The Eye and Some Effects of Light on Locomotor Activity in *Nephrops norvegicus*

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Abstract

The compound eye of *Nephrops norvegicus* (L.) is of the "superposition" type, well-adapted to the low levels of light prevailing at the sea bed during the activity periods of the species. Only the proximal retinal shielding pigment responds to light, the distal retinal shielding pigment being in the dark-adapted position at all times. The response of the proximal pigment appears to vary seasonally. Field observations compared light intensity at the sea bed with the numbers of *N. norvegicus* caught by trawl at various times of day in the Irish Sea in summer and winter. Laboratory experiments were combined with these field data to indicate that light is an important modulator of locomotor activity in this species.

Introduction

Previous workers have demonstrated a relationship between the locomotor activity of the Norway lobster *Nephrops norvegicus* (L.) and environmental illumination. When trawling at various times of the 24-h cycle at depths between 27 and 58 m in the Irish Sea in September, O'Riordan (1961, 1964) caught most lobsters at sunrise and at about 1.5 h before sunset. At 30 to 50 m in Faroe waters (62°N), however, maximum catches occurred at night during July and August (Andersen, 1962). A more systematic analysis was undertaken by Simpson (1965), who trawled throughout the 24-h cycle at various depths ranging from 20 to 160 m in the Irish Sea, Minches and North Sea, re-sampling some stations at different times of year. He concluded that the hours of highest catch vary, depending on depth and season, in such a manner as to suggest that the common environmental influence is light. Both O'Riordan (1964) and Simpson (1965) suggest that Andersen's (1962) observations of high nocturnal catch are explicable on the basis of the day length at 62°N during summer, the level of light intensity at night being comparable to the dawn or dusk levels in other areas or seasons. Höglund and Dybern (1965) have reported similar diurnal fluctuations in the numbers of lobsters trawled at various seasons and depths, again implicating light as the unifying factor. Further evidence along these lines is supplied by the Department of Agriculture and Fisheries, Dublin (1969, 1970), Hillis (1971a, b, 1972) and Farmer (1974). Only Hillis (1971b, 1972) supplemented his trawling programme with light measurements at the sea bed.

The observations described above are based on the assumption that *Nephrops norvegicus* are caught only when they naturally leave their burrows. The validity of such an assumption has been reinforced by direct observations with underwater television (Cole, 1967) and by diving (Chapman and Rice, 1971), and it is by combining these two techniques with measurements of light at the sea bed that the most comprehensive scheme relating the activity of *N. norvegicus* to light intensity has been produced (Chapman et al., 1972, 1975). From observations in Scottish waters, these authors conclude that the out-of-burrow activity of *N. norvegicus* is restricted

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to an optimum range of light intensity from about $10^{-5}$ to $10^{-1}$ m-c (metre candles). Thus, in shallow waters *N. norvegicus* are active at night, in deep water by day, and in intermediate depths the peaks of out-of-burrow activity occur around dawn and dusk. The data of Farmer (1974) are not wholly explicable on this basis, as is discussed later. Hillis (1971b) found an optimum level of light for peak catches of $10^{-2}$ m-c, although in some shallow hauls, the catch was high at intensities of 1 m-c or more.

So far, all the information reported relating the activity of this species to light derives from field observations. The present work describes the eye, including the effect of light on the retinal shielding pigments, notes the range of light intensity at the sea bed in the locality of the *Nephrops norvegicus* population selected for study, and presents initial results of an investigation into the effect of light on activity under controlled experimental conditions.

**Materials and Methods**

**Morphological Techniques**

The eyes of *Nephrops norvegicus* (L.) were processed for histological analysis in two ways. When only the position of the screening pigments was to be determined, fixation was accomplished by dipping the eyes in water at 80°C to 90°C for 20 to 30 sec and transferring them afterwards to 5% formalin in sea water. For finer histological analysis, either Carnoy's or Bouin's fixative was used. Under fixative, the chitinous exoskeleton was removed from the eyestalk. After fixation, eyes were dehydrated in a series of graded alcohols, cleared in chloroform and embedded in paraffin of melting point 54.5°C. Sections of 4 to 6 µm thickness were prepared for staining, and of 20 µm for the determination of screening pigment position. The most commonly used staining techniques were standard haematoxylin and eosin and Cason's (1950) modification of the Mallory-Heidenhain technique. When neurosecretory structures were investigated, the modification by Cameron and Steele (1959) to the aldehyde-fuchsin technique was used.

To determine the positions of distal and proximal screening pigments, the criterion followed was that put forward by Bruin and Crisp (1957), expressing the position of the pigments as a proportion of the length of the eye covered by each band of pigment. Thus:

$$I_{DP} = \frac{D_1 + D_2}{2D_4} \quad \text{and} \quad I_{PP} = \frac{D_3}{D_4},$$

where $I_{DP}$ = distal pigment index, $I_{PP}$ = proximal pigment index, $D_1$ = distance from cornea to distal end of distal pigment, $D_2$ = distance from cornea to proximal end of distal pigment, $D_3$ = distance from basal membrane to distal end of proximal pigment, and $D_4$ = distance from cornea to basal membrane.

**Field Observations**

*Nephrops norvegicus* were trawled at intervals over 24-h periods from between 70 and 80 m depth in the Irish Sea west of the Isle of Man at various times of the year. Trawling was conducted with a 15-mm-mesh beam trawl fishing for 15-min periods. Light intensity was determined immediately after each haul using several cross-calibrated light meters, but mostly by means of a photomultiplier tube (Craig and Lawrie, 1962) fitted with a green filter ($\lambda_{max} = 530$ nm) and calibrated from $10^2$ to $10^{-5}$ m-c. Since the intensity of illumination at the sea bed fell below the range of the light meter at certain times of day, the corresponding values were calculated by extrapolating figures obtained within the meter's working range after determining the attenuation coefficient and assuming it to be the same below the level of detection.

**Actographic Recording**

Since the daily pattern of locomotor activity of some crustacean species may be influenced by the type of apparatus used to record their movements (Atkinson and Naylor, 1973), an actograph was designed that incorporated an acrylic tube 30 cm long and 41 mm internal diameter, simulating a burrow. The tube was shrouded with black polythene and both ends opened into chambers measuring 30 x 15 x 15 cm (Fig. 1). The system was filled with running sea water maintained at 8°C. Movements of a specimen in an actograph were detected when beams of infra-red light (Kodak 88A filter) impinging on 2N5777 photocells were interrupted, producing digital pulses which were stored in a system of uniselectors and printed out hourly (Atkinson et al., 1974). These beams monitored activity in the centre of the tube, in the openings of the tube, and out of the tube. This apparatus was suggested