Chapter 12: Clyde Sea (MNCR Sector 12)*

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Synopsis

The Clyde Sea is mostly enclosed and leads inland to several sea lochs. It receives water from a major estuary, the Clyde estuary. A wide range of studies which describe benthic species and communities in the Clyde Sea have been undertaken, mainly from the marine biological station at Millport on Great Cumbrae, by the Clyde River Purification Board (now part of the Scottish Environment Protection Agency), and as MNCR surveys. The area, in contrast to the west coast of Scotland, supports significant populations of cold-water species such as the crab *Lithodes maia* and the anemone *Bolocera tuediae*. There are typical sea loch communities present, although the lochs near the Clyde estuary are species-poor. Loch Fyne is particularly notable and includes dense beds of the fireworks anemone *Pachycerianthus multiplicatus*, extensive examples of the sealoch biotope characterised by the anemone *Protanthea simplex* and the brachiopod *Neocrania anomala*, and in deep water, dense burrowing communities and populations of the echiuran *Amalosoma eddystonense*. Extensive maerl beds occur in the Clyde. The lagoons at Ballantrae are brackish habitats and are poor in species.

12.1 Introduction

The Clyde Sea area (Figures 12.1 and 12.5) comprises the Firth and estuary of the Clyde, including the sealochs to the north and Loch Ryan in the extreme south of the area. The islands of Bute, Arran and the Cumbraes lie within the main body of the Firth. The Clyde encompasses a wide variety of habitats, ranging from the estuarine mudflats of the Clyde estuary to the deep fjordic sealochs, such as Loch Fyne, and the open coast habitats of the Mull of Galloway. Nowhere is very exposed to wave action, excepting the Mull of Kintyre and much of the Clyde can be considered to be sheltered or very sheltered from such water movement. Tidal streams throughout the area are generally weak, but reach 4 to 5 knots (2 to 2.5 m s^{-1}) in parts of the North Channel of the Irish Sea and the Kyles of Bute. The area lacks the very strong currents present on both the open coast and in the rapids or narrows systems which are common on Scotland's west coast.

Mean surface temperatures in the area range from about 7 °C in the winter to 13.5 °C in the summer (Lee & Ramster 1981), although the shallow waters of the lochs and estuaries experience much greater temperature fluctuations. Surface ice forms at the heads of some lochs in winter, and a thermocline is established during the summer. Edwards *et al*. (1986) considered the area of the Clyde to be a vast fjord with a broad sill, the Great Plateau, separating the area from the North Channel of the Irish Sea whilst a front on the Great Plateau separates tidally mixed waters in the North Channel from less saline waters in the Clyde itself.

Throughout the Clyde, the surface salinity is reduced to less than 33‰ (Edwards *et al*. 1986). The salinity barrier this creates with the open sea may be paralleled in a biogeographic separation of the Clyde from both the Irish Sea and the west coast of Scotland. Amongst the fauna of the Clyde are the spiny spider crab *Lithodes maia* and the large anemone *Bolocera tuediae* (Davies 1989): both are cold-water species which are more commonly recorded in the North Sea, but which are quite rare on Scotland's west coast. The Clyde algal flora also shows anomalies compared with that of the rest of the west coast of Scotland. There are fewer red algae but

* This review was completed from published and, where available, unpublished sources of information on benthic habitats and communities as well as interviews with relevant workers undertaken up to 1991. That work was published in Connor (1991). The review has been revised to take account of major additional studies up to the end of 1994 by the second author and up to the end of 1996 by the series editor. It does not include benthic survey information summarised for or published in the MNCR *Regional Reports* series or work now being undertaken to describe and map biotopes in candidate Special Areas of Conservation. For information on conservation status and an analysis of rare and scarce seabed species, the reader is referred to the *Coastal Directories* series.

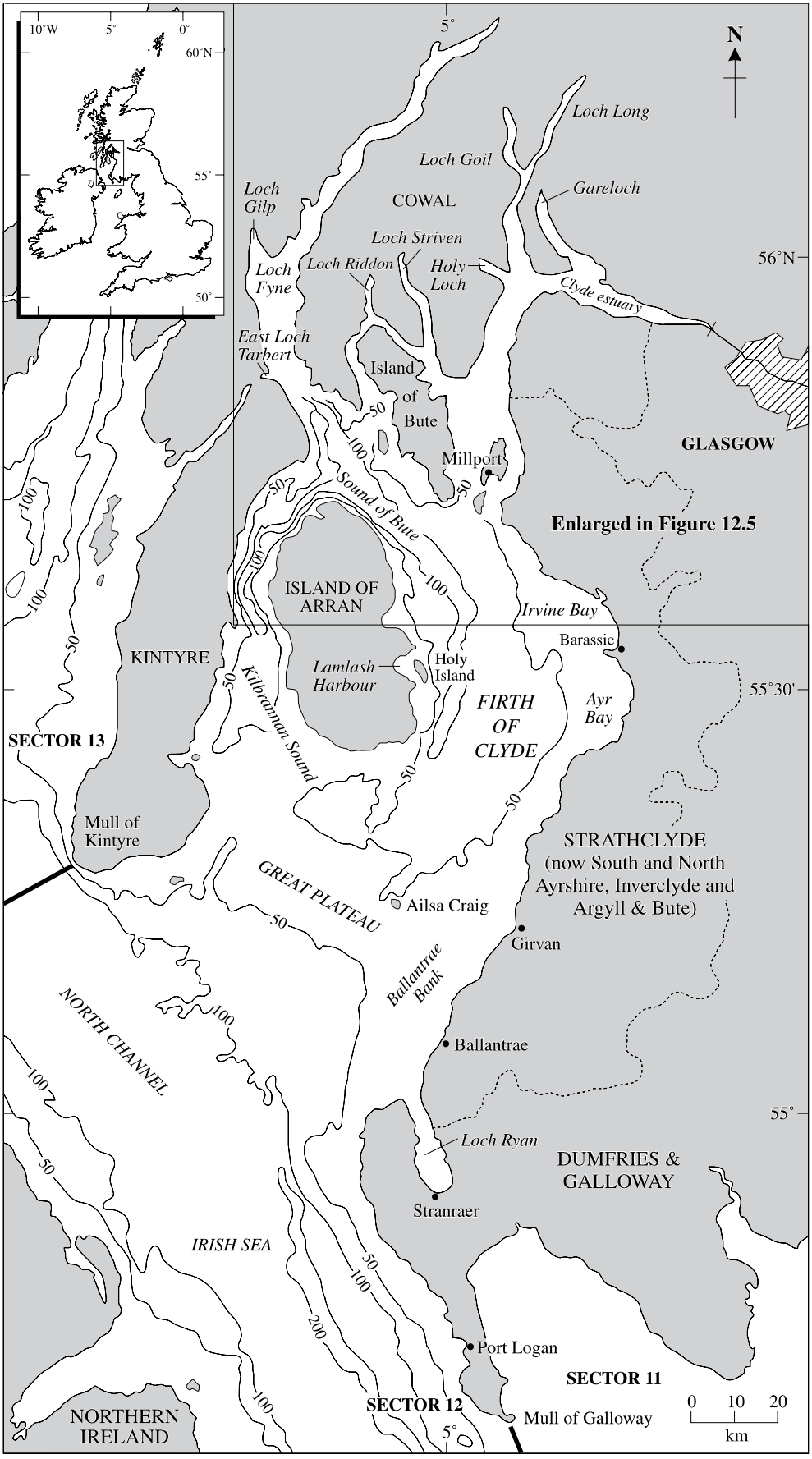

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Figure 12.1. The Clyde Sea (MNCR sector 12) showing places mentioned in the text.

