Hokkaido C. Erimo	Hokkaido C. Siokubi	Aomori C. Siriya	Iwate C. Todo	Miyagi Enosima	Hukusima C. Sioya	Tiba Tyosi	Mean Pacific N. Coast
Year	Era	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	a_{10}	a_3–a_{10}
1910	Meidi 43	—	—	—	—	—	—	—	+0.5	—	—	+0.5
11	44	—	—	—	—	—	—	—	+0.2	—	—	+0.2
12	45	—	—	—	—	—	—	—	0	—	—	0
13	Taisyo 2	—	—	−3.1	−1.7	−2.9	−2.4	—	−1.7	−0.4	—	−2.1
14	3	—	—	0.0	+0.2	+0.1	+0.3	—	+0.6	+0.4	—	+0.3
15	4	—	—	−1.5	−1.1	−0.2	+0.3	—	+0.2	--0.8	—	−0.5
16	5	—	—	0.0	+0.1	+0.5	+0.4	—	+0.8	+0.7	—	+0.4
17	6	—	—	−0.6	−0.4	+0.3	−0.4	—	+0.5	−1.1	−0.2	−0.3
18	7	—	—	+0.1	−0.3	−0.5	0.0	—	−0.3	−1.2	−0.0	−0.3
19	8	−0.2	+0.2	−0.5	−0.4	+0.3	−0.1	−0.2	+0.2	−0.4	+0.2	−0.1
20	9	+0.3	−0.2	+0.2	+0.3	−0.8	−0.2	−0.7	+0.1	−0.3	+0.8	−0.1
21	10	+0.2	−0.3	−0.0	+0.4	+0.2	+0.1	−0.0	+2.2	+2.3	+1.5	+1.0
22	11	−0.2	0.0	+0.3	−0.1	−0.2	+0.3	−0.3	+1.0	+0.9	+1.5	+0.5
23	12	+0.4	0.0	+0.1	0.0	+0.4	+0.1	−0.7	−0.3	−0.5	+0.3	−0.1
24	13	+0.4	0.0	−0.4	−0.4	−0.4	+0.3	−0.8	−0.4	+0.3	+0.1	−0.2
25	14	+0.3	+0.9	+0.5	−0.2	−0.5	−0.2	−0.8	−0.4	−0.2	+0.2	−0.2
26	15	−2.0	−0.6	−0.5	−1.7	+0.1	+0.2	+0.2	−0.7	−1.1	−1.1	−0.7
27	Syowa 2	0.0	+0.9	+0.1	−0.2	−0.1	−0.3	−0.1	−0.8	−0.9	−0.2	−0.4
28	3	+1.1	+1.1	+0.3	+1.0	+0.4	+0.2	+0.4	−0.6	−0.5	−0.7	+0.1
29	4	+0.0	−0.1	−0.5	0.0	−0.9	−0.1	−0.5	−0.5	−0.8	−0.5	−0.5
30	5	+0.5	−0.1	−0.1	+1.1	+0.1	+0.3	+0.5	0.0	+1.1	+1.2	+0.6
31	6	−0.8	−1.0	−0.2	−0.2	−0.9	−0.2	−0.5	−1.0	−0.8	−0.1	−0.5
32	7	+0.1	0.0	+0.4	+0.1	+0.6	+0.5	+0.8	+0.1	0.0	+0.1	+0.4
33	8	+1.1	+0.5	+0.2	+0.2	+0.6	−0.3	−0.1	+0.1	+0.9	+0.6	+0.3
34	9	+0.6	−0.7	+0.1	−0.2	−0.5	−0.9	−0.7	−1.7	−0.7	−0.5	−0.7
35	10	+1.1	0.0	+0.2	−0.1	+0.6	−0.1	+0.1	−1.0	−0.8	−0.9	−0.3
36	11	+1.5	+0.1	−0.2	−0.6	0.0	−0.1	−0.3	−1.2	−1.5	−1.5	−0.8
37	12	+1.7	+0.3	+0.4	+1.1	+0.8	+0.3	+0.6	−0.2	−0.0	+0.1	+0.4
38	13	+0.7	+0.6	+0.7	+1.4	+0.5	+0.4	−0.5	−1.1	−0.2	+0.2	+0.2
39	14	+0.0	0.0	+0.4	+0.1	−0.1	+0.0	+0.3	+0.1	+0.3	+0.4	+0.2
40	15	+0.4	+0.3	+0.4	+0.2	+0.3	+0.1	−0.1	−0.4	−0.5	+0.0	0.0
41	16	−3.3	−0.7	+0.1	−0.4	+0.2	−0.1	+0.3	−0.3	−0.2	−0.1	−0.1
42	17	−2.4	−0.4	+0.4	−0.1	+0.6	+0.4	+0.3	+1.0	+1.5	+1.1	+0.7
43	18	−2.1	—	+0.2	+0.5	−0.5	−0.5	−1.0	−1.2	−0.7	−0.4	−0.5
44	19	−3.0	—	+0.0	−0.5	−0.5	−0.6	−1.1	−3.1	−1.4	−1.2	−1.1
45	20	—	—	−0.4	+0.1	−1.5	−1.5	−1.2	—	−1.6	−1.1	−1.0
46	21	—	—	+0.2	+0.6	+0.2	—	+0.3	—	0.0	—	+0.3
47	22	—	—	−0.3	−0.1	+0.1	—	−0.6	—	−0.5	—	−0.2
48	23	—	—	+1.0	—	+0.4	—	+0.2	—	+0.6	—	+0.6
49	24	—	—	+0.5	—	+0.7	—	+0.4	—	+0.3	—	+0.5
50	25	—	—	+0.8	—	+1.0	—	+0.6	—	+1.5	—	+1.0
Statistical Year		26	24	38	35	38	33	32	35	38	29	

Table 3. (B) Anomaly of annual mean water temp. (°C) on the coast of Southern Pacific side.

Location			Tiba Pref. Katuura	Tiba C. Nozima	Idu Miko-moto Is.	Wakayama Sionomisaki	Kōti Pref. C. Muroto	Kōti Pref. C. Asizuri	Miyazaki Utimi	Miyazaki C. Kurasaki	Kagosima C. Sata	S. Pacific Coast
Year	Era		b_1	b_2	b_3	b_5	b_6	b_7	b_{10}	b_{11}	b_{13}	Mean
1900	Meidi	33	—	—	—	+0.7	—	—	—	—	—	+0.7
1		34	—	—	—	+1.2	—	—	—	—	—	+1.2
2		35	—	—	—	+0.9	—	—	—	—	—	+0.9
3		36	—	—	—	+0.6	—	—	—	—	—	+0.6
4		37	—	—	—	+0.9	—	—	—	—	—	+0.9
5		38	—	—	—	(+2.5)	—	—	—	—	—	(+2.5)
6		39	—	—	—	—	—	—	—	—	—	—
7		40	—	—	—	—	—	—	—	—	—	—
8		41	—	—	—	—	—	—	—	—	—	—
9		42	—	—	—	—	—	—	—	—	—	—
10		43	—	—	—	−0.1	—	—	—	—	—	−0.1
11		44	—	—	—	+0.8	—	—	—	—	—	+0.8
12		45	—	—	—	+0.4	—	—	—	—	—	+0.4
13	Taisyō	2	—	−0.1	−1.0	−0.9	—	—	—	—	—	−0.7
14		3	—	+0.2	−0.2	+1.1	—	—	—	—	—	+0.4
15		4	—	+0.4	+0.2	+0.9	—	—	—	—	—	+0.5
16		5	—	+0.5	+0.4	+1.5	—	—	—	—	—	+0.8
17		6	—	−0.5	−0.2	−0.7	—	—	—	—	—	−0.5
18		7	—	+0.3	−0.1	−2.3	—	—	—	—	—	−0.7
19		8	+0.3	+0.2	+0.6	−1.2	−0.3	−0.7	−0.3	+0.5	+0.2	−0.1
20		9	+1.0	+0.5	+0.2	−0.9	+0.3	−0.1	+0.2	+0.8	+0.3	+0.3
21		10	−0.0	−0.2	−0.8	−0.7	−0.6	−0.2	+0.2	+0.3	−0.1	−0.2
22		11	+0.3	+0.4	−0.4	+0.2	+0.4	−0.3	+0.0	+0.9	+0.4	+0.2
23		12	+0.9	+0.4	−0.1	+0.2	+0.1	−0.1	−0.2	+0.2	−0.5	+0.1
24		13	−0.3	−0.1	−0.7	+0.1	−0.1	+0.2	−0.3	−0.5	−0.4	−0.2
25		14	−0.3	−0.1	−0.2	−1.0	−0.2	+0.1	−0.1	+0.1	+0.2	−0.2
26		15	−0.6	−0.1	−0.5	−1.5	−0.6	−0.7	−0.5	−0.2	−0.2	−0.5
27	Syōwa	2	−0.7	−0.2	−0.7	−0.5	−0.2	−0.4	−0.3	−0.0	+0.2	−0.3
28		3	+0.5	+0.5	−0.2	−0.8	+0.5	+0.3	+0.2	+0.4	+0.3	+0.2
29		4	−0.2	−0.0	−0.8	−1.3	+0.1	+0.6	+0.1	−0.4	−0.7	−0.3
30		5	+0.4	+0.7	−0.3	+0.3	+0.5	+0.5	+0.5	+0.1	+0.1	+0.3
31		6	+0.2	+0.6	−0.6	+1.0	+0.3	+0.3	+0.1	−0.4	+0.4	+0.2
32		7	+0.6	+0.2	−0.7	+1.3	−0.3	±0.0	+0.1	+0.4	−0.1	+0.2
33		8	+2.3	+0.5	+0.4	+1.9	+0.4	+0.4	+0.3	+0.1	+0.1	+0.7
34		9	−1.0	−1.0	−0.0	−0.1	−0.6	−0.0	−0.4	−0.4	−0.8	−0.5
35		10	−1.5	−0.7	+0.7	+0.5	−0.1	−0.1	+0.1	+0.1	+0.2	−0.1
36		11	−1.0	−1.0	−0.1	+0.1	−0.7	−0.3	−0.3	−0.4	−0.2	−0.4
37		12	−0.6	−0.5	+1.1	+0.8	−1.0	+0.1	+0.6	+0.4	+0.6	+0.2
38		13	−0.1	+0.1	+0.8	−0.4	−0.7	0.0	−0.0	+0.0	+0.2	0.0
39		14	−0.3	−0.4	+0.9	−0.2	−0.1	−0.1	+0.0	+0.1	−0.2	0.0
40		15	−0.3	−0.2	+0.7	−0.7	−0.3	−0.4	−0.9	−0.8	−0.3	−0.4
41		16	+0.4	−0.5	+1.0	+0.4	+0.0	+0.2	−0.6	−1.1	+0.0	0.0
42		17	+1.0	−0.1	+1.4	+0.7	+0.2	+0.2	−0.0	−0.9	+0.2	+0.3
43		18	+0.5	+0.1	+0.5	−0.0	−0.0	+0.0	−0.4	−0.6	−0.6	−0.1
44		19	+0.5	−0.2	—	+0.9	−0.1	−0.0	—	−0.1	+0.2	+0.2
45		20	+0.4	−0.3	—	+0.4	−1.3	−0.3	—	−0.4	−0.4	−0.3
46		21	+1.4	+0.1	—	+0.2	−0.8	—	—	0.0	—	−0.2
47		22	−0.8	−0.1	—	−0.0	−0.1	—	—	−0.4	—	−0.2
48		23	−0.2	+0.8	—	+0.4	0.0	—	—	+0.3	—	+0.3
49		24	+0.1	+0.6	—	+0.4	−0.1	—	—	+0.1	—	+0.2
50		25	+0.2	+0.5	—	+0.6	+0.5	—	—	+0.3	—	+0.5
Statistical Year			32	38	31	47	32	27	25	32	27	

