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A Consideration on the Long Years Trend of the Fisheries Fluctuation in Relation to Sea Conditions

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Since the fish populations (P) in nature report their growth and decay (accompanied with extension and contraction of their areas) under some invisible influences of natural environmental conditions, the fisheries conditions and the resulting amount of catch (Y) for each fish species (cod, herring, tuna, etc.) vary year by year, especially in the high or low (some irregular ways) with near a century or twenty to thirty years intervals. (See Table 1, a, b, in general as for the periodic fluctuation for numerous fish species.)

Table 1. a. Historical fluctuation of important fisheries in Japan

Year (A-C)	Fluctuation (Hokkaido)	Year (A-C)	Fluctuation (Hokkaido)
1935-1937	Rich	1900-1902	Rich
1938-1940	Rich	1903-1905	Rich
1941-1943	Rich	1906-1908	Rich
1944-1946	Rich	1909-1911	Rich
1947-1949	Rich	1912-1914	Rich
1950-1952	Rich	1915-1917	Rich
1953-1955	Rich	1918-1920	Rich
1956-1958	Rich	1921-1923	Rich
1959-1961	Rich	1924-1926	Rich
1962-1964	Rich	1927-1929	Rich
1965-1967	Rich	1930-1932	Rich
1968-1970	Rich	1933-1935	Rich
1971-1973	Rich	1936-1938	Rich
1974-1976	Rich	1939-1941	Rich
1977-1979	Rich	1942-1944	Rich
1980-1982	Rich	1945-1947	Rich
1983-1985	Rich	1948-1950	Rich
1986-1988	Rich	1951-1953	Rich
1989-1991	Rich	1954-1956	Rich
1992-1994	Rich	1957-1959	Rich
1995-1997	Rich	1960-1962	Rich
1998-2000	Rich	1963-1965	Rich
2001-2003	Rich	1966-1968	Rich
2004-2006	Rich	1969-1971	Rich
2007-2009	Rich	1972-1974	Rich
2010-2012	Rich	1975-1977	Rich
2013-2015	Rich	1978-1980	Rich
2016-2018	Rich	1981-1983	Rich
2019-2021	Rich	1984-1986	Rich
2022-2024	Rich	1987-1989	Rich
2025-2027	Rich	1990-1992	Rich
2028-2030	Rich	1993-1995	Rich
2031-2033	Rich	1996-1998	Rich
2034-2036	Rich	1999-2001	Rich
2037-2039	Rich	2002-2004	Rich
2040-2042	Rich	2005-2007	Rich
2043-2045	Rich	2008-2010	Rich
2046-2048	Rich	2011-2013	Rich
2049-2051	Rich	2014-2016	Rich
2052-2054	Rich	2017-2019	Rich
2055-2057	Rich	2020-2022	Rich
2058-2060	Rich	2023-2025	Rich
2061-2063	Rich	2026-2028	Rich
2064-2066	Rich	2029-2031	Rich
2067-2069	Rich	2032-2034	Rich
2070-2072	Rich	2035-2037	Rich
2073-2075	Rich	2038-2040	Rich
2076-2078	Rich	2041-2043	Rich
2079-2081	Rich	2044-2046	Rich
2082-2084	Rich	2047-2049	Rich
2085-2087	Rich	2050-2052	Rich
2088-2090	Rich	2053-2055	Rich
2091-2093	Rich	2056-2058	Rich
2094-2096	Rich	2059-2061	Rich
2097-2099	Rich	2062-2064	Rich
2100-2102	Rich	2065-2067	Rich
2103-2105	Rich	2068-2070	Rich
2106-2108	Rich	2071-2073	Rich
2109-2111	Rich	2074-2076	Rich
2112-2114	Rich	2077-2079	Rich
2115-2117	Rich	2080-2082	Rich
2118-2120	Rich	2083-2085	Rich
2121-2123	Rich	2086-2088	Rich
2124-2126	Rich	2089-2091	Rich
2127-2129	Rich	2092-2094	Rich
2130-2132	Rich	2095-2097	Rich
2133-2135	Rich	2098-2100	Rich
2136-2138	Rich	2101-2103	Rich
2139-2141	Rich	2104-2106	Rich
2142-2144	Rich	2107-2109	Rich
2145-2147	Rich	2110-2112	Rich
2148-2150	Rich	2113-2115	Rich
2151-2153	Rich	2116-2118	Rich
2154-2156	Rich	2119-2121	Rich
2157-2159	Rich	2122-2124	Rich
2160-2162	Rich	2125-2127	Rich
2163-2165	Rich	2128-2130	Rich
2166-2168	Rich	2131-2133	Rich
