RESEARCHES ON THE FISHERIES GROUNDS IN RELATION TO THE SCATTERING LAYER OF SUPERSONIC WAVE [INTRODUCTORY REPORT]

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Reprinted from the Journal of the Tokyo University of Fisheries,
Vol. 42, No. 2, March, 1956.

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(Received Jan. 25, 1956)

Introduction

The world-wide wonderful phenomenon in the submarine waters named DSL (Deep Scattering Layer), which was first discovered by 3 American physists (C. EYRING, R. CHRISTIENSEN, R. RAITT)[1] in the Scripps Institution of Oceanography in U.S.A and afterwards suggested by MARTIN JOHNSON (marine biologist)[2] as a

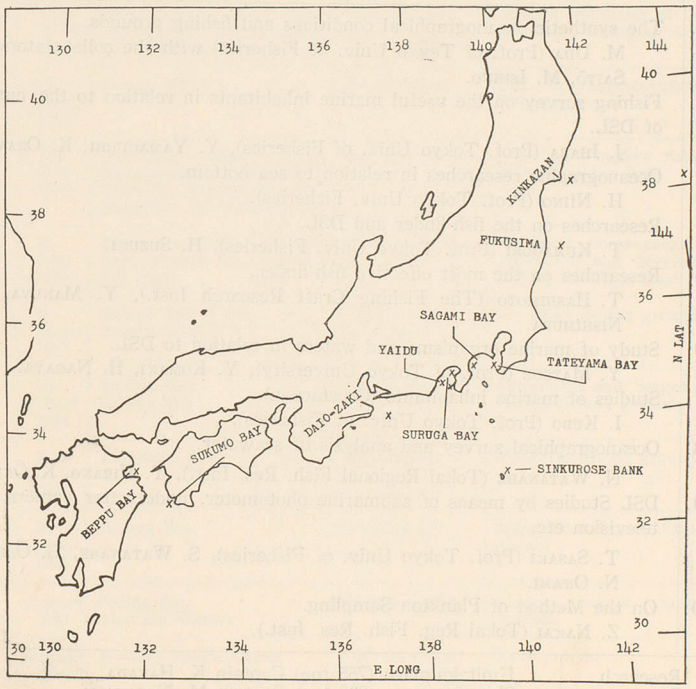

Fig. 1. General Map Showing the Locations of DSL Surveyed (× mark).

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concentrated layer of macroplankton groups due to the vertical diurnal migration.

Since then a series of researches on DSL was followed by the marine scientists in many countries as an up-to-date problem of modern oceanography and reported the world-wide occurrence in seas and oceans including the antarctic ocean and have discussed these phenomena formerly so-called as "ghost", "phantom bottom", "false bottom", "plankton bottom" etc. as the concentrated layer of zooplanktons, or deep sea fishes (inclusive squids) or both with active discussions. (Refer to literatures quoted in this paper.)[1-31]

In Japan the first supersonic wave type fish-finder (piezoelectric pattern of 200 KC) constructed and experimented with success in 1929 by K. KIMURA[29] under the supervision of Prof. Dr. M. TAUTI in the Imperial Fisheries Inst. and again

Table I. DSL Research Project (with Research members).

No.	Terms
1.	The synthetic oceanographical conditions and fishing grounds. M. UDA (Prof. of Tokyo Univ. of Fisheries) with the collabolators Y. SAITŌ, M. ISHINO.
2.	Fishing survey on the useful marine inhabitants in relation to the nature of DSL. J. IHARA (Prof. Tokyo Univ. of Fisheries), Y. YAMAGUCHI, K. OZAWA.
3.	Oceanographic researches in relation to sea bottom. H. NIINO (Prof. Tokyo Univ. Fisheries).
4.	Researches on the fish-finder and DSL. T. KUMAGORI (Prof. Tokyo Univ. Fisheries), H. SUZUKI.
5.	Researches on the most effective fish-finder. T. HASHIMOTO (The Fishing Craft Research Inst.), Y. MANIWA, M. NISHIMURA.
6.	Study of marine organisms and waters in relation to DSL. Y. MATSUE (Prof. of Tokyo University), Y. KOMAKI, H. NAGAYA.
7.	Studies of marine inhabitants (Crustacean). I. KUBO (Prof. Tokyo Univ. of Fisheries),
8.	Oceanographical survey and analysis of seawater. N. WATANABE (Tokai Regional Fish. Res. Inst.), T. HIRANO, K. ŌKUBO.
9.	DSL Studies by means of submarine photometer, underwater camera and television etc. T. SASAKI (Prof. Tokyo Univ. of Fisheries), S. WATANABE, G. ŌSHIBA, N. OKAMI.
10.	On the Method of Plankton Sampling. Z. NAKAI (Tokai Reg. Fish. Res. Inst.).
Research Boats Used	Umitaka-maru (755 ton) Captain K. HARADA Shinyō-maru (236 ton) Captain M. NAGAYAMA Seichō-maru (62 ton) Captain K. NARUSE Sitigō-tei (15 ton) Captain ≈. MANDOKORO

