The Habitat of *Procerodes ulvæ*.

By

A. D. Ritchie,

Department of Physiology, Victoria University of Manchester.

THE relation of *Procerodes ulvæ* (*Gunda ulvæ*) to its environment has recently been studied by Pantin. In a series of papers (Pantin, 1931 (1) and (2); Weil and Pantin, 1931) a number of interesting facts have been brought out, which can be summarised as follows: This turbellarian is one of a very small number of marine forms which successfully colonise a region where there are large abrupt changes in osmotic pressure. It is found under stones in the intertidal zone and mainly where a stream of fresh water flows down the beach, though it occurs elsewhere too. In this habitat it is immersed in sea-water at high tide but between tides it is in perfectly fresh water (less than 0·01% sea-water). Procerodes is not water-tight, but swells up in fresh water. The swelling is controlled, however, and the animal loses salts in the process. The animal does not come into osmotic equilibrium with fresh water, as it does with sea-water, but can maintain a " steady state " for a time by means of an increased expenditure of energy as shown by increased oxygen intake (Beadle, 1931). The steady state is much better maintained and the swelling controlled in the presence of an appreciable concentration of calcium salts. The particular stream examined by Pantin, at Wembury near Plymouth, contains 58–65 mgm. of calcium per litre. For comparison sea-water contains 420 mgm. Ca per litre. Very hard spring water may contain as much as sea-water, while upland surface water may contain as little as 1 or 2 mgm. per litre.

The question now arises, is Procerodes confined to regions of hard water streams or if it lives in soft water streams is it driven further down the beach, where it has a shorter interval in fresh water? With a view to answering this question I have examined many miles of coast in different parts of the country and, though I never failed to find Procerodes wherever conditions were suitable, for a long time I failed to find a soft water stream on the coast. Whatever the nature of the underlying rock, surface water from cultivated land contains 20 mgm. or more of Ca per litre, generally more. The amount will vary of course with the weather, time of year, and treatment of the soil, and immediately after heavy rain may sink to quite low values. Even where there is no cultivation concentrations

between 10 and 20 mgm. are likely. But lower values have been found in two regions, one in the Isle of Man, the other in Morar, Invernesshire.

Place.	Date.	Calc. mgm. per litre.
West of St. Ives, Cornwall (2 streams)	15.7.32	12, 15
St. David's Head, Pembroke	2.7.31	14
South of Carmel Head, Anglesey (2 streams)	13.9.32	17, 18
Bay Fine, Southern end of Isle of Man	8.4.32, 24.9.32	19, 16
Bay Stacka ,, ,, ,, ,,	10.4.32, 25.9.32	18, 13
Near Fleshwick Bay, W. coast of Isle of Man	18.5.33	6
The Stacks, W. coast of Isle of Man	24.9.32, 17.5.33	5, 4
Loch nan Ceall, Morar	19.8.33	5
Bourblach House ,,	19.8.33	5
Sgeir Mhor ,,	19.8.33, 13.9.33	5, 12
Boagha Dearg ,,	13.9.33	8

None of these waters were acid. The Morar waters, though coming from deep peat and coloured with it, were alkaline (pH 7·2 to 7·6) and had an appreciable alkali reserve (combined CO_2). This is presumably the result of active vegetation ; in winter the results might be different. The nearest approach to pure water is that found at The Stacks, Isle of Man. This place is perhaps worth a fuller description.

About $3\frac{1}{2}$ miles north of Port Erin a stream is marked on the One-Inch Ordnance Map entering the sea near a point marked " The Stacks." The stream drains quite uncultivated land, covered with a scanty growth of heather and gorse. The soil is thin and somewhat peaty. The stream drops 500 feet in the course of a quarter of a mile. About half-way down it falls over a small cliff into a shallow ravine where there is much loose soil and stones. Above the ravine the water was found to contain 2–3 mgm. Ca per litre, at the beach 4–5 mgm. Evidently it picks up some from the soil on the way down. The beach is sheltered by outlying rocks and consists of large stones. It is an excellent habitat for Procerodes, which is abundant at all levels.

There is another more accessible stream with low calcium content near Fleshwick Bay, but here the upper beach is shingle and devoid of life so that Procerodes is confined to the lower levels. The Morar beaches are more accessible and have the advantage that High Water at Neaps occurs at less awkward times of day than in the Isle of Man. Observations of the upper limit of Procerodes have been made in both places but before discussing them something ought to be said about what in general constitutes a suitable habitat.

