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BIOLUMINESCENCE OF ZOOPLANKTON IN THE ANTARCTIC FIORD EZCURRA INLET*

1. Introduction

Marine bioluminescence i.e. luminescence of marine organisms has long been studied by physicists, biochemists and biologists. A comprehensive review of these studies can be found in papers [1, 2, 6]. Several groups, dealing with different aspects of the problem, can be distinguished in the publications on marine bioluminescence. Some of them concentrate on oceanographic aspects such as spatial and temporal distributions of the light emitted by living marine organisms [3], while others are devoted to biological investigations on the occurrence and bioluminescence activity of various microorganisms or biological analyses and experiments on the mechanisms of luminescence [1, 4, 6, 7].

The investigations on bioluminescence described in this paper are a part of oceanographic studies of the marine environment in the Ezcurra Inlet on King George Island, close to the Polish „Henryk Arctowski" Antarctic Station. In the exploration of this environment during the Polish Academy of Sciences Second Antarctic Expedition in the Antarctic summer of 1977/1978, three-month joint experiments were carried out in the fields of meteorology and marine physics, chemistry and hydrobiology [5], including tests on bioluminescence activity of the zooplankton encountered in the inlet.

The depth of water about 80 m in the area in which the measurements were conducted (from an enchored vessel), was insufficient for recording spontaneous bioluminescence in situ against the background of natural light, even at night. The tests were therefore carried out with zooplankton samples taken directly from the sea. Zooplankton species

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with bioluminescence properties were sought by this method in the Ezcurra Inlet waters. The basic characteristics of the light emitted by this zooplankton such as intensity, frequency and duration of bioluminescence flashes were also analyzed. The long series of measurements also permitted the distinguishing of certain regularities in the behaviour of samples of luminous zooplankton and made it possible to draw conclusions about some functions of bioluminescence in the life of these organisms.

2. MEASURING METHOD AND TECHNIQUE

Zooplankton samples for bioluminescence investigations were taken with a 250 μm Hensen plankton net. Sampling was conducted from a vessel at anchor, with an oceanographic winch. A vertical column of water, from a depth of 70 m to the surface, was filtered each time. Taking into account that the inlet diameter of the net was about 60 cm, the water volume filtered was about 20 m^3. The zooplankton caught and residual water were immediately poured into a glass measuring tray with 1 litre of fresh sea water and immediately placed in a light-proof measuring chamber. Sea water for the tray was taken with a bathometer from an intermediate depth of about 40 m. The glass measuring tray with zooplankton sample examined was placed in a measuring chamber in thermo-stable bath, to keep the water at about 0°C, close to the natural temperature [5]. A schematic diagram of the measuring chamber is shown in Fig. 1.

The recording of bioluminescence flashes emitted by a zooplankton sample so prepared, was usually initiated after about 1 minute had elapsed from the moment of sampling and was then continued for several hours. After bioluminescence tests, the species composition of the zooplankton in a sample was determined in a Bogorov camera placed under a stereoscopic microscope.

The photometer designed at the PAS' Institute of Oceanology and used in our tests, consisted of a sensitive irradiance meter with an interference filter with transmittance band at $\lambda = 480$ nm and a half-band width of less than 10 nm. In the selection of these spectral characteristics of the detector it was taken into account that most marine organisms have wide bioluminescence peaks in the blue region of spectrum. Simultaneously, the optical narrow-band filter damped much of the background interference and photomultiplier noise. An EMI photomultiplier type 9659QB supplied with a precisely stabilized voltage of 1080V, was used in the investigations.

A Hewlett-Packard 7000A model XY recorder, recorded signals from the photomultiplier, preamplified in an additional DC amplifier, opera-

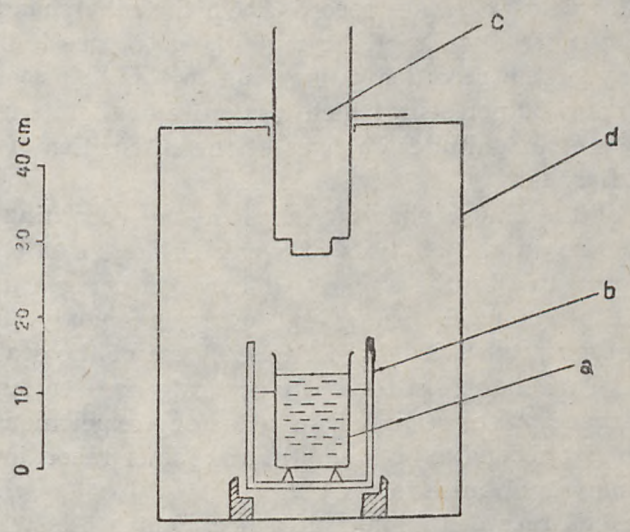


Fig. 1. Schematic diagram of the measuring chamber with photometer used in bioluminescence studies: *a* — measuring tray with sample; *b* — mirror shield with thermostable bath; *c* — photometer; *d* — light-proof chamber

Rys. 1. Szkic komory pomiarowej z fotometrem, stosowanej w badaniach bioluminescencji: *a* — kuweta pomiarowa z próbą; *b* — osłona lustrzana z kąpielą termostatującą; *c* — fotometr; *d* — obudowa światłoszczelna

ting from 0 to 100 dB, in 10 dB subranges. The apparatus was thoroughly protected against disturbance from the ship's electric network.

The photomultiplier was kept in the darkness for many hours prior to measurements, as considerable increase in nosise was observed after its illumination in daylight.

The maximum sensitivity of the measuring system was $3.1 \cdot 10^{-9}$ $\mu W/cm^2$ nm of detector irradiance per 1 cm of recorder pen deflection. The noise and inaccuracy of records did not exceed 10 per cent of this value. However, the absolute magnitude of irradiance given in $\mu W/cm^2$ nm may contain a certain systematic error, as the absolute sensitivity of the device was computed indirectly from spectral characteristics of the photomultiplier and other parameters of the measuring system. The combination of a few ranges of amplifier sensivity and recorder sensitivity permitted accurate recording of bioluminescence flashes corresponding to irradiance of 10^{-9} to 10^{-5} $\mu W/cm^2$ nm from an average distance of about 20 cm in the tested wavelengths of 480 nm, the sensitivity ranges being chosen to suit the intensities of flashes recorded in a given sample.

The distances of light sources (luminous organisms) from the detector in the one-litre measuring tray could obviously vary within limits of the volume of water in the sample. To a certain degree, this variation

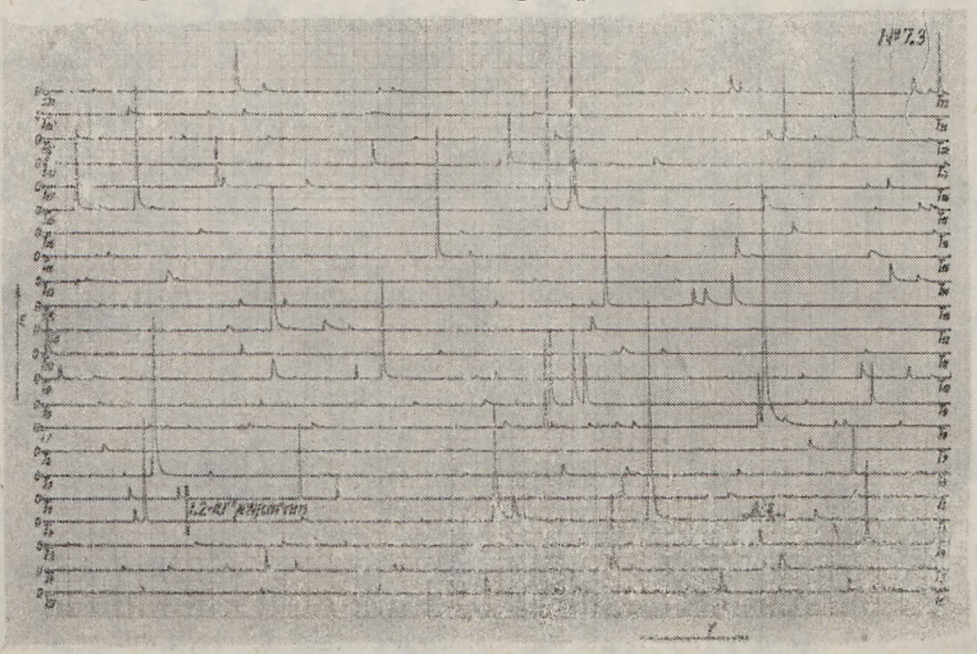
affected the intensity of flashes recorded. On the other hand, it was also compensated by mirror walls of the measuring tray casing. The scatter of the intensity of the recorded pulses due to this variation can be assumed to be below 30 per cent, which was quite negligible in comparison with the orders of magnitudes changes of the intensities of emitted bioluminescence flashes.