more brown algae than would be expected for this part of the British Isles, with a number of conspicuous and generally widespread red algae apparently absent from the Clyde (Maggs 1986). The physical characteristics of the Clyde have not been static and long-term changes in temperature were described by Barnett & Watson (1986) who noted the virtual disappearance of the bivalve *Spisula subtruncata* from the area since the 19th century, possibly as a result of temperature changes.

The area has received a much greater research effort than the rest of Scotland's west coast, due primarily to the presence for over a hundred years of a marine research laboratory at Millport on Great Cumbrae and the close proximity of the Universities of Glasgow, Strathclyde and Paisley, and other institutes. Much of the Clyde River Purification Board's (CRPB) (now part of the Scottish Environment Protection Agency – SEPA) work on hydrography, pollution and the benthos has been within the Firth of Clyde. Pollution studies in the Clyde Sea Area were reviewed by Steel, McIntyre & Johnston (1973) and were also discussed within the Clyde Study Group's assessment (Natural Environment Research Council 1974). A broad outline of pollution inputs to the marine environment of much of the western Scottish area including the Clyde was provided by the CRPB (1985, 1986).

Marine research at Millport began in 1885 when Dr John Murray brought the *Medusa* and the *Ark*, vessels converted for marine research, to Great Cumbrae to continue studies initiated earlier at the Scottish Marine Station at Granton on the Firth of Forth (Marshall 1987). The Marine Biological Association of the West of Scotland was founded at Millport in 1901, changing its name to the Scottish Marine Biological Association (SMBA) in 1911 and more recently (1992) to the Scottish Association for Marine Science (SAMS). In 1970 the SMBA transferred to Oban, at which time the Universities of London and Glasgow jointly funded the laboratories as the University Marine Biological Station, Millport (UMBSM). There was also a marine station on the Island of Bute for a brief period in the early part of the twentieth century. The station's curator was L.P. Renouf, who later moved to University College, Cork and started studies at Loch Hyne. The University of Strathclyde has laboratory facilities at Porthkil.

Much of the available information on the Clyde Sea was drawn together in a symposium volume by Allen *et al*. (1986) which described the physical, chemical and biological nature of the region and discussed resources, uses and conservation strategies. This review followed a similar assessment by the Clyde Study Group (Natural Environment Research Council 1974).

Marine faunal and floral lists for the Clyde Sea have been published over the past 80 years, starting with general accounts by King (1911) and Chumley (1918) and continuing with lists for specific groups:

The Clyde, being within easy reach of Glasgow, is a popular area for sports diving, for which Ridley (1984) gives information on dive sites and Agnew *et al*. (1986) provided guides to the more common invertebrates present in the area.

Taxonomic group(s)	**Reference(s)**
Algae	Clokie & Boney 1979
Hydromedusae	Vannucci 1956
Polychaeta	Clark 1960
Tardigrada	Morgan & Lampard 1986
Mysidacea	Mauchline 1971
Amphipoda	Moore 1984
Arthropoda: Crustacea; Euphausiacea & Decapoda	Allen 1967
Mollusca	Allen 1962
Echinodermata	Wilkie 1989
Ascidiacea	Millar 1960
Fishes	Bagenal 1965; Gibson 1980
Mammals	Gibson 1976

12.2 Firth of Clyde

12.2.1 General and autecological studies

Studies of algae within the Clyde date back to the 1890s when Batters (1891) first collated algal records for the area. Gibb's (1939) study, both on the shores and in the sublittoral around Cumbrae, added considerably to these earlier records. More recent algal studies were reviewed by Norton (1986) who discussed a possible reduction in the Clyde flora resulting from industrial pollution.

As with algal studies, faunistic work and autecological studies in the Clyde are numerous and date back to the early naturalists' collections of the nineteenth century. The following gives an indication of the range and subject of species and groups studied: speciation in polychaetes (Clark 1952); spread of the non-native barnacle *Elminius modestus* (Barnes & Barnes 1960); euphausiid and mysid biology (Mauchline 1958, 1967); distribution of amphipods *Gammarus* species (Elmhirst 1935); amphipod biology (Shillaker 1977); cumacean biology (Corey 1966); grazing by the chiton *Lepidopleurus* (now *Leptochiton*) *asellus* and the limpet *Acmaea* (now *Tectura*) *virginea* (Farrow & Clokie 1979); feeding of ascidians (Robbins 1981); and the fauna associated with algae (Moore 1986). Amongst the many postgraduate studies undertaken at Millport have been those relating to the ecology of species common to the area, for example barnacles (Connel 1956), amphipods (Powell 1990), hermit crabs *Pagurus* spp. (Mitchell 1975), the crab *Ebalia tuberosa* (Schembri 1980), the swimming crab *Liocarcinus puber* (Kershaw 1986), limpets (Spencer Davies 1963), tellins (Wilson 1976a), the bivalve *Venerupis pullastra* (now *Venerupis senegalensis*) (Quayle 1948), the sea urchin *Echinus esculentus* (Bishop 1985), epibenthic scavengers (Nickell 1989) and flatfish (Downie 1990).

The Clyde Sea has a productive fishery for demersal and pelagic fish and for shellfish. Bailey, Morrison & Saville (1982) discussed the stocks of herring *Clupea harengus*, the Clyde's most important pelagic fishery, and the less important mackerel *Scomber scombrus* and sprat *Sprattus sprattus* fisheries. Cod *Gadus morhua*, whiting *Merlangius merlangus*, saithe *Pollachius virens*, hake *Merluccius merluccius* and haddock *Melanogrammus aeglefinus* account for over 80% of demersal fish landings in the Clyde (Hislop 1986). The Clyde's main spawning ground for herring on the Ballantrae Bank was investigated by Napier (1993a; 1993b). He found evidence that herring were selecting well sorted gravel as spawning grounds and that the herring spawn did not increase the organic carbon content of the gravel on a long-term basis. The biology and ecology of other fish in the area, particularly flatfish, has also been studied (e.g. Bagenall 1961; Poxton 1976; Poxton, Eleftheriou & McIntyre 1983). Populations of the mud-dwelling red band fish *Cepola rubescens* and Fries' goby *Lesueurigobius friesii* are known to be present in the area (Howard 1982; Nash 1980, 1982), the former now considered as well established within the Clyde and taken frequently by scampi (*Nephrops*) trawlers. The fishery for scampi *Nephrops norvegicus* is the largest of the shellfish catches in the Clyde, with less valuable fisheries for scallops *Pecten maximus* and queen scallops *Aequipecten opercularis*. The *Nephrops* fishery was discussed by Bailey, Howard & Chapman (1986) whilst Smith (1987) reported on the biology of larval and juvenile *Nephrops norvegicus* within the area. Creel fishing for lobsters and crabs is not as common as elsewhere on the west coast of Scotland (Mason & Fraser 1986).

