

THE FURTHER SPREAD OF *ELMINIUS* *MODESTUS* IN THE BRITISH ISLES TO 1959

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(Text-fig. 1)

Since the surveys described in our last report (Crisp, 1958) on the distribution in north-west Europe of the immigrant Australasian barnacle, *Elminius modestus* Darwin, the species has become much commoner along the western coasts and has finally spread to Ireland (Beard, 1957). In this report we present the results of surveys made in 1958-9 along the eastern side of the Irish Channel and in the Isle of Man, as well as full records of a survey of the Irish coast in 1958. The methods employed were similar to those described previously (Crisp, 1958; Bishop & Crisp, 1958).

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EASTERN SIDE OF THE IRISH CHANNEL

The changes in distribution of *Elminius* along the west coast of England and Wales have been described up to 1956 (Crisp, 1958). At that time an extension was just beginning around the Lleyn peninsula into the north end of Cardigan Bay. Between 1956 and 1958 the species spread southward over most of the north end of the bay; but, except for the area between Pwlheli and Barmouth, where heavy settlements occurred, it was otherwise confined to harbours and estuarine areas (Fig. 1).

At the south end of Cardigan Bay a relatively local settlement was discovered around the port of Fishguard. This colony, and a smaller one in the harbour at Solva, are believed to have originated from Milford Haven, where *Elminius* has been common for 10 years. The slow spread from this direction, in comparison with the rapid extension from the north, must be due to the lack of suitable habitats for the species along the wave-beaten Pembroke coast and the probable presence of adverse currents inshore. Similar factors may have prevented the spread of the species around the Lizard and Lands End in west Cornwall.