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No.	Period	
1.	VIII 19–29 1952	Kum regio (Yok
2.	IX 10–15 1952	Suru
3.	XII 2–13 1952	Suō- Bung Kiisu gami
4.	II 6–20 1953	Zuna Bay, Adj.
5.	X 24–26 1953	Out Tate
6.	III 12–19 1954	Saga Suru
7.	X 16–20 1954	Tate
8.	III 14–20 1955	Suru
1′.	summer 1953	Berin Aleu
2′.	summer 1954	West
3′.	winter 1954	Zuna Hyōt

in 1942 a new type fish-finder constructed of magnetostriction pattern by K. MIYOSHI and T. MIYAZAKI in the same laboratory[30].

In 1941 a curious layer called "N" layer was found by the Japanese naval experts (Mr. HASHIMOTO and others)[31], which in fact corresponds to DSL at present. After the World War II (about 1949) the fish-finders of various pattern submitted to general use through industrial mass production. In 1952 we organized a research group for DSL in relation to fishing grounds under the aids of the scientific research grant supplied by the Ministry of Education, which has the purpose to study the nature of DSL and to find the relation between the swarming, dispersal, movement of fishes etc. and DSL, and to obtain a effective method to evaluate the productivity of the sea, fishing grounds and fishing conditions unfavourable or favourable. Its project and research members are tabulated in the Table I, and the list of our surveys are shown in the following Table II.

Table II. List of the Main DSL Survey (Refer to Fig. 1).

No.	Period	Seas surveyed	Research Vessel	Purpose to study
1.	VIII 19–29 1952	Kumano-Nada, Zunan-Sea-region, NE. Sea of Japan (Yokkaiti-Onagawa)	Umitaka-maru	General searching of DSL in pelagic fishing grounds.
2.	IX 10–15 1952	Suruga Bay	Seichō-maru	DSL in Sergestes-shrimp fiishing ground
3.	XII 2–13 1952	Suō-Nada, Beppu Bay, Bungosuidō, Tosa Bay, Kiisuidō, Ensyūnada, Sagami Bay. (Simonoseki-Ito)	Umitaka-maru	Squid and sardine fishing grounds in the Bays
4.	II 6–20 1953	Zunan-Sea-region, Sagami Bay, Suruga Bay, Gaibō Adj. Sea.	Umitaka-maru	Mackerel, horse-mackerel, yellow-tail and Sergestes-shrimp fishing ground
5.	X 24–26 1953	Out of Tokyo Bay, Tateyama Bay	Seichō-maru No. 7-Boat	Mackerel fishing ground
6.	III 12–19 1954	Sagami Bay, Suruga Bay	Seichō-maru	Yellow-tail and Sergestes-shrimp fishing grounds
7.	X 16–20 1954	Tateyama Bay	Seichō-maru	Mackerel fishing ground
8.	III 14–20 1955	Suruga Bay	Seichō-maru	Sergestes-shrimp fishing ground
1′.	summer 1953	Bering Sea, Aleutian Waters	Umitaka-maru	Alaska pollack, salmon grounds
2′.	summer 1954	Western Pacific Ocean	Umitaka-maru	Tuna ground
3′.	winter 1954	Zunan-Sea-region, Hyōtan Bank	Shinyō-maru	Mackerel and horse-mackerel grounds

Results

In the following the author wishes to report on the general results on behalf of the DSL Research Group[32].