12.2.2 Littoral

One of the earliest quantitative studies of sediment shore communities was undertaken in Kames Bay and at five other locations in the Firth of Clyde by Stephenson (1929). *Tellina* (now *Angulus*) *tenuis* was the most consistently present species and had the highest numerical abundance. The most widespread littoral survey was undertaken by Paisley College of Technology (1979) who examined 90 rock and sediment shores both within the sealochs and on the open coasts of the Firth. Four main rocky shore types were identified:

- Sealoch boulder shores, common throughout the lochs and dominated by a dense band of the knotted wrack *Ascophyllum nodosum*;
- Sealoch rocky shores, with a distinct zonation pattern;
- Open coast flat boulder and broken bedrock shores, with a dense kelp *Laminaria* zone and often the greatest variety of habitat types;
- Open coast steep or smooth rocky shores, with a less diverse biota than the more broken rocky shores.

The rocky shores of Lochs Riddon and Striven, the Kyles of Bute and the southern coast of Arran were considered to be the richest in the area with high habitat diversity.

In contrast, the Paisley College (1979) survey suggested that the richest sediment shores were concentrated towards the more sheltered parts of the Clyde, in Lochs Fyne, Riddon, Striven and Gareloch. Sediment shores on the more exposed coasts of Ayrshire, the Kintyre peninsula and the south-west coast of Arran tended to have both fewer individuals and a lower species-richness. The infauna of the majority of sites was dominated by bivalves (*Angulus tenuis*, *Cerastoderma edule*), amphipods (*Bathyporeia* spp.) and polychaetes (*Scoloplos armiger*, *Pygospio elegans*, *Arenicola marina*, *Phyllodoce maculata*, *Spio filicornis*, *Eteone flava*, *Nephtys hombergii*, *Nephtys cirrosa*).

The intertidal fauna of sandy beaches in the Clyde, together with shores elsewhere in Scotland, was also studied by Eleftheriou & McIntyre (1976). They examined shores between Barassie (near Ayr) and Port Logan on the Galloway peninsula, these falling into their 'moderately exposed' and 'sheltered' beach categories. The former were numerically dominated by crustaceans and polychaetes, with the bivalve *Angulus tenuis* present in significant numbers on the lower shore. On the sheltered beaches crustaceans were generally less common, and although polychaetes remained numerically abundant, bivalves often represented the greatest biomass on the shore.

More localised studies within the Firth have concentrated on shores with easy access from research establishments, notably around Cumbrae, Portencross, Hunterston and the Garnock estuary. The mainland shores have been extensively used, mainly for student projects, by the University of Glasgow, Heriot-Watt University and Paisley College of Technology (now Paisley University).

Moore (1988) reported on the lagoons at Ballantrae as part of the Nature Conservancy Council's (NCC) national survey of lagoons. The Ballantrae lagoons were found to have a rather impoverished fauna and flora, and were most interesting because of their considerable change in structure over the past century. The shingle beach at Ballantrae is a nature reserve and SSSI for its botanical and ornithological interest.

The shores around Great Cumbrae have long provided the subject matter for studies in population biology and behaviour of a range of species. Amongst early studies in Kames Bay were Watkin's (1941, 1942) observations on the night tidal migration of crustaceans, particularly *Bathyporeia* spp., and Smith's (1955) correlation of the distribution of the polychaete *Nereis* (now *Hediste*) *diversicolor* with lowered salinity in interstitial sands. Elmhirst (1931) described a diverse crustacean fauna, mainly composed of amphipods, from this sandy bay, while Stephen (1930a) and Wilson (1976a; 1976b) concentrated their attentions on populations of *Tellina* (now *Angulus*) *tenuis*, representing a long series of studies on this bivalve. The shores at Ballochmartin Bay are a classic study area originally described by Flatterly & Walton (1922). The Bay is particularly interesting for its populations of the phoronid *Phoronis muelleri* and the anemone *Cerianthus lloydii*, the latter a sublittoral species unusually occurring on the shore here. Aronson (1989) investigated the abundance of brittlestars and noted

beds of *Ophiothrix fragilis* and *Ophiocomina nigra* in this part of Scotland and elsewhere in the British Isles. Aronson (1989) viewed these aggregations in relation to predator pressure from fish, starfish and crabs, which is relatively low, and concluded that such aggregations survived where fish and crab populations were low. Evans *et al*. (1994) investigated dogwhelk *Nucella lapillus* populations at seven sites around Great Cumbrae, and found evidence of recovery between 1988 and 1993, following legislation to limit the use of tributyltin antifoulants.

The slightly more remote shores of Arran were surveyed by Smith (1984) who considered the molluscan fauna to be limited due to a lack of habitat diversity around the island. She pointed to Lochranza, the southern end of Arran and the Lamlash – Holy Island areas as the richest surveyed. Of about 300 species of mollusc recently recorded in the Clyde, Smith (1984) found only 170 around Arran. Lambshead (1986) used the relatively unpolluted shores of Bute for comparison with those in the more polluted Irvine and Ayr Bays to assess the use of nematodes in "biomonitoring for sub-catastrophic sewage and industrial waste contamination". Certain statistical models, and the use of abundance data and analysis of feeding types, were found to be effective in indicating sediment contamination on the Ayrshire coast. Other Clyde meiofaunal studies have been undertaken by McIntyre & Murison (1972, 1973), Hummon (1976), Jayasree (1976), Hummon & Hummon (1977) and Hardy & Barnett (1986).

