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ON BIOLUMINESCENT *NOCTILUCA* SWARMS ASSOCIATED WITH THE MOVEMENT OF EXTENSIVE SHOALS OF FLYING-FISHES AND SCHOOLS OF DOLPHINS IN THE NORTHERN ARABIAN SEA IN FEBRUARY, 1974

By

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(With 1 Text-figure)

INTRODUCTION

During the oceanographic expedition on INS DARSHAK in the northern Arabian Sea from December 1973 to May 1974, a greenish colouration of the sea during the day and a bluish-green bioluminescence during the night caused by the swarming of the dinoflagellate *Noctiluca miliaris* Suriray was observed over an extensive area on the 18th and 19th February 1974, as the vessel moved along its cruise-track establishing Stations during the first lap (5.2.74 to 20.2.74) of the IIIrd Scientific Cruise. During the night of the 18th/19th February, 1974, this swarming bioluminescent phenomenon was associated with the movement of extensive shoals of flying-fishes and schools of dolphins from the relatively feebler bioluminescent areas located at the periphery of the 'bloom' towards the brighter zone of the bioluminescent region centered over the "CORIE HIGH" area. The swarming of *Noctiluca* and the associated greenish colouration-bioluminescent phenomenon had disappeared when this and adjoining areas were revisited from 23.2.1974 to 28.2.1974 during the second lap of the IIIrd Scientific Cruise. No evidence of dead, decaying or floating fishes and other marine organisms was observed. These observations are recorded in this paper.