In view of the linear characteristics of the recording system and high amplification in the analysis of weak flashes, single, very strong pulses were truncated by the apparatus. This can be seen in the presented records, in places where sharp high peaks are partly cut off.

The recording rate varied from 1 to 1/50 cm of the scale per second and even less. This enabled sufficiently accurate observation of the form of bioluminescence pulses recorded. Introductory experiments proved the rate of 1/5 cm per second to be the optimum; faster recording was mainly used in the analysis of pulse forms.

Examples of recorded bioluminescence, which illustrate the techniques of recording and description of diagrams, are given in Fig. 2.

In the course of the present preliminary investigations of bioluminescence in Ezcurra Inlet, about 30 different samples of zooplankton were tested; the analysis of spontaneous bioluminescence was supplemented by a number of experiments involving chemical induction of bioluminescence and studies on bioluminescence of artificial zooplankton communities, composed of individuals of a single species.



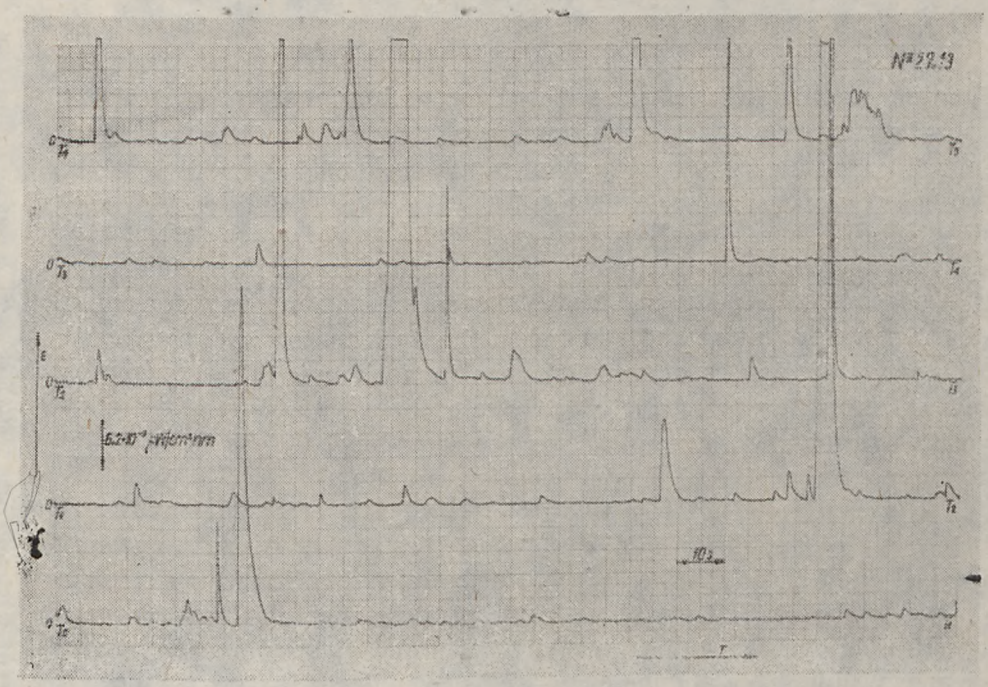


Fig. 2. Examples of bioluminescence records showing recording technique and notation for co-ordinates

Time lapses from the left to the right in consecutive lines, from T_0 to T_{22} in diagram No. 7.3 and from T_0 to T_5 in diagram No. 27.13. Peaks visible in the record are produced by light flashes emitted by zooplankton organisms in the sample. Zero intensity of bioluminescence pulses moves upwards for consecutive lines of records and is shown on the left of each line. — Zero shift different in various diagrams: depending upon the denstiy and amplitudes of recorded pulses, selected so as to ensure legibility of the diagram. — The intensity scale is marked with vertical arrows and figures giving vertical deflection for two layer grids. Figures are given in microwatts per 1 irradiated cm² per 1 nanometer of wavelenght in 480 nm waveband and from a distance of about 20 cm — The scale of time T is given by horizontal arrows; two larger grids horizontal direction denote 10 seconds, so that one line is recorded for 180 seconds, the break between lines, used for zero shift, lasts about 3 seconds.

Rys. 2. Przykładowe zapisy impulsów bioluminescencyjnych wyjaśniające technikę rejestracji i sposób oznaczeń współrzędnych

Czas na tych zapisach przebiega (od lewej strony w prawo) w kolejnych wierszach od T_0 do T_{22} na diagramie N° 7.3 i od T_0 do T_5 na diagramie N° 27.13 W czasie tym pojawiają się widoczne na zapisie piki odpowiadające błyskom świetlnym wysyłanym przez poszczególne osobniki zooplanktonu zawarte w badanej próbie. — Zero intensywności impulsów bioluminescencyjnych przesuwane jest w górę dla kolejnych wierszy zapisu i oznaczone z lewej strony każdego wiersza. Skok tego przesuwu zera jest różny na różnych diagramach, zależny od zagęszczenia i amplitud rejestrowanych impulsów, tak by diagram był czytelny. — Skala intensywności zaznaczona jest strzałkami pionowymi na wykresie z podaniem wartości odpowiadającej wychyleniu pionowemu na wysokość dwóch dużych kratek. Wartości te podane są w mikrowatach na cm² oświetlenia na 1 nanometr długości fali światła w paśmie 480 nanometrów — z odległości ok. 20 cm. — Skala czasu T zaznaczona jest strzałkami poziomymi; w tym wypadku 2 duże kratki w poziomie odpowiadają upływowi czasu 10 s, tzn. 180 s trwa zapis 1 wiersza i ok. 3 s trwa przerwa między wierszami na przesunięcie zera.

3. RESULTS AND DISCUSSION

Spontaneous bioluminescence without forced luminescence of organisms, was observed in practically all samples of zooplankton caught in Ezcurra Inlet. The species composition of zooplankton in selected typical samples presented in this paper is shown in Table 1. The bioluminescence records show sharp peaks, densely spaced on the time-axis, which reflect the irradiance flashes emitted by individual zooplankton organisms in a sample. Considerably higher frequencies and intensities of flashes were recorded shortly after sampling and keeping in the dark measuring chamber than after several minutes of quiet storage in darkness. Three examples of record series shown in Fig. 3 illustrate these intensive and gradually weaken flashes. On these diagrams the recording of T_0 is shown to have commenced about 1 to 1.5 minutes after sampling.