(1) By our survey in the adjacent waters of Japan the scattering layers were found broadly throughout the sea-regions of inland sea, coastal waters, in bays, gulfs and offings, such as in the Kurosiwo current-area and Oyasiwo current-area (off Kinkazan), and found throughout the seasons (summer, autumn and winter) in the year. In summer we found DSL in the offiing and near shore, but in winter only conspicuous appearance in the coastal water region, and scanty in the open ocean.

(2) The frequent and dense occurrence of DSL corresponds to the regions near the shelf edge (or in the vicinity of fish-bank) which indicates the steep increase of the bottom slope and conspicuous upwelling there.

In general we can say the frequent and dense localities of DSL coincides with the favourable fishing grounds and we can see the assemblage of many fishing boats and the favourable fishing conditions there, for example, in Dec. 1952 in the Beppu Bay the squid fishing-ground, in Tateyama Bay in the autumn mackerel fishing-ground, in winter the yellow-tail fishing-ground in the Sagami Bay and the Sergestes-shrimp fishing grounds in the Suruga Bay. Also the frequent occurrence of DSL at the front of water masses (e.g. a zone of convergence off Kinkazan where the cold and warm current meet together).

Along our coast the region of the steepest slope near the shelf edge we have observed a cospicuous upwelling together with DSL, especially during the seasons of autumn and winter the north-westerly monsoon prevailing at the head of the sea valley (the portion of the maximum curvature of the 200 m. isobath contour) upwelling most developed localities, a very conspicuous DSL trace corresponding to the favourable coastal fishing ground. The regions around fishing banks indicating the developed topographical upwelling in particular on the rear and front portion of banks, show also the frequent occurrence of DSL. For example Hyōtan-Se and Kinsu correspond to the mackerel and horse mackerel fishing grounds, and Shinkurose the skipjack fishing ground. The current boundary of cold and warm currents (front) off Kinkazan has shown DSL which indicates frequently the skipjack and whale fishing grounds.

DSL occurs also frequently near the coastal front between oceanic and neritic water which corresponds to the coastal fishing grounds such as sardine, anchovy, mackerel, horse mackerel, squid and yellow-tail fishing grounds. Moreover, we can find DSL in the core portion of eddies (especially of cyclonic eddies) where the favourable fishing grounds produced, and perhaps due to some accumulated scatterers such as plankton-swarms.

(3) The typical DSL shows the phenomena of morning descent and evening ascent in the dawn and dusk (at the time of twilight) near the moments after sun-set and before sunrise can explain the dense swarming of fishes and the most active feeding of fishes. Now we can agree the above to the generally accepted experiences of fishermen.

Sergestes-shrimps begin to ascend just when sun sets down and arrive at

the top-layer at the beginning of the darkness of night (at the end of the astronomical twilight).

By means of SASAKI's Submarine Photometer the diurnal ascent and descent of DSL (vertical migration following the surface of some definite iso-submarine illumination, in other words the echo-trace of DSL corresponding to the vertical migration of some concentrated living organisms as the scatterers of supersonic waves.

In spite of our incomplete sampling of the living organisms of DSL, we can prove the substancial scatterers in this case as the macro-zooplankton groupes mingled by the small-size fishes and shrimps showing all compound band-like echo-trace (for those animals attracted by light i.e. due to phototaxis). Here we can infer the mechanism constituting a fishing ground.

The vertical migration with the velocity of 1–8 cm./s. or 0.6–5 m/min. and also the ascending speed less than the descending one (e.g. in some cases the ascending speed after sun-set of the order 1 cm./s. and the descending one before sun-rise of the order 2 cm./s.) Accordingly the average velocity 4–5 cm./s. (2–3 m./min.) corresponds to the locomotive migrating velocity of the scatterer plankton in DSL conceivably.

