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## RECENT SPREAD AND PRESENT DISTRIBUTION OF THE BARNACLE *ELMINIUS MODESTUS* DARWININ SOUTH-WEST SCOTLAND

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*Elminius modestus* is now well established in Great Britain (Crisp, 1958). In the north-west, following on independent colonization of Morecambe Bay, slow marginal dispersion took place along the Cumberland coast and was followed by more rapid progress in the Solway Firth. By the end of 1955 he records that *Elminius* was occasional at the Isle of Whithorn and he found a single specimen at Drummore near the Mull of Galloway. Crisp (1958) also records the presence at Stranraer in Loch Ryan of a separate population which has existed since 1950 but whose numbers have not increased; it is considered that the density has been inadequate to give rise to an expanding population. Apart from that for Stranraer Harbour the only other record of the occurrence of this species within the Clyde Sea Area is that of Connell (1955) who found a single specimen at Millport.

The entry and spread of *Elminius* into the Clyde Sea Area would have important consequences for several lines of work at present in progress in this laboratory and the discovery of an isolated specimen at Ayr in 1959 and of a vigorous population in Loch Ryan has led to a more detailed examination of the south-western coasts being included in the annual survey that is being made of the intertidal barnacles of this region; the results regarding *Elminius* in 1959 are given below (see also Fig. 1).

### DETAILS OF THE SURVEY

#### POWFOOT

This is at the entrance to the estuary of the Eden. The beach is largely sand with some scattered stones at high water and a

large concrete 'bathing' tank further down the shore; the tide recedes some 500 metres down the shore. On the more stable stones *Elminius* is common with adults at a density of

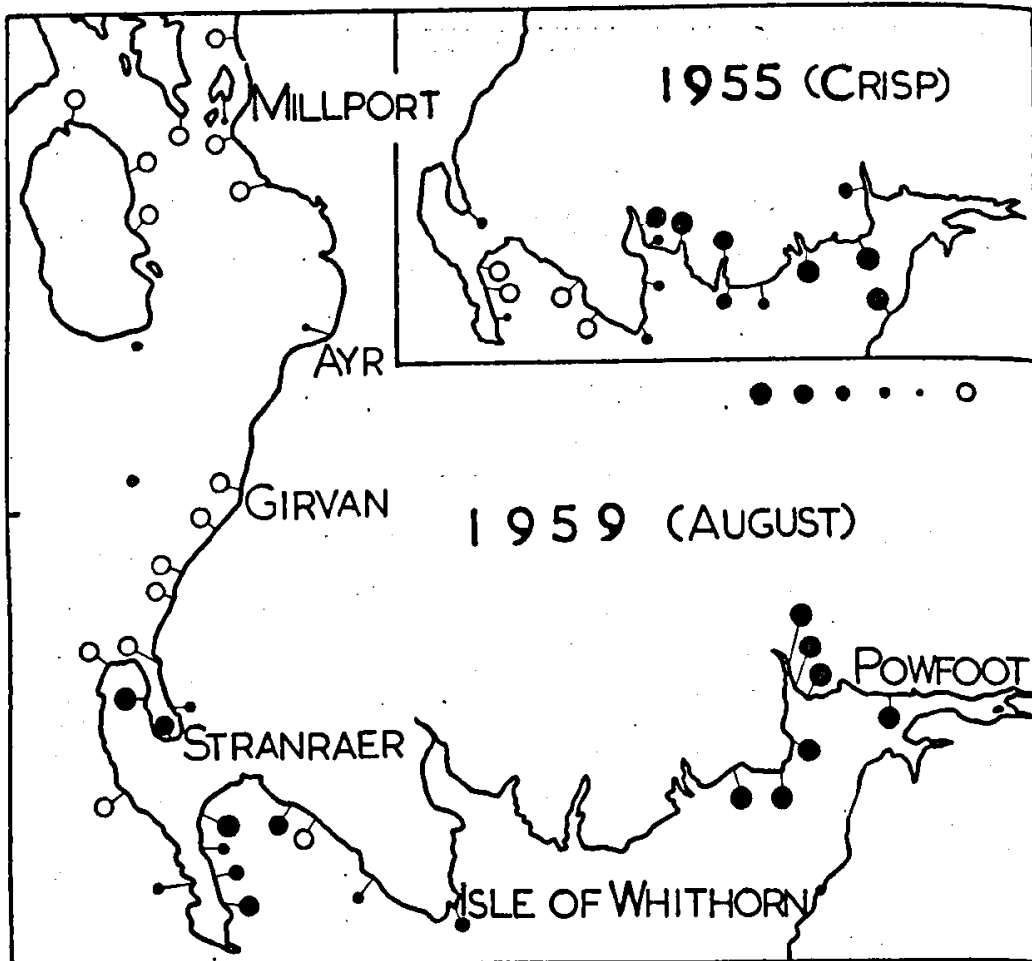


FIG. 1. Distribution of *Elminius modestus* in south-west Scotland. Inset figure shows the distribution on the basis of 1955 survey by Crisp (1958). Symbols under the inset figure read, from left to right: abundant, common, frequent, occasional, rare and absent.