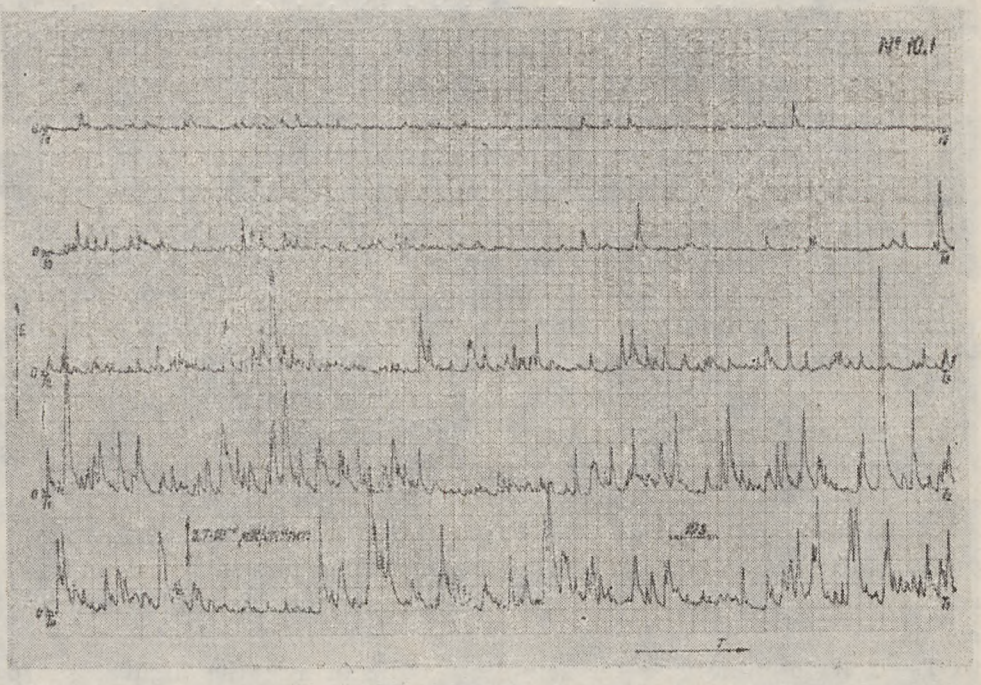
The analysis of all results of this type leads to conclusions as to the behaviour of organisms in the samples. First of all it can be seen that intensities of initial flashes reach 10^{-6} or even 10^{-5} $\mu W/cm^2$ nm of irradiance in the studied wavelengths, from a distance of about 20 cm. Decreasing intensities and frequencies of these flashes in time are also clearly visible. This phenomenon seems to indicate that pronounced bioluminescence during the first period after sampling is a typical shock suffered by the organisms caught. This optical symptom of shock is strikingly similar to the acoustic reactions (roars, noise and other sounds of fright) of suddenly entrapped wild terrestrial animals.

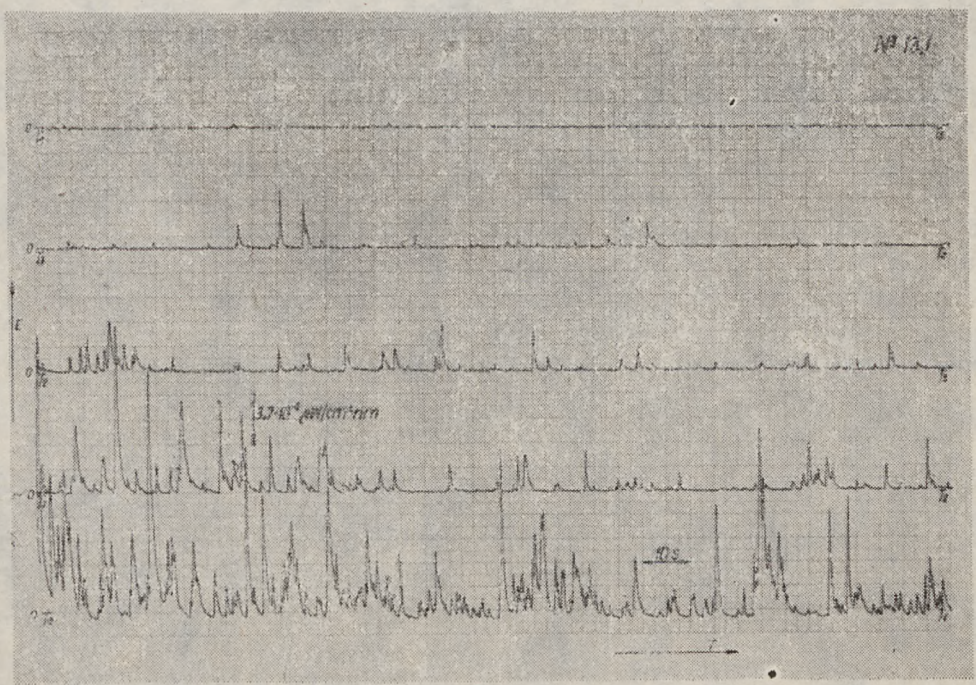
Keeping a sample in the darkness and quietness over several minutes shows a decrease in bioluminescence activity until a certain steady condition is reached. In this steady state after shock, the frequency of flashes is smaller by an order of magnitude than the initial frequency, while the intensity of the strongest flashes usually falls by two orders of magnitude as can be seen from diagrams. The subsequent gradual decrease in mean bioluminescence activity of organisms sampled is insignificant, it lasts for many hours and is characterized by fluctuations of flashes in time. In the final phase of experiments, after several hours. despite the apparent viability of individuals in the sample tested the bioluminescence activity of the sample dropps to the level of random pulses with a frequency of one pulse per hour. Therefore, if samples containing relatively few bioluminescence active individuals are to be studied, the initial phase of the shock should be preferentially exploited. On the other hand, studies of organisms in conditions similar to their natural environment, together with investigation of the role of bioluminescence in their life, should be conducted about half an hour after sampling, plus a few hours in quietness and darkness. The quasistationary level of biolumi-

nescence activity throughout this period depends both on the number of individuals able to show bioluminescence and on the composition of species in the sample. As will be shown later, one can assume interaction of different species, especially in a densely populated sample, so that the level of bioluminescence is controlled by the above factor.

The decrease of sample bioluminescence activity after many hours of experimenting can result from changes in the biochemical and physicochemical properties of the sample, with the water as a whole. It is well known that the effect of luciferin, for example, depends on environmental pH, pressure, temperature and even concentration of deuterium monoxide [1]. The clear dependence of bioluminescence activity on the composition of zooplankton species in a sample is illustrated by the diagrams, for an isolated Metridia individuals and one of the natural communities of zooplankton compared in Fig. 4. The community of 30 isolated Metridia organisms is presented in diagram No. 21.1. (in the first few minutes) and diagram No. 21.6 (after T_o=1.5 hour to T_{45} about 2 hours after sampling and storing in tray). The natural community of zooplankton compared with this Metridia community is depicted in diagrams No. 27.1. (in the first few minutes) and No. 27.10. (after T_o=2 h to T_5=2 h 16 minutes after sampling and storing); the highest sharp peaks in these diagrams should also be attributed to Metridia organisms present in this sample. It follows from the comparison that the bioluminescence activity of both samples is similar in the first few minutes of recording (during shock) but changes completely after about 2 hours of quietness in the measuring chamber. The distinctly higher activity of the natural sample of zooplankton can be attributed to the luminescence of different species of zooplankton in the sample and their interaction in this natural community. Time pattern of bioluminescence activity of zooplankton was clearly dependent on the species composition of the sample. These results indicate some biological functions of bioluminescence: it may be a signal for individual of a particular species to aggregate, an instinctive distress warning, a deterrent to agressors, concealment of location by flashes emitted during fast motion (especially in the case of Metridia sp., which eject luminous components into the environment [1]), and/or an expression of the aforementioned emotional conditions.

The experiments permitted the dominant role of Metridia sp. to be exposed bioluminescence of the Ezcurra Inlet zooplankton studied of Fig. 5. Frequencies of flashes were thus recomputed for 100 Metridia individuals in a sample (although this is rather conditional for natural communities). Fig. 6 shows recomputed temporal changes in pulse frequencies observed in various samples having the composition of species





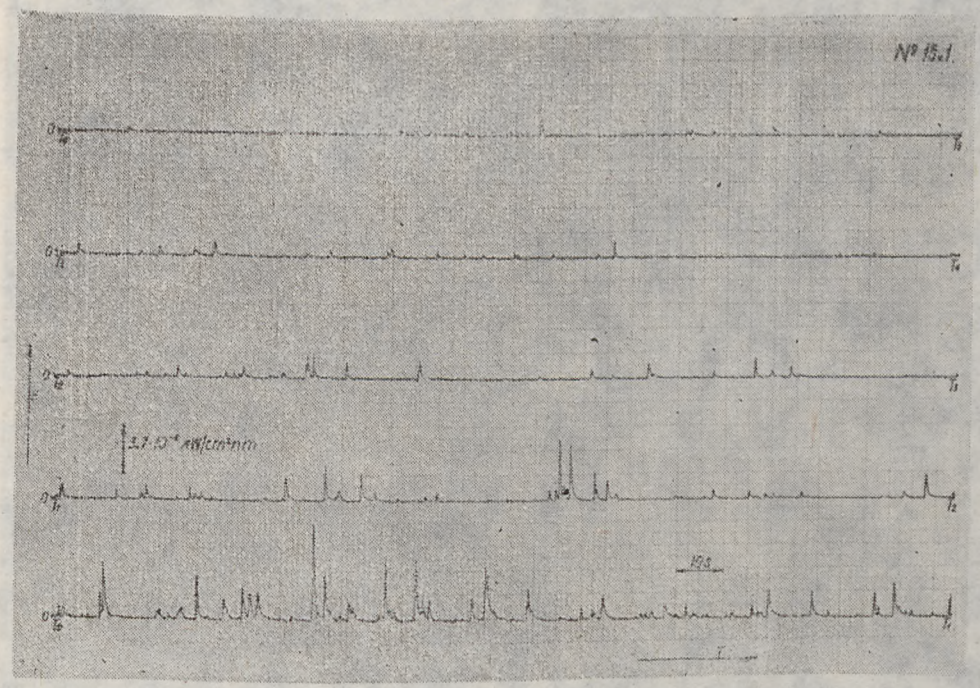


Fig. 3. Bioluminescence pulses characteristic for Ezcurra Inlet zooplankton during the initial 20 minutes after sampling and after storage in a dark measuring chamber

