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Phosphorescent Wheels: Fact or Fiction?

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At 1803 GMT on May 15th 1879 H.M.S. *Vulture*, while in the Persian Gulf, encountered so remarkable a phenomenon that her master, Commander Pringle, sent back an account of it from Bahrain to the Hydrographer of the Navy. He had seen 'luminous waves or pulsations in the water, moving at great speed and passing under the ship from the SSW. On looking toward the East the appearance was that of a revolving wheel with centre on that bearing and whose spokes were illuminated and on looking towards the West a similar wheel appeared to be revolving, but in the opposite direction.' This was the first detailed account of the phenomenon which has subsequently become known as the 'phosphorescent wheel'. Since then many other reports of similar phenomena, involving bands of luminescence travelling rapidly in a circular, spiral or horizontal trajectory, have been entered in the log books of vessels round the world. Many of these vessels have been members of the Voluntary Observing Fleet and the reports have been logged by the Meteorological Office and usually published in the pages of *The Marine Observer*.

Descriptions of the phenomena vary considerably. At the simplest level a series of parallel luminous bands or waves are observed moving rapidly over the sea surface. The direction of the bands may change suddenly and several sets may be visible at once travelling in different directions. The *Deucalion* in the Sunda Strait reported that 'Rays of light appeared on the surface of the water coming from the south-east passing across the ship at regular intervals of half a second. . . . After a few minutes the direction of the beams of light changed. . . . From then until 1.40 a.m. the direction of these beams continually changed, passing across the vessel from all points of the compass.' In some cases the bands appear to be travelling several feet above the sea surface, e.g. the *City of Khios*, off Karachi: 'Shafts of pale white light were observed moving swiftly NE–SW. They appeared to be just above the surface of the sea and parallel with each other.' Parallel waves of light may be preceded by flashing patches, as reported by the *Tokyo Bay* in the South China Sea, 'Vessel passed through a patch of bioluminescence. . . . It took the form of a "rash" of lights . . . flashing at a rate of about 120 flashes per minute. This was followed . . . by fast-moving bands of light converging on the vessel from either beam, and then from astern.' The parallel bands may change into bands (or spokes) rotating round a central hub, in a typical wheel appearance, and the wheel may change back into parallel bands. The wheels may rotate in either direction and even reverse. The *British Patrol* in the Gulf of Oman reported luminous waves which 'appeared as if streaks of sand were being blown across the surface of the sea. . . . They came in an effortless pulsating rhythm. These parallel waves lasted about four minutes then changed to what appeared to be arcs turned back at their centre . . . after which four wheels appeared, one on each bow and quarter. On the starboard bow there were two concentric wheels rotating in the opposite direction to each other. The port bow wheel rotated anticlockwise. The port quarter wheel turned clockwise and the starboard quarter one anticlockwise. Once again the duration was about four minutes. The waves then commenced to move towards the ship, parallel to our course. At the same time other waves moved astern at right

angles. This phenomenon only lasted about two minutes and reverted back to the four wheels, but the starboard bow wheel was now a single one rotating clockwise.' The hub or centre of rotation is described in some reports as bright, in others as dark and in many cases is at too great a distance to be visible (often described as 'on the horizon'). The spokes, like the bands, are sometimes described as travelling well above the sea surface, even over the deck.

No two reports are the same in the timing, dimensions or duration of the phenomenon, though the latter is usually between five and 35 minutes. Even when reports are received from more than one observer on the same vessel the accounts may differ substantially. In 1963 the *Kent* encountered luminous waves in the Persian Gulf. Three observers reported as follows:

1. 'A remarkable display of bioluminescence . . . began. It took the form of luminous bands of light moving at great speed in wave formation. At first the impression was one of extremely active phosphorescence glowing just below the sea surface and illuminating the whole area in a manner resembling the effect produced by strong reflected moonlight'.

2. 'As the vessel approached, the patches were seen to pulsate over the whole area, apparently in the form of waves. When the middle of the area was traversed by the ship at 2030, the phosphorescence consisted of rays of light striking the surface from below. Some of them took the form of two cartwheels, one abeam of the port bow and ahead; the other abeam of the starboard bow and ahead of it'.

3. 'The first impression was of patches of frothing luminosity on the sea surface approaching the port bow, one after the other, at intervals of one second. . . . The general effect was similar to the beam of light from a light-house flashing across a swell. . . . The approaching bands of light were very straight and regular'.