Table 3. (C) Anomaly of annual mean water temp. (C°) on the South-Western Sea coast.

Location		Kagosima Yaku Is.	Riukiu Ie Is.	Riukiu Tuken Is.	Formosa Hōkasyo Is.	Formosa Goarampii	SW-sea District c_1–c_5	Pacific Side a_3–c_5
Year	Era	c_1	c_2	c_3	c_4	c_5	Mean	Mean
1915	Taisyo 4	—	—	—	+ 0.7	(+1.3)	+ 1.0	+ 0.3
16	5	—	—	—	+ 0.7	(+3.4)	+ 2.0	+ 1.1
17	6	—	—	—	—	—	—	− 0.4
18	7	—	—	—	+ 1.5	+ 1.3	+ 1.4	+ 0.1
19	8	+ 0.5	+ 0.1	+ 0.1	+ 0.4	+ 0.8	+ 0.4	+ 0.1
20	9	+ 1.0	− 0.3	− 0.1	+ 0.9	+ 0.7	+ 0.4	+ 0.2
21	10	+ 0.4	− 0.3	− 0.5	− 0.0	+ 0.3	0.0	+ 0.3
22	11	+ 0.7	+ 0.1	− 0.5	+ 0.1	+ 0.6	+ 0.2	+ 0.3
23	12	− 0.0	+ 1.1	− 1.1	0.0	+ 0.3	+ 0.1	0.0
24	13	− 0.4	+ 0.1	− 0.2	+ 0.1	+ 0.3	0.0	− 0.1
25	14	− 0.6	− 0.8	− 0.4	− 0.2	+ 0.4	− 0.3	− 0.2
26	15	− 0.8	+ 0.1	− 0.2	− 0.2	+ 0.4	− 0.1	− 0.4
27	Syowa 2	− 0.9	− 0.2	− 0.3	− 0.4	+ 0.6	− 0.2	− 0.3
28	3	− 0.1	− 0.2	− 0.2	+ 0.4	+ 0.7	+ 0.1	+ 0.1
29	4	− 0.3	− 0.2	− 0.1	− 0.7	+ 0.2	− 0.2	− 0.3
30	5	+ 0.2	+ 0.8	+ 0.8	− 0.3	+ 0.3	+ 0.4	+ 0.4
31	6	+ 0.2	+ 0.7	+ 0.8	+ 0.6	− 0.2	+ 0.2	0.0
32	7	− 0.2	− 0.4	− 0.3	− 0.0	− 1.0	− 0.4	+ 0.1
33	8	+ 0.3	+ 0.1	+ 0.2	+ 0.8	− 1.3	0.0	+ 0.3
34	9	− 0.0	− 0.1	− 0.6	− 0.1	− 2.3	− 0.6	− 0.6
35	10	+ 0.2	− 0.2	− 0.1	− 0.2	− 0.5	− 0.2	− 0.2
36	11	− 0.3	+ 0.1	− 0.3	− 0.2	− 0.6	− 0.3	− 0.5
37	12	+ 0.6	+ 0.3	+ 0.6	+ 0.1	0.0	+ 0.3	+ 0.3
38	13	+ 0.1	+ 0.2	+ 0.5	+ 0.3	− 1.0	0.0	+ 0.1
39	14	− 0.4	− 0.6	− 0.1	− 0.4	− 0.8	− 0.3	0.0
40	15	+ 0.4	− 0.4	− 0.3	− 0.5	− 0.6	− 0.4	− 0.3
41	16	+ 0.2	+ 0.1	+ 0.6	− 0.0	+ 0.4	+ 0.3	+ 0.1
42	17	+ 0.4	− 0.2	+ 0.7	+ 0.1	+ 0.1	− 0.1	+ 0.3
43	18	− 0.3	− 0.1	− 0.3	− 0.5	—	− 0.3	+ 0.3
44	19	− 0.6	− 0.4	+ 0.1	+ 0.3	—	− 0.1	− 0.1
45	20	− 0.8	—	—	(−0.2)	—	−(0.8)	− 0.7
46	21	—	—	—	—	—	0.0	0.0
47	22	− 1.5	—	—	—	—	(−1.5)	− 0.6
48	23	− 1.4	—	—	—	—	(−1.4)	—
49	24	− 1.7	—	—	—	—	(−1.7)	—
50	25	− 1.3	—	—	—	—	(−1.3)	—
Statistical Year		31	26	26	30	27	31	33

Table 3. (D) Anomaly of annual mean water temp (°C) on the Northern coast of Japan Sea side.