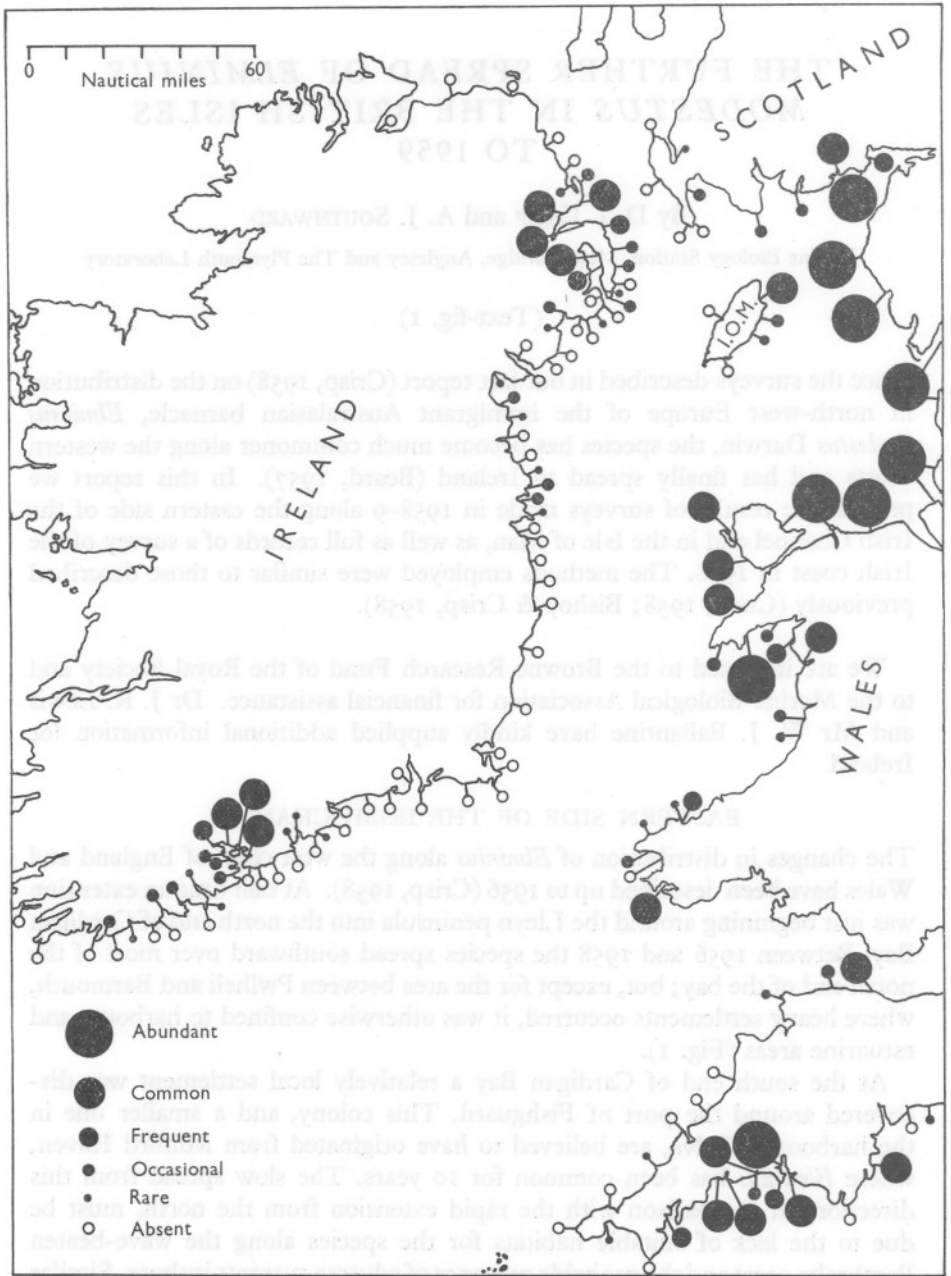


Fig. 1. The distribution of *Elminius modestus* in 1958-9. Stations visited in Ireland in 1958 are shown in full only for the east and south coasts. Isle of Man records made in 1959, those on west coast of Britain in 1958 or 1959. In localities where the species is common or abundant not all stations can be shown. For quantitative meaning of symbols refer to Table 1.

Outside the Bristol Channel, *Elminius* has, so far, failed to establish itself on the exposed coasts of north Devon and Cornwall, or even in Mounts Bay. Along the south Devon and Cornish coasts, from the Exe to the Helford estuaries, *Elminius* is present, and often abundant, in most of the harbours, and since our last report has been slowly increasing on the wave-beaten open coast. West of the Lizard, however, the previously reported settlement at Penzance appears to have failed: only a few old specimens could be found there in 1959, and the filling in of the inner harbour appears to have removed the only suitable habitat for *Elminius* at that end of Mounts Bay. The earlier record (rare) for St Ives in 1955 (Crisp, 1958) has not been confirmed, in spite of extensive searches, and since the specimen was not kept, we cannot now be sure whether this was a true sporadic settlement or a mis-identification of a distorted example of *Balanus balanoides*. Genuine sporadic settlements seem to have occurred in the Newquay area in 1958, when one individual was seen on the open coast, and in 1959, when another was found in the harbour. The species was not seen elsewhere along this coast, and it would be an idle speculation to discuss the probable origin of such few specimens.

Along the northern part of the Irish Channel there has been little further extension of range. *Elminius* is, as in 1956, abundant in the Solway Firth and common in Wigtown Bay. It is now present on wave-beaten promontories such as Burrow Head and Meikle Ross, but is still relatively rare in Luce Bay and has not yet passed the Mull of Galloway. Similarly, there has been little change in the isolated and sparse colony in Lough Ryan at the entrance to the Clyde Sea.

ISLE OF MAN

Except at Ramsey, where the species has become more common, there has been little change in the distribution and abundance of *Elminius* in the Isle of Man (Fig. 1). It is present in small numbers in the harbour at Laxey, south of Ramsey, and one specimen was found at Douglas after more than 1 h searching of suitable habitats, but is absent from the west and south coasts of the Island. The apparent failure of *Elminius* to spread southward from Ramsey must be due to the local hydrography. The residual flow through the Irish Sea is northward, and the set of the tidal currents is such that there is little chance of larvae being carried direct from the north end of the island to the south.