This difference in the interpretations of a single event is hardly surprising in such unusual and ephemeral circumstances in which changes occur with great rapidity and which are variously described as 'eerie', 'weird', 'almost frightening' and 'alarming'. The results in one case were that 'the lookoutman came on the bridge quite scared, believing he was suffering from hallucinations' and in another 'the Chinese quartermaster became panic stricken, left the wheel and did not return until he had been called three times'. The differences do, however, highlight the subjective nature of each account and emphasise how difficult it is to achieve accurate estimates of speed or size. This is a problem apparent to any watchkeeper who has had to report hazy events noted at night in the absence of fixed reference points. It is equally familiar to the police, who are frequently confronted with conflicting accounts of the same event by different witnesses!

We have so far collated almost 230 reports which describe either wheels, spirals or moving bands of luminescence. It is unlikely that all describe the same phenomenon; inevitably some will be of dissimilar events with superficially similar appearances but different causes. Nevertheless we believe that the great majority do describe the visible features of a single type of phenomenon, which we assume has a common cause.

The first question to be answered is the source of the light. There are several physical mechanisms by which light might be produced. One of these, electroluminescence, has been suggested by Staples (1966). He noted the possibility that a shock wave might induce light from bubbles of oxygen produced by the phytoplankton during daytime photosynthesis. Under certain conditions sound waves and cavitation can produce similar effects. It seems doubtful, however, whether such bubbles would survive during the dark hours when no photosynthesis occurs, yet when the phenomena are visible. It is far more likely that the light is bioluminescence produced by the small luminous organisms in the water, particularly the dinoflagellates and small planktonic animals. This surmise is supported by the fact that larger luminous objects are often observed

in the bands as they pass. On one occasion a water sample was obtained at the same time and was found to contain numerous luminous dinoflagellates, as would be expected if the light was indeed bioluminescence.

The second fundamental question is what produces the observed patterns of bands or wheels of light. A few are undoubtedly produced by the stimulatory effect of shoals of fish or squid on luminous plankton. In April 1984, for example, the *ACT 7* in the eastern Atlantic encountered 'large whirling spirals containing thousands of fish (luminescent)', an appearance which would have led to its identification as an ill-defined phosphorescent wheel had the 'fish' (probably squid) not been visible. The *British Fulmar*'s observation (also in the Atlantic) of a 15 m diameter 'circular patch of extreme intensity . . . appearing to rotate rapidly clockwise about a centre point' is probably of similar origin. Most reports are clearly quite different and there have been several suggestions as to their cause but none satisfactorily explains all the observations. A Russian writer, Tarasov (1956) tried to explain them as 'eddies of whirling water' while Leslie and Adamski (1953) in their book *Flying Saucers Have Landed* regarded them as indications of extraterrestrial visitations by UFOs. Hilder (1962) interpreted them as magnetic phenomena induced by the combined effects of local variations in the earth's magnetic field and the magnetic effects of the introduction of iron and steel ships. This neatly explained the fact that there is a general lack of reports from the days of wooden sailing vessels (though that of H.M.S. *Vulture* is a notable exception), but gave no clear rationale for the formation of waves or wheels, though Hilder explained how the rotation direction could depend on the polarity of the ships' magnetic fields. He also argued that they were restricted to southern Asiatic waters because of the local magnetic variations. This is less convincing in regard to the Persian Gulf which is also a major area of 'wheel' activity.

Consideration of the positions of the various reports (Figure 1) shows that there is a restriction to tropical regions, between 35°N and 25°S and that it is a predominantly Indo Pacific phenomenon, 95 per cent of the observations occurring in this area. Even within this general region there are areas of particularly frequent reports. These are, the Persian Gulf and Straits of Hormuz