Notation as in Fig. 2. The zooplankton composition in samples of diagrams 10.1., 13.1 and 15.1 is presented in Table 1 under numbers 10, 13, 15. Digits before point denote the numbers of samples, while digits after the point — the consecutive number of given records. Distortion of some pulses in diagram 13.1 due to damage to the recorder.

Rys. 3. Impulsy bioluminescencyjne, charakterystyczne dla zbiorów zooplanktonu fiordu Ezcurra, w pierwszych ok. 20 minutach po wyłowieniu próby z morza i zamknięciu w ciemności w komorze pomiarowej

Oznaczenia objaśniono pod rys. 2. Skład gatunkowy zooplanktonu w próbach odpowiadających kolejnym diagramom 10.1, 13.1 i 15.1 wyszczególniony jest w tab. 1 pod nr 10, 13, 15; cyfry przed kropką oznaczają w tej pracy numery prób, a cyfry po kropce jedynie kolejny numer rejestrogramu z danej próby. Zniekształcenia niektórych impulsów na diagramie 13.1 wynikły z uszkodzenia rejestratora.

presented in Table 1. It follows from the drawing that a quasisteady state of bioluminescence activity in a sample, after initial shock, is reached about 25 minutes after sampling. The frequency of bioluminescence flashes then becomes stable at 1 to 10 flashes per minute per 100 Metridia individuals so that it can be concluded that a single act of luminescence by a given individual is rare. Examples of mean frequencies of flashes, $\overline{N}$, per 100 Metridia in a sample, 30 to 120 minutes after sampling and keeping in quietness and darkness, for various typical samples, are presented in Table 2.

The second component of figures in the brackets of Table 2 stands for standard deviation. The table indicates that a single zooplankton or-

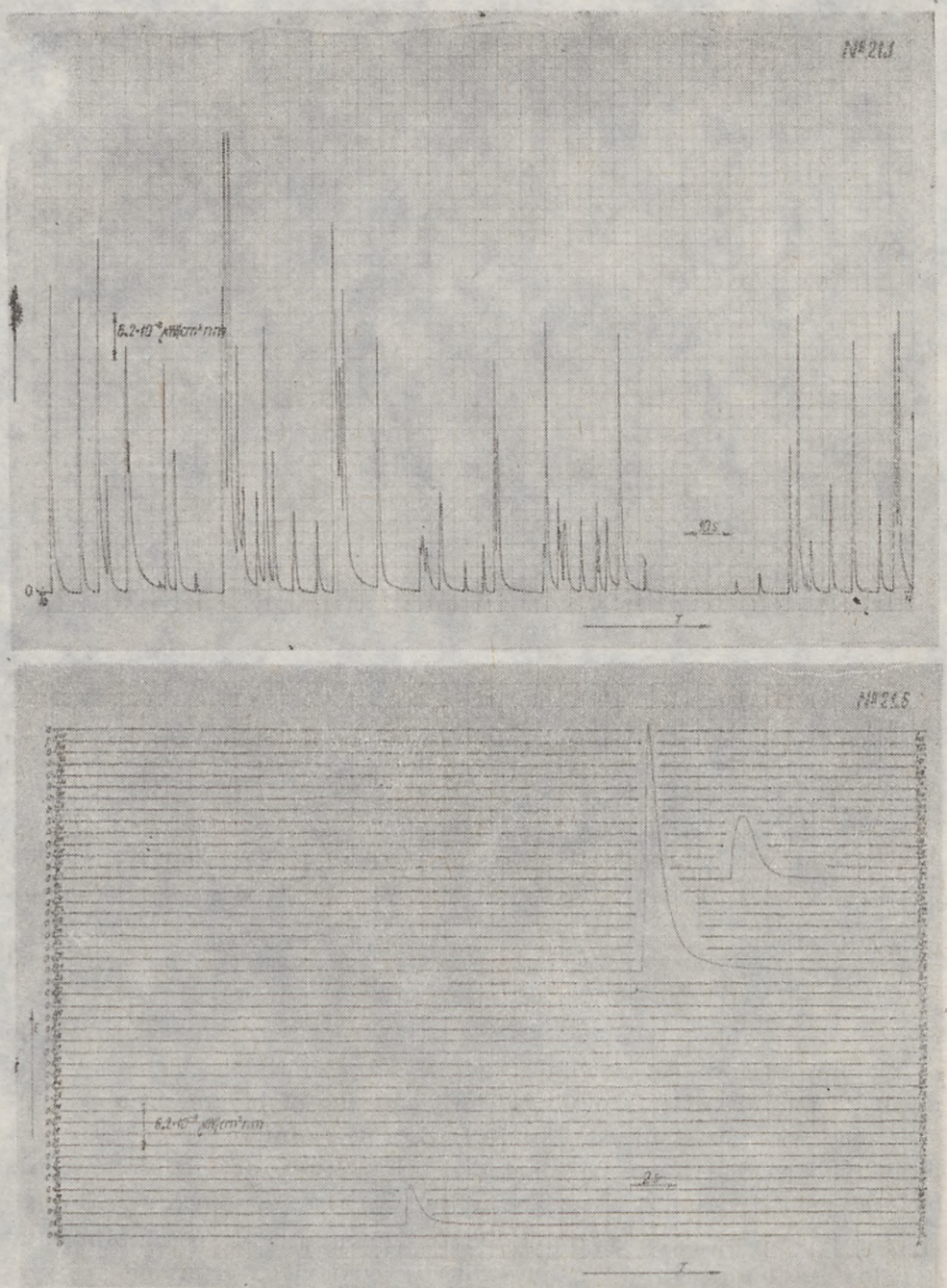
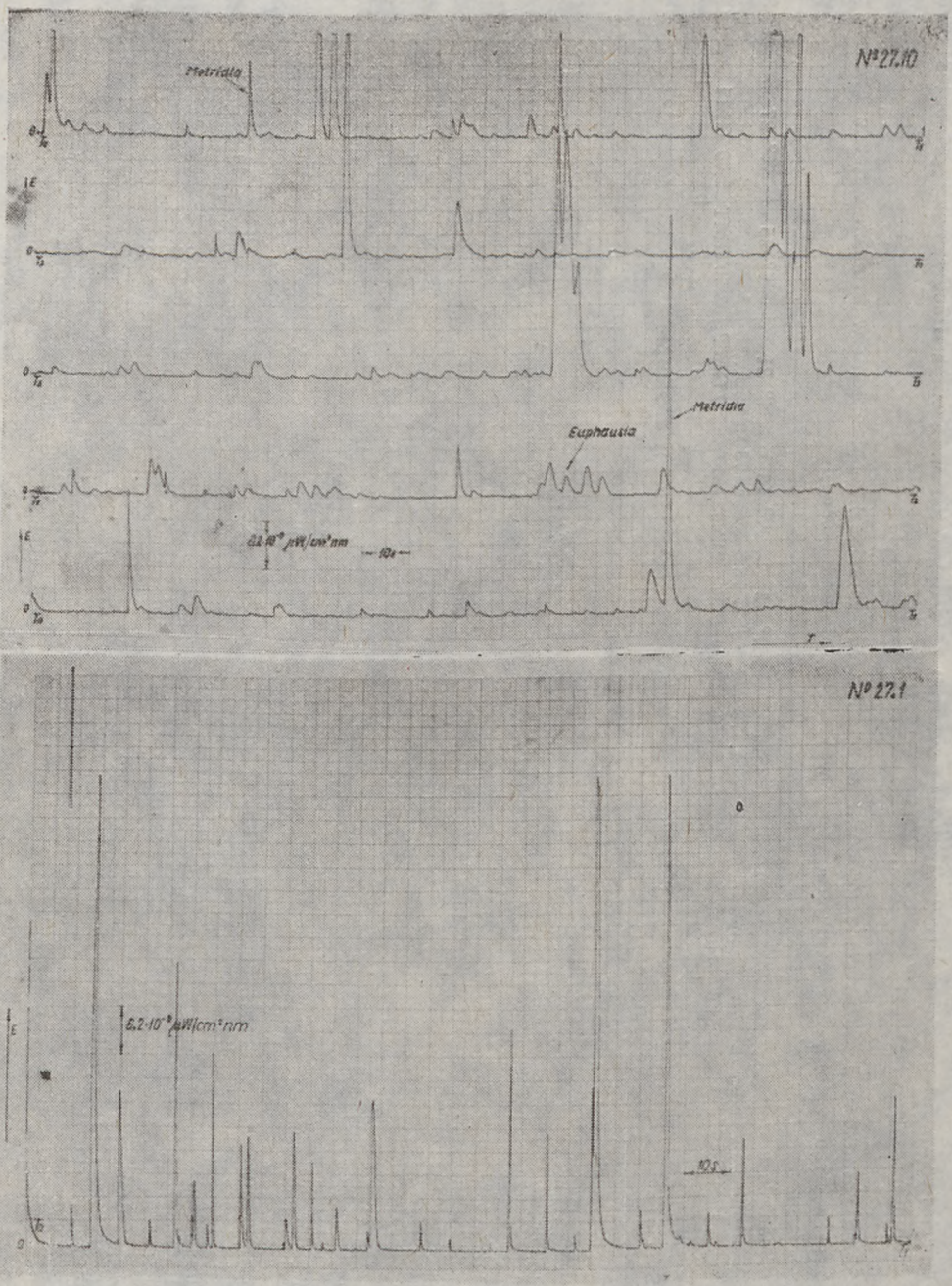