Location			Saghalin C. Nisinotoro	Hokkaidō Osidomari	Hokkaidō Yanziri Is.	Hokkaidō C. Kamui	Hokkaidō C. Inaho	Hokkaidō C. Sirakami	Akita Pref. C. Nyūdō	Yamagata Tobisima	Niigata C. Hime	Isikawa C. Rokugō	d_1 — d_{10}
Year	Era		d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	Mean
1913	Taisyō	2	−0.5	—	—	—	−2.7	−1.8	−1.0	—	−1.9	−1.3	−1.5
14		3	−0.1	—	—	—	−0.1	+0.9	+2.0	—	+1.1	+0.5	+0.7
15		4	+0.4	—	—	—	−0.4	−0.3	+0.7	—	+0.6	−0.1	+0.2
16		5	+2.9	—	—	—	−0.3	−0.0	+0.8	—	+0.9	—	+0.9
17		6	+1.7	—	—	—	−0.1	−0.1	+0.8	—	+0.2	−0.5	+0.3
18		7	+2.0	—	—	—	−1.1	+0.2	−0.2	—	−0.2	−0.5	0.0
19		8	+0.9	0.0	+0.3	−0.1	−0.5	+0.3	+0.6	−0.4	−0.5	+0.4	+0.1
20		9	+2.4	+0.3	+0.9	+0.3	+0.1	+0.6	+0.9	+0.7	+0.5	+0.1	+0.7
21		10	−0.7	−0.1	+0.3	0.0	−0.5	0.0	−0.1	+0·2	0.0	−1.1	−0.2
22		11	−0.5	−0.2	+0.5	+0.2	+0.5	+0.2	−0.1	+1.0	+1.0	+0.0	+0.3
23		12	−0.2	−0.7	+0.3	+0.5	−0.4	−0.8	−0.2	+0.5	+0.3	−1.0	−0.2
24		13	−1.1	+0.7	+1.4	+0.4	−0.1	−0.6	+0.3	+0.8	+0.6	−1.2	+0.1
25		14	−0.0	+1.3	+1.0	+0.2	+1.6	−0.4	−0.6	+0.6	+0.5	−0.8	+0.2
26		15	−0.1	+0.3	+0.2	−0.5	+1.2	−1.0	−1.5	−0.8	+0.3	−0.6	−0.3
27	Syōwa	2	−0.7	+0.9	+0.2	−0.2	+0.9	−1.3	−1.2	−0.7	−0.5	+0.5	−0.2
28		3	+0.7	+1.2	+1.2	+0.5	+1.1	−0.5	−1.1	+0.2	+0.4	+1.1	+0.5
29		4	−0.8	−0.5	−0.2	+0.0	+0.4	−1.5	+0.0	+0.0	+0.5	+0.4	−0.3
30		5	−0.7	0.0	−0.0	+0.2	+0.4	−1.0	+0.3	+0.6	+1.3	+1.0	+0.2
31		6	−1.8	−0.5	−0.9	+0.6	−0.8	−0.1	−0.8	−1.6	±0.0	−0.2	−0.6
32		7	−0.5	−0.2	−0.2	+0.7	+0.6	+0.5	+0.5	−1.2	+1.0	+0.4	+0.2
33		8	−0.4	−0.3	−0.3	+0.1	−0.1	−0.5	+0.9	−0.6	+0.8	+0.8	+0.0
34		9	−0.3	−0.5	−0.9	−0.3	−0.7	−0.3	−0.3	−1.3	−1.4	−0.5	−0.7
35		10	−0.7	−0.5	−0.6	−0.2	0.0	+0.7	+0.4	−0.6	−1.2	+0.2	−0.3
36		11	−0.3	−0.5	−0.7	−0.0	−0.3	+0.6	+0.5	−0.3	−2.0	−0.6	−0.3
37		12	−0.5	+0.1	−0.4	−0.1	+0.3	+1.4	+0.8	+0.5	−1.1	+0.9	+0.2
38		13	+0.4	+0.6	+0.3	+0.3	+0.3	+1.0	−0.2	+0.4	−1.2	−0.0	+0.2
39		14	−0.3	−0.1	−0.4	−0.3	−0.1	+1.0	+0.1	+0.7	−1.0	+0.2	0.0
40		15	−0.8	−0.1	−0.3	+0.1	−0.3	+0.9	−0.0	+0.2	−0.2	+0.2	0.0
41		16	−0.7	−0.4	−0.7	−0.5	−0.2	+0.8	−0.4	+0.2	−0.4	−0.3	−0.2
42		17	−1.1	−0.4	−0.9	−0.5	+0.2	+0.9	+0.1	+0.4	+0.1	+0.5	−0.1
43		18	−0.9	−0.1	+0.2	−0.4	+0.6	+0.5	+0.1	+0.2	−0.3	0.0	0.0
44		19	−1.7	−0.1	−0.7	−0.1	+0.2	+0.1	+0.1	−0.2	−0.6	+0.3	−0.3
45		20	(−0.5)	−0.0	(−1.0)	−0.3	−1.0	−1.0	−0.7	−1.7	−2.2	−0.5	−0.9
46		21	—	(+1.1)	—	+1.0	+1.3	(+0.8)	+0.3	−1.2	−0.2	+1.0	+0.4
47		22	—	+0.2	+0.2	+0.1	+0.2	−0.2	−0.9	+0.1	−0.5	−0.5	−0.1
48		23	—	+1.2	+1.4	—	+0.8	+0.8	+0.0	+1.3	+0.7	+0.2	+0.8
49		24	—	(+0.8)	+0.5	—	+0.5	+1.0	+0.1	+0.7	+0.4	+0.6	+0.6
50		25	—	—	−0.7	—	(+0.6)	(+1.5)	+0.8	(+1.5)	(+0.8)	+0.7	+0.7
Statistical Year			33	31	31	29	38	38	35	29	38	35	38

Table 3. (E) Anomaly of annual mean water temp. (°C)
On the Southern coast of Japan Sea side.

Location			Kyōto Pref. C. Kyōga-misaki	Idumo Hinomisaki	Simane Hamada	Yamaguti Misima	Yamaguti Tunozima Lt. hs.	Yamaguti Hutaizima	Tusima Channel Okinosima	Tusima Channel Misima	Tusima Kōsaki	Gotō Is. Osezaki	e_1 — e_{13}
Year	Era		e_1	e_3	e_5	e_6	e_7	e_9	e_{10}	e_{11}	e_{12}	e_{13}	Mean
1913	Taisyō	2	—	−1.0	—	—	−1.1	—	—	−0.3	—	+0.0	−0.6
14		3	—	−0.1	—	+0.7	+0.8	−0.4	—	+0.5	—	+0.5	+0.3
15		4	—	+0.9	—	+0.4	+0.2	+0.3	—	+0.5	—	−0.0	+0.4
16		5	—	+1.2	—	+0.6	+0.7	+0.7	—	+1.0	—	+0.9	+0.9
17		6	—	−0.1	—	−0.8	−0.8	+0.1	—	−0.4	—	−0.2	−0.4
18		7	—	−0.4	−0.7	−1.1	−0.6	−0.6	—	−0.5	—	−0.5	−0.6
19		8	+0.6	+0.0	−0.3	+0.0	−0.3	+0.4	+0.1	+0.4	—	+0.2	+0.1
20		9	+0.2	+0.1	−0.3	−0.4	−0.2	−0.4	−0.1	−0.3	—	+0.3	−0.1
21		10	−0.0	−0.2	−0.3	−0.4	−0.6	−0.3	−0.5	−0.4	—	−0.2	−0.3
22		11	+0.8	+0.4	+0.4	0.0	+0.6	+0.8	−0.5	+0.5	—	+0.0	+0.3
23		12	−0.2	+0.3	+0.1	+0.0	+0.4	+0.6	+0.2	+0.4	—	+0.2	+0.2
24		13	−0.7	+0.3	0.0	+0.1	−0.1	−0.3	+0.7	−0.1	−0.2	+0.1	0
25		14	−0.2	+0.4	−0.2	+0.1	+0.0	+0.0	+0.3	−0.1	+0.1	+0.1	+0.0
26		15	−0.1	+0.5	+0.1	+0.1	−0.3	+0.3	+1.7	+0.3	+0.5	−0.0	+0.2
27	Syōwa	2	+0.0	+0.3	−0.1	−0.1	−0.1	+0.3	−0.1	+0.1	−0.5	−0.0	−0.0
28		3	+0.1	−0.1	−0.3	+0.1	+0.1	+0.3	−0.7	−0.2	−0.6	±0.0	−0.1
29		4	+0.8	−0.2	+0.0	+0.1	+0.1	+0.7	−0.1	+0.3	−0.1	+0.2	+0.2
30		5	+0.7	−0.1	+0.5	+0.5	+0.2	+1.1	−0.3	+0.9	+0.1	+0.4	+0.4
31		6	+0.7	−0.6	−0.0	+0.1	−0.3	+0.7	−1.0	−0.1	−0.1	+0.2	0
32		7	+0.2	−0.3	+0.1	−0.3	−0.2	+0.9	+0.1	−0.4	−0.1	−0.2	0
33		8	−0.5	−0.2	+0.2	+0.2	+0.3	−0.1	0.0	−0.1	+0.2	−0.2	0
34		9	−0.9	−0.9	−0.7	−0.7	−0.1	−0.8	−0.8	−0.7	−0.5	−1.0	0
35		0	−0.6	−0.1	+0.1	−0.1	+0.1	−0.3	−0.2	−0.2	+0.3	−0.4	−0.7
36		11	−0.9	−0.6	−0.6	−0.6	−0.5	−2.5	−0.4	−0.7	−0.5	−0.3	−0.1
37		12	+0.2	+0.3	+0.3	+0.5	+0.6	−0.9	+1.1	+0.0	+0.4	+0.6	−0.8
38		13	−0.2	−0.2	−0.0	−0.2	+0.0	−1.1	+0.4	−0.1	+0.1	+0.1	+0.3
39		14	+0.1	−0.0	−0.1	+0.3	+0.1	−1.0	± 0	+0.3	+0.2	+0.1	−0.1
40		15	−0.2	−0.4	−0.1	−0.3	−0.0	+0.1	−0.1	−0.0	+0.5	−0.3	0
41		16	−0.6	−0.6	−0.5	−0.1	−0.2	−0.5	−0.1	+0.8	−0.1	+0.3	−0.2
42		17	−0.0	± 0	+0.2	+0.5	+0.4	+0.2	+0.3	−0.4	+0.3	+0.4	+0.2
43		18	−0.4	−0.8	−0.6	−0.6	−0.1	−0.2	−0.4	−1.3	−0.5	−0.2	(−0.6)
44		19	−0.1	−0.5	0.0	+0.5	+0.6	+1.0	−0.5	−0.7	−0.8	−0.1	(−0.1)
45		20	−1.4	−1.1	—	—	0.0	—	−1.5	−2.2	−1.9	−0.4	(−1.2)
46		21	−0.0	−0.2	—	—	−1.0	—	+1.5	−1.4	−2.0	−0.1	(−0.6)
47		22	−0.8	−1.0	—	—	+0.2	—	−0.4	−1.0	−0.5	−0.3	(−0.6)
48		23	+0.7	+0.3	—	—	+0.4	—	+0.4	−0.6	−2.1	+0.5	(−0.1)
49		24	−0.8	−0.6	—	—	−0.3	—	−0.6	−0.9	—	−0.0	(−0.5)
50		25	(−0.2)	+1.7	—	—	(+1.4)	—	+1.1	(0)	—	+1.1	(−0.8)
Statistical Year			32	38	27	31	38	31	32	38	25	38	38

Table 3. (F) Anomaly of annual mean water temp. (°C)
On the Eastern coast of Korea.