2169-2171	Rich	2134-2136	Rich
2172-2174	Rich	2137-2139	Rich
2175-2177	Rich	2140-2142	Rich
2178-2180	Rich	2143-2145	Rich
2181-2183	Rich	2146-2148	Rich
2184-2186	Rich	2149-2151	Rich
2187-2189	Rich	2152-2154	Rich
2190-2192	Rich	2155-2157	Rich
2193-2195	Rich	2158-2160	Rich
2196-2198	Rich	2161-2163	Rich
2199-2201	Rich	2164-2166	Rich
2202-2204	Rich	2167-2169	Rich
2205-2207	Rich	2170-2172	Rich
2208-2210	Rich	2173-2175	Rich
2211-2213	Rich	2176-2178	Rich
2214-2216	Rich	2179-2181	Rich
2217-2219	Rich	2182-2184	Rich
2220-2222	Rich	2185-2187	Rich
2223-2225	Rich	2188-2190	Rich
2226-2228	Rich	2191-2193	Rich
2229-2231	Rich	2194-2196	Rich
2232-2234	Rich	2197-2199	Rich
2235-2237	Rich	2200-2202	Rich
2238-2240	Rich	2203-2205	Rich
2241-2243	Rich	2206-2208	Rich
2244-2246	Rich	2209-2211	Rich
2247-2249	Rich	2212-2214	Rich
2250-2252	Rich	2215-2217	Rich
2253-2255	Rich	2218-2220	Rich
2256-2258	Rich	2221-2223	Rich
2259-2261	Rich	2224-2226	Rich
2262-2264	Rich	2227-2229	Rich
2265-2267	Rich	2230-2232	Rich
2268-2270	Rich	2233-2235	Rich
2271-2273	Rich	2236-2238	Rich
2274-2276	Rich	2239-2241	Rich
2277-2279	Rich	2242-2244	Rich
2280-2282	Rich	2245-2247	Rich
2283-2285	Rich	2248-2250	Rich
2286-2288	Rich	2251-2253	Rich
2289-2291	Rich	2254-2256	Rich
2292-2294	Rich	2257-2259	Rich
2295-2297	Rich	2260-2262	Rich
2298-2300	Rich	2263-2265	Rich
2301-2303	Rich	2266-2268	Rich
2304-2306	Rich	2269-2271	Rich
2307-2309	Rich	2272-2274	Rich
2310-2312	Rich	2275-2277	Rich
2313-2315	Rich	2278-2280	Rich
2316-2318	Rich	2281-2283	Rich
2319-2321	Rich	2284-2286	Rich
2322-2324	Rich	2287-2289	Rich
2325-2327	Rich	2290-2292	Rich
2328-2330	Rich	2293-2295	Rich
2331-2333	Rich	2296-2298	Rich
2334-2336	Rich	2299-2301	Rich
2337-2339	Rich	2302-2304	Rich
2340-2342	Rich	2305-2307	Rich
2343-2345	Rich	2308-2310	Rich
2346-2348	Rich	2311-2313	Rich
2349-2351	Rich	2314-2316	Rich
2352-2354	Rich	2317-2319	Rich
2355-2357	Rich	2320-2322	Rich
2358-2360	Rich	2323-2325	Rich
2361-2363	Rich	2326-2328	Rich
2364-2366	Rich	2329-2331	Rich
2367-2369	Rich	2332-2334	Rich
2370-2372	Rich	2335-2337	Rich
2373-2375	Rich	2338-2340	Rich
2376-2378	Rich	2341-2343	Rich
2379-2381	Rich	2344-2346	Rich
2382-2384	Rich	2347-2349	Rich
2385-2387	Rich	2350-2352	Rich
2388-2390	Rich	2353-2355	Rich
2391-2393	Rich	2356-2358	Rich
2394-2396	Rich	2359-2361	Rich
2397-2399	Rich	2362-2364	Rich
2400-2402	Rich	2365-2367	Rich
2403-2405	Rich	2368-2370	Rich
2406-2408	Rich	2371-2373	Rich
2409-2411	Rich	2374-2376	Rich
2412-2414	Rich	2377-2379	Rich
2415-2417	Rich	2380-2382	Rich
2418-2420	Rich	2383-2385	Rich
2421-2423	Rich	2386-2388	Rich
2424-2426	Rich	2389-2391	Rich
2427-2429	Rich	2392-2394	Rich
2430-2432	Rich	2395-2397	Rich
2433-2435	Rich	2398-2400	Rich
2436-2438	Rich	2401-2403	Rich
2439-2441	Rich	2404-2406	Rich
2442-2444	Rich	2407-2409	Rich
2445-2447	Rich	2410-2412	Rich
2446-2448	Rich	2413-2415	Rich
2449-2451	Rich	2416-2418	Rich
2452-2454	Rich	2419-2421	Rich
2455-2457	Rich	2422-2424	Rich
2458-2460	Rich	2425-2427	Rich
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2479-2481	Rich	2446-2448	Rich
2482-2484	Rich	2449-2451	Rich
2485-2487	Rich	2452-2454	Rich
2488-2490	Rich	2455-2457	Rich
2491-2493	Rich	2458-2460	Rich
2494-2496	Rich	2461-2463	Rich
2497-2499	Rich	2464-2466	Rich
2500-2502	Rich	2467-2469	Rich