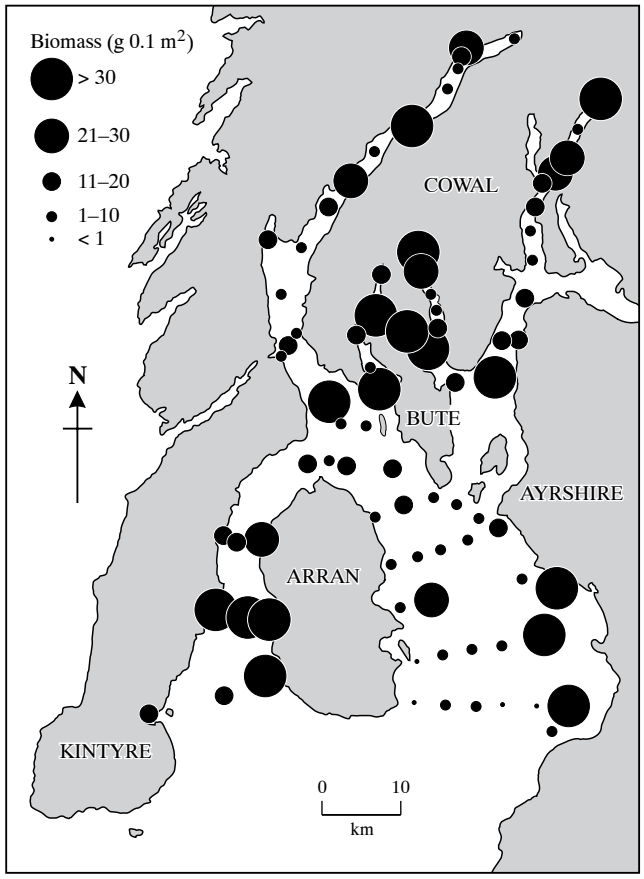

Figure 12.2. Variation in total biomass (g wet weight/m^2) of benthic infauna in the Firth of Clyde (from Pearson, Ansell & Robb 1986).

12.2.2 Sublittoral

In the sublittoral zone Kain (1962) used sites around Cumbrae for some of her extensive studies on the biology of the kelp *Laminaria hyperborea*. More recently Gordon (1983) studied populations of small fish in the bulbs of the kelp *Saccorhiza polyschides*. The sublittoral fauna of Kames Bay and White Bay were compared by Clarke & Milne (1955) who found broadly similar communities in each bay, with the exception that the niche of the opisthobranch mollusc *Philine aperta* in Kames Bay was largely taken up by the prosobranch mollusc *Natica alderi* (now *Lunatia poliana*) in White Bay. Further offshore around the Cumbraes there are large populations of brittlestars, the most widely distributed of which is *Ophiocomina nigra*. Gorzula (1976) related their distribution to substrata and discussed their abundance and habitat preferences. Nickell & Moore (1991) used baited creels to compare epibenthic scavenging invertebrates at 13 m and 113 m depth off Great Cumbrae. They found consistently higher species diversity at the deeper station.

Work on the sublittoral biology of the Firth has centred particularly on the influence of sewage disposal in the region of the Garroch Head sludge dumping-ground off the southern tip of Bute. A number of workers have examined the impact of the waste disposal on the benthic communities. Bett (1991) found a strong gradient of organic enrichment and reduced diversity in the meiofaunal and nematode population at the dump site. Bett & Moore (1992) discussed possible strategies for biological monitoring

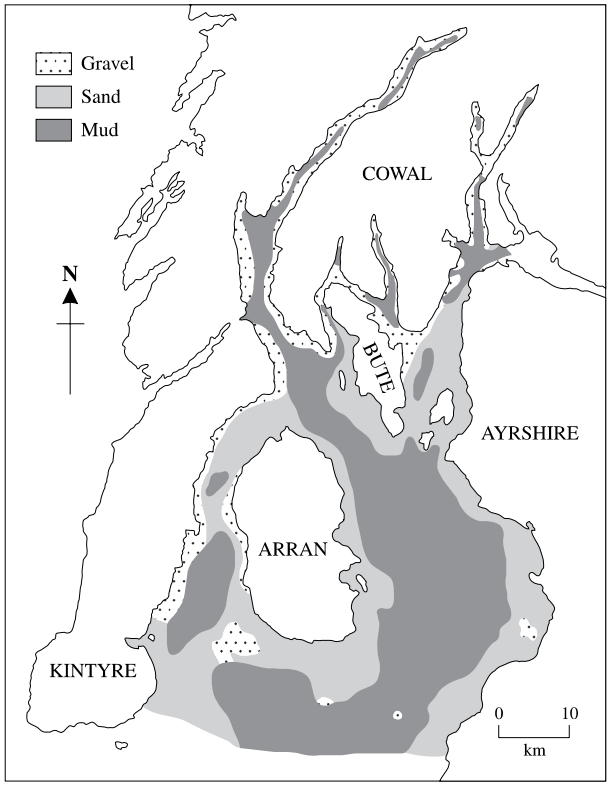

Figure 12.3. Distribution of sediment types in the Firth of Clyde (from Pearson, Ansell & Robb 1986, based on Deegan *et al*. 1973).

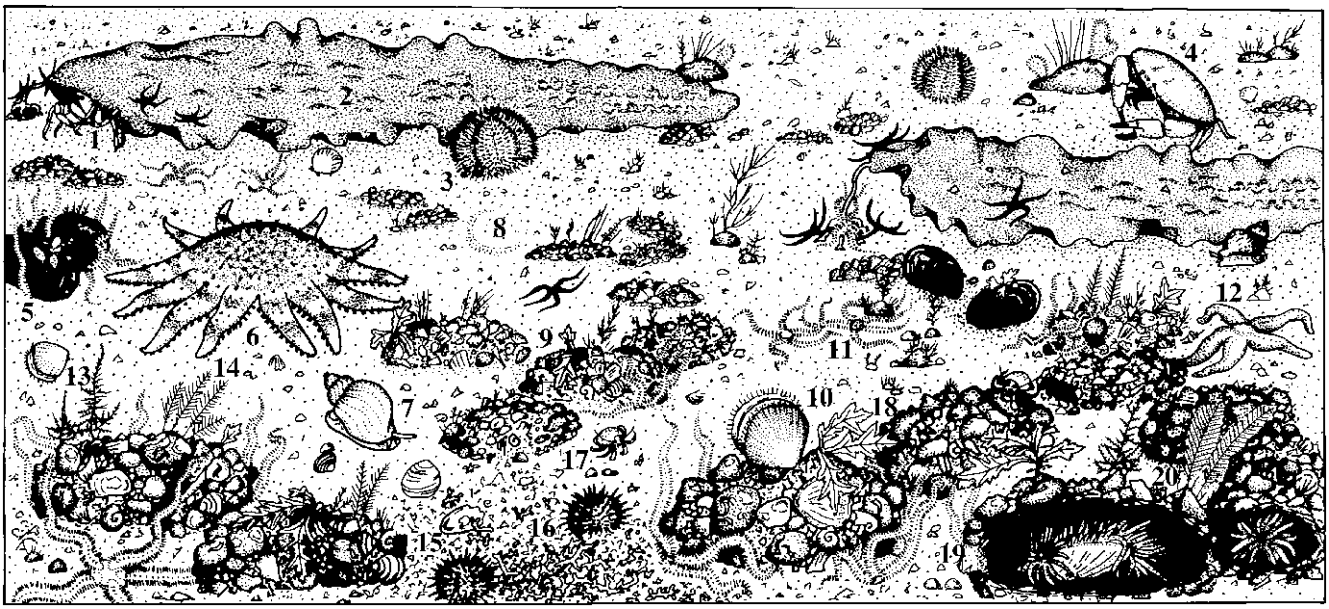

Figure 12.4. Nests of the file shell *Limaria hians* (shown in section bottom right) and associated biota. (From Howson, Connor & Holt 1994. Drawing by Sue Scott.) Major species shown are: 1. *Hyas araneus*; 2. *Laminaria saccharina*; 3. *Echinus esculentus*; 4. *Cancer pagurus*; 5. *Modiolus modiolus*; 6. *Crossaster papposus*; 7. *Buccinum undatum*; 8. *Pecten maximus*; 9. 'nests' of *Limaria hians*; 10. *Chlamys opercularis*; 11. *Ophiothrix fragilis*; 12. *Asterias rubens*; 13. *Brongniartella byssoides*; 14. *Abietinaria abietina*; 15. *Psammechinus miliaris*; 16. *Phymatolithon calcareum*; 17. *Pagurus bernhardus*; 18. *Phycodrys rubens*; 19. *Limaria hians*, and 20. *Delesseria sanguinea*.