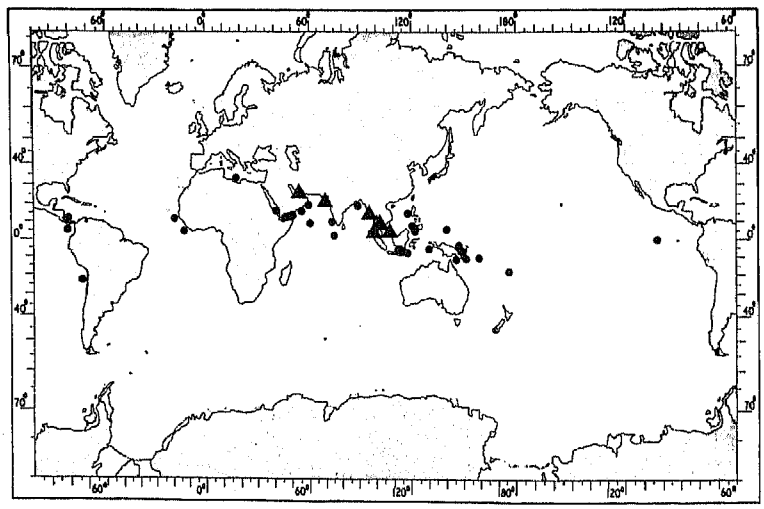

Figure 1. Geographic distribution of 'phosphorescent wheels' and moving 'parallel band' observations. Dots are single observations, triangles indicate areas of particularly numerous observations. Report clearly ascribable to fish, etc. (see text) are not included.

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The unusual cloud formation observed from m.v. *Mairangi Bay* (*see* page 179)

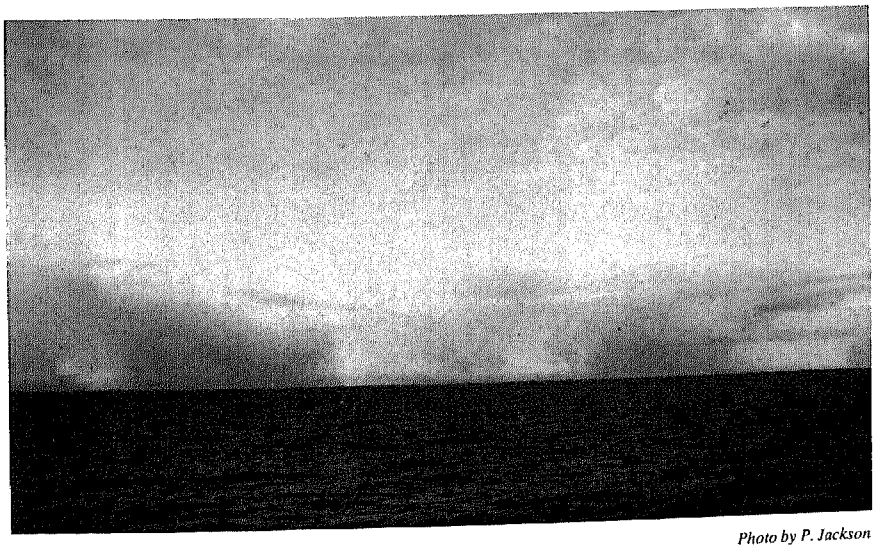

Photo by P. Jackson

Stratocumulus cloud observed from m.v. *City of Durban* (*see* page 180)