IRELAND

An earlier survey of the entire coast of Ireland was made in 1952, and further observation in 1953 between Lough Foyle and Dublin showed that *Elminius* had not then been able to colonize Ireland (Crisp & Southward, 1953; Southward & Crisp, 1954). Its failure to reach Ireland was attributed to the isolation of the coast from the mainland of Britain by the wide channel of deep water, which prevented normal dissemination of the planktonic larvae

by water-currents. In 1957, however, *Elminius* was reported to be present in small numbers outside Lough Ine, Co. Cork (Beard, 1957), while we were planning another survey. The new survey was made over the whole coast, as well as in the neighbourhood of this record, particular attention being paid to the eastern coast which might be vulnerable to direct infection from the stronger populations now present on the opposite side of the Irish Channel (see p. 429).

Full details of localities where *Elminius* was found in Ireland in 1958 are given in Table 1; the distribution on both sides of the Irish Channel is shown in Fig. 1. The whole of the north and west coast, from Glenarm to Bantry Bay, was apparently free of *Elminius*, even in the vicinity of the ports of Londonderry and Galway. On the south and east coasts there were several distinct regions where *Elminius* was found. The most northerly colonization extended from Larne Harbour to Newcastle, Co. Down; dense populations were found in Belfast Lough and Strangford Lough, and in places reached one individual per cm^2 of surface.

South of this strong entrenchment there were two thinly settled patches, one from Dundalk to Port Oriel, another from Skerries to Howth. These settlements nowhere exceeded 100 per m^2 and the density was often much less. Farther south along the east coast we did not find any more specimens of *Elminius*, not even in the busy harbours at Dun Laoghaire, Wicklow, Arklow and Wexford, nor in the estuary at Waterford.

The remaining area in which *Elminius* was found corresponded to that first reported by Beard (1957). The settlement apparently extended from Ardmore to Lough Ine, but the species was common only in the sheltered bays and channels of Cork harbour. Here, in favourable places such as Rathcoursey, populations up to one individual per cm^2 were sometimes found, with spat settling at the rate of 3 per cm^2 , but over most of this large enclosed area the density did not exceed 0.1 per cm^2 . No specimens were found at any of the wave-beaten open coast stations in this region.

The origin of the Elminius colonization of Ireland

Before discussing the way *Elminius* spread to Ireland it is worth while considering how suitable the Irish coast is for the establishment of the species. By analogy with the known distribution of *Elminius* in other parts of Europe (see Den Hartog, 1953; Crisp, 1958; Bishop & Crisp, 1958), most of the north and west coasts would be expected to be as unfavourable for the species as are the equally wave-beaten coasts of Cornwall and Brittany. The larger estuaries and bays, such as Lough Foyle, the River Shannon and Bantry Bay should eventually support isolated populations similar to those of the drowned valley systems of Cornwall and Brittany. The south-east and east coasts of Ireland, which are sheltered from swell and the prevailing south-westerly winds might be expected to be more favourable to *Elminius*, but these shores

have nowhere the drowned alluvial coast, termed 'côtes à estuaires' by de Martonne (1935), which in south-east England and the Netherlands is so particularly favourable to the species. The stretch of coast from Wicklow to Wexford comes nearest to these conditions, but the sand and gravel shores are subject to severe scouring, the tidal range is small and the shore fauna as

TABLE 1. DISTRIBUTION OF *ELMINIUS MODESTUS* IN IRELAND, 1958

Observations were made between May and September: many negative records are omitted here, as are the whole of the stations on the north and west coasts where the species was not found.

- A Density over 1 per cm², covering 30% or more of available area.
 C Density from 1 to 0.1 per cm², most specimens close enough to breed.
 F Density, from 0.1 to 0.01 per cm², some of them close enough to breed.
 O Density 100 to 1 per m²; often local and needing to be searched for; rarely close enough to breed.
 R Less than 1 per m²; only a few isolated specimens in a 1 h search.
 N None found in 1 h search in suitable place.