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A Consideration on the Long Years Trend of the Fisheries Fluctuation in Relation to Sea Conditions

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Since the fish populations (P) in nature repeat their growth and decay (accompanying with extension and contraction of their areas) under some invisible influences of natural environmental conditions the fisheries conditions and the resulting amount of catch (N) for each fish species (sardine, herring, tuna etc.) vary year by year cyclically (in periodic or some irregular ways) with near a century or twenty to thirty, fifty to sixty years intervals. (See Table 1 a, b) In general as for the periodic decaying (or growing) yield,

$$N = N_0 e^{-\lambda t} \sum \cos(\omega t - \mu) \dots \dots \dots (1)$$

Table 1 a. Historical fluctuation of important fisheries in Japan

Years (A. C.)	Herring * (Hokkaidō)	Years (A. C.)	Sardine *	Years (A. C.)	Bluefin * Tuna
1447	Fishery began	Ca 1500	Fishery began	1377	Gotō-Net began
1596~1614	▲ Bad	~1600	developed	(1106 ?)	Miyagi " "
1661~1681	◎ Favourable	1660	(Tyōsi ◎)	1596~1614	◎
1688~1703	▲ Min	1680~1730	◎ Rich	1624~1643	◎
(1716~1762)	◎ Good	(1716~1724)	◎ Max	1644~1708	◎ W N. Kyūsyū
1775~1791	▲ Min	1736~1789	▲ Bad	1700~1845	Kagosima ◎
1814~1840	◎ Rich	(1768~1780)	▲ Min	1784~1834	Tusima ◎
1847~1857	▲ Min	1818~1859	◎ Rich	1799	Aomori ◎
1858~1898	◎ Max	(1830)	◎ Max	1830~1853	Hokkaidō ◎
1900~1912	▲ Min	1864	(Tyōsi ◎)	1847	Hitati began
1913~1920	◎ Rich	1870~1890	▲ Bad	Rich Years	
1938	▲ Min	(1884~1888)	▲ Min	1900~1911	Aomori ◎
1944~1945	◎ Rich	(1917~1921)	Japan Sea ◎	1887~1907	◎ Hitati
1955~1957	▲ Min (?)	1929~1939	◎ Rich	1897, 1905	◎ Noto
			Max	1908~1912	▲ Bad
		1941~	▲ Bad	1933~1940	◎ Max
		(1941~1947)	▲ Min	1941~1948	▲ Min
		Japan Sea		1955~1956	◎ Rich
S O U R C E	* Hokkaidō Gyogyōsi (History of Hokkaidō Fisheries, 1957), and other Manuscripts.	* UDA, M. (1952) J. Tokyo Univ. of Fisheries 38 (3) ITO, S. (1956) YAMAGUTI, K. (1947) etc.		* UDA, M. (1957) Teiti Z. Sasazawa (1956): Simokita Hantō Si, S. Nagata (1957) Teiti, T. YAMAGUTI (1947) T. YAMADERA & others	