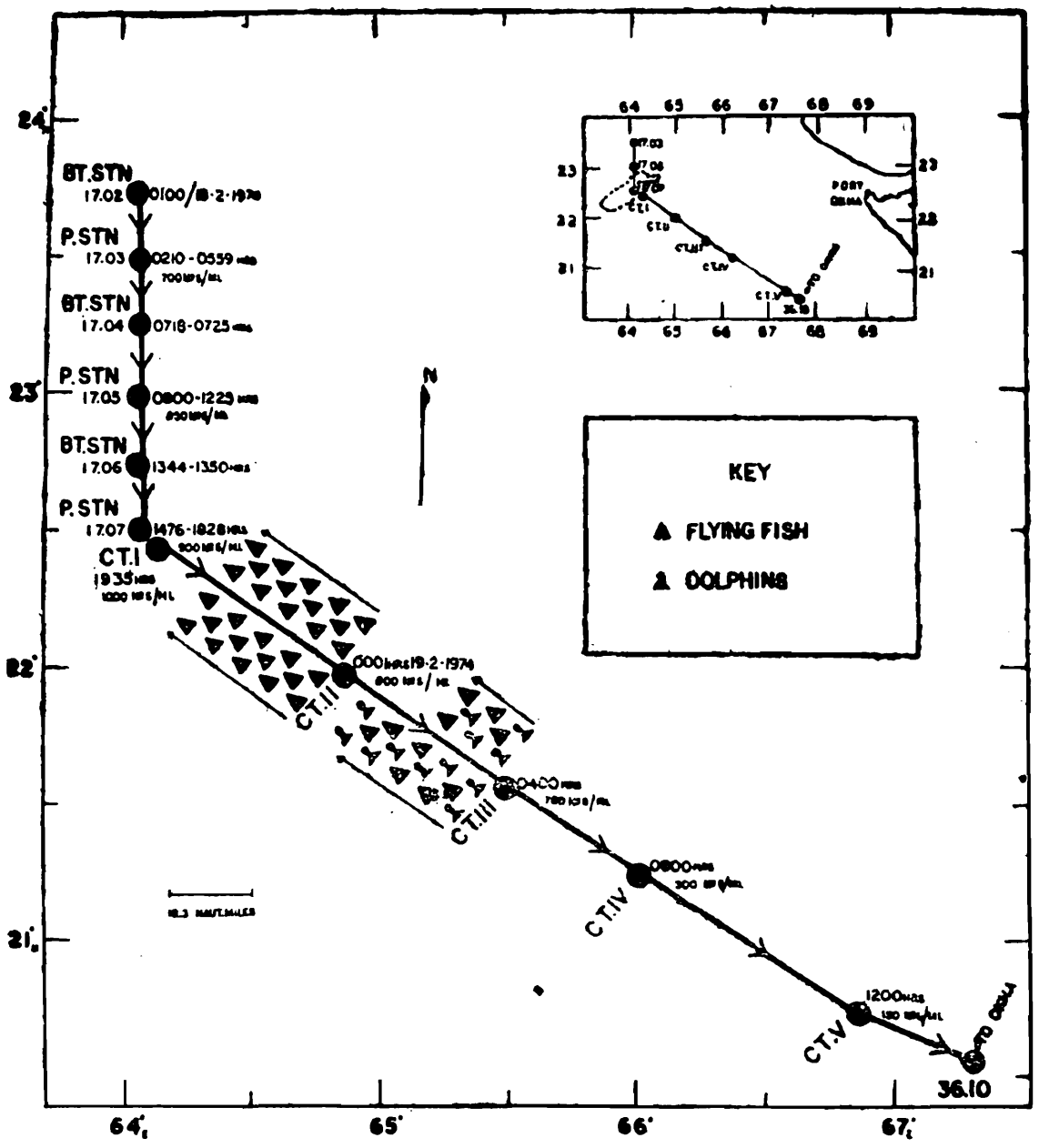

FIGURE EXPLANATION

Text-Fig. 1.—The cruise track of vessel, station positions with date and time. movement of flying-fish shoals and dolphin schools together with numbers of *Noctiluca* per standard surface subsamples of a ml.

B. T. STN. Bathythermograph Station, P STN. Parameter Station, CT.I—V. Cruise Track Stations.

Arrow directed downwards indicates cruise track direction. Long arrow indicates direction of the movement of the fish shoals and dolphin schools. *Insert* : Cruise track and stations positions in relation to shallow "CORIE HIGH" and Port Okha, India.

Material and Methods

Continuous observations during the night and day at the various Stations and also all along the cruise track (Text-fig. 1) were made to detect the extent of colouration of the sea surface by day, bioluminescence by night and the extent and direction of movement of the shoals

of flying-fishes and schools of dolphins. From the bridge of the INS DARSHAK, the range of visibility during this period using high power binoculars ranged from approximately 10 to 12 nautical miles.

Collections of surface, plankton (100-0 metres) and flying-fish samples were made at the Stations indicated in Table 1. Surface samples were collected with a compact sampler consisting of a rectangular metallic frame (55 cms × 15 cms) with a streamlined float provided with a stabilizing keel and fitted with a conical net of 190 cms. length made of bolting silk bearing 60 meshes to the linear centimetre. Plankton samples from 100-0 metres were collected with a "standard" net (50 cm. mouth diameter/225 cm. total net length/bolting silk-60 meshes per linear centimetre) hauled vertically at a speed of one metre/second over a davit. Details of the surface net are given by Daniel and Jothinayagam (in press) and those of the "Standard" plankton net by Sverdrup, Johnson and Fleming, 1942 and Daniel and Krishnamurthy (in press). The flying-fish samples were collected by hand nets. The total displacement volumes in millilitres and the numbers of each biconstituent occurring in the entire surface sample collected during a 5-minute haul and the entire plankton sample from 100-0 m. were analysed for estimating the number of organisms. The flying-fish samples were examined soon after capture to elucidate the major items of the diet; scrapings of luminescent particles adhering to the bodies and gills were examined microscopically for determining the cause of the luminescence. Samples of the surface, plankton and the flying-fishes were preserved in 5% neutral formalin for detailed laboratory studies. The dolphins could not be captured and were identified by their characteristic snouts, with the help of binoculars, as *Delphinus* sp.