Place	Shore*	Abundance	Place	Shore*	Abundance
Larne, coast road	R, B, I	N	Dun Laoghaire	R, P	N
Larne Harbour	P, B, M	R	Dalkey	R, B, G	N
Port Muck	RIE (chalk), B	O	Ardmore	RE, B	R
Whitehead	P, B, G,	C	Ardmore Head	RS	N
Carrickfergus	R, P, B, S, M	C (spat A)	Youghal, bridge	P	R
Bangor Harbour	P, S, M	C	Pilmore, bridge	P	R
Bangor	RI	F	Knockadoon Head	RS	N
Donaghadee, north end	RI, B	F	Ballycotton	RIE, P	N
Donaghadee Harbour	P, S, M	F	Power Head	RS	N
Donaghadee, south	RE, B	N	Inch Strand	R	N
Ballywalter	P, S, M	O-R	Gyleen	RE, B	N
Burr Pt., Ballyhalbert	RE, B, S	O-R	Farsid, nr. Aghada	RI, P, G, S, M	C-F (little spat)
Kearney Pt.	RSIE	N	Cobh	P	F
Ballyquintin Pt.	B	O-R	Rathcoursey	P, B, G, M	C (spat A)
Portaferry	B, S, M	R	Ballynacorra	B, M (fresh water)	N
Kirkubbin	P, B, S, M	F (spat A)	Belvelly	P, B, G, M	C (spat C)
Greyabbey	B, S	C	Cobh Junction	B, M	O-R
Kilclief	R, S	N	Cork	P	F
Ballyhornan	RS, G	N	Passage West	RS, M	O (W.J.B.)
Ardglass Harbour	P, M	R	Monkstown	B, G, M	O (W.J.B.)
St John's Pt.	RSE, B	N	Myrtleville	RSI	O (W.J.B.)
Rossglass	R, B, S	N	Kinsale Harbour	P	R
Dundrum	B, G, S, M	O-R	Oldhead Harbour	P, B, G	R
Newcastle	R, B, S	R	Kinsale		
Annalong	R, P, B	N	Courtmacsherry	B, G, M	O
Clashbridge	RS, B	N	Clonakilty, North	P	O-R
Rostrevor	P, B, M	N	Ring		
Greenore Pt.	P, B, S	N	Inchydoney	P	N
Dundalk Harbour	P, B, S, M	R (1 only)	Dunowen	RIE	N
Annagassan	B, S	O-R	Ballinglanna	RIE, B, G, S	N
Port Oriel	R, P, B	R	Galley Head	RSI	N
Baltray	P, M	N	Glandore Harbour	P, M	O
Balbriggan	R, B, S	N	Toe Head	RSI	N
Skerries	RI, B	R	Toe Head Bay	RIE, B	N
Rush	P, S	O-R	Tragumna	RSI, B	N
Malahide	R, S, M	O-R	Barloge Creek, harbour	P, B, G	O-R
Howth	R, P, G	R	Baltimore	R, P, B, G, M	N
			Berehaven	R, B, G	N

W.J.B.: records by Mr W. J. Ballantine.

* R, rocks (S, steep; I, irregular; E, extensive); B, boulders; G, gravel; S, sand; M, mud; P, artificial substrata.

a whole is impoverished (Southward & Crisp, 1954). Under such conditions it is unlikely that *Elminius* would be common on the open coast, although it would be expected to be present in areas of sheltered water such as at Rosslare and Wexford. Apart from the loughs and estuaries, the region of the east coast around Dundrum and Dundalk bays would appear to be the most favourable in Ireland to *Elminius*. Wave action is less and the extensive bays and areas of shallow water should result in local warming-up during the summer and hence increase breeding and settlement of the species (Southward & Crisp, 1954; Crisp & Davies, 1955; Crisp, 1958).

In addition to suitability of the coast we must consider its accessibility to invasion by the two possible means of dispersal: marginal dispersal by larvae liberated into the sea and carried by currents, and remote dispersal, by adults carried on ships, shellfish and floating objects later liberating larvae when in harbour or washed up on the shore (see Crisp, 1958). The nearest accessible point on the Irish coast is Co. Down, which lies some 40 miles from the populations of *Elminius* in Wigtown Bay and the Isle of Man. The Co. Dublin coast is about 60 miles from the population in Anglesey. These distances exceed, though not greatly, the apparent minimum critical distance for colonization by *Elminius* across a sea barrier in British Waters (Crisp & Southward, 1953). However, the northward flow through the Irish Sea passes to the east of the Isle of Man, and thus close to the dense populations of *Elminius* on that side of the channel, before travelling through the North Channel. Although, in the earlier parts of the year, at least (Williamson, 1956), the northward flow is separated from the Antrim and Down coasts by a tongue of southgoing cold water, the possibility of colonization of this coast by marginal dispersal cannot, therefore, be ruled out.