Fig. 4. Comparison of bioluminescence activity of an isolated community of 30 Metridia (sample No. 21) and a natural community of zooplankton (sample No 27) during the first few minutes after sampling (No. 21.1 and 27.1) and after about 2 hours in a measuring tray in the dark and quiet (No. 21.6 and 27.10).



Rys. 4. Porównanie aktywności bioluminescencyjnej wyizolowanego zbioru 30 osobników Metridia (próba 21) i zbioru naturalnego (próba 27) w pierwszych kilku minutach po złowieniu próby (nr 21.1 i 27.1) i po ok. 2 h pozostawania próby w spokoju i ciemności w kuwecie pomiarowej (nr 21.6 i 27.10).

Table 1. Species composition and density (individuals per 20 m³) of zooplankton in Ezcurra Inlet samples presented here in bioluminescence diagrams

Tab. 1. Skład gatunkowy i zagęszczenie (osobniki w 20 m³ wody morskiej) zooplanktonu w próbach z fiordu Ezcurra prezentowanych w tej pracy w diagramach i wykresach bioluminescencji

Number of sample and time of sampling Numer próby i czas pobrania	N° 7 28 Jan. 78 21.00 GMT	N° 9 31 Jan. 78 03.10 GMT	N° 10 1 Febr. 78 15.10 GMT	N° 13 4 Febr. 78 21.30 GMT	N° 15 5 Febr. 78 21.00 GMT	N° 21 10 Febr. 78 21.50 GMT	N° 25 15 Febr. 78 03.00 GMT	N° 27 23 Febr. 78 22.00 GMT	N° 31 7 March. 78 01.30 GMT
Species Gatunki	Abundance of individuals in sample Liczebność osobników w próbie								
CALANOIDA									
Metridia longa Lubbock	60	10	103	70	124	28		22	336
Metridia lucens Boeck	20	10	45	10	5	2		6	5
Metridia gerlachei Giesbrecht			5	25	20			6	14
Metridia curticauda Giesbrecht								1	1
Calanoides acutus Giesbrecht			12	8	9			30	73
Calanus propinquus Brady	13							14	12
Rhincalanus gigas Brady	1		1		1	selected wybrane	selected wybrane	5	2
Solecithricella glacialis Giesbrecht	20	5	27	43	5			46	12
Pluromamma robusta Dahl	23							22	2
Drepanopsis pectinatus Brady	253	7	96	45	21			567	108

Table 1, cont.
Tab. 1, c.d.

CYCLOPOIDA								
Oithona frigida Giesbrecht	71	2	156	201	10		2720	14
Oithona similis Claus	896	3	98	792	5			
Oncea sp.	250	2		96				8
EUPHAUSIACEA							100	8
Euphausia superba Dana and Euphausia crystalorophias	58			2	2	5	1	15
HARPACTICOIDA								
Microsetella sp.			4					
OTHERS								
Cheotognatha Polychaeta Amphipoda Coelenterata Nematoda Ostracoda	7	1	12	1	4		20	2

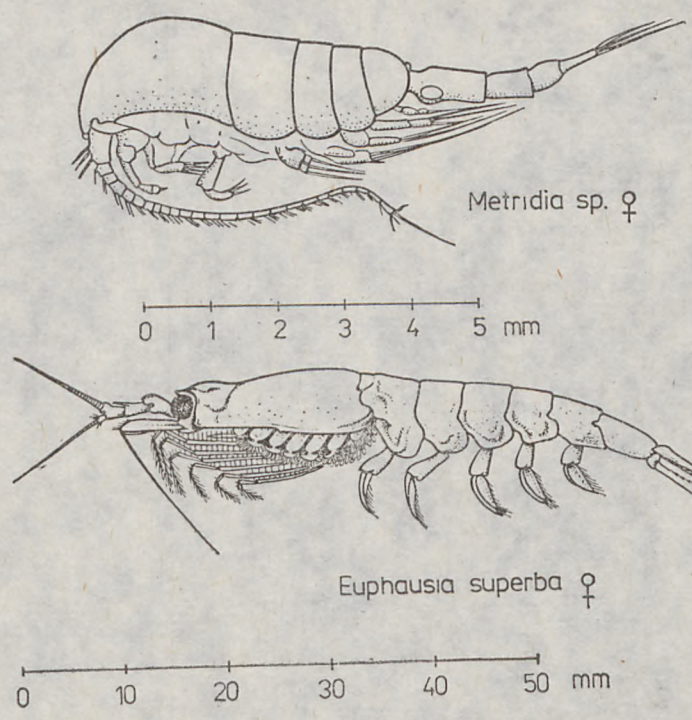


Fig. 5. A schematic histological diagram of Metridia and Euphausia individuals identified as bioluminescence-active in tested Ezcurra Inlet zooplankton samples

Rys. 5. Szkic budowy ciała Metridii i Euphausii, które zidentyfikowano jako bioluminescencyjnie aktywne w badanych próbach zooplanktonu z fiordu Ezcurra

Table 2. Mean frequencies of bioluminescence flashes $\bar{N}$ per 100 Metridia in a sample after shock, 30 to 120 minutes after sampling

Tab. 2. Średnia częstość błysków bioluminescencyjnych $\bar{N}$ przypadająca na 100 osobników Metridia sp. w próbie, po okresie szoku — w czasie od 30—120 min. po wyłowieniu próby

Sample No. Numer próby	Frequency $\bar{N}$ Częstość
7	(6.1±2.5) min^{-1}
10	(2.6±1.0) min^{-1}
13	(1.9±1.2) min^{-1}
21	(1.2±1.1) min^{-1}
31	<1 min^{-1}