OBSERVATIONS

The sea was first observed to be feebly luminescent with a bluish green glow from 0100 hrs of 18th February, 1974. when the vessel was cruising from Station 17.02 to 17.03 (Text-fig. 1). At Station 17.03, the luminescence at the sea surface was observed to be brighter, extending upto the range of visibility through a highpower binocular *i.e.* 10-12 nautical miles approximately. Thus, the actual extent of the luminescence phenomenon was at least 20 nautical miles across the ship's track. During the rest of the night, when the ship was cruising from Station 17.03 towards Station 17.04, the bioluminescence was observed to extend in an unrboken tract. After daybreak, the sea surface was observed to be greenish in colour, and this colouration extended upto the range of visibility through a field binocular, throughout the cruise-track. Station 17.05 was established at 08.00 hrs of 18th February when the sea surface was dark green. During the cruise from Station 17.05 to

17.07 (between 1230 and 1550 hrs), on 18th Feb. '74, the colour of the sea surface was dark green. Station 17.07 was located over the shallow "Corie High" at a depth of 522 metres when the sea surface was dark green (almost black). The ship left Station 17.07 at 1830 hrs. when bioluminescence was again noticed at the sea surface; as it became darker, the bioluminescence intensified, and at 1935 hrs shoals of flying-fishes were first observed moving against the ship's direction towards the 'CORIE HIGH' area, astern. These shoals were very extensive and extended upto the range of visibility through the field binocular *i.e.* 20 nautical miles across the ship's track. Station CT-I was established for studying this phenomenon.

At this Station, CT-I, the flying-fishes appeared to be luminescent. During the cruise from Station CT-I to Station CT-II (1950 to 0001 hrs) of 18th/19th February, the vessel was literally ploughing through extensive shoals of fiying-fishes; these shoals were so closely packed that the sea appeared to be covered with these luminescent fishes. Schools of dolphins chasing the flying-fishes were sighted for the first time at 0001 hrs of 19th February, and this phenomenon extended upto the range of visibility through a field binocular. Station CT-II was now established. The bioluminescence-flying-fishes-dolphins phenomenon was observed to extend until 0400 hrs of 19th February, 1974, when Station CT-III was established. From Station CT-III onwards, the intensity of luminescence decreased and the flying-fish shoals and dolphin schools gradually disappeared. The ship cruised from Station CT-III and reached Station CT-IV at 0800 hrs of 19th February. The greenish colouration of the sea was still discernible and as the ship cruised from Station CT-IV towards CT-V, the greenish colouration of the sea gradually disappeared. At Station CT-V, established at 1200 hrs and at Station 36.10 established at 1350 hrs of 19th February, the sea surface did not show any trace of the greenish colouration.

(a) Constituents of surface and plankton (100-0 m) samples: Tables 2 and 3 give the total displacement volumes and of the numbers of organisms (i.e., *Noctiluca, Ceratium, Peridinium,* Ostracods shrimps and other zooplankters including Amphipoda, copepoda, mysids, Polychaeta, pteropods, medusae and other decapod larvae) occurring in each haul, for the surface and plankton (100-0 m) samples respectively. From Tables 2 and 3 it is seen that *Noctiluca* was the dominant constituent and the other organisms were in comparatively insignificant numbers in the surface and plankton (100-0 m) hauls at all the stations sampledi except Station 36.10, at which station in the surface hauls, the other zooplankton constituents (*i.e.*, Amphipoda, copepoda, mysids, Polychaeta, pteropods, medusae, and other decapod larvae) were dominant while *Noctiluca, Ceratium, Peridinium,* Ostracods and shrimps occurred

TABLE 1.—The location of each station, date and time of working, total depth, type of haul observations on luminiscence, colouration of the sea and sightings of shoals of flying fishes and schools of dolphins.

STATION	DATE	TIME (HRS)	LATITUDE N	LONGITUDE E	TOTAL DEPTH (m)	TYPE OF HAUL	REMARKS
17.03	18.2.74	0215—0220	23°30″00′	64°05″00′	2500	Surface	Luminiscence bright
,,	,,	0215—0219	,,	,,	,,	100—0	,,
17.05	,,	0855—0900	23°00″00′	64°05″30′	1980	Surface	Sea surface green
,,	,,	0857—0901	,,	,,	,,	100—0	,,
17.07	,,	1550—1555	22°30″00′	64°04″30′	522	Surface	Sea surface dark green
	,,	1555—1600	,,	,,	,,	100—0	,,
CT—I	,,	1935—1940	22°29″30′	64°09″30′.	1316	Surface	Luminiscence very bright
,,	,,	,,	,,	,,	,,	Handnet	Flying fish shoals sighted
CT—II	19.2.74	0001—0006	21°59″30′	64°53″30′	1400	Surface	Luminiscence very bright
,,	,,	,,	,,	,,	,,	Handnet	flying fish shoals Dolphin schools sighted
CT—III	,,	0400—0405	21°35″00′	65°30″30′	1540	Surface	Luminiscence bright
,,	,,	,,	,,	,,	,,	Handnet	Flying fish shoals Dolphin schools still present
CT—IV	,,	0800—0805	21°14″00′	66°06″30′	1500	Surface	Sea surface with greenish hue
CT—V	,,	1200—1205	20°44″00′	66°57″00′	1580	Surface	Sea surface without green colouration
36.10	,,	1350—1355	20°35″00′	67°25″00′	1500	Surface	,,