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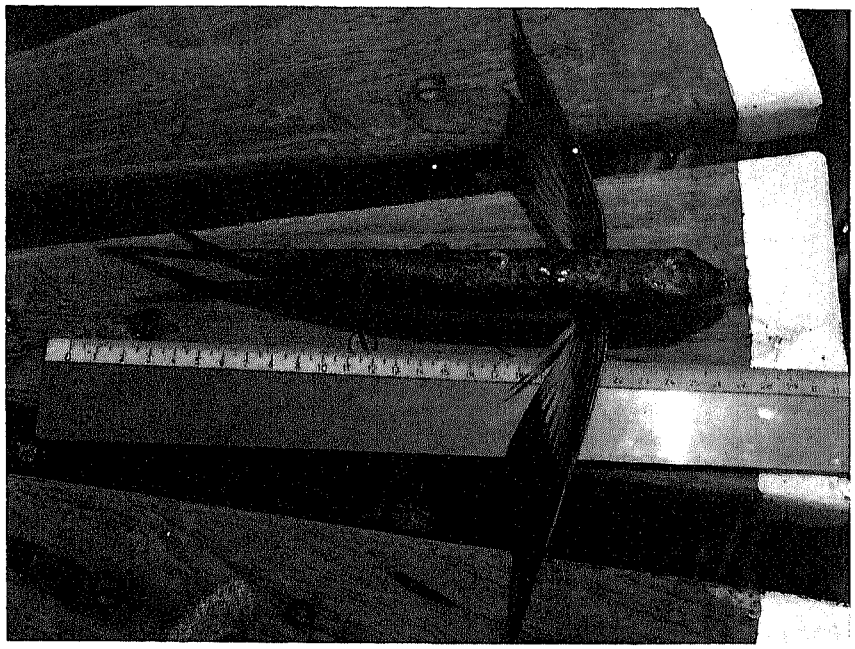
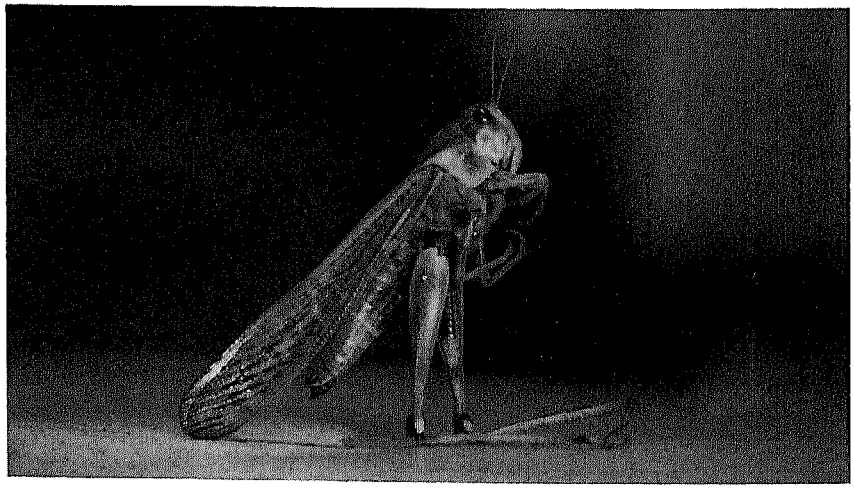


Photo. by B. A. Mullan

The flying fish found on board m.v. *Moreton Bay* (*see* page 184).



The locust which was discovered on board m.v. *ACT 7* (*see* page 190)

(48 reports) (Figure 2), the Gulf of Thailand (47), the South China Sea (42), the Strait of Malacca (26) (Figure 3) and the coastal seas adjacent to Karachi (11), Rangoon (7) and Bombay (6). The number is inevitably biassed by the frequency of shipping in different areas but a consistent pattern of distribution is clear. All these areas are relatively shallow, with water depths of less than 200 m, and the majority of other reports are from waters of similar depths, though a few are from deep water.

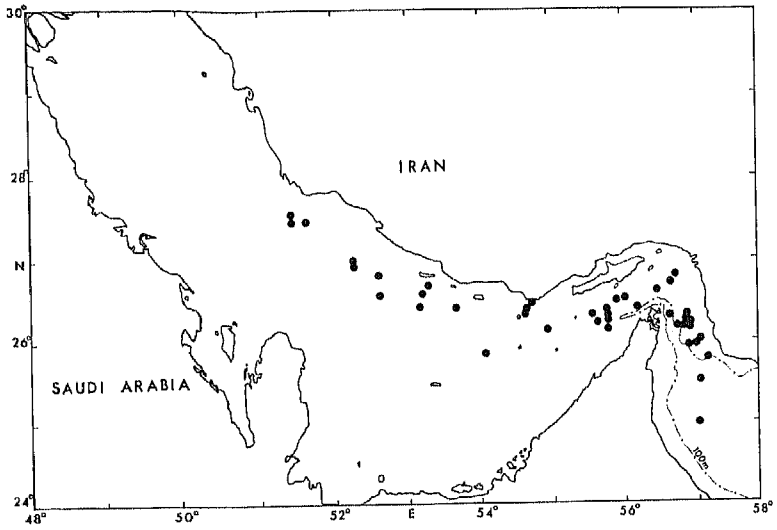


Figure 2. Known positions of 41 observations in the Persian Gulf and Straits of Hormuz. The 100 metres depth contour is indicated.