Location		Ranto Is.	Seisin	Busuitan	Zyōsin	Byō Tō	Rei Tō	Su gentan	Tyūmonsin	Tappen	Hokō	C. Tyanzen	C. Urusaki	f_1 — f_{12}
Year	Era	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	Mean
1919	Taisyō 8	—	–	+0.1	—	—	—	+0.5	+0.4	+0.3	−1.0)	—	—	+0.3
20	9	—	–	+1.1	—	—	—	+1.5	+0.9	+1.6	+1.5	—	—	+1.3
21	10	—	+1.0	+1.1	—	—	—	+1.2	+0.8	+1.5	—	—	—	+1.1
22	11	—	+0.5	+0.1	—	—	—	+0.4	+0.9	+1.3	—	—	—	+0.6
23	12	—	+0.2	+0.6	—	—	—	+0.2	+0.2	+0.6	—	—	—	+0.4
24	13	—	−0.3	−0.5	—	−0.4	+0.1	−0.4	−0.0	+0.2	—	—	—	−0.2
25	14	—	+0.2	−0.2	—	+0.5	+0.1	−0.2	−0.8	+0.4	—	—	—	0
26	15	—	−0.2	−0.2	—	−0.4	−0.3	−1.2	−1.9	−1.0	—	—	—	−.9
27	Syōwa 2	—	+0.3	−0.0	—	−0.6	+0.3	−0.3	−0.7	−0.8	—	—	—	−.3
28	3	—	−0.1	±0.0	—	−0.3	−0.3	+0.0	−1.5	+0.7	—	—	—	−.2
29	4	—	−0.4	−0.1	—	−0.6	−0.1	−0.1	+1.0	−0.2	—	—	—	−.1
30	5	—	+0.3	+0.2	—	+1.3	+0.3	+0.9	+1.1	+1.1	—	—	—	+.7
31	6	—	−1.2	+0.7	−0.8	−1.0	−0.7	−0.8	+0.2	+0.1	−0.4	+0.1	—	−0.4
32	7	—	−0.5	−0.8	−0.6	−0.7	−1.9	−1.2	−0.9	−0.0	−0.3	+0.0	—	−0.8
33	8	—	+0.4	+0.3	+0.6	+0.4	−0.5	+0.6	+0.3	+0.6	−0.0	−0.4	—	+0.2
34	9	—	−0.6	−1.0	+0.2	−0.6	−0.5	−0.6	−0.0	± 0	−0.5	−0.5	—	−0.4
35	10	+0.2	+0.3	+0.1	+0.4	+0.3	+0.6	+0.5	+0.7	+0.8	−0.1	+0.2	—	+0.4
36	11	−0.2	−0.1	−0.7	−0.1	−0.5	−0.9	−1.2	−1.5	−1.6	−1.7	−1.9	—	−1.0
37	12	+0.1	+0.6	+0.1	+0.5	+1.2	+0.8	+1.0	+0.4	−0.4	+0.3	+0.2	—	+0.5
38	13	+0.4	+0.3	+0.3	+0.2	+0.2	+0.1	−0.2	+0.4	−0.7	+0.1	−0.1	—	+0.1
39	14	+0.9	+0.7	+0.9	+0.8	+1.0	+0.7	+0.3	+0.1	+0.7	+1.1	+1.7	+0.5	+0.8
40	15	−0.2	−0.2	−0.2	−0.4	−0.1	+0.4	+0.9	−1.3	−0.9	−0.7	−0.1	−0.6	−0.3
41	16	−0.6	−0.6	−0.3	−0.7	−0.1	+0.3	−0.9	−0.7	−0.7	+0.2	−0.3	−0.1	−0.4
42	17	−0.4	−0.7	−0.3	−0.4	−0.1	−0.2	+0.8	+1.2	+0.3	+0.5	−0.1	+0.0	0.0
43	18	+0.2	+0.2	+0.2	+0.4	+0.5	+0.4	+0.2	—	—	—	—	—	+0.3
44	19	+0.2	+0.5	+0.2	+0.0	+0.5	+0.4	+1.6	—	—	—	—	—	+0.5
45	20	−1.1	−0.6	−0.4	−1.5	−0.1	+0.3	−0.1	—	—	—	—	—	−0.5
Statistical Year		11	25	27	15	22	22	27	24	24	14	12	4	

ther with the poor transport of the youngs into the coastal area owing to the weak inflow of Kuroshio Branch in spring, were clearly recognized since after 1942 and were not recovered during several years. (See Fig. 4).

(iii) It is considered that the cause of the northern displacement of the main sardine spawning ground, accordingly of the main fishing ground, to the region centered in Gotō Nada off Nagasaki Pref. may be partly in the decrease of the coastal water temperature along the coast of Japan in recent years, especially in the southern coastal water off Kyūshū. (Fig. 2). Corresponding to the development of the Tsushima Current, the fishing areas in 1949 and 1950 indicate more prosperous extension than that in the former years along the coast of the Japan Sea side.

The rich years of the oriental sardine fishing (abundant period) such as the recent rich period 1926–40 correspond to the prosperous northern extension period of warm current and to the weak cold current, in particular the abundant sardine period in the northern waters (Hokkaidō, North Korea and the NE Sea-region of Japan). On the contrary, during the bad years of sardine fishing such as the period of 1942–48 the decline of the yield in the northern waters correspond to the decay of warm current and to the prosperity of the cold current.

The general feature of the decline of sardine fishing began first from the northern region and then gradually propagated to the south (See Fig. 3). The decline of the sardine yield began in Hokkaidō from 1941, in Miyagi Pref. from 1943 and in Chiba Pref. rapidly from 1945. Conversely the rich fishing period began from the southern waters and propagated gradually to the north. However, in the NE Sea-region of Japan the phase of max. yield lags from north to south. (Fig. 3) Or in other words, entering in the bad years the extension of sardine fishing areas shrink year by year to the south in accompany with the shrinkage of the migration route. The delay of the beginning and the prosperous fishing period, the offshore-going tendency of sardine shoals (not approaching near the coast), the decrease of the fat content in the fish body are the common signs of bad years. It is noted that in the bad fishing years of sardine the water temperature falls commonly, especially a conspicuous descent in the southern coastal waters off Kyūshū. In general the period of cold water temperature (i. e. the period of the weak warm current and the strong cold current along the Japan coast) coincides well with the bad fishing years of sardine.

(iv) Basing on the literatures [10)–15)] in the historical past ages we can find the three maxima and minima in the fluctuation of sardine yield in our country. The first good fishing period (its max. in 1716–19) of the years 1680-1730 and the first bad fishing period (its minimum in 1768–80) of the years 1736–89, the second good fishing period (its max. in about 1830) of the years 1818–54 and the second bad fishing period (its min. in about 1885) of the years 1875–1902, the third good fishing period (its max. in about 1936–37) of the years 1929-39 and the recent bad fishing period (its min. 1946–47) of the years 1941–49 can be found. Thus the interval between the first max. and second max., and that between the second and third max. are 113 aud 106 years respectively. Hence it seems that a long cyclic change of nealy one century interval exists in the fluctuation of sardine yield.

The recent decline of the sardine yield is the world-wide phenomenon, not only in the waters adjacent to Japan but in the whole oriental waters, also in the pacific American waters including the California fishing area, further presumably in the European waters. The origin of the phenomenon may be attributed to the cosmic one or geophysical (oceanographical or meteorological) one. It was already reported that the fluctuation of the European herring fishery[5)] and that of the tunny fishery in the Mediterranean seas [16)] show the long period of 110 years, and also of the cod fishery in the Atlantic Ocean the period of about one century [17)].