of the effects of waste disposal and use the Garroch Head benthic communities as an example. Halcrow, Mackay & Thornton (1973) found the area affected by sludge dumping to be limited, with an enriched fauna including the polychaete *Capitella capitata* and cirratulid worms at the centre of the dumping-ground. Pearson, Ansell & Robb (1986) (Figure 12.2) related the fauna of the dumping grounds to that in the rest of the Clyde Sea area and concluded that the benthic populations in the inner sealochs, in Kilbrannan Sound and along the Ayrshire coast were also somewhat enriched. They found that most of the deep-water communities complied with the '*Amphiura*', '*Abra*' or 'boreal offshore' communities of Thorson (1957) and Jones (1950), whilst the shallower coarser sediments were similar to the '*Venus/Modiolus*' or 'sand/gravel' communities of Thorson (1957) and Jones (1950) respectively. The organic enrichment of sediments at Garroch Head, and also in Loch Eil near Fort William (MNCR Sector 13), was further examined by Pye (1980), who related megafaunal burrow type to the level of enrichment and to sediment types. Shallow sealoch sediments were characterised by the deep U-shaped burrows of the bivalve *Thracia*, whilst deeper sediments had a paucity of burrows due to lowered oxygen levels. Atkinson's (1986) study on mud-burrowing megafauna in the Clyde Sea revealed extensive bioturbation of sublittoral muds by decapod crustaceans and fish. Warwick (1988), using data from Garroch Head and Loch Eil, provided a basis for determining levels of pollution in the benthos and used the Garroch Head dataset to evaluate techniques for detecting pollution effects on benthic communities (Warwick 1987). The benthic fauna of Irvine Bay, an area receiving both industrial and urban effluents, was the subject of a study by the Department of Agriculture and Fisheries for Scotland (DAFS) carried out in 1972/73 (Eleftheriou, Robertson & Murison 1986) and from 1973 has been repeatedly surveyed by CRPB and others to monitor long-term pollution effects on the benthic communities – for example CRPB (1976a) and Lockhart (1987).

Amongst other studies of the seabed in the Clyde Sea have been those of the Institute of Geological Sciences (Deegan *et al*. 1973; Eden *et al*. 1971) (Figure 12.3). Although these were primarily aimed at investigating the geology of the area, the use of submersibles and sampling gear usefully also revealed some biological features. Amongst these are descriptions from the deepest parts of Loch Fyne with reports of bedrock cliffs to 150 m, and notes on a large bed of the file shell *Lima* (now *Limaria*) *hians* off the south-east Kintyre coast (Deegan *et al*. 1973).

12.3 Clyde estuary

The Clyde estuary was defined by Smyth & Curtis (1974) as extending seawards to a line from Gourock to Kilcreggan, excluding Gareloch north of Rhu and Rosneath (Figure 12.5). The estuary is subject to the pollution pressures from both industry and the sewage effluent from the dense population which surrounds its shores. It was considered to be highly polluted in parts (CRPB 1968) and much of the biological study undertaken has been concerned with or takes account of such environmental pressures. Long-term monitoring undertaken by CRPB suggested an improvement in water quality as indicated by its status according to the