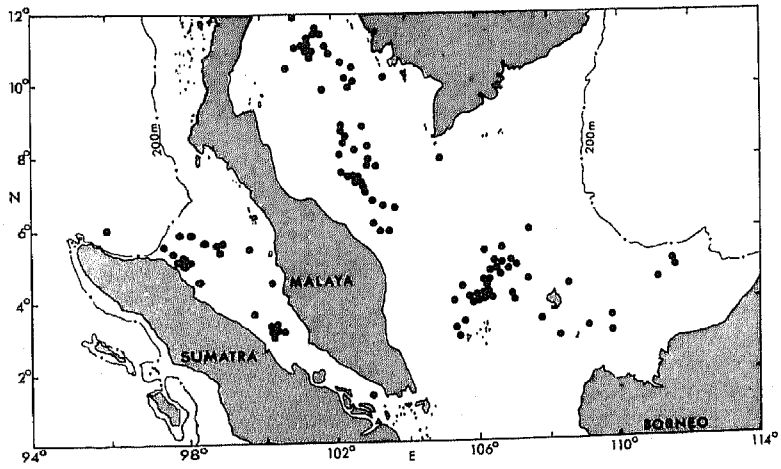


Figure 3. Known positions of 111 observations in the Strait of Malacca, Gulf of Thailand and South China Sea. The 200 metres depth contour is indicated.

This shallow distribution led the German hydrographer Kalle (1960) to a most ingenious explanation. He took the view that the observed patterns derived from the shock waves produced by submarine earthquakes and other seismic activity. He concluded that when these occurred in deep water the 'erupting ball' type of luminescence resulted but that when it occurred in shallow water 'phosphorescent wheels' were produced by the interference patterns set up by multiple reflections of shock waves at the surface and the bottom. He was able to show theoretically that under a variety of reflective conditions rotating wheels, parallel bands and concentric circles could be produced by these interference patterns. If these patterns stimulated the luminous organisms then the observed luminous phenomena would be produced. This explanation predicts that there should be a mirror symmetry in the wheels thus produced, with each half rotating in opposite directions, and that they should be observed only in regions (and at times) of high seismic activity. Both these predictions are difficult to test. The patterns of activity of the wheels are rarely described as symmetrical, though this might be the cause of the occasional impressions of their reversal. Although both south-east Asia and the Middle East are areas of known seismic activity a closer correlation with the observations is not obvious in the detailed distribution of submarine earthquakes and volcanic activity. The line of peak activity is to the south-western margin of the area of the south-east Asian reports, and the Gulf of Thailand, for example, is almost devoid of seismic events, despite its high frequency of wheel reports.

A more prosaic explanation of the parallel waves was provided in 1910 and 1921 by G. F. Tydeman, later Vice-Admiral of the Royal Dutch Navy, and based on the observations of the *Valentijn* in the China Sea in 1910. This was amplified by Dr Termijtelen of the Dutch Meteorological Institute in 1950 in *The Marine Observer*. The explanation assumed that the vessel encountered a long patch of luminous plankton. The interference between the existing waves and the bow wave produced breaking points at their intersections in the patch which in turn resulted in lines of light moving along the existing waves. The perspective effects of the parallel lines of light would make them seem to converge at the horizon and the relative movement of the ship would give the impression of rotating spokes. If the ship then passed through the middle of the patch the wheel on one side would disappear, only to reappear apparently rotating in the opposite direction on the other side. Tydeman accounted for those waves of light reported to be travelling above the surface by assuming that in these cases the luminous organisms were deeper in the water and that the surface waves acted as long cylindrical lenses focussing the deep, uniform, luminescence as lines of light on any superficial mist or haze. Perspective effects still produce the illusion of converging spokes, and the direction of their apparent rotation is determined by whether the observer is above or below the focussed lines of light.

The theoretical geometry of this explanation has been examined in some detail by Verploegh (1968) who finds it entirely consistent with many of the reports and emphasises the frequent allusions by the shipboard observers to rotating underwater searchlights or lighthouse effects. The speeds of the waves or spokes are usually reported to be 'very rapid' or 'tremendous' and estimates vary between 30 miles per hour and 30 miles per minute! However Verploegh calculated from the data in five reports that their true speed was 9 metres per second (20 miles per hour) and, making various assumptions about the wave forms, that waves of the observed periods (1·3–3 seconds) had theoretical focal lengths (2·5–14 metres) very close to the reported wavelengths of the bands in the eight 'most reliable' reports (5·5–9 metres).