According to the results of our investigation, the fluctuation of the yield of sardine appears hand in hand with those of tunnies (albacore, yellowfin tuna, bluefin tuna and skipjack) and inversely to those of herring, squids, pacific saury and cod (See in Fig. 5). Now, remarking on the tendency of

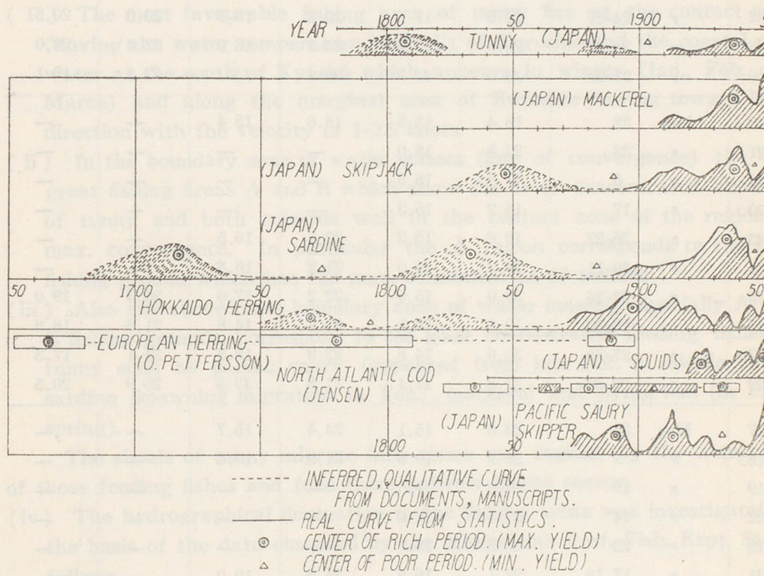


Fig. 5. Long period variations of the catches of the important fishes.

rising water temperature from the lower level gradually from south to north and glancing on the past history of fluctuation, we can see the present state of sardine fisheries, passing through the min. gradually and entering into a new small undulation superposed upon the large undulation of secular period.

Table 4. Water temperature in the regular hydrographical section observed by the Kagoshima Pref. Fish. Expt. St. (θmax., θmix.···max. and min. temp in the section.)

Year	Date		Ōsumi Strait		Tokara Strait		Yokoate Is. W.	
			θmax.	θmin.	θmax.	θmin.	θmax.	θmin.
			(0m)	(150m				
1922	Feb.	18	19.5° C	17.6° C	—	—	—	—
1928	〃	27	20.5	16.2	—	—	—	—
1931	〃	26	20.8	16.9	21.7° C	18.5° C	—	—
1932	〃	11–12	21.0	17.8	21.7	20.0	20.7	19.5
1933	〃	15–16	19.0	14.7	21.5	17.0	—	—
1934	〃	18–19	18.4	15.1	21.5	19.1	—	—
1935	〃	10–11	18.0	14.5	20.6	16.5	21.5	*15.8*
1936	〃	13–14	18.5	14.3	21.3	17.8	21.5	16.3
1937	〃	24–27	22.0	17.1	22.8	19.3	23.0	20.5
1938	〃	23–24	20.0	*13.8*	22.3	18.0	22.4	20.0
1940	〃	21–25	*16.5*	*12.7*	*20.4*	*15.1*	22.1	19.1
1918	Mar.	28	16.4	13.5	18.6	15.4	—	—
1921	〃	23	22.3	18.0	—	—	—	—
1929	〃	6	17.9	15.5	—	—	—	—
1930	〃	17	18.2	15.3	—	—	—	—
1933	〃	26–27	18.6	15.2	22.5	16.5	—	—
1934	〃	10-11	19.2	*13.0*	21.2	16.8	—	—
1935	〃	22–26	20.0	15.5	22.2	17.0	24.3	19.0
1936	〃	28–30	19.3	16.1	21.1	14.8	21.6	18.8
1937	〃	27–30	20.6	14.8	22.9	19.3	24.1	17.3
1939	〃	29–30	*17.9*	*12.4*	21.8	*12.5*	25.9	20.5
1917	May	28	23.8	15.1	24.4	15.7	—	—
1918	〃	2	22.2	19.6	21.9	19.4	—	—
1919	〃	19	20.6	*14.0*	—	—	—	—
1922	〃	14	22.4	16.0	—	—	—	—
1928	〃	22	22.5	15.7	—	—	—	—
1931	〃	17–18	22.1	16.5	25.0	19.0	—	—
1932	〃	13–14	21.5	15.2	25.4	17.2	26.0	18.8
1935	〃	15–17	21.0	16.3	25.5	17.2	26.5	20.0
1936	〃	11–15	22.5	*15.0*	25.1	18.2	26.2	17.5
1937	〃	14–16	24.6	17.4	26.0	17.7	26.2	19.0
1939	〃	22–24	23.0	*14.5*	24.5	*16.8*	25.9	20.5
1940	〃	14–19	23.2	*15.0*	23.3	18.3	24.5	19.0

3. The Relation Between the Fluctuation of Bluefin Tuna* and the Oceanographical Conditions in the Southern Seas of Japan

Hitherto it was considered that the tuna fishery in the pacific ocean is not yet disturbed by overfishing and obeys to the natural fluctuation of its yield due to the oceanographical conditions.

Formerly S. Iehisa (1939) has described the tunny fishing ground south off Kyuūshū during Jan.-March in 1939 correlated intimately with the boundary of water masses [18], and T. Kawana (1934) [19] and T. Kida (1936) [20] discussed the tunny fishery in the southern sea off Hokkaidō in ralation with the sea condition. The present author investigated the materials in the Semi-annual Report of Oceanographical Investigation (1935–41) published by the Imperial Fisheries Experimental Station and obtained the following results. (See Fig. 6).

(i) The most favourable fishing area of tunny lies at the contact zone (having the water temperature 18–20°C) of Kuroshio and the coastal cold water at the south of Kyūshū which appears in winter (Jan., Feb. and March) and along the marginal area of Kuroshio flowing toward NNE direction with the velocity of 1-2.5 knots.

(ii) In the boundary zone of water masses (line of convergence) the two great fishing areas A and B which show the most concentrated shoaling of tunny and both coincide well in the contact zone of the region of max. convergence. In particular the A region corresponds to the best fishing ground which has the max. concentration of tunnies.

(iii) Also the above cited boundary zone of water masses, especially A and B fishing grounds, correspond to the good concentrated feeding fishes of tunny such as pacific saury (appeared from late Dec. to middle Feb.), sardine (spawning migration in Feb.), mackerel and flying fish (in early spring).

The shoals of tunny migrate into those sea regions by the attraction of those feeding fishes and feed them actively in the season.

(iv) The hydrographical fluctuation in the fishing areas was investigated on the basis of the data observed by the Kagoshima Pref. Fish. Expt. St. as follows.

(a) The intensity of warm current flowing through the Ōsumi Strait easterly in winter (Feb.) of 1933-36 shows its considerable decay in comparison with those of 1928, 1931 and 1932. The values of θ max. (max. temperature in the hydrographic section) and θ min. (min. temperature in it) falls down, particularly low during 1934–36.

* Kuromaguro, *Thunnus Orientalis* (SCHLEGEL).

(b) In the Tokara Strait, before 1934 the water temperature is higher than normal, but in March, 1934 θ min. exhibits the remarkable lowest water temperature and the bottom cold water-mass near the coast. Also the bottom water was cold in Feb. 1935. In the years of 1936 and 1937, the boundary of the water-masses was sharply defined. Moreover in the winters of 1937 and 1938 the north-flowing intensity of Kuroshio denoted by the warm water zone (among the isotherms of 16°, 18° and 20° C the 18° C isothermal line is the most useful indicator) has shown its max. prosperity and flow to the western seas of Kyūshū strongly (with the remarkable high temperature of θ max.)

(c) The water temperature in the Kuroshio area to the west of Amami Ō-shima (west of Yokoate Is.) was comparatively higher in the years during 1937–40 and the temperature gradient between the warm Kuroshio water and the cold coastal water was remarkable in the years of 1938 and 1940.

(v) Abnormal rich fishing of tunny with the hydrographical variation.

(a) In the year of 1938 the Kuroshio water in the East China Sea was warmer than normal generally, and the whole Tsushima Current area

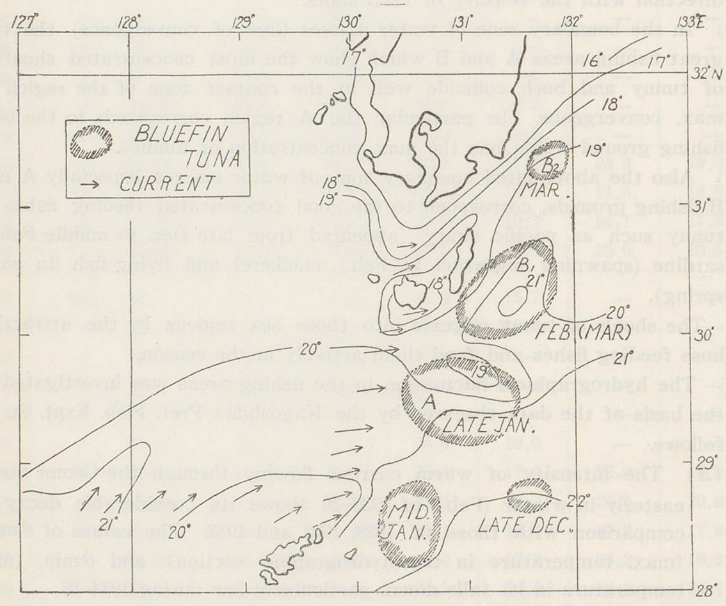


Fig. 6 a. Bluefin tuna fishing grounds in winter of 1935 and the distribution of corresponding water temp. θ at the depth of 100 m. and the surface currents.

in the Japan Sea was also warmer than normal. In the winter of that year the preliminary favourable catch of tunny in the western seas of Kyūshū was reported.