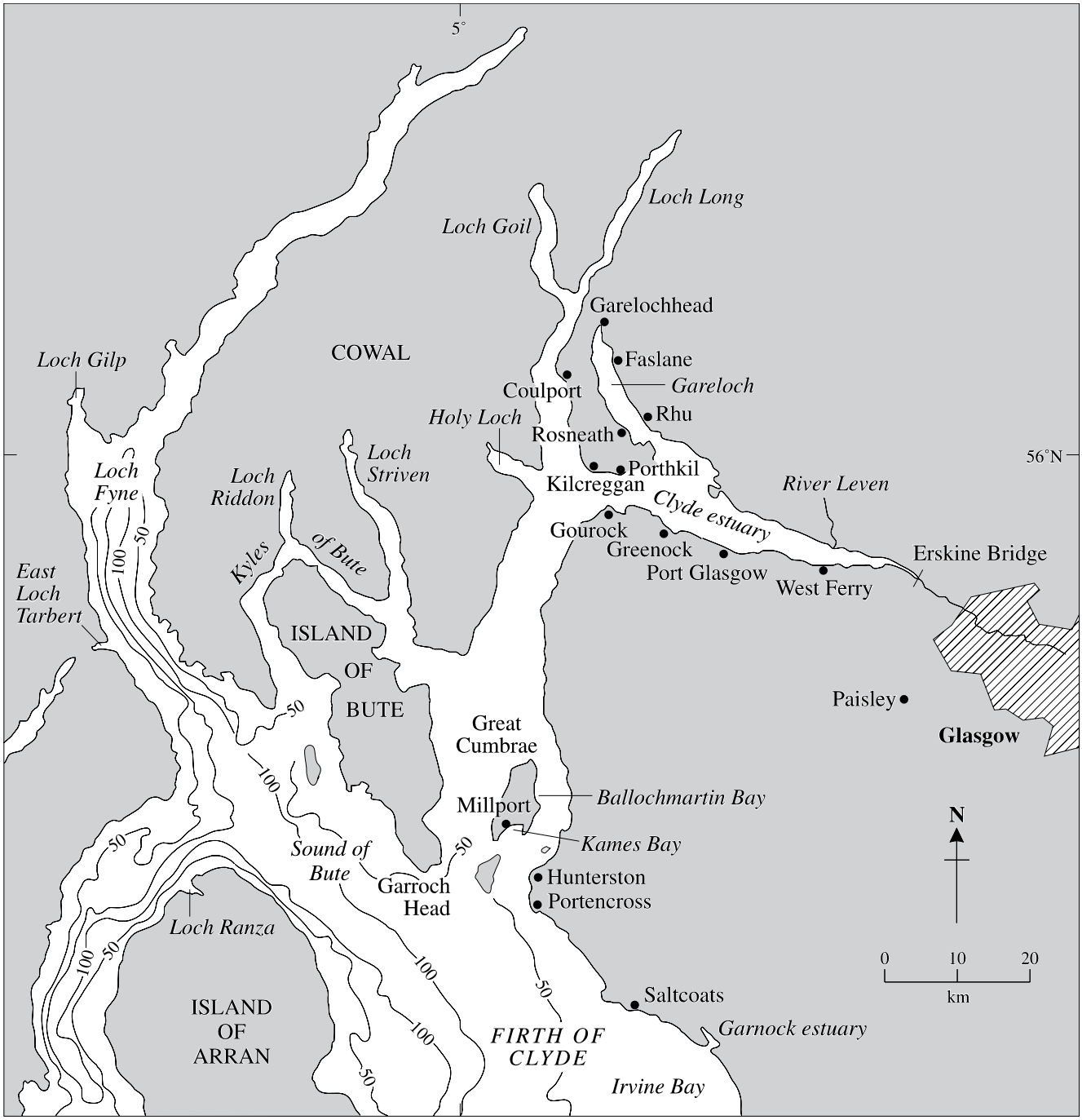

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Figure 12.5. The inner Firth of Clyde, Clyde estuary and northern Clyde sealochs, showing locations mentioned in the text.

Estuary Classification System (Scottish Development Department 1987) in 1989–90. This has been illustrated by improvements in the invertebrate populations (Mackay, Taylor & Henderson 1978; Henderson 1980); the recovery of estuarine fish communities (Henderson & Hamilton 1986) and the return of migratory salmonids (Mackay & Doughty 1986; Mackay 1990). The Natural Environment Research Council (1974) and Allen *et al.* (1986) reviewed environmental aspects of the estuary. The water quality, habitats and the conservation status of the Clyde estuary were summarised by Buck (1993).

Wilkinson (1973) recognised two main zones of algae within the Clyde estuary. In the upper estuary, shores lacked red algae and were characterised by blue-green algae and *Melosira nummuloides*, a diatom present in much greater densities than in most other estuaries (Wilkinson, Fuller & Rendall 1986). The shores downstream of West Ferry supported fucoids and

associated red algae. High levels of pollution around Port Glasgow and Greenock were indicated by the dominance of the mat-forming polychaete *Fabricia sabella* (Smyth 1973), whilst the large mud- and sandflats of the lower estuary were dominated by the amphipod *Corophium volutator*, mud snails *Hydrobia ulvae*, mussels *Mytilus edulis* and the polychaete *Nereis* (now *Hediste*) *diversicolor*, with other worms characteristic of polluted sediments also thriving (Smyth & Curtis 1974; Curtis 1978). The effect of pollution on the distribution of rocky shore species was described by Smyth (1973). There have been a large number of projects from the University of Glasgow and Paisley College of Technology (now University) covering various biological aspects of these sediment flats (e.g. Girling 1984; Abdula 1985). Thompson, Curtis & Smyth (1986) and others discussed the importance of these areas for bird feeding. Many of the mudflats are notified SSSIs, and both the Royal Society for the Protection of Birds and Scottish Wildlife Trust have nature reserves in the outer part of the estuary.

Microscopic algae of the Clyde estuary received attention from Rendall & Wilkinson (1983) (*Melosira* spp.), and McLean *et al*. (1986) (diatoms). Sublittoral investigations in the estuary are very limited, although fish populations have been examined (Henderson & Hamilton 1986).

12.4 Clyde sealochs

12.4.1 Introduction

Much of the recent information for sealochs in Sector 12 is based on surveys undertaken for the MNCR by the University Marine Biological Station, Millport, the results of which were described in Howson, Connor & Holt (1994) and in a series of separate survey reports cited below.

12.4.2 Loch Ryan

Loch Ryan lies to the extreme south of the Clyde Sea area (Figure 12.1), and is geographically separated from the other Clyde and west coast sealochs. This relative isolation is reflected in the communities present which show a closer affinity to warmer inlets in southern Britain than to other Scottish sealochs (Howson 1989). This large shallow sealoch is notable for its seagrass *Zostera* beds, the rare red alga *Spyridia filamentosa*, and the largest natural oyster *Ostrea edulis* beds in Scotland, features which provide the basis for the loch's Marine Consultation Area status (Nature Conservancy Council 1990) (Figure 12.6). The oyster beds were commercially fished until 1954, but subsequent overfishing and poor spatfall allowed only an intermittent fishery to survive. Millar (1968) and Mason & Key (1977) reported on various aspects of the fishery which is presently undergoing some improvement, and which continues to support Scotland's only remaining regularly exploited commercial oyster fishery (D. Donnan pers. comm.). The mollusc *Calyptraea chinensis*, a southern species, was probably introduced into Loch Ryan along with oysters before 1944, and a population continues to thrive in the loch (Smith 1991). Prior to the MNCR survey of the loch (Howson 1989), Wilkinson (1980) reported on the rarer algae of the area, and the sediment fauna was examined in connection with effluent discharge from a creamery at Stranraer (Craig, Lewis & Tapp 1980; CRPB 1982, 1984; Rendall 1990; Rendall & Bell 1992).

12.4.3 Gareloch, Loch Long, Loch Goil and Holy Loch

These innermost lochs of the Clyde, situated in close proximity to the Clyde estuary (Figure 12.5), with its industrial base and dense population, are probably subject to the greatest environmental pressure of any sealochs in Scotland. The lochs receive pollutants from the Clyde estuary, support moorings for considerable numbers of pleasure craft, and are the home of a number of naval installations. Much of Gareloch and the heads of Loch Goil and Holy Loch are given over to

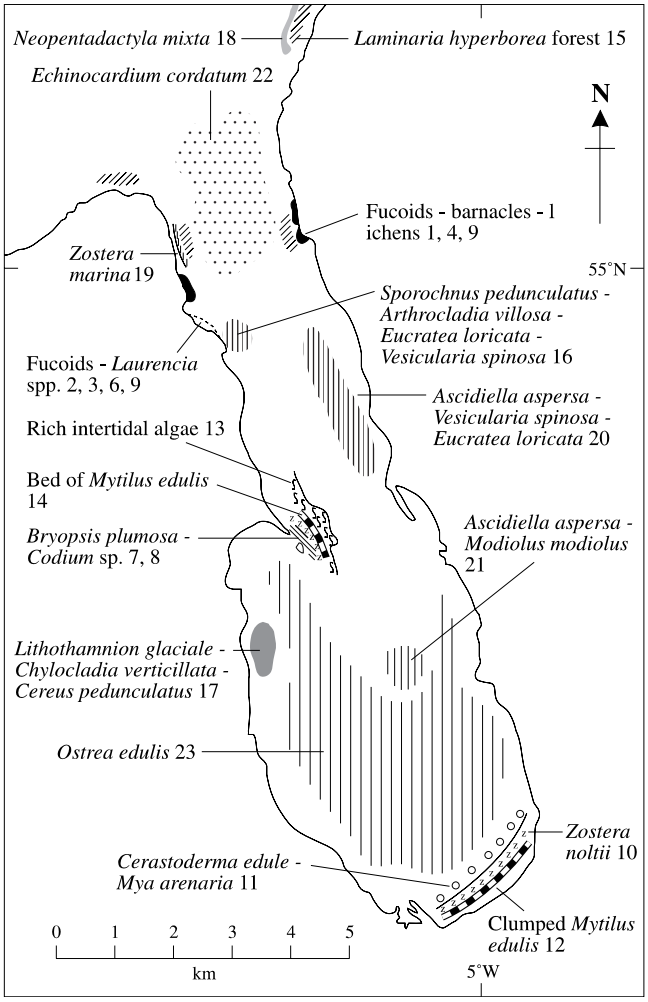

Figure 12.6. Distribution of the main communities in Loch Ryan. (Figures refer to community descriptions in Howson 1989.)