If all these correlations are correct, and applicable in every case, the resulting conclusions are that (1) parallel waves are produced either by the refractive effects of surface waves on deeper luminescence, or by the interaction of

intersecting surface waves, and (2) 'Wheels' and their rotation are illusions of perspective effects acting on parallel bands. One of the best examples of support for the latter supposition comes from Pringle's 1879 observations from H.M.S. *Vulture*. After describing the wheels he writes, 'I then went to the mizen top (50 feet above water) with the 1st lieutenant, and saw that the luminous waves or pulsations were really travelling parallel to each other and that their apparently rotatory motion as seen from the deck was caused by their highspeed and the greater angular motion of the nearer than the more remote part of the waves.' Another report tallying almost exactly with the predicted effects of perspective is that of the *Szechuen* in the South China Sea in 1952: 'bands of light on the port side began to revolve in a clockwise direction . . . As the centre of rotation came more on the beam the apparent direction of rotation was reversed. When the centre had passed the bridge, the revolving motion ceased . . .' Several other vessels also report wheels whose direction of rotation reverses as they come abaft the beam, and this evidence strongly supports the supposition that these wheels are illusions. Any illusory wheels can be expected to have very long spokes and indeed most estimates vary between several hundred metres and 'to the horizon'. If all wheels are illusory then no more than half a wheel should ever be visible. Nevertheless many reports include drawings of whole wheels. There are a few reports of much smaller wheels, ranging from 5–50 metres radius, and it is difficult to interpret these as similar illusions. The *Tokyo Bay* in the South China Sea in 1978 saw two rotating wheels 15–20 metres in diameter, one on each bow and rotating in opposite directions. These moved into the vessels side and then veered off astern. Another problem is the explanation of concentric spreading rings, which cannot be a similar product of perspective, nor do they match either of the two theories (in (1) above) by which waves of light may be produced.

One explanation of concentric rings of light, put forward in 1879 to explain the *Vulture* report, postulated a central flashing point source whose light stimulates adjacent organisms and the luminous response then propagates outwards as a series of rings, whose period reflects the flash frequency of the organism (or patch of organisms) at its centre.

The extensive series of observations in our collection suggests that another factor may often be involved, namely the vessel itself. This is not a novel conclusion and was voiced by M. Rodewald in 1954 as well as by many observers. One feature commonly noted is the frequency of waves (or spokes). 130 of our reports include an estimate of frequency and 121 of those were between 0·5 s^{-1}, and 3 s^{-1}, with 96 between 1 and 2 s^{-1}. This is the frequency range of the engine revolutions of most vessels. In some cases there is a very close correlation indeed; the *Malaita* reported patches pulsating at 94 min^{-1}, the same frequency as the engines. The *Bulolo* reported flashing lines pulsating away from the vessel at 90 min^{-1}. Flashing patches reported by the *Yochow* were at 102 min^{-1} and were seen as another vessel passed by. Other evidence is the frequent appearance of the vessel as the centre of the phenomenon. The *Glengarry* reported 'Concentric circles converging on the vessel from the horizon at approximately the same frequency of 95 r.p.m. as the engine revolutions'; the *Dione* was similarly at the centre of a wheel; the *Stanrae Bangkok* 'had the impression that the vessel was causing it'; the *Hecate* had 'the subjective impression that it centred round the ship' and the *Glenfalloch* reported wheels whose intensity increased with their proximity to the ship. The *Brandon Priory* described 'pulsating sheets of light radiating from the vessel to the horizon'; the *Titan* noted how 'sound and vibration noises given off by the ship's engine was seen to agitate . . . luminescence' (of dinoflagellates); the *Kowloon Bay* suggested that the engine caused the 'circular waves emanating from the vessel on each side', and a similar description was given by the *Mahsuri*. Other vessels have reported wheels apparently maintaining station with the vessel's track and in

many cases the wheels were either symmetrical about the vessel or alternated from one side to the other. The *Tabangao* reported that the wheels stopped when the vessel stopped.