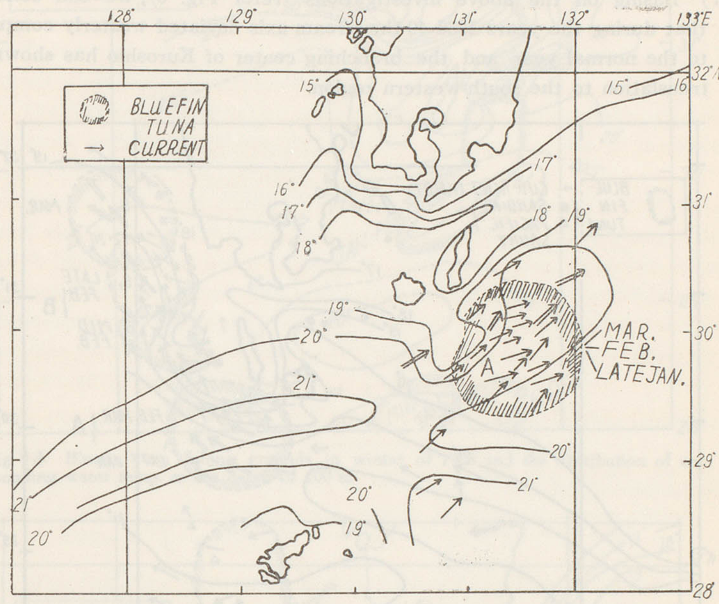


Fig. 6 b. Bluefin fishing grounds in winter of 1936 and the distribution of corresponding water temp. at the depth of 100 m. and the surface currents.

(b) In the winters of 1939 and 1940 the coastal water-mass along the southern coast of Kyūshū, extended to to the south and covered the nieghbouring region of Yakushima.

(c) Soon after the storm of Feb. 5–6, 1939 the water temperature has fallen suddenly and with the decay of catch in the region of Tanegashima, the schools of large tuuny rushed to north along the west coast of Kyūshū in Feb. and March which brought an unexpected abundant catches to the coastal fishing grounds and in April entering in the Japan Sea still the abundant catches continued. In March of that year the upwelling of an anomalous cold water-mass was found in the bottom layer near the coast of Kagoshima Pref. In the next winter of Feb. 1935 again the adjacent waters of Kagoshima Pref. has shown remarkably low temperature (in Ōsumi Strait……… θ max. 16.5° C, θ min. 12.7° C), in Tokara Strait ……… θ max. 20.4° C, θ min.

15.1°C). And the good tunny catch along the western seas of Kyūshū resembled to the previous year with less abundance (which migrated to the north-western region of Kyūshū from late Jan.)

(vi) Basing on the above investigations (refer Fig. 6), we can conclude that during the years 1936-40 the stream-axis deviated westerly compared to the normal year and the branching center of Kuroshio has shown its translation to the south-western region.

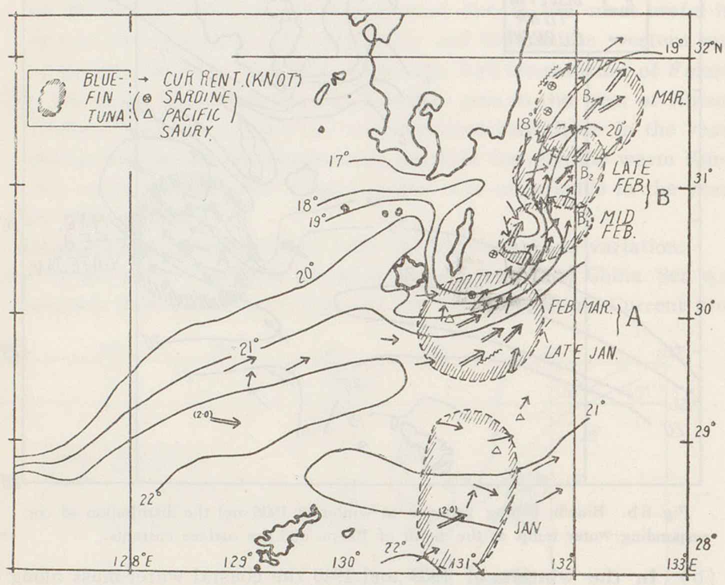


Fig. 6 c. Bluefin tuna fishing grounds in winter of 1937 and the distribution of corresponding water temp. at the depth of 100 m. and surface cnrrents (knots) with the food-fishes.

(vii) According to the sectional observation in the Ōsumi Strait in spring (May), during in the years 1936–40 the water temperature is relatively high, showing its maximum prosperity in 1937 of θ max. 24.6°C (in Tokara Strait 26.0°C).

(vii) In the sea-region south of Kagoshima Pref. in winter as similar to the anomalous cold water-mass in the sea-region south of Sio no Misaki (Kumano Nada) in spring, during the same years 1936–40 the coastal cold water-mass appeared from the deeper layer.

The origin of this coastal cold water-mass is concluded almost as the upwelling of the coastal deeper water corresponding to the southwestern re-

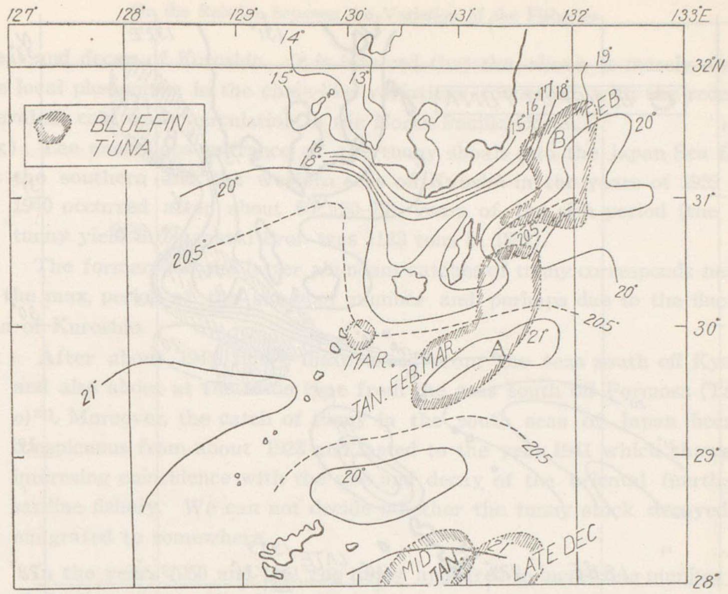


Fig 6 d. Bluefin tuna fishing grounds in winter of 1938 and the distribution of corresponding water temp. at the depth of 100 m.

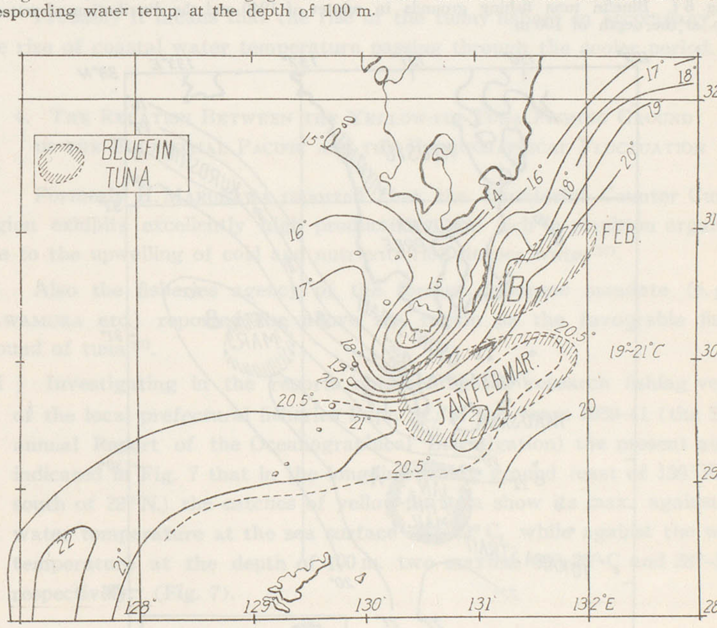
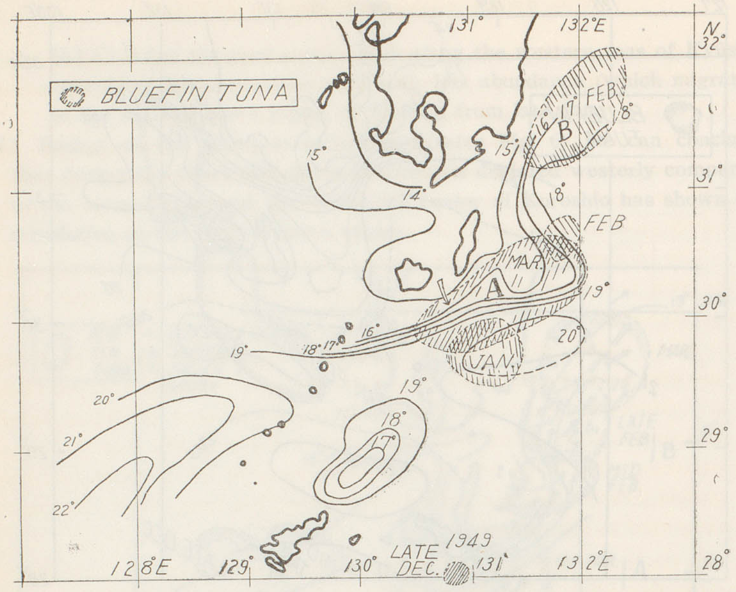