Procerodes lives on the undersides of stones that are large enough or well enough imbedded to be seldom moved. But it needs clean well aerated conditions so that the underside should be on rock, gravel, or coarse sand. Consequently it is scarce or absent in really sheltered waters where the beaches are usually muddy. It is always to be found on beaches of the open coast where the conditions are suitable. In general the best habitat is where the stream is small so that there is not enough flood water to move stones about and where it runs down a gully in rocks or down a beach of large stones in a cove with some shelter from outlying rocks or big boulders. I have found Procerodes flourishing at an exposed part of the southern coast of the Land's End peninsula, where there is a " beach " of huge granite boulders firmly pounded and wedged together by the seas. Underneath the boulders are pools with stones and coarse gravel evidently quite sheltered from the heavy seas of this coast.

On many beaches the higher part from the level of Spring High Water down to the Neap High Water level or lower is shifting gravel or shingle where nothing can live, so that only the lower part of the beach is suitable for Procerodes and other intertidal forms. Where there is a question of the upper limit of Procerodes it is necessary to consider only places where the upper zones are physically suitable.

It is noticeable that, where a stream runs down, the beach is cleaner and less liable to contain putrefying algal detritus. This fact and the fact that the stream keeps things cool and moist makes the region of the stream a better habitat in other respects than the rest of the beach for an organism that can endure large osmotic changes. In the middle of the tidal zone Procerodes is often to be found well away from the stream but higher up it is confined to it. Elsewhere the underside of stones high up the beach will dry up and warm up between tides and may be sticky with decayed weed. Gammarus and a few Isopods can flourish there but nothing else.

Pantin (1931, 1) found Procerodes at Wembury living up to about the level of High Water Neaps, and it was clear from an examination of many beaches that the upper limit is somewhere in this region, but further observation was evidently necessary. When I examined the beach of the Stacks, I.O.M., at Neap High Water of May 17th, 1933, it was surprising to find that the highest Procerodes were more than a foot above the highest point reached by the sea. There was a light offshore wind and the splash zone was quite small. By approximate calculation from the tide tables it was clear that on this beach the uppermost Procerodes were liable to be in pure stream water containing only 5 mgm. Ca per litre for 3 days, possibly 5 days, if there was calm weather with a Neap Tide period, and it had been seen that they could stand at least 2 days without harm. In rough weather of course they would always get splashed. Observations were also made at Bay Stacka using a tape dyed with silver chromate

which is stained white by salt water. The highest Procerodes there were at a similar level above high water and they were found alive after 3 days without sea-water in water containing 13–18 mgm. Ca per litre.

It was noticed on these two beaches that the upper limit of Procerodes was very close to the upper limit of *Fucus spiralis* on adjacent rocks. As the line is very sharp and as the upper limit of *Fucus spiralis* is also the lower limit of *Pelvetia canaculata* these two weeds provide an excellent point of reference which may be taken as marking the same tidal level on all beaches, i.e. about Mean High Water Neaps (Colman, 1933).

The Morar coast was visited in August, 1933, and a region for observation was found on the coast below Bourblach Hill to the west of the road to Mallaig just north of the estuary of Morar River (*cf.* One-inch Ordnance Map). This region is entirely uncultivated and the soil is peat. It contains several small streams, of which two are specially suitable. One just north of Sgeir Mhor runs down a cleft in the rocks forming shallow pools with stones. The other is further north, by Bogha Dearg, where a stream is marked on the map. This stream runs down a very gently shelving stony beach sheltered by outlying rocks. A third stream running into the Morar estuary just below Bourblach House with some slight cultivation on its course, was also examined. Although in shelter the beach is clean and suitable for Procerodes. In this region Procerodes is not abundant but is found in all suitable places, the upper limit was seen to be very close to that of *Fucus spiralis* in all three places.

Further observations were made at the low Neap Tides in September (lowest on September 13th). From the data in the Admiralty Tide Tables it is clear that the predictions for Stornoway can be applied to this coast without appreciable correction for height. Fortunately there was a spell of fine weather with calm sea and mainly offshore winds at this time, so that the splash zone was small.