TABLE 2.—The total displacement volumes (ml) of each surface haul of 5 minute duration, with the number of organisms occurring each haul at the various stations.

STA. NO.	TOTAL VOLUME ml.	NUMBER OF ORGANISMS PER FIVE MINUTE HAUL					
		NOCTILUCA	CERATIUM	PERIDINIUM	OSTRACODS	SHRIMPS	OTHERS*
17.03	5.4	3800	54	43	43	65	915
17.05	2.0	1700	30	16	20	16	54
17.07	2.0	2000	24	10	24	12	—
CT—I	5.4	5400	81	27	32	11	—
CT—II	4.6	3680	55	28	55	18	23
CT III	2.0	1400	30	20	24	24	16
CT—IV	1.6	480	16	19	24	32	19
CT—V	1.2	180	14	18	14	48	30
36.10	1.2	12	8	18	12	96	540

NOTE: * "Others" include Amphipoda, Copepoda, mysids, Polychaeta, pteropods, medusae, and other decapod larvae.

TABLE 3.—The total displacement volumes (ml) at plankton haul (100-0 m) with the numbers of organisms occurring in each haul at the stations.

STA. NO.	TOTAL VOLUME ml.	NUMBER OF ORGANISMS PER VERTICAL HAUL FROM 100-0 m					
		NOCTILUCA	CERATIUM	PERIDINIUM	OSTRACODS	SHRIMPS	OTHERS*
17.03	4.0	3000	80	60	240	48	120
17.05	8.5	6800	128	85	340	60	213
17.07	10.0	9500	150	80	400	160	200

NOTE: * "Others" include Amphipoda, Copepoda. mysids, polychaeta, pteropods, medusae, and other decapod larvae.

only in insignificant numbers. In the surface samples, the maximum number of 1000 *Noctiluca* per ml (*i.e.* 2000 Nos./2 ml. and 5400 Nos./ 5.4 ml.) occurred at Station 17.07 and CT-I, at which stations the sea surface was dark green (almost black) during the day, and intensely bioluminescent during the night. Relatively high numbers of *Noctiluca* ranging from 700 to 850 per ml (*i.e.* 3800 Nos./5.4 ml, 1700 Nos./2ml, 3680 Nos./4.6 ml, 1400 Nos./2 ml) occurred at Station 17.03, 17.05, CT. II & CT-III when the sea surface was greenish during the day and moderately bioluminescent during the night. At Station CT-IV, the *Noctiluca* occurred in a density of 480 nos/1.6 ml (*i.e.* 300 per ml) when the greenish hue of the sea surface was still discernible. At Stations CT-V and 36.10, the *Noctiluca* numbers were reduced to 180 nos./1.2 ml and 12 nos./1.2 ml *i.e* 150 per ml and trace values respectively, when the sea surface was without any trace of the greenish colouration. These observations indicate that there was intense swarming of *Noctiluca* at the sea surface over the area traversed from Stations 17.03 to CT-IV, with the peak swarming over the shallow "Corie High" area. The occurrence of the other constituents in the surface and plankton (100-0 m) hauls in insignificant numbers at these Stations may be attributed to the swarming *Noctiluca* displacing the other phyto-and zoo-plankton constituents into insignificance.

(b) *Organisms contributing to the bioluminescence* : Analyses of the surface and plankton (100-0 m) hauls in the shipboard laboratory revealed that *Noctiluca* was mainly contributing to the bioluminescence along with the ostracod *Cypridina dentata*, the protozoan *Peridinium* sp., and the flagellate *Ceratium tripos*.