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Table 1 b. Recent fluctuation of the fisheries conditions in the JAPAN SEA.
(Δ bad, \blacktriangle very bad, \odot good, \ominus rich yields)

	Periods (Interval Years)	Sardine	Tuna	Squid	Herring
1	1868~1905	Δ	\circ		\circ
2	1906~1912	\odot	Δ		Δ
3	(1913~1917)	(\odot)		\circ	\odot
4	1917~1921	\circ		Δ	(1913~1920)
5	1923~1931	Δ		\circ	
6	1932~1940	\ominus	\odot		Δ
7	1941~1948	Δ	\blacktriangle	\odot	\circ
8	1949~1955	\odot	\odot	\ominus	Δ
9	1956, 1957		\ominus	Δ	\blacktriangle

The actual fluctuation of fish population (or catch) proceeds on the base line of its natural fluctuation modified by some artificial fluctuation (e. g. fishing intensity or some bad effects of industrial wastes).

Following the pioneer works by F. I. BARANOV¹⁾, J. HJORT²⁾, M. GRAHAM³⁾, E. S. RUSSEL⁴⁾, W. E. RICKER⁵⁾, and M. B. SCHAEFER⁶⁾, M. TAUTI⁷⁾, J. C. MARR⁸⁾, et al, fish population dynamics should be established on the consideration of the fluctuating environmental conditions into the basic constants of the equations (e. g. natural increase $f(P)$, reproduction potential, rate of survival, rate of natural mortality, rate of fishing (k), rate of growth, rate of recruitment, availability, fishing effort (F) etc) to fit the actual fluctuation of fisheries. Following to SCHAEFER⁶⁾

$$\frac{dP}{dt} = f(P) - kPF \dots \dots (2)$$

(where k, F, P , are all functions of environmental factors.)

In accompany with the movement of predominant warm currents and cold currents the regional zones of favourable catch and unfavourable catch shift and undulate from north to south or from south to north meridionally (y -direction) along the coast and from offing to nearshore or from nearshore to offing laterally (x -direction). As the function of the movements in each directions x, y with velocities c_1, c_2 resp.

$$N = \emptyset (x - c_1 t, y - c_2 t) \dots \dots (3)$$

The migration-route of fish shoals approaches to the coast in rich years and next further away from the coast in poor years (e. g. sardine, yellow-tail etc).

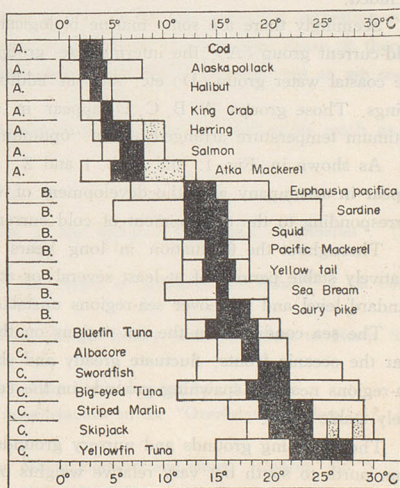


Fig. 1 Optimum water temperature spectra of important fishes in Japan.

Table 2. Phase lag of the mode (maximum) of catch curves and their optimum temperature.