DSL daytime descends to the level of the depth 300–400 m. perhaps defined by the optimum submarine illumination and water temperature with thermocline and settles there. (For example at the station 20 SM south off Daiō-zaki of Kumano Nada, bottom depth 1000 m. we found DSL at the level of 410 m. depth, and also in Suruga Bay DSL off Yaizu at the level 324 m. depth in that case the bottom depth 380 m. Sometimes DSL changes its echo-trace pattern such as curtain-like or laminar, spotty and turbulent alike to some bushes subjecting to the state of aggregation or movement of scatterers including fishes. The thickness of DSL varies from 10 m. to 150 m., sometimes representing double or triple, multiple stratified layers of DSL, and suggesting seemingly the concentration of different sorts of scattering organisms. J. B. HERSEY, H. R. JOHNSON, L. C. DAVIS (1952) have reported on DSL of different characteristic echo-trace due to the accumulated various kinds of scattering elements by means of the echo sounders having frequencies of 2–19 KC at some time interval, and at some localities, and at some depths.

The variation of submarine illumination due to the moon light and cloudiness reflects sensibly to the state of DSL and causes its temporary descent or ascent and diffusion or vanishment of DSL trace. The diffusion of DSL echo-trace (perhaps indicating the dispersal of food animals) may interprete the reason of bad fishing in the period of moon light for the fisheries of Sergestes-shrimp, squid, sardine, mackerel, pacific saury etc. using the method of attraction (lure) by fishlamp. In summer season of 1953 in the Bering Sea on board of Umitaka Maru the echo-traces of DSL associated with salmon and alaska pollack schools were observed, which migrating up and down with the variation of concentration in accompany with the variation of the moon illumination during the full moon period of 13–18 moon-age nights i.e. with the higher altitude of full moon DSL descends to the lower and shows the broader diffused layer corresponding to the dispersal of the scatterers.

In general the diurnally migrating DSL of mainly composed by macro-plankton groupes seems to contribute to the formation of the favourable fishing grounds. We can infer that DSL of this sorts may be well associated with the fishing grounds. However we could not recognize DSL by the concentrated layer of phyto-plankton such as diatoms in spite of remarkable abundance for example showing brownish color of the sea water in Sagami-Bay in February 1953 and Beppu Bay in December of 1952.

(4) The appearance of DSL for the acoustical range of frequencies 14, 24, 50, 100, 200 KC was ascertained by the remarkable difference of the trace pattern as laminar or massive structure due to probably the size of the scatterers and the ecological state of its swarming. We can expect a newly designed DSL proper recording fish-finder by means of supersonic wave in near future commercially as the result of development by Messrs. Hashimoto and Maniwa and may get the characteristic features of DSL pattern for the indicators of Sergestes-shrimp, sardine, anchovy, yellow-tail and ala[illegible]pollack fishing grounds etc. It may become a new useful oceanographic tool to exploit new fishing grounds including pelagic fishes and trawl fishes.

(5) The echo-trace of our oceanographic instruments suspended in the submarine water can be detected down to the depth of 200 m. and abled us easily to ob-

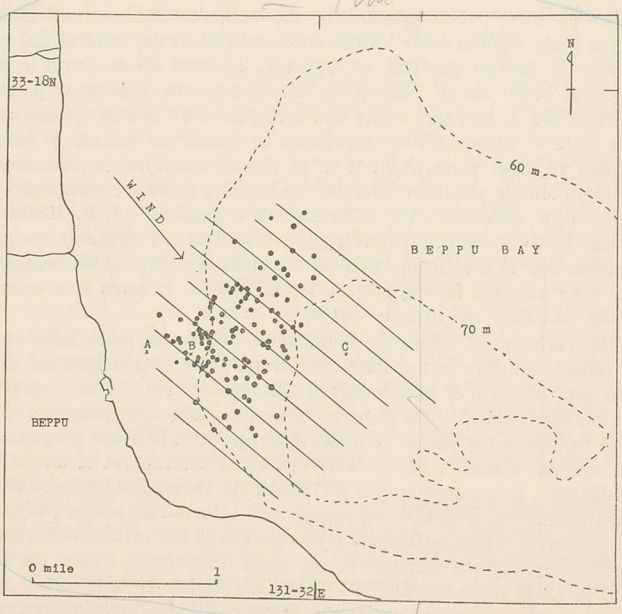

Fig. 2-a. Fishing Ground and DSL Surveyed in Buppu Bay. (× mark—Station Surveyed, black circle—Squid Fishing Boat, hachure area—DSL.)

serve and to sample in the DSL layer as we will, with the accuracy to detect the falling noise of messenger on the water bottle, plankton net or water surface. When the nets or other equipments hauled and suspended in DSL we can observe the DSL descending and diffusing temporarily (e.g. in the yellow-tail fishing ground in the Sagami Bay).