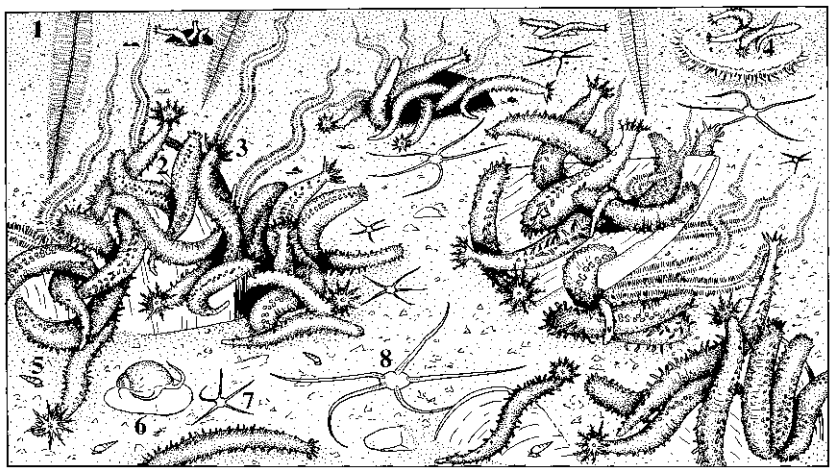

Figure 12.7. Aggregation of the holothurian *Ocnus planci*. (From: Howson, Connor & Holt 1994. Drawing by Sue Scott). Main species shown are: 1. *Virgularia mirabilis*; 2. *Ocnus planci*; 3. *Ophiopholis aculeata*; 4. *Pecten maximus*; 5. *Turritella communis*; 6. *Polinices catena*; 7. *Ophiura albida*, and 8. *Ophiura ophiura*.

moorings. Naval bases are situated at Faslane in Gareloch, and at Coulport in Loch Long, with additional naval facilities in Loch Goil. The submarine facility in Holy Loch closed down in 1992.

A survey for the MNCR in 1989 (Holt & Davies 1991) found the littoral and sublittoral communities in the turbid waters of these four sealochs, particularly in Holy Loch and the Gareloch, to be impoverished. Beds of the horse mussel *Modiolus modiolus* were widespread and extended into depths as shallow as 2 m below chart datum. Algal communities were extremely impoverished and many sublittoral areas were covered by a barren gravel scree. A dense aggregation of the rare sea cucumber *Ocnus planci* in Loch Goil (Figure 12.7), and a rich ascidian fauna in a deep sedimentary basin of Loch Goil were, however, of particular interest.

Prior to the survey by Holt & Davies (1991) the biology of the four sealochs was only poorly known. The CRPB (1967a, 1967b) examined Gareloch and Holy Loch for potential pollutants, commenting on floating rubbish and sewage as particular problems in Gareloch. Sewage dumping grounds near Garelochhead and off the mouth of Holy Loch were studied by Paisley College of Technology (MacMaster 1977; Lees 1981). MacMaster (1977) found the enriched sediments off Holy Loch to be dominated by polychaetes (mainly *Capitomastus minimus* and *Capitella capitata*) and oligochaetes. The sediments in Loch Long and Loch Goil have also attracted attention. Shand (1987) reported on the biological control of marine sediment stability by the mussels *Mytilus edulis* and *Modiolus modiolus*, whilst Pye (1980) described the burrowing fauna from these lochs and other areas in the Clyde. Dipper (1981) offered a brief description of sublittoral habitats in Loch Long from a collection of photographs by Gordon Ridley. Rocky communities characterised by the anemone *Protanthea simplex* and large solitary ascidians appeared to be widespread. Loch Long experienced a pronounced non-toxic plankton bloom in July 1990 (CRPB 1991, UMBSM 1991). More recently, SOAEFD have undertaken surveys under the EC IMPACT II project in fished and unfished sections of Gareloch in order to assess levels of seabed disturbance from fishing.

12.4.4 Loch Striven and Loch Riddon

These two small sealochs (Figure 12.5), also surveyed in 1989 for the MNCR (Holt & Davies 1991), showed many similarities to the Loch Long/Loch Goil system to the east, with a restricted range of fairly impoverished habitats. Of particular note in the sublittoral sediment communities in Lochs Striven and Riddon were dense populations of burrowing holothurians, mainly *Psolus phantapus* and *Trachythyone elongata*. In the lochs to the east, similar sediments appeared to lack these species, possibly because they remain buried in the sediment for certain periods in the year (i.e. at the time of the survey).

Loch Striven, together with Loch Fyne, has suffered toxic plankton blooms which have resulted in high mortalities in caged salmon stock (Tett *et al*. 1986). In Loch Riddon the burrowing fauna in general (Pye 1980) and Fries's goby *Lesueurigobius friesii* in particular (Nash 1980) have been examined as part of wider studies on these subjects.

The sediment shores at the head of Loch Riddon were surveyed by Stephen (1930b) and re-surveyed by McLusky & Hunter (1985). McLusky & Hunter (1985) described communities in what they considered to be an unpolluted small estuary and suggested that the area had changed little in the 53 years since Stephen's (1930b) study in 1929. The upper part of the estuary had an estuarine fauna with *Hydrobia ulvae*, *Nereis* (now *Hediste*) *diversicolor* and *Corophium volutator*, whilst the fine sands of the middle reaches had a high biomass of the bivalves *Macoma balthica*, *Cerastoderma edule* and *Angulus tenuis* and the polychaetes *Nephtys hombergii* and *Scoloplos armiger*. In the coarser and more marine sands of the lower part of the estuary mussels *Mytilus edulis* and the barnacle *Semibalanus balanoides* were prominent.