At all three stations the upper limit of Procerodes coincided very closely with that of *Fucus spiralis*, it was certainly not lower. The high water of the afternoon of the 13th (9·4 ft.) was more than a foot below this line at Sgeir Mhor and that of the afternoon of the 14th (10·0 ft.) at least a foot below at Sgeir Mhor and Bogha Dearg. The morning tide of the 14th was predicted as 9·2 ft. so that it was not necessary to make an observation of it. The morning tide of the 15th (9·9 ft.) was observed at Sgeir Mhor by means of silver chromate tape. The wind was S.W. and freshening, raising some sea. Although the splash zone was now considerable the highest Procerodes pool cannot have been reached by sea-water. On this morning (September 15th) the Procerodes at Sgeir Mhor and Bourblach House, which cannot have been in sea-water since the night of September 10th to 11th (10·8 ft. tide) and possibly not since the previous night, were mobile and apparently in good condition if a little swollen. There was no

time to visit Bogha Dearg again, but the Procerodes there were alive on the afternoon of the 14th. The afternoon tide of the 15th (10·8 ft.) almost certainly covered the whole Procerodes zone, with the onshore wind then blowing, but if the weather had been calm might have barely reached the upper limit.

It was disappointing to find that the calcium content of the Morar waters was higher than in August, presumably owing to the dry weather. However, the quantities, 8 and 12 mgm. per litre, were not excessive.

For comparison with Morar, the coast to the east of St. Andrews Bay, Fife (Kinkell Braes), was examined on September 11th. A number of small streams partly from springs in the sandstone and partly drainage of cultivated land occur here. In many places the upper beach is pure shell sand and not suitable for Procerodes, but one excellent place was found just west of Kinkell Ness. The water here contained 39 mgm. Ca per litre and Procerodes was living up to the line dividing *Fucus spiralis* and *Pelvetia canaliculata*. By reference to these algæ there was no perceptible difference between the upper limit here and in Morar, or in fact in any region examined.

It must be concluded (1) that Procerodes is not limited in its distribution by the calcium content of the fresh water stream it colonizes down to a minimum of 5 mgm. Ca per litre : (2) that it can survive about 5 days without sea-water, a contingency that may occur whenever a low neap tide period coincides with calm weather. It has been pointed out by Orton (1933) that the combination of neap tides, calm sea, and hot weather may be very lethal to the population of the upper part of the tidal zone (i.e. above the lowest Neap High Water level). The habitat chosen by Procerodes has at least the advantage that it is never exposed to high temperature or dessication, and the animal is not confined to short and uncertain periods of immersion in sea-water for obtaining its food.

In the laboratory Procerodes does not seem able to survive more than about 2 days in pure water ; but it must be remembered that laboratory conditions are probably much severer than its natural habitat on account of high temperature, exposure to strong light, and absence of food supply. So that it is not altogether surprising that it should succumb more quickly.

SUMMARY.

Procerodes ulvæ has been found living in streams with calcium content as low as 5 mgm. per litre. Its upper limit does not appear to be affected by the calcium content of the water. The animals at the upper limit are liable to about 5 days' exposure to fresh water if calm weather coincides with Neap Tides. Animals living in water of 8–12 mgm. Ca per litre have been found alive at the end of such a period.

REFERENCES.

BEADLE, L. C. 1931. The Effect of Salinity Changes on the Water Content and Respiration of Marine Invertebrates. Journ. Exp. Biol., Vol. VIII, pp. 211–227.

COLMAN, J. 1933. The Nature of the Intertidal Zonation of Plants and Animals. Journ. Mar. Biol. Assoc., N.S., Vol. XVIII, pp. 435–476.

ORTON, J. H. 1933. Some Limiting Factors in the Environment of the Common Limpet, *P. vulgata*. Nature, Vol. CXXXI, pp. 693–694.

PANTIN, C. F. A. 1931 (1). The Adaptability of *Gunda ulvæ* to Salinity. I. The Environment. Journ. Exp. Biol., Vol. VIII, pp. 63–72.

PANTIN, C. F. A. 1931 (2). The Adaptability of *Gunda ulvæ* to Salinity. III. The Electrolyte Exchange. *Ibid.*, Vol. VIII, pp. 82–94.

WEIL, E., and PANTIN, C. F. A. 1931. The Adaptability of *Gunda ulvæ* to Salinity. II. The Water Exchange. *Ibid.*, Vol. VIII, pp. 73–81.