	Fish species	Period I (Years)	Period II (Years)	Optimum Water Temp
A	Herring	1944~1945	—	3°~8°C
A	Atka Mackerel	1944~1948	(1951~1953)	2°~6° (~13°C Youngs)
B	Squid	1941~1943	1951 (1952)	12°~16°C (10°~18°)
B	Sardine	1933~1939	1947~1950	12°~16°C
B	Yellowtail	1942~1943	1951~1952	14°~16°C
B	Pacific Mackerel	1939	1954(1951~52, JAPAN SEA)	13°~18°C
B	Pacific Saury	1932~1940	1955	15°~18°C
B	Horse Mackerel	1940~1941	1954~1957	15°~18°C
C	Bluefin Tuna	1936~1941	1956, 1957	(12°)~14°~19°~(21°C)
C	Albacore	1935~1940	1954~1957	18°~21°C
C	Skipjack	1936~1938	1955~1957	20°~24°C
D	Anchovy	—	1955	17°~19°~(21°C)

The fishing gears fitted to each fishing locality changes from set-net near the coast, in the intermediate waters to purse-seine net, drift gill-net, and to long lines in the offing etc.

We can find those groups of important fish species which show some positive or negative variations respectively and some indicator species for each group (euphausia, copepods, sagitta, needled-puffer, tiny horse mackerel, some kinds of jelly fishes etc.) included.

Seemingly there are some marine biological sequences in the seas and oceans i. e. cold-current group (A), the intermediate group (B), the warm current group (C), and the coastal water group (D) etc. and in addition to them their representative indicator beings. Those groups A, B, C, D appear in succession, corresponding to the order of optimum temperature arranged as the "optimum-temperature spectra" in recent years.

As shown in Fig. 1. and Tab. 1 and 2. the growth and flourishing of C group appear in accompany with the development of warm current contrary to those of A group corresponding to the development of cold current.

Throughout the fluctuation in long years we can distinguish unstable periods and relatively stable periods of at least several or at most ten-several years, referred to some standard level and moreover sea-regions unstable and relatively stable.

The sea conditions in the sea regions on the course of feeding migration, especially near the oceanic fronts, fluctuate greatly and show unstable (rich or poor) catch and in sea-regions near the spawning grounds on the course of spawning migration show comparatively stable catch.

The spawning grounds and nursery grounds move not only from south to north or from north to south but vary relative weights of abundance in the distributed grounds as we see in the cases of sardine, herring etc. The abrupt change in the secular variation are brought by the abrupt growth or decay of warm and cold currents (e. g. in the years of 1923, 1941, 1951). Except the artificial cause (over-fishing, water pollution etc.)

the ultimate cause of the fisheries fluctuation may be found in the variation of reproduction potential, survival, recruits and availability etc. following to the variation of environmental conditions.

The fisheries fluctuation of some important pelagic fishes (sardine, tunas, salmon etc.) seems to occur in some world-wide scale which may corresponds to the global geophysical variation (climatic changes or the fluctuation of oceanic currents, polar-ice, precipitation and evaporation over the oceans or zonal regions). Even in the case of bottom fishes (haddock, cod etc.) the effects of environments, especially the wind conditions in the larval stage are very serious (HACHEY⁸⁾, CARRUTHERS⁹⁾).

Dominant year-classes of the important fish populations (e. g. sardine, herring, bluefin tuna etc.) prevail during several, ten to about twenty years and the appearance of large sized (old aged) fish population without the youngs (small sized) foretell us the warning of the approaching end of fisheries.

The increase of youngs and adults year by year may foretell the growing fishery.

The feeders swarmed on the boundaries of water masses, upwelling, thermocline and thermoantycline, eddies such as loopsacks of warm or cold water masses corresponding to the particular sea-conditions (meander or collision of currents etc.) attract the predators and consequently constitute fisheries grounds. The reversal relations between sardine and anchovy or others may suggest us some law of balance or law of alternative predominance in the seas.

Concerning sardine, mackerel, herring, pacific saury or other fish populations we can find the fluctuation of the spawning grounds in the course of spawning migration-route and the corresponding environmental fluctuation may be the fundamental cause of them.

Special phase for each prosperity of fish populations can be pointed out as we see in Table 1, Table 2.

In conclusion we should define the abundance and maximum sustainable catch as the function of the environmental factors.

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The authors of the present paper have been particularly interested in the question of the effect of environmental factors on the abundance of haddock in the North Sea. The authors have been particularly interested in the question of the effect of wind conditions on the abundance of haddock in the North Sea. The authors have been particularly interested in the question of the effect of wind conditions on the abundance of haddock in the North Sea.

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