Remote dispersal by ships carrying the adults depends on the likelihood of the infected ships remaining long enough in port to liberate larvae, and of the port being in an area suitable for the retention of larvae during development and for their later settlement. Belfast, lying at the head of a suitable lough, and frequently visited by ships of all kinds from across the Irish Sea, is a likely port of entry, as to a lesser degree are the ports of Londonderry, Larne, Wexford, Waterford and Cork. The ports of Dublin, Dun Laoghaire, Wicklow and Arklow, though likely to receive infected shipping, are less suitable for the establishment of *Elminius*.

The probable history of the colonization

All stretches of coast where *Elminius* was found in 1958 were situated on the more favourable east and south coasts, and two were clearly centred on the ports of Belfast and Cork. Remote dispersal is therefore indicated.

The population on the north-east coast may in fact be presumed to have been introduced by ships in, or close to, the port of Belfast. Within the lough, the size-groups of adult barnacles indicated an initial settlement prior to 1957.

The other dense population, in this region, in Strangford Lough, may be presumed to have been colonized by marginal dispersal from Belfast, and subsequently increased within the lough. If we assume that the open coast and the other loughs were also settled by marginal dispersal from Belfast Lough, the maximum spread northwards has been little more than 10 miles, whereas to the south it has extended to Newcastle, some 40 miles down the coast. This relative failure of the species to extend northwards may be ascribed to the presence of the south-going current along the Antrim and Down coasts. In addition, the region north of Belfast Lough experiences lower sea temperatures which would discourage an animal such as *Elminius* which depends on high summer temperatures for rapid breeding (Crisp & Davies, 1955). In contrast, conditions south of Strangford Lough would appear much more suitable for *Elminius*, as for the several southern forms that occur there in some abundance (Southward & Crisp, 1954). In general, the whole of the Antrim coast north of Belfast Lough seems unsuitable for barnacles; the native species are often sparse, and may rarely be present at all on the predominantly chalk rocks. It is worth noting that similar factors to these, viz. south-going currents, lower temperatures and less favourable substrata, are believed to have prevented the extension of *Elminius* north of the Humber on the east coast of England since 1950 (Crisp, 1958).

The areas of colonization lying between the Belfast settlement and Dublin Bay are smaller and more thinly populated than the other Irish populations. The main reason for regarding them as distinct from Belfast centre is that no trace of settlement was found in Carlingford Lough. This lough appears to offer as suitable an environment as Belfast Lough or Strangford Lough, and it is difficult to believe that marginal dispersal along the coast could have reached Dundalk without some larvae entering Carlingford Lough and establishing themselves there. Similar, but less cogent, arguments can be applied to the gap separating the two minor settlements, for the mouth of the River Boyne and the port of Balbriggan would seem to be no less suitable than the settled harbours of Port Oriel and Skerries on either side. In both areas of settlement the population density was so low that few, if any, individuals could have been capable of breeding. It is therefore difficult to account for these settlements unless there exists one or more centres of dispersal not discovered during the survey, containing individuals close enough to breed. There is a distinct possibility that these sparse settlements might have been derived from numbers of small craft which had become infected in other ports, and one such vessel, carrying many adult specimens was indeed observed at the quayside in Howth, where *Elminius* was scarce. The difficulty in accepting this possibility of multiple dissemination is that *Elminius* was entirely absent south of Howth. The harbours at Dun Laoghaire, Bray, Wicklow and Arklow would be expected to receive as many infected craft as

the smaller and more exposed harbours of Port Oriel and Skerries. Further investigations after the passage of time may allow the correct interpretation to be chosen from these alternatives.

The most widespread settlement of *Elminius* in Ireland, that in the south-west, shows every sign of having arisen from an initial introduction somewhere in the sheltered channels and inlets of Cork harbour. From this area it has extended over 40 miles to the west but little more than 20 miles eastward: here again we have the possibility of a coastal current, this time from the east, influencing the dispersal of larvae. On account of the exposed nature of the coast, the spread has been confined to enclosed bays and harbours, as on the Cornish coast.