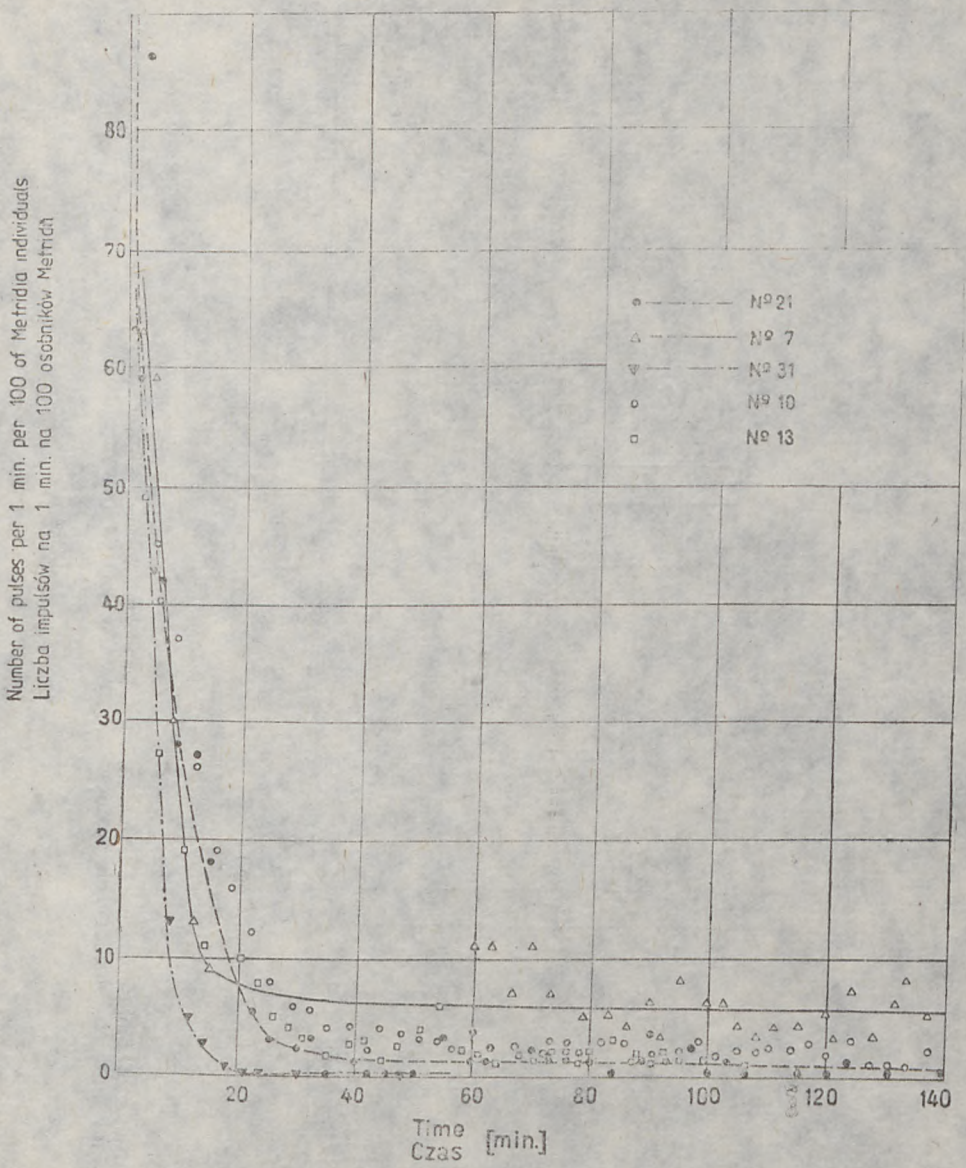


Fig. 6. Temporal variation of frequencies of bioluminescence flashes for few typical zooplankton samples, the species composition of which is given in Table 1

Rys. 6. Wykres zmian częstości błysków bioluminescencyjnych w czasie dla kilku typowych prób, których skład gatunkowy podany jest w tab. 1

ganisms in a sample kept in quietness emits less than about 3 flashes per hour, an average, or even less if one takes into account that a fraction of all flashes in natural samples does not originate from Metridia.

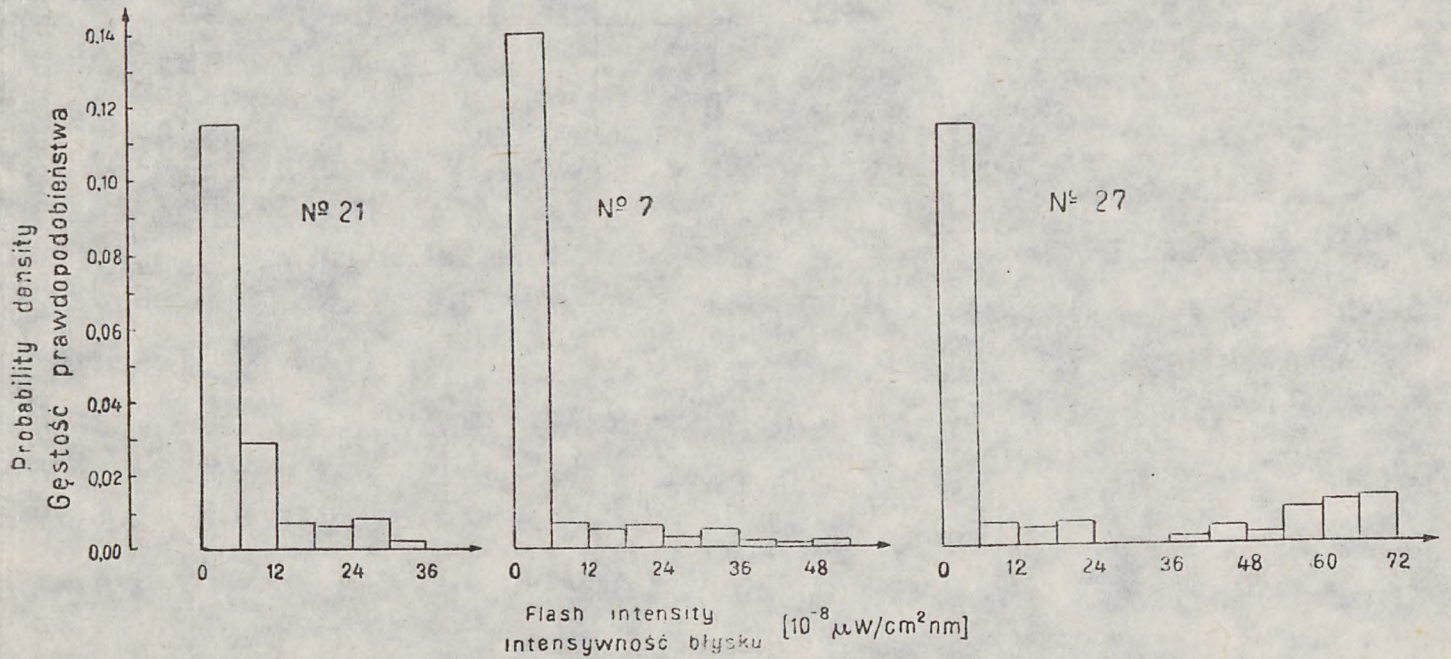


Fig. 7. Statistical distributions of bioluminescence intensity in typical zooplankton samples
Rys. 7. Statystyczne rozkłady natężeń błysków bioluminescencyjnych w kilku typowych próbach

However, the results collected so far suggest that these values should be treated as estimates that require more complete experimental verification. The diagrams indicate that amplitudes of some light flashes emitted almost simultaneously differ by orders of magnitude, so that the summation of these weakest pulses with intensities close to apparatus noise level is inaccurate. Nevertheless, one should be aware that each pulse, even the weakest, is an indication of a certain reaction of individual organisms constituting a given sample, and should be taken into account in the analysis. Fig. 7 shows fairly accurate integral statistical distributions of flash intensities under conditions of stationary bioluminescence activity in selected samples.

The Fig. 7 indicates that all distributions have strong maxima in the interval of very low intensities of flashes, and are considerably elongated towards higher intensities, which depends on details of the species composition of the sample. The experiments prove that flashes with differentiated intensities can originate from single species, e.g. Metridia.