12.4.5 Loch Fyne, including Loch Gilp and East Loch Tarbert

At 70 km long and 200 m deep, Loch Fyne is the longest and deepest of the Scottish sealochs (Figure 12.5). As with other fjordic sealochs, Loch Fyne is predominantly fringed by bedrock and boulders which have barnacle-dominated communities at the more exposed and steeply sloping sites, and fucoids covering the more sheltered rocky areas. The estuarine sediments at the head of Loch Gilp were described by McLusky (1986), who compared the area with Stephen's work of 1929

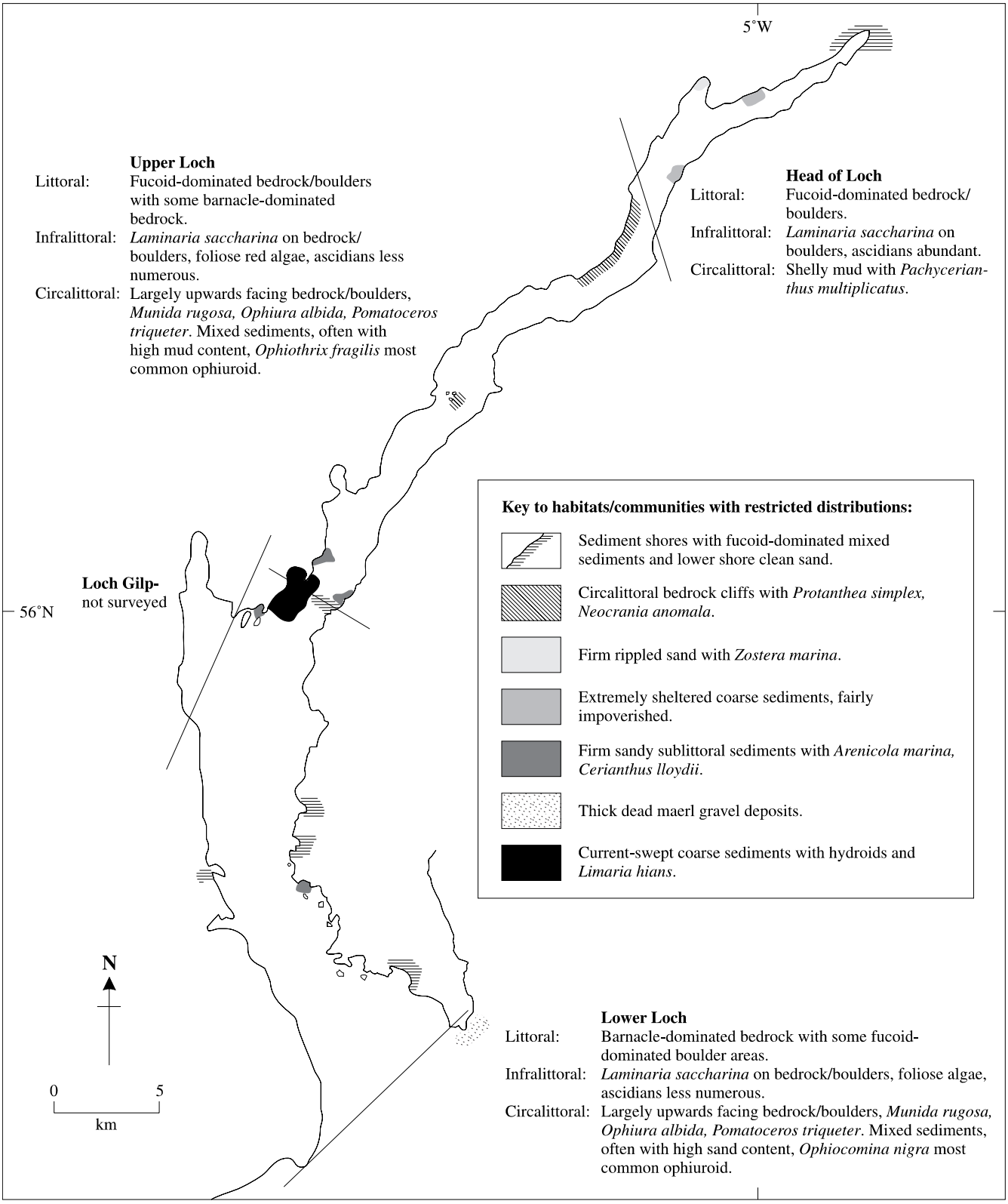

Figure 12.8. Distribution of communities in Loch Fyne (from Davies 1989).

(Stephen 1930b). The shore communities here were little changed and supported a fauna principally of polychaetes and oligochaetes, with extensive areas of seagrass *Zostera marina* in the upper reaches of the estuary.

A survey of Loch Fyne for the MNCR (Davies 1989) found both littoral and sublittoral habitat diversity to be relatively low (Figure 12.8). However, at the head of the Loch, one of the densest populations known in the British Isles of the rare anemone *Pachycerianthus multiplicatus* was recorded. Another important feature of the upper loch area was the deep bedrock which supported a good example of a community characterised by the anemone *Protanthea simplex* and the brachiopod *Neocrania anomala*. The upper part of Loch Fyne was consequently promoted as a Marine Consultation Area (Nature Conservancy Council 1990). Eden *et al*. (1971) provided valuable details of the deeper areas of lower Loch Fyne, gathered during geological investigations using a manned submersible. They described sublittoral cliffs which extend from 85–151 m depth, on which ascidians, fan worms, anemones and sponges grew. Elsewhere, dense beds of brittlestars and featherstars were recorded, while the sediment plains below 150 m were occupied by a range of burrowing species including the Norway lobster *Nephrops norvegicus*. More recent examination of the seabed by remote video camera for the MNCR (Howson & Davies 1991) showed the upper loch to support dense megafaunal burrowing communities, in contrast to the outer loch where trawling activities had disturbed the deep mud faunas. An extensive population of the nationally scarce echiuran worm *Amalosoma eddystonense* was found at the mouth of Loch Fyne, and large numbers of the cold-water anemone *Bolocera tuediae* were present on hard ground within the loch.

Other studies in Loch Fyne include work on the brachiopod and clam populations. Populations of the pectinid clam *Chlamys* (now *Pseudamussium*) *septemradiatum* in the upper loch were described in Allen's (1953) work on the species. *Terebratulina retusa*, a brachiopod common in the deep rocky areas in the loch, was investigated by University of Glasgow staff (Cohen *et al*. 1993) concerned with population genetics and physical requirements. The Dunstaffnage Laboratory produced a geographic information system for future development of fish farming in the loch (NERC/SMBA 1992). The CRPB (1976b) examined the benthic communities near the construction site of a gas-production platform off East Loch Tarbert. The samples revealed a modified '*Amphiura filiformis/chiajei*' community in which polychaetes were prominent, but the urchins *Brissopsis lyrifera* and *Echinocardium cordatum* were present in lower numbers than in similar communities elsewhere.

The phytoplankton ecology of Loch Fyne has been studied from the SMBA laboratory at Dunstaffnage, particularly in connection with toxic blooms which have caused fish mortality in salmonid farms (Gowen, Lewis & Bullock 1982; Jones *et al*. 1982; Tett *et al*. 1986). Zooplankton studies have been undertaken within the loch since the 1920s, with the emphasis on euphausiid biology (e.g. Mauchline 1966).

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