In the case of the Cork settlement, we are fortunate in having two means of estimating, albeit very approximately, the probable date of introduction of *Elminius*. The rate of spread along a coast of similar type, that of south Devon and Cornwall, is of the order of 10–15 miles a year (Crisp, 1958). Measuring from the Lough Ine and Glandore settlements, this would place the original entry some time in 1955. Further evidence was obtained from settlements present on piles which had been removed from the estuary just downstream of Cork, and were lying on the bank. According to local workmen the piles had been removed at various times, some that year, some in 1957, and some as early as 1956, but unfortunately they had not been kept separate. The oldest looking piles had lost all growth, but others had a mixed population of *Balanus improvisus* and *Elminius modestus* still attached, the latter at densities of up to 0.03 per cm². Many of the *Elminius* measured 9–10 mm diameter, and must therefore have settled in 1957, probably quite early in the season, and certainly in considerable numbers. This evidence suggests that the original settlement must have been present as long ago as 1956, and possibly earlier. *Elminius* was absent (or present in numbers too small to be revealed by survey) in 1952 when we inspected several stations in Cork harbour, and in 1953 when Dr J. R. Lewis examined the same area. From the two independent estimates, and the negative records, it seems reasonably probable that *Elminius* was established between 1954 and 1956. This original population must have been introduced by remote dispersal, since Cork harbour is far removed from any other locality where *Elminius* is plentiful.

SUMMARY

Since 1956, *Elminius modestus*, the immigrant Australasian barnacle, has increased its range and abundance along the west coast of Britain. At the same time it has established itself in Ireland, and is now common in two areas, centred on Belfast and Cork, respectively. Both areas have been independently colonized since 1953, the former probably and the latter certainly by remote dispersal on ships. Two further sparse settlements were discovered on

the east coast of Ireland from Dundalk to Howth, but further evidence is needed to determine whether these finds represent a southerly extension of the Belfast population, or independent invasions.

REFERENCES

- BEARD, D. M., 1957. Occurrence of *Elminius modestus* Darwin in Ireland. *Nature, Lond.*, Vol. 180, p. 1145.
- BISHOP, M. W. H. & CRISP, D. J., 1958. The distribution of *Elminius modestus* Darwin in France. *Proc. zool. Soc. Lond.*, Vol. 131, pp. 109-34.
- CRISP, D. J., 1958. The spread of *Elminius modestus* Darwin in north-west Europe. *J. mar. biol. Ass. U.K.*, Vol. 37, pp. 483-520.
- CRISP, D. J. & DAVIES, P. A., 1955. Observations *in vivo* on the breeding of *Elminius modestus* grown on glass slides. *J. mar. biol. Ass. U.K.*, Vol. 34, pp. 357-80.
- CRISP, D. J. & SOUTHWARD, A. J., 1953. Isolation of intertidal animals by sea barriers. *Nature, Lond.*, Vol. 172, p. 208.
- DEN HARTOG, C., 1953. Immigration, dissemination, and ecology of *Elminius modestus* Darwin in the North Sea, especially along the Dutch coast. *Beaufortia*, Vol. 4, pp. 9-20.
- MARTONNE, E. DE, 1935. *Traité de Géographie Physique*. Paris.
- SOUTHWARD, A. J. & CRISP, D. J., 1954. The distribution of certain intertidal animals around the Irish Coast. *Proc. R. Irish Acad.*, Vol. 57, Sect. B, No. 1, 29 pp.

Note added in proof

One of us (D.J.C.) was able to re-examine part of the north and east coasts of Ireland during a brief visit in July 1959, and *Elminius* was found at the following stations (to be added to Table 1):

Londonderry, main channel in L. Foyle	R, P, M	R
Dublin, North Wall	P, M	O-F

The species seemed well-established at Dublin, with a fresh spatfall of 2-3 per cm²; this confirms the existence of a separate invasion of the Co. Dublin area. The record for L. Foyle cannot be regarded as establishing the species in that area. Only three old specimens of *Elminius* were found, all on piles marking the channel, while none were present on the rocks along the shore. This clearly represents a sporadic settlement, probably derived from infected ships.