Fig. 6 e. Bluefin tuna fishing grounds in winter of 1939 and the distribution of water temp. at the depth of 100 m.



Fsg. 6 f. Bluefin tuna fishing grounds in winter of 1940 and the distribution of water temp. at the depth of 100 m.

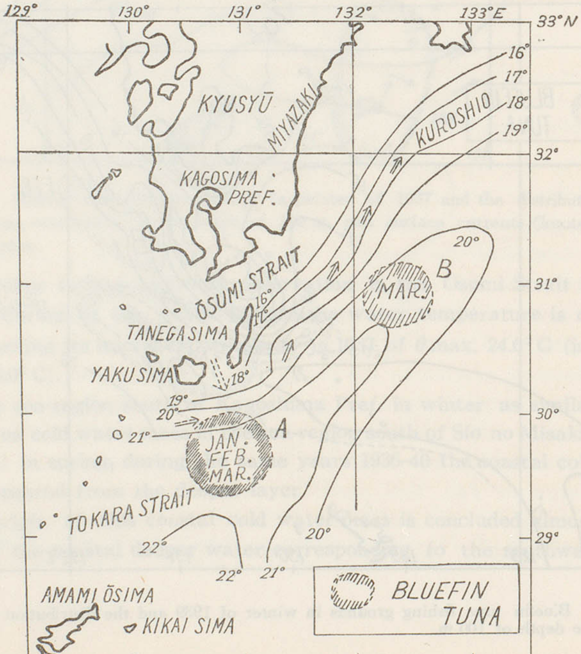


Fig. 6 g. Bluefin tuna fishing grounds in water of 1941 and the diftribution of water temp. at the depth of 100 m.

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(ix) The anomalous entrance of the tunny shoals into the Japan Sea from the southern and the western seas off Kyūshū in the years of 1939 and 1940 occurred after about 60 (50-70) years of the rich period (the last tunny yield in Nagasaki Pref. was 1123 tons in 1891).

The former and the latter abundant catches of tunny corresponds nearly to the max, period of the sun-spot number and perhaps due to the fluctuation of Kuroshio.

(x) After about 1941 tunny disappeared from the seas south off Kyūshū and also about at the same time from the seas south off Formosa (Takao)[21]. Moreover, the catch of tunny in the south seas of Japan became conspicuous from about 1923 and lasted to the year 1941 which shows an interesing coincidence with the rise and decay of the oriental (northern) sardine fishery. We can not decide whether the tunny stock decayed or emigrated to somewhere.

In the years 1950 and 1951 the tunny appeared in increasing number and especially the relative abundance of the youngs was observed.

Probably it means that the rise of the tunny fishery in accompany with the rise of coastal water temperature passing through the cooler period.

4. The Relation Between the Yellow-fin Tuna Fishing Ground in the Equatorial Pacific and the Hydrographical Fluctuation

Formerly H. Marukawa reported that the Equatorial Counter Current region exhibits excellently high productivity and rich in plankton organisms due to the upwelling of cold and nutrients rich deeper water[22].

Also the fisheries agency of the former Japanese mandate (e. g. H. Kawamura etc.) reported the above sea region as the favourable fishing ground of tuna[23].

(i) Investigating in the reports obtained by the research fishing vessels of the local prefectural fisheries Expt. St. in the years 1939-41 (the Semi-annual Report of the Oceanographical Investigation) the present author indicated in Fig. 7 that in the long-line fishing ground (east of 130° E. and south of 22° N.) the catches of yellow-fin tuna show its max. against the water temperature at the sea surface 28°-29° C, while against the water temperature at the depth of 100 m. two maxima 24°-25° C and 28°-29° C respectively. (Fig. 7).

The maxima of the number of the fishing boats in a year and its yield of ths yellow-fin tuna at Misaki Harbour occur in winter, Dec. and Feb. (winter monsoon period and the most prosperous period of NE trade wind and the North Equatorial Current) and the minima occur in summer-autumn of Aug. Sept. and Oct. (typhoon period). The catches of black marlin and the big-eyed tuna indicate also the nearly similar annual variation.

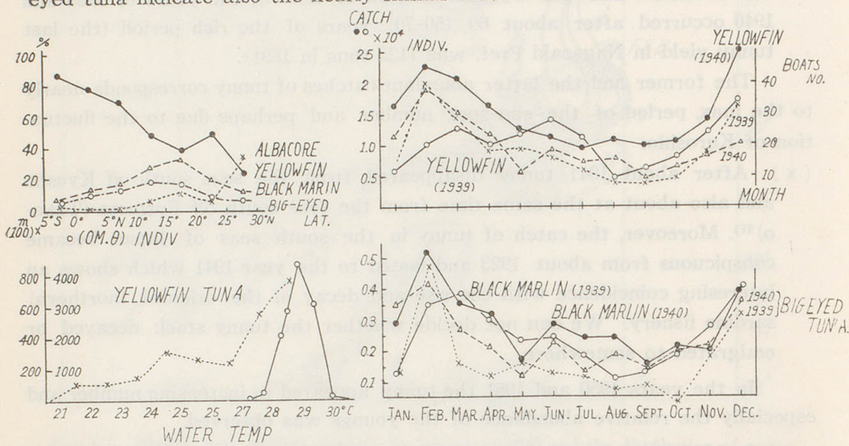

Fig. 7. (i) Annual variation (in 1939, 1940) of the catch of Yellowfin and the number of fishing boat; (ii) Annual variation (in 1939, 1940) of the catch of Black Marlin and Big-eyed Tuna; (iii) Meridional distributions of Albacore, Yellowfin, Black marlin and Big-eyed Tuna in the NW-Pacific; (iv) The optimum temp. of Yellowfin Tuna.

(ii) The distribution of the catch of the yellowfin tuna is most abundant at 0–10 N., and then toward north unto about 30°N., decreases gradually. Since the water temperature changes abruptly near about the line of the subtropical convergence of 20–25° N, a small max. of the catch is shown probably due to the accumulation of fish shoals by the existence of convergence.

Proceeding in detail at that period the main fishing ground of the yellow-fin tuna lies in the region of the Equatarial Counter Current and around it, especially most abundant in the zone 145–150° E.∴ and second abundant areas in 140–145 E. and 150–155° E.

Amid them the fishing ground of the black marlin** has its max. catch in 15–20° N. and the fishing ground of big-eyed tuna† has its max. catch in 10–20° N. Accordingly both lies in the region of the North Equatorial Current.

On the contrary albacore (Binnaga Maguro)※ is abundant in the sea-

* Kiwada Maguro, *Neothunus macropterus* (TEMMINCK & SCHLEGEL)
** Kurokawa, *Makaira Mazara* (JORDAN & SNEYDER)
† Mebati, *Parathunnus Sibi* (TEMMINCK & SCHLEGEL)
※ Binnaga, *Germo germo* (LACÈPÈDE)
∴ It coincides well with the charts for yellowfin[2)].

region to the north of 25° N, and rapidly it decreases to the south of 25° N. Therefore we may consider that albacore is distributed and migrated in the Kuroshio and its extension-area together with in the Kuroshio Counter Current area, which covers the broad sea-region between the Subarctic Convergence (Polar Front) and the Subtropical Convergence.