1-2/cm<sup>2</sup> and spat (diameter < 2 mm) at 5/cm<sup>2</sup> in many places. *Balanus balanoides* is still abundant on these stones. At the lower edge of the twenty-metre-wide stony upper beach there were 15-20/cm<sup>2</sup> *Elminius* spat. On the sides of the concrete tank, which is some 150 m down the beach, *Elminius* (30/cm<sup>2</sup>, all size groups) is rapidly replacing the indigenous species; not only are all the bare spaces occupied by the immigrant but both the adults and current year's settlement of *Balanus balanoides* are covered by young *Elminius*.

#### CAERLAVEROCK CASTLE

The banks of the Nith estuary—marshland intersected by a system of erosion channels—lead to wide expanses of mud exposed at low tide. The only surfaces suitable for settlement

are the semi-permanent net stakes driven into the mud at various places. *Elminius* is abundant on these stakes; old adults ( $1/\text{cm}^2$ ) and spat ( $16\text{--}20/\text{cm}^2$ ) were present even 5 ft above the mud surface. Just above the mud the *Elminius* formed a dense crust which was in some places breaking away leaving the bare wood. *Balanus balanoides* was absent.

#### GLENHOWAN

This is further up the Nith estuary and *Elminius*, old adults and a range of size groups, covered the wooden stakes; the spat density was  $15\text{--}20/\text{cm}^2$ . In places the dense settlement was again breaking away. *Balanus balanoides* was absent.

#### GLENCAPLE

At this point in the estuary a stone jetty fronts on the channel of the estuary, which is here narrowing. *Elminius* is abundant even though the stones carry a thick greasy layer of mud on their upper surfaces. Spat up to  $10\text{--}15/\text{cm}^2$  was observed, being rather more abundant at the upper levels. There was a settlement of small *Elminius* adults on the *Fucus* fronds. *Balanus balanoides* was absent.

#### CARSETHORN

This is on the right bank of the Nith estuary at its entrance and a short bank of stones leads to extensive mud flats. *B. balanoides* is still present on these stones but it is being rapidly replaced by *Elminius*. Adults, two years old, of the latter species are common and spat density is  $10\text{--}15/\text{cm}^2$ . Bare places are being rapidly covered by *Elminius* which is also smothering the young *Balanus* and covering the adults, on one of which 30 small *Elminius* were counted. The situation is similar on the wooden remains of a ship's hull, where in many places dense *Balanus* had broken away and *Elminius* was well on the way to dominance.

#### SOUTHERNESS

This is in a relatively exposed position and a large rock reef stretches out for a considerable distance. *Elminius* is very abundant. Even in the zone above the main *Balanus balanoides* belt there are  $2\text{--}4/\text{cm}^2$  *Elminius* spat and at this level it is competing with *Chthamalus stellatus*. In the mid-tide zone *Elminius* is somewhat commoner than the indigenous *Balanus balanoides* but towards the lower tidal levels the latter is still abundant, the current year's spat being abundant and showing good growth.

## SANDY HILLS

There is a rock outcrop in the sandy shore and again *Elminius* is abundant particularly in the upper levels; both adults and spat are present. *Balanus balanoides* is still plentiful particularly at the lower levels but available space is rapidly being colonized by *Elminius*.

## ISLE OF WHITHORN

Here there is a small bay and harbour flanked by rocky walls. *Balanus balanoides* is abundant on the shingle and under the weeds in the bay. *Elminius* both adults and a small amount of spat ( $0.5/\text{cm}^2$ ) may be found in places but much of the area is still free from it; there is, however, heavy weed cover. On the outer side of the harbour wall *Elminius* is comparatively infrequent. On the exposed coast outside the bay there are scattered adult *Elminius* and a little spat somewhat locally distributed. *Balanus balanoides* is common.

## MONREITH BAY

This is situated at the entrance to Luce Bay. The beach is sandy with some large stones and boulders and on these *Balanus balanoides* is dominant. Only scattered *Elminius*—adult and spat—were present. An occasional adult is often present amongst the *Chthamalus* which in this relatively exposed position forms a fairly well defined band above *Balanus balanoides*.

## NEAR PORT WILLIAM (COCK INN)

The sides of Luce Bay, both east and west, show a curious development of beach shingle which is set along the coast in the form of a series of loops between which lie small sandy stretches. These boulder spits carry a heavy cover of *Fucus* and other weeds. The occurrence of *Elminius* was very variable. On some of these spits very few were found, on others it was fairly common. Everywhere, however, on the east side of Luce Bay *Balanus balanoides* was dominant. On this particular spit *Elminius* was absent.