Together with possibility of observing the behaviour of organisms through bioluminescence, another opportunity is offered by studies of forms of recorded bioluminescence flashes, characteristic for individual zooplankton species. After a number of experiments, we could distinguish the forms of Metridia pulses from those of Euphausia, compared in Fig. 8. Distinct sharp and more numerous peaks of Metridia with rise times of 0.2—0.3 second and relaxation times of 3 to 10 seconds are visible; an accurate analysis of test diagrams with a high rate of recording indicates considerable differentiation of these times. At locations with dense pulses, distorted forms of some flashes are caused by superpostion of two or more individual pulses. This is particularly pronounced for high congestion of pules, e.g. during initial shock (Fig. 3) or in very abundant communities. However, pulses different from those of Metridia and Euphausia are also visible in the deawing, these are still unidentified. More sophisticated luminescence patterns seem to appear in sample No. 27, for example, which is confirmed by diagrams 27.13 in Fig. 2 and 27.10 in Fig. 4.

Bioluminescence of Euphausia differs distinctly from that of Metridia (as is known that the mechanism of this bioluminescence differs [1]): pulses usually increase more slowly, regulated by the nervous system of Euphausia, they last for tens of seconds, and have irregular forms (Fig. 8, diagrams No. 9.1., No. 9.3., and No. 25.8). The Euphausia from the Ezcurra Inlet has a weaker bioluminescence activity; isolated organisms kept quiet emit light very rarely, while isolated full-grown organisms do not sparkle at all if not stimulated chemically. In dense samples of mixed zooplankton, the luminescence of Euphausia is visible, although weaker than

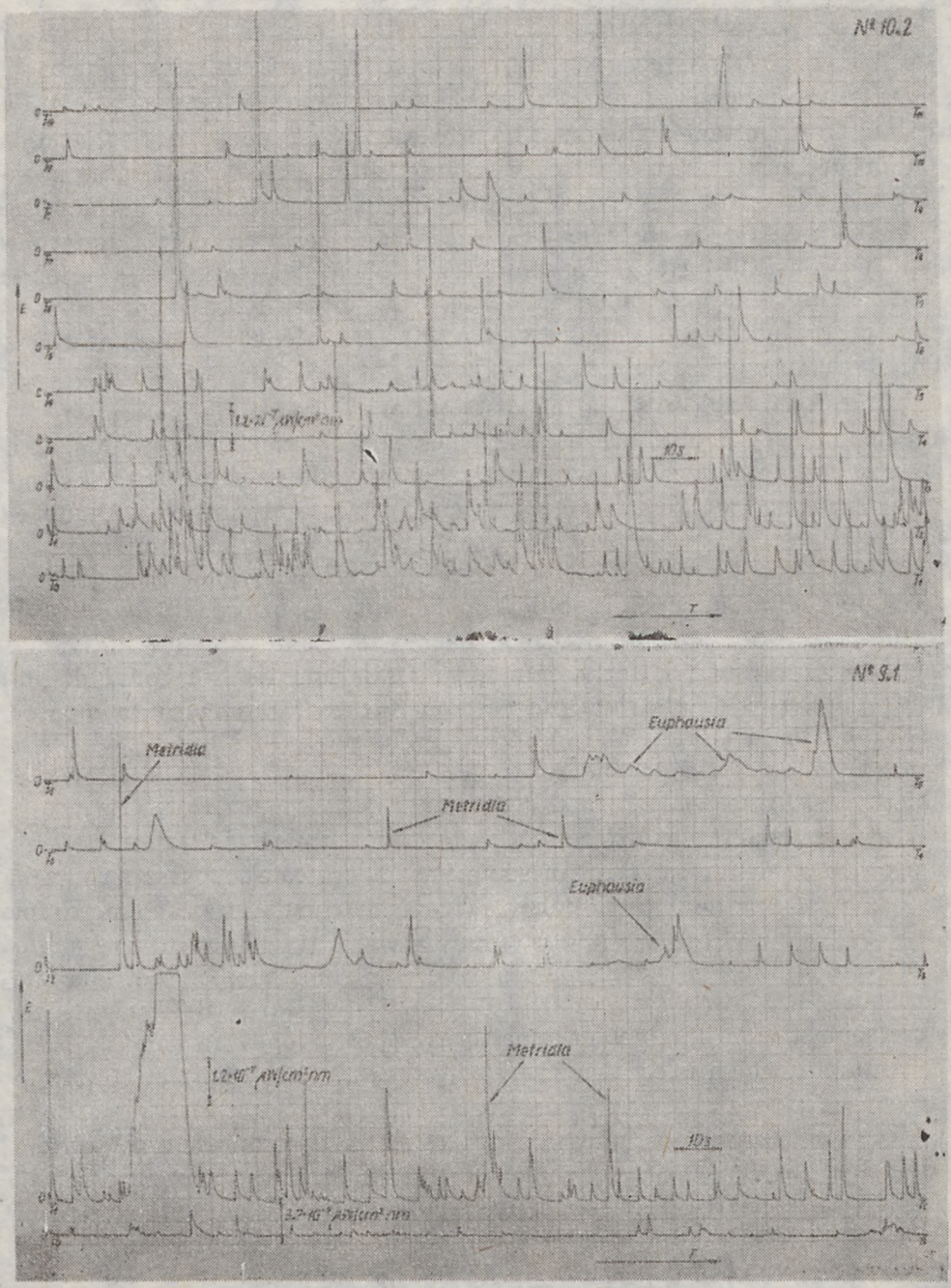
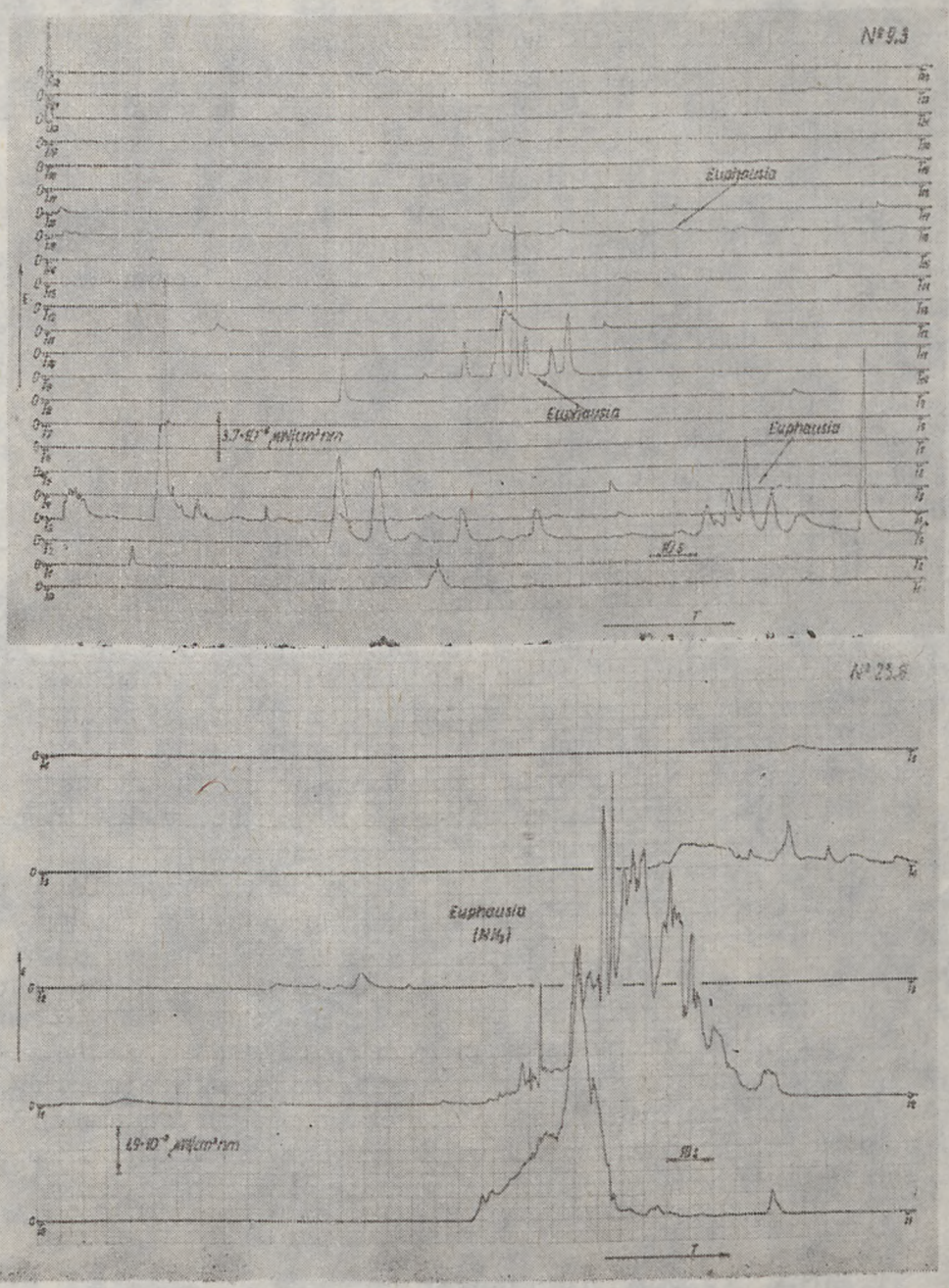


Fig. 8. Comparision of forms of bioluminescence pulses for Metridia, Euphausia and other unidentified organisms
The species composition is shown in Table 1. Other explanations are in the text.