Scrapings of the luminescent particles on the bodies and gills of he flying-fishes when examined under a microscope revealed that the luminescence was caused by the adhering *Noctiluca* individuals, to these parts.

(c) *Species involved in the flying-fishes shoals*: The flying-fish samples were assigned to two species:

(a) *Hirundichthys coromandelensis* (Hornell)

(b) *Oxyporhamphus micropterus* (Val.)

of which the former species formed the bulk of the fish shoals. Examination of the stomach contents of both the species have confirmed that *Noctiluca* was an important item of their food.

(d) *Effect of this Noctiluca 'bloom' on marine life*: No signs of moribund, dead or decaying fish and/or other marine life were to be seen during the entire period of observations on the 18th, 19th, and later during the second lap (23rd to 28th Feb. '74) of the IIIrd Scientific Cruise, in the region affected by the swarming of *Noctiluca*. Hence it is inferred that the swarming of *Noctiluca* did not have any harmfu

effects on the fish and other marine life. The movement of the flying-fishes is probably caused by the 'attraction factor' exhibited by the bioluminescing *Noctiluca* swarms, and support is available to this view because during the present series of observations it was noticed that the flying-fishes were definitely heading in large numbers directly to the most luminescent area, *viz.*, the 'Corie High' region, which had the greatest density of *Noctiluca.*

Remarks

The swarming of a variety of planktonic organisms such as diatoms, algae, flagellates and protozoans displacing the other phyto-and zoo-plankton constituents into insignificance and causing colouration of sea water is well known (Daniel, Nagabhushanam & Krishnamurthy, 1976). Some of these 'blooms', specially the dinoflagellates, exhibit bioluminescence at night (Hardy, 1956) and have often been reported to cause harmful effects on other marine life (Brongersma-Sanders, 1957; Prasad, 1953). In Indian waters, the dinoflagellates *Noctiluca miliaris* Suriray, *Chattonella subsalsa* (syn: *Hornellia marina* Subramaniam), *Ruttnera* sp., *Gymnodinum* spp., and *Gonyaulax* spp. are known to cause dense blooms (Prasad, 1953; Subramanyan, 1954, 1959; Prakash & Sarma, 1964). Of these, *Noctiluca miliaris* swarms have been recorded from several localities in the Indian Seas and have always been reported to cause harmful effects on other marine life (Aiyar, 1935; Devanesan, 1942; Panikkar, 1949; Bhimachar & George, 1950; & Prasad, 1953, 1958). Prasad (1953, p. 46) remarked, "from what had already been reported regarding the swarming of *Noctiluca* and its effect on fish and fisheries both along the east and west coasts of India together with the present observations and the report of the local fishermen it seems almost certain that whenever there is a *Noctiluca* swarm in the inshore waters the pelagic fishes avoided that area." The present observations show that the *Noctiluca* swarms have attracted shoals of flying-fishes in the oceanic region of the Arabian Sea, which is probably caused by the attraction factor of their bioluminescence during the night. The dolphins were chasing the shoals of flying-fishes, presumably for preying on them. Swarming of the *Noctiluca* over the 'Corie High' region may be attributed to the upwelling of nutrient rich water masses in this area during this period.

In Indian waters, the 'blooming' of the diatom, *Fragilaria oceanica* Cleve during the south-west monsoon on the west coast of India has been reported to be followed by a season of high landings of oil sardines (Nair & Subramaniam, 1955). As observed by Russell (1935) the importance of watching for possible correlation between the presence or absence of certain planktonic organisms with that of fish and larger

animals are necessary, underlining the need for further observations/ record on swarming of bioluminescent organisms-fishes-other marine associations, in the inshore and oceanic regions of the tropical Indian Ocean.

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SUMMARY

In this paper, the swarming of *Noctiluca miliaris* Suriray causing greenish colouration of the Sea during the day and a bluish-green bioluminescence during the night in February, 1974 in the northern Arabian Sea observed to be associated with the movement of extensive shoals of two species of flying-fishes (i.e. *Hirundichthys coromandelensis* (Hornell) and *Oxyporhamphus micropterus* (Val.) and the dolphin, *Delphinus* sp. are reported. The effects of this *Noctiluca* 'bloom' on marine life in the light of recent reports are discussed.

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