## COCK INN

On some spits near the inn, *Elminius* was quite common, being present on almost every boulder: this was in marked contrast to some of the spits nearer Port William. There were scattered old adults, one or two years old, with corroded shells and some spat ( $8/\text{dm}^2$ ) on many of the stones.

## SANDHEAD

Both *Balanus balanoides* and *Elminius modestus* are present on the lower stones of the narrow stretch of shingle above the

extensive sand-mud flats; this shingle is at high tide level. On a drainpipe running out across the beach, however, competition between the two species is severe. Adults ( $1/\text{cm}^2$ ), young ( $8-10/\text{cm}^2$ ), and spat ( $5-10/\text{cm}^2$ ) of *Elminius*, are present although there is still a good growth of *Balanus balanoides*, the current year's settlement of which was abundant and showed good growth; in places it covered the previous summer's settlement of *Elminius*. The *Elminius* is more abundant on the west side of Luce Bay than on the east side and more abundant even than at Isle of Whithorn.

#### ARDWELL

On one of the larger spits, with dense algal cover, *Balanus balanoides* was common under the stones at all tidal levels. *Elminius* was, however, quite rare.

#### ARDWELL-DRUMMORE

On a spit further to the south, *Elminius* was more abundant, both adults and spat being quite easily found.

#### DRUMMORE

Here there is a small harbour, partly protected by a shingle spit, and into the harbour projects a large boat slip. *Elminius* is abundant and mixed with *Balanus balanoides*. On the slipway, old and corroded *Elminius* are present that are clearly several years old. The overall adult density in places was quite adequate for breeding (average in places  $0.5/\text{cm}^2$ ), while small individuals ( $1-2$  mm) reached a density of  $2.0/\text{cm}^2$ . In places—on, for example, individual stones—the density was much greater. *Elminius* was also present on the remains of a hull. *Balanus balanoides* is still, however, dominant even though *Elminius* is making rapid inroads into the indigenous population.

#### PORT LOGAN

This lies in a small rocky cove on the outer coast of Galloway and except for the local shelter the coast here is much more exposed than in the Solway Firth. On the stones near the jetty and on a pipe crossing the beach adult *Elminius* were present. The species was infrequent and no spat was seen. Even so, some of the small groups of adults were sufficiently dense to result in a breeding population.

#### PORT PATRICK

This is a small cove-like harbour on the outer exposed coast of Galloway and only a few miles to the north of Port Logan. Only a limited inspection was made. Nevertheless, the stones in the harbour, where there was considerable mud, the jetty

and nearby stoneworks were examined without finding *Elminius*. *Balanus balanoides* was present but the settlement in the spring had not been abundant and the year's growth appeared to be poor.

#### CORSEWALL POINT

This is the northern exposed point of Galloway. There is no harbour and the rocks go steeply down to the water. There was a very dense cover of *Balanus balanoides*, a good spatfall and excellent growth at all the levels examined. *Elminius* was absent.

#### LOCH RYAN, NEAR KIRKCOLM

This is a sheltered north-facing loch. At this particular point there is a large concrete slip on the western shore of the loch and much stony ground on the nearby shores, the stones being well covered with weeds. On the slip *Elminius modestus* is abundant, particularly in the open places, which are completely covered with young adults and spat. In places the adult density is 1/cm<sup>2</sup>, size group 1–5 mm, 2/cm<sup>2</sup> and spat at 5/cm<sup>2</sup>. The density was as great as that at many places in the Solway Firth. It was most noticeable that spaces cleared by the browsing of *Patella* were quickly colonized by *Elminius*; where the spring settlement of *Balanus balanoides* had been removed in this way *Elminius* had completely taken over the space. The stones on the shore, which were heavily covered by weed also had some *Elminius* on them—both young and old, but the density was far less than on the slip. In this area of the loch there is without doubt a thriving population of *Elminius* which is, in places, replacing *Balanus balanoides*.

#### LOCH RYAN—STRANRAER HARBOUR

*Elminius modestus* is common on the left harbour wall, all sizes from spat to 10–12 mm individuals being present; the species is commoner on the inner side. On the outer wall adults have a density of 8–10/dm<sup>2</sup> and spat 0.5/cm<sup>2</sup>. A small concrete tank in the sandy shore at the upper tidal levels had abundant *Elminius* both young and adults. To the side of this wall there is stony beach; the stones are often heavily covered by mud and they carry a small quantity of both *Balanus balanoides* and *Elminius*. The situation here was, however, not favourable for settlement and in winter and spring the stones are probably subject to much abrasion.