(6) Dr. SASAKI and others constructed a new type of self-recording submarine thermometer of thermister type having the accuracy of 10^{-2}°C down to the depth of 360 m., a newly designed submarine photometer having the accuracy of 10^{-6} lux and a new useful underwater camera and applied all the above to our DSL research. The law of exponential decay concerning on the submarine illumination and the deviation of it due to the light scattering in DSL, thermocline etc. were found particularly.

(7) The experiment on the board of our boat has shown the echo-trace by means of sand particles thrown in the sea below to the depth of several ten meters. In the innermost shore water of Suruga Bay we have found the striped pattern echo-trace due to the fiberous turbid scatterers in the bottom water which discharged from the estuaries by the pulp-mill factories where indicates brownish water pollution with bad smell.

On board of Umitaka Maru in Isikari Bay K. OZAWA remarked a DSL of nonstationary type due to probably the turbid mud particles discharged from Isikari River with snow-melted water and suspended along the pycnocline layer.

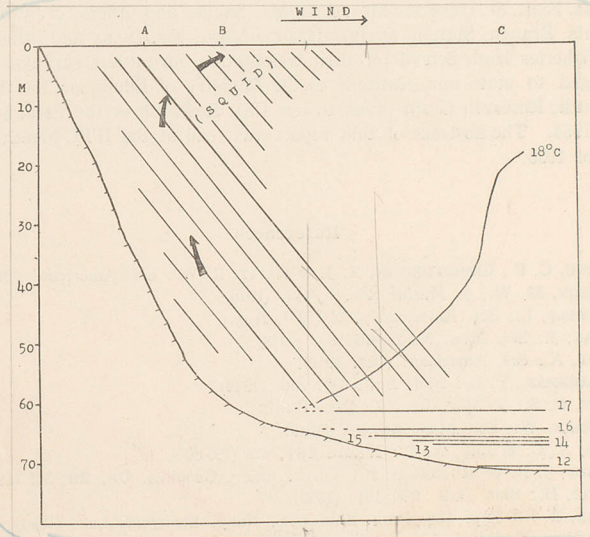

Fig. 2-b. The Distribution of Temp. and DSL in the Sectional Chart. (arrow—Direction of Upwelling, hachure area—DSL.)

He found herring shoals migrating only in the layer above the pycnocline in that season.

(8) In the central core region of eddies (whirls) we see frequently DSL (e.g. "Ōsaki-Dasi" bank off Itō where squids, horse mackerel, bonito etc. swarms). In the Uwazima Bay we observed the same DSL in the sardine fishing ground due to perhaps the accumulated scatterers in the eddies.

(9) In Dec. 1952 on board of Umitaka Maru we observed in the central concave basin of Beppu Bay having the bottom depth of 70–75 m. and found a stagnated cold bottom water (10°C), poor in dissolved oxygen, the upper homothermal water (about 14°C) above the depth of 60 m., and near at the level of 60 m. depth a discontinuity layer (thermocline or pycnocline) in neighbouring DSL layer, perhaps due to the accumulation of scatterers including planktons and suspended turbid matters. (See fig. 2 a, b). The northwestern steep slope of the basin some prosperous upwelling by the strong north west monsoon and the corresponding dense DSL in the range of water temperature of 10°–20°C where several tens fishing boats operating active squid fishing were observed.

Acknowledgement

In concluding this report the author wishes to state of his heartiful thanks as the representative of our DSL Research Group to the Ōita Prefectural Fisheries Experimental St. (Director and Mr. NŌDU, crew of Hayasui-Maru), the Siduoka Pref. Fish. Expt. St. (Director Mr. ANDŌ, Mr. SEKINO and others, crew of Asitaka-Maru), its Branch Station at Itō (Hasima-Maru, Mr. INABA and others), to the Yaidu Fisheries High School for their cooperation during our surveys. Also we are obliged to state our gratitude to the Ministry of Education for the aids by the Scientific Research Grant given to our DSL Research in the fiscal years from 1952 to 1954. The abstract of this report was read at the IPFC Meeting (Tokyo) in Oct. of 1955.

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