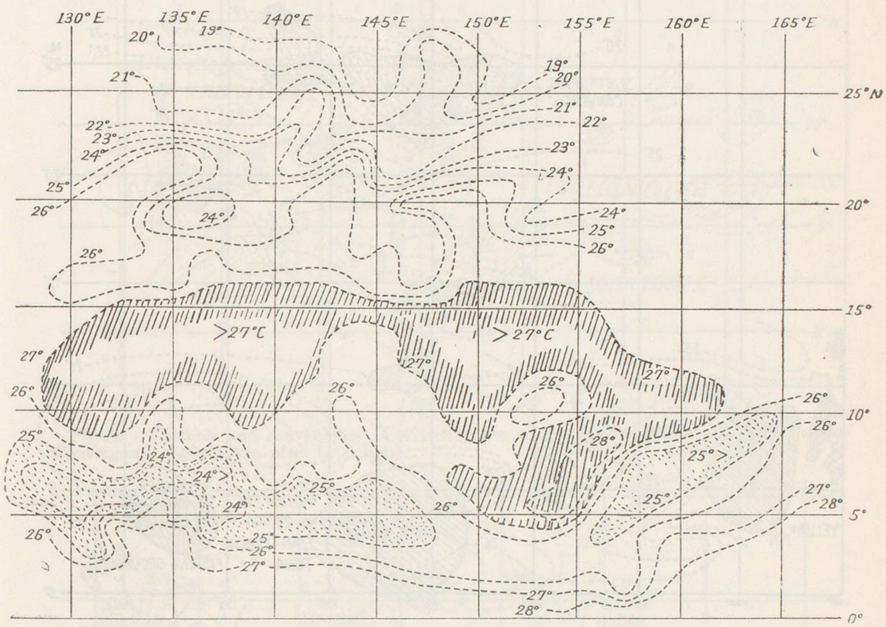

Fig. 8. Distribution of water temp. (°C) at 100 m. depth ("Mansyū" survey. 1925–1928) in the NW–Pacific.

(iii) As for the Equatorial Counter Current, comparing the distribution of currents in the paper by G. Schott[24] with that the distribution of the water temperature at 100 m. depth in the H. M. S. "Mansyū" Reports (1925–28 survey)[25], we can easily show the belt of cold water (min. temperature less than 25° C) in the zone of 5–10° N. (against the high temperature above 27° C in the zone 9°–16° N. of the North Equatorial Current area. However, the results of observation obtained by the fisheries research boats in the equatorial pacific ocean during 1939–41 are very different from the results above-mentioned.

Compared to the period before more than ten years the Equatorial Counter Current area is far broader and in its portion of lowest water temperature remarkably lower (1°–2° C) than the former, moreover in accompany with the northern displacment of the portion of the highest water temperature to 10–15° N. and its shrinkage in the North Equatorial Current. (Fig. 8 and 9.).

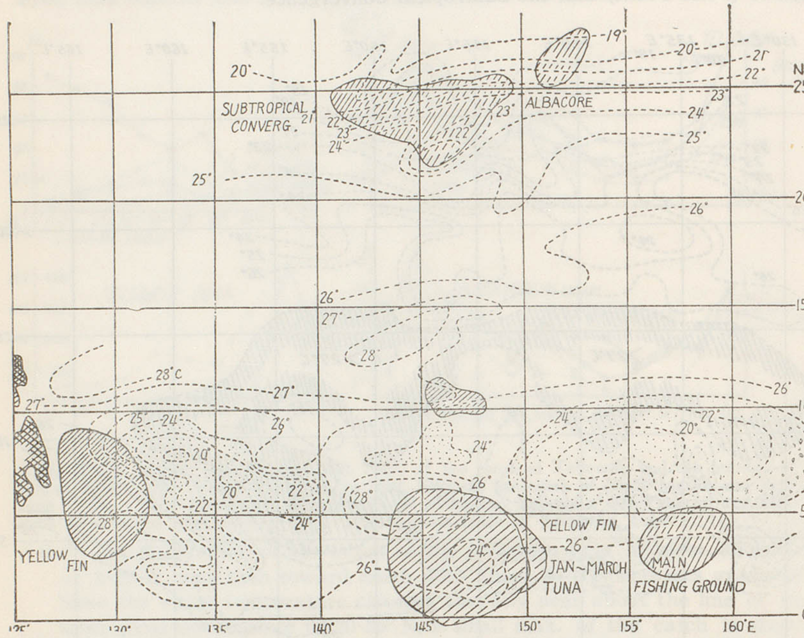

Fig. 9. Distribution of water temp. at 100 m. depth and tuna fishing grounds (Winter in 1939–41) of Japanese fishing boats.

Summarizing the above discussion we can conclude that in the period of the years 1939–41 owing to the prevalent cold water circulation in the North Western Pacific Ocean (from the seas adjacent to Japan to the equatorial pacific) the water temperature in the Equatorial Counter Current is lower than that of the former period. At present, after the World War II, the water temperature at 100 m. depth observed by the fisheries research boat "Sagami Maru" of the Kanagawa Prefectural Fish. Expt. St. during Jan. May in 1951 [26] in the sea region (1°–6° N., 154°–162° E.) lies between 27°–28.7° C, which are above 2° C higher than the temperature in 1939–41, and slightly higher than that in 1925–28 ("Mansyū" Rep.) i. e. it shows the recovery from the abnormal low temperature in 1939–1941.

(iv) Estimating the values of convergence and divergence numerically in winter and summer on the current charts by G. Schott for every rectangle (Lat. 1° Long. 1°) and plotting them in the charts, we get the distributions as shown in Fig. 10 and 11.

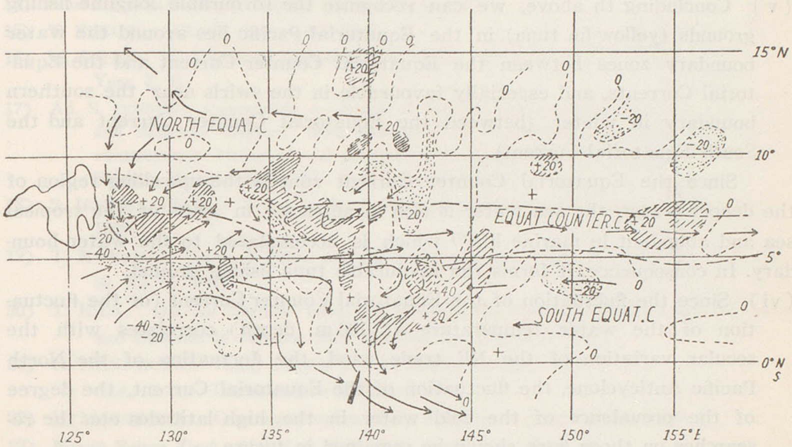

Fig.10. Currents and convergence in winter in the equatorial divergence (−). NW–Pacific. Convergence (+), (Curr. after G. Schott).

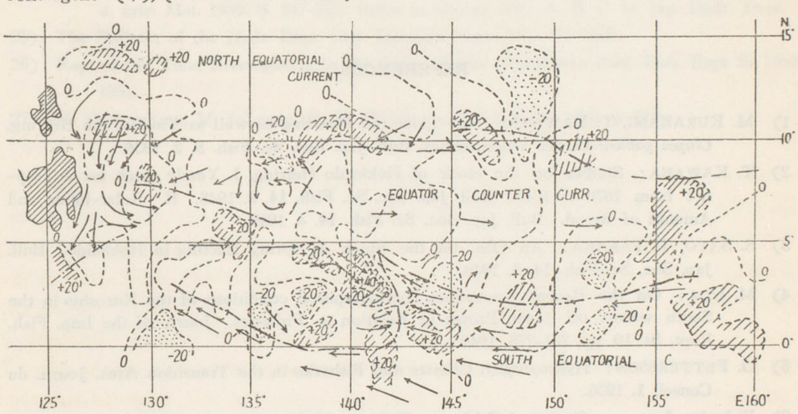

Fig. 11. Currents and convergence (computed) in Summer. in the Equatorial NW–Pacific. (Curr. after G. Schott).

	u_1	u_2	
v_1	K		u_2
v_4			v_3
	u_4	u_3	

$$K=-\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)=\frac{1}{2}\begin{Bmatrix}(u_1+u_4-u_2-u_3)\\+(v_4+v_3-v_1-v_2)\end{Bmatrix}$$

+, Convergence; −, Divergence

The anti-clockwise swirls including the areas of maximum convergence above computed which exist east off Mindanao Is. and in the region (0°~5°N, 140°~150° E) correspond clearly to the favourable fishing grounds of yellow-fin[21].

(v) Concluding th above, we can recognize the fovourable longline fishing grounds (yellow-fin tuna) in the Equatorial Pacific lies around the water boundary zones between the Equatorial Counter Current and the Equatorial Currents, and especially favourable in the swirls near the southern boundary in winter (between the Equatorial Counter Current and the South Equatorial Current).

Since the Equatorial Counter Current zone is the upwelling region of the deeper water, the sea water is rich in nutrients in spite of the tropical sea and abundant in marine life[27] which is accumulated to the water boundary. In consequence, it forms the favourable tuna fishing ground.

(vi) Since the fluctuation of the Equatorial Counter Current (or the fluctuation of the water temperature at 100 m. depth) correlates with the secular variation of the NE trade wind, the fluctuation of the North Pacific Anticyclone, the fluctuation of the Equatorial Current, the degree of the prevalence of the cold water in the high latitudes etc. the researches on those lines should be remained in future.

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