#### LOCH RYAN—CAIRN RYAN

The now disused dock area was examined. No *Elminius* was found on the pier but on the groyne running out from the

concrete wall and under dense algal growth a few small isolated individuals were found.

#### PORT SALLY

This is on the exposed north-eastern entrance to the loch, and there is an outcrop of rock in a pebbly and steeply shelving beach. There was very considerable scour so that *Balanus balanoides* formed a conspicuous zone separated from the beach by bare scoured rock. At the higher levels on the rocks there was some, though not abundant, *Chthamalus stellatus*. *Elminius* was absent.

#### AYR

A single adult individual of *Elminius*—probably a year old at least—was found on the north wall of the harbour amongst abundant *Balanus balanoides*.

#### THE AYRSHIRE COAST AND CLYDE SEA AREA

Apart from the single individual at Ayr, no *Elminius* has been found on the eastern shores of the Clyde Sea Area nor has the species been found elsewhere in the area during a series of annual shore surveys.

#### DISCUSSION

It is evident from the foregoing that *Elminius modestus* is now more abundant than when Crisp made his surveys in 1950-55. With the exception of a single specimen at Drummore (and the small dwindling population at Stranraer, see below) it was not found west of Isle of Whithorn, where it was only occasional, i.e. "very local and must be searched for." It is now common throughout Luce Bay and in places abundant, and has rounded the Mull of Galloway to reach Port Logan. However, all along the north coast of the Solway, both in the bays and estuaries the species is irregularly distributed and there can hardly be said to be an advancing front. It would seem that settlement takes place from a larval population liberated into the Firth from places where it is abundant (and settlement is variable and dependent upon local conditions) rather than by frontal spread by coast-wise currents. The exposed Mull of Galloway and that part of the outer coast to Corsewall Point constitutes a distinct barrier to the entry into the Firth of Clyde but the population of the north Solway coast has now been built up to a sufficient density to pass the Mull. It may be anticipated that further spread and increase in density along this coast will still be slow. It is still infrequent on this coast as at Port Logan. A more potent potential source of infection for the Clyde Sea Area is the well developed population in Loch Ryan. This

loch is in many ways ideally suited to *Elminius*. The entrance is narrow, the waters are sheltered and in the inner parts muddy, and summer temperatures are high: it would be anticipated that the loch will come to sustain a dense population at all suitable places along the shore. The origin of this population is uncertain; Crisp (1958) describes a population in the harbour present in 1950 which had not increased by 1953, but the location was not given precisely. It is unlikely that the well established populations here recorded would not have been seen by Crisp, although his most recent observations at Kirkcolm were made in 1953. They may have reached the loch since 1955. The fact that the species is rare at Cairn Ryan suggests that these populations were not initiated there by war-time shipping. That *Elminius* is abundant on the slipway near Kirkcolm, that was used during that war as a sea-plane base, prompts the suggestion that infection may even have been directly from the south of England. The situation would then resemble the introduction of *Balanus amphitrite* into the saline but not marine Salton Sea in California. Under these conditions, however, the colonization of Loch Ryan would have been expected to be much more advanced than is the case. In any event this population might now be expected to expand and not only to link up with that proceeding northwards from the Solway but also, in view of the frequent strong northerly coastal drift along the eastern shores of the Clyde Sea Area (Barnes and Goodley, in press), to initiate colonization of the Clyde.

#### SUMMARY

1. An account is given of the further spread of *Elminius modestus* along the north coast of the Solway Firth and towards the Clyde Sea Area.
2. *Elminius modestus* is now common in Luce Bay and has rounded the exposed Mull of Galloway to reach Port Logan.
3. There are well established populations in Loch Ryan.

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#### NOTE ADDED IN PROOF

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Since submitting this paper for publication two further notes have been published on the presence of *Elminius modestus* in the Clyde Sea Area and a number of new observations have



been made. Powell (1960) has recorded two specimens at Keppel, Millport: relevant to this it should be stated that during 1959-60 occasional individuals were constantly being found on collected material, particularly mussels at about low tide level and a rare specimen on the shore here and also at Fairlie. During the summer of 1960 the species was quite common, with groups at breeding density, on a number of piles drawn from the pier at Largs; these included both spat and well grown adults, of which the latter may well have been one year old. Crisp (1960) has found small numbers of young individuals in the Gareloch, but since they only settled in late 1959 they could hardly be the source of the population at Largs. Crisp's (1960) chart of the distribution indicates that in 1959-60 *E. modestus* was absent from the Ayrshire and Renfrewshire coasts; this does not agree with the above observations. In view of the extensive pleasure steamer services in the Clyde, heaviest during the summer months when *E. modestus* is very actively breeding, it would seem that the area will be subject to constant although irregular infection; it is perhaps significant that the piers, where the ships often lie for periods, rather than the shore are first becoming infected.

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