Rys. 8. Porównanie kształtów impulsów bioluminescencyjnych Metridia, Euphausia i innych niezidentyfikowanych
Skład gatunkowy prezentowanych prób opisuje tab. I. Inne objaśnienia w tekście.

that of Metridia. This can be concluded from diagram No. 9.1. in Fig. 8, which illustrates 58 young Euphausia in a combined sample. Stimulated chemically (with a droplet of ammonia) Euphausia emits intensive light, as shown in diagram No. 25.8 in Fig. 8. The diagram illustrates high bioluminescence potentials of Euphausia and regulation of light with its nervous system. The presence of a large number of Euphausia in a sample modifies the above picture of changes in bioluminescence activity of the samples tested. However, the definition of Euphausia bioluminescence pulse remains unclear, as its single act of light emission with varying intensity and direction of emission, can last for some time (Fig. 8). Fast decolouring of the Euphausia body in the darkness from pink to lucid, colourless is also observed. This is one of the indications of biochemical reactions in the organism, in the complete absence of external illumination, and can be coupled with a later deficiency of bioluminescence capabilities.

Finally one should call attention to the sensitivity of the visual organs of the tested organisms and their accomodation to life under the conditions of a polar winter. In January, daylight irradiance in the studied water area reaches 100 $\mu W/cm^2$ nm in the visible wavelengths very close to surface. The weakest, and most numerous pulses of bioluminescence, which can be referred to as signal used by the tested organisms, fall to 10^{-9} $\mu W/cm^2$ nm. It can be presumed that these weak flashes are strong enough to be visible by the zooplankton studied. This means that the vision of these organisms is adapted to receive light signals with intensities even 10 orders of magnitude weaker than summer daylight at the water surface. Hence, the shock suffered by the organisms after extracting them from deep water and bringing them into daylight with possible paralyses of the organs of vision, is entirely understandable. (In our experiments, samples were usually taken at night or dusk, in the light of a distant lamp). Vertical downward migration of these organisms can be accordingly explained as an escape from the day-light while the migration towards the surface at night results from different reasons. Thus, these organisms can flourish in productive waters of the Antarctic regions during the polar winter, with weak daylight, when bioluminescence flashes facilitate their aggregation and emitting of warning signals.

4. SUMMARY AND CONCLUSION

Investigations of the bioluminescence of zooplankton samples in Ezcurra Inlet during the Antarctic Summer of 1977—1978 have shown that the samples caught in the water column from the surface close to the bot-

tom a depth of 70 m are bioluminescence-active, which appears as light flashes emitted by individual zooplankton organisms. The intensity of these flashes in 480-nm wavelengths is equivalent to irradiance of 10^{-9} to 10^{-5} $\mu W/cm^2$ nm from a distance of 20 cm from the source of light their duration being several to tens of seconds. The bioluminescence activity of the samples can differ, depending on the composition of species and is generally higher in samples taken at night. In almost all natural samples tested three distinct stages of bioluminescence activity can be observed. The first phase, lasting from 20 to 30 minutes after sampling, is characterized by intensive bioluminescence associated with the shock to the organisms sampled, and which decrease gradually. During this initial period the number of bioluminescence flashes in a sample falls by about one order of magnitude, while their peak intensities change most often by about two orders of magnitude. The second phase (after 30 minutes) shows relatively stationary activity for many hours. The level of this activity (intensities and frequencies of flashes) depends on the composition of species in the sample, as well as the interaction of zooplankton species, which regulates the activity of given species. In the third phase after many hours, the bioluminescence activity in the sample fades, which may be due to subtle physico-chemical changes in the water in the tray, lack of external light and other unexplored factors.

Metridia, with its characteristic flashes recorded as sharp peaks growing in order od 0.1 sec. and vanishing after 3 to 10 seconds, prevails in the samples caught in Ezcurra Inlet. The frequencies of Metridia flashes in the second phase (stationary) vary from 1 to 10 per minute per 100 organisms in the sample. The spontaneous bioluminescence of Euphausia, also present in considerable quantities, is weaker and of different character: infrequent weak flashes last for many seconds and even over one minute, with variable intensity. This effect can be intensified by the excitation of Euphausia with ammonia. The experiments indicate that some other zooplankton species, present in the samples tested, can produce bioluminescence effects. This finding, however, was not fully confirmed in our Ezcurra Inlet survey.

The observed bioluminescence of the zooplankton samples seems to elucidate the role played by this phenomenon in the life of the organisms studied. Among other effects, one should mention the substitution of acoustic signals by bioluminescence, aggregation given species, warning etc. The so-called forced bioluminescence, excited by mechanical or chemical means, seems to be a special display of emotions, i.e. reaction to danger. The bioluminescence capacity of zooplankton organisms is undoubtedly their accomodation to life in the darkness, especially in the absence of acoustic organs. Thus, this phenomenon is of particular im-

portance in oceanic polar regions, with poor light over long periods, also in the upper more fertile layer. The role played by bioluminescence in the life of polar organisms is therefore an interesting and important factor, which should be recommended for future research.

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BIOLUMINESCENCJA ZOOPLANKTONU WE FIORDZIE EZCURRA

Streszczenie

Przeprowadzono eksperymentalne badania aktywności bioluminescencyjnej prób zooplanktonu morskiego z fiordu Ezcurra (obok Stacji Antarktycznej PAN-u) za pomocą czułej aparatury fotometrycznej zainstalowanej na pokładzie statku „Antoni Garnuszewski". Stwierdzono obecność wielu gatunków zooplanktonu wykazujących bioluminescencję w postaci gęsto pojawiających się w czasie impulsów świetlnych, o czasie trwania kilku sekund, i intensywnościach odpowiadających oświetleniu 10^{-9}—10^{-5} $\mu W/cm^2$ nm z odległości ok. 20 cm w paśmie fal 480 nm.

Wyróżniono trzy charakterystyczne fazy aktywności bioluminescencyjnej prób: 1) okres szoku, po wyłowieniu prób z morza, z intensywnością bioluminescencyjną zanikającą stopniowo w ciągu 20—30 min. 2) okres aktywności względnie stacjonarnej trwającej wiele godzin i 3) okres szybkiego całkowitego zaniku bioluminescencji w próbie.

W próbach zooplanktonu morskiego z fiordu Ezcurra w aktywności bioluminescencyjnej dominował rodzaj Metridia sp., wysyłający charakterystyczne impulsy świetlne zidentyfikowane na rejestrogramach jako ostre piki, o czasach narastania rzędu 0,1 s. i czasach relaksacji 3—10 s.c. Stwierdzono, że w przeciętnej próbie z naturalnym zespołem zooplanktonu, po okresie szoku, przypada średnio mniej niż trzy impulsy świetlne na godzinę na 1 osobnika Metridia sp. Spontaniczna biolumi-

nescencja rodzaju Euphausia (głównie E. superba) jest słabsza i ma całkowicie inny charakter, tj. objawia się rzadkim i słabym, lecz wielosekundowym świeceniem, ze zmiennym natężeniem. Przeprowadzono szereg obserwacji i eksperymentów, których wyniki wskazują na pewne funkcje życiowe bioluminescencji badanych organizmów. W szczególności sygnały świetlne zastępują im sygnały akustyczne dla wyrażenia stanów emocjonalnych i utrzymywania kontaktów w naturalnym skupisku w toni wodnej.

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