The circumstantial evidence for an involvement of the vessel itself is therefore strong, though some observations could equally well be explained as illusions of perspective. It also accounts for the infrequency of reports from the era of sail or from twentieth century vessels under sail. The critical experiment of stopping the engines has never been done, though the *Tabangao* report is highly suggestive. If the wheels do continue after stopping engines then clearly the ships vibrations are not involved. We do not suggest that the vessel is always the cause of parallel bands. We do, however, believe that interference between vibrations emanating from the vessel and other wave patterns, such as wind-generated surface waves and swell or even internal waves, do produce some of the local wheels and other effects. Very large wheels are probably illusory, as Tydeman and Verploegh have convincingly argued. An analogous illusion can be experienced in a train passing a ploughed field whose furrows are 'end-on' to the observer. An apparent clockwise rotation is seen to the left and an anticlockwise one to the right. The immensely complex events of the phenomenon reported by Kuzmanov (1983) from the *Siam* in the South China Sea contain almost all the elements related in other accounts. Three to four wheels were observed at once, arranged around the vessel and travelling with it. In addition they appeared to rotate around a common centre and alternated with four sets of parallel bands coming towards the vessel at right-angles to each other. Patches flashing with a frequency very close to that of the *Siam*'s engines were also observed and the frequency was unaffected by changes in the vessel's course. A survey vessel some 17·5 n. mile north of the *Siam* saw nothing unusual. The tantalising nature of this and other accounts still lies in our uncertainty about the precise causes of the patterns and their restriction to certain areas of the world's oceans. It could be argued that it is the biological features of the particular areas that allow the stimulatory wave patterns to become visible by their luminescence, but there is no obvious biological factor that can be recognised as common to the main areas of the reports. Until and unless more observations are made, bearing in mind the various possible explanations, it will be impossible to distinguish between the suggested causes. Any observer fortunate enough to encounter any of these events should try to distinguish in particular whether a whole wheel is visible at once, whether it has a mirror symmetry of rotation and whether stopping engines stops the phenomenon.

Perhaps one of the more surprising factors is that no-one has located any descriptions of these phenomena made by local fishermen or other small boat traffic. Dramatic appearances of this sort might be expected to be enshrined in local folklore. The absence of any such stories from small boats is perhaps another fact supporting the involvement of the large vibratory source provided by the naval and commercial vessels from which most of the reports derive. Polynesian and Micronesian folklore does include descriptions of waves of light in the sea and their use as navigational aids. 'Te lapa' (as this phenomenon is known) is only encountered at least 8 or 9 n. mile offshore, though said to be best seen 80–100 n. mile out, and is described as like underwater lightning some way below the surface. Its direction indicates where land lies and its flickering rate gives an intimation of the range. According to Lewis (1972) it is probably produced by reflected swells but it appears to be unrelated to 'phosphorescent wheels' and parallel bands, which are extremely rare in the area concerned.

There is one aircraft observation on a moonless night over the South China Sea that describes patterns of bands that were probably luminous bands and clearly were not related to any vessels. Two aircraft of 210 Squadron at 6000 feet on 21 November 1949 saw disturbances that 'resembled that of shock waves. . . . The waves were moving quite rapidly with a speed and nature similar to

those caused by dropping a stone in the water. . . . There was no breaking of the surface, the impression being of enormous ripples. There were several isolated instances of disturbance; some appeared curved, others square in shape.' Each patch had groups of parallel waves, and in each patch they had a different direction. No submarine earthquakes were recorded at the time. The speed and wavelength of the bands are not recorded in the aircraft report, but the description of the wave patterns is typical of internal wave trains. Internal waves usually travel relatively slowly (0·3–1·5 m s^{-1}) and have wavelengths of 50 metres or more. In these reports they do not correlate well with most of the ship reports of faster trains of shorter wavelengths. There are also a very few observations of parallel bands by sailing vessels (which could not have been the source of the waves), including the first recorded report, that of H.M.S. *Bulldog* in 1875 when becalmed north of Vera Cruz, and that of the wooden hulled H.M.S. *Vulture*.

Perhaps the shipboard observations will one day also be augmented by simultaneous space shuttle or satellite observations but until that circumstance arises we are largely dependent for our information about these extraordinary events upon the powers of observation of the Voluntary Observing Fleet (VOF), and the care and detail of the records in the logbooks.

Acknowledgements

Most of the cited reports are from VOF vessels whose logbooks are deposited at the Meteorological Office. An unpublished catalogue of 'phosphorescence' reports by the late Mr E. W. Barlow of that office has proved invaluable. We also thank Dr R. H. Kay for access to his correspondence, Dr T. Wyatt for locating some of the Dutch reports and Mrs H. Noordhuyn for translating them. Lt.-Cdr. G. A. Franklin of the Hydrographic Department, Taunton kindly provided copies of some of the early naval reports. We are most grateful to Dr S. A. Thorpe for his comments on the manuscript and information on internal waves.

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