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Kames Bay, Isle of Cumbrae, Scotland: unexplored aspects of a Site of Special Scientific Interest

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Kames Bay, Millport, Isle of Cumbrae, Scotland (Fig. 1) is one of the classic sandy beaches of the world. Probably more has been published on the identity, biology and distribution of macrofauna and meiofauna living there than on that of almost any other beach (King & Elmhirst, 1914; Stephen, 1928, 1929, 1931, 1932, 1938, 1945, 1953; Elmhirst, 1931, 1932; Nicholls, 1935, 1939; Watkin, 1938, 1939, 1941, 1942; Dixon, 1944; Clark & Milne, 1955; Smith, 1955; Ansell, 1961; Ansell & Trevallion, 1967; Mauchline, 1967; Ansell, 1969; Corey, 1969; McIntyre, 1970; Barnett, 1971; Ansell, 1972; Barnett & Watson, 1986; Powell & Moore, 1991; Moore & Beare, 1993; Beare & Moore, 1996, 1997, 1998; Cowie & Hannah, 2002, 2006; Moore, 2017).

Fig. 1. Kames Bay, Millport, Isle of Cumbrae, Scotland, 22nd March 2020, showing the glistening area of wetted sand on a receding tide revealed after two dry days but extensive rainfall in the previous weeks, with freshwater draining-up through the beach. (Photo: J. Moore)

For generations fieldwork classes have used this beach for practical and project work based at the Millport Marine Station (first under the Scottish Marine Biological Association (SMBA), then as the University Marine Biological Station Millport (UMBSM), and now as the Field Studies Centre Millport (FSCM)). Its designation as a Site of Special Scientific Interest (SSSI) was based on these educational considerations, but its uniqueness vis-à-vis its salinity conditions should guarantee such status. Intelligent decision-making about how best to manage SSSIs, and coasts in general, in a sensitive and sustainable way in order to conserve biodiversity, requires basic science at the heart of an Integrated Coastal Zone Management (ICZM) policy.

The physical environment of Kames Bay has been known since the mid-1950s to be particularly interesting in terms of the freshwater upwelling that percolates through its upper regions (though this may occur to varying degrees down its whole extent). Rainfall from the island's catchment is channelled southwards along the underlying Great Cumbrae Fault – a geological feature that is responsible for the position of the embayment in the first place – until it surfaces through the beach (Smith, 1955). A thorough analysis of the physical environment of the beach, or its seasonal variability, has not been published (apart from extensive *in situ* temperature recordings by P.R.O. Barnett; see Barnett & Watson, 1986), although student classes have habitually sampled its physical properties.

Salinity is well known as a key environmental determinant in many aquatic ecosystems (Kinne, 1971), from rockpools (Daniel & Boyden, 1975; Morris & Taylor, 1983; McAllen *et al.*, 1998) to estuaries and lagoons (Barnes, 1996). However, little attention has been paid to the role of brackish water inside the beach at Kames Bay, which is needed because of its possible role in affecting macrofauna and other organisms on and within it. A clearer understanding of the salinity distribution in the beach aquifer would provide context for interpreting the long history of associated biological measurements.

Freshwater is often assumed to run-off beach surfaces with little impact on underlying salinity conditions in the sand (Reid, 1930; Hayward, 1994). Thus, Brown & McLachlan (1990) stated that "dramatic changes in beach water salinity seldom occur" (see also Barrett, 1974); but on Kames Bay, where brackish-water conditions prevail underground below Mean High Water Neap Tide (MHWN) level in an otherwise fully marine locality, they do (Smith, 1955; Hayward, 1994). Kames Bay thus merits particular consideration. As stressed by Eltringham (1971) "the work at Kames Bay ... shows that under certain unusual conditions, salinity can exert a limiting effect on the shore". Large-scale perturbations in surface water salinity have been recorded in the water column off Millport (Thomason *et al.*, 1997), and such stochastic events with a high rate of change of salinity, may have a profound effect on the physiology, behaviour, distribution and abundance of marine organisms (Smith, 1955; Davenport *et al.*, 1975; Hayward, 1994; Barnes, 1996; Little & Kitching, 1996; Santos *et al.*, 1996).

Intermittent low salinity conditions may have a profound, and locally unrecognised, significance in terms of the behaviour and performance of beach-dwelling infauna, even to the extent of modifying productivity (Cowie & Hannah, 2002). Unpublished observations by P.R.O. Barnett (pers. comm.) made offshore in Kames Bay after a period of sustained heavy rainfall some years ago revealed the sublittoral population of the infaunal bivalve *Fabulina* (previously *Tellina*) *fabula* all lying on top of the submerged sand. The suspicion is that groundwater pressure created inimical salinity/thixotropic conditions (in this case even extending to the immediate offshore), prompting their evacuation from the sand. Such a mechanism could result in whole populations of sensitive species being made vulnerable to transportation and/or predation, as also happens after some red tides (Griffith *et al*., 2019). Groundwater discharge from the low-tide line has been shown to lead to the formation of algal blooms (Paerl, 1997). Many sandy beach-dwelling organisms, such as cockles (*Cerastoderma* spp.) and lugworms (*Arenicola* spp.), are economically important, so such data would not only be of academic interest.

The extent to which Kames Bay is unusual in terms of freshwater ingress interstitially is, as yet, to be established and it could well be that all pocket sandy beaches in hard landscape coves and embayments (and even extensive earth-backed sand strands) are generally subject to similar subterranean freshwater percolation influences after heavy rain.

Subterranean interfaces in littoral sediments also have a profound evolutionary significance. Brown & McLachlan (1990) noted that the discharge of groundwater through beaches, as unconfined aquifers, provides a path for the interstitial fauna to evolve landwards to terrestrial and freshwater habitats (Warwick, 1989). These authors note as well that towards the backshore of most sandy beaches a rapid change in interstitial salinity occurs, as percolating seawater gives way to inflowing groundwater. As Jansson (1967) has indicated, however, the importance of rain on interstitial salinity is mainly via increasing groundwater pressure (rather than by overflowing beaches). The up/downshore positioning of the interface between saline and fresh water influences within sandy beach aquifers and its temporal variability under different tidal regimes have been reported elsewhere (Robinson *et al*., 2007; Heiss & Michael, 2014; McAllister *et al.*, 2015, Fig. 1) and these are known to drive microbial geochemical processes (Paerl, 1997; Cowie & Hannah, 2002; McAllister *et al.*, 2015). On Kames Bay, this universal interface is certainly slipped seawards, providing unique opportunities for research generating comparisons with estuarine interfaces (Phillips & Fleeger, 1985; Santos *et al*., 1996; Robinson *et al*., 2007). Cowie & Hannah (2002) associated the extremely low numbers of naked (non-testate) amoebae in the beach sand at Kames Bay with the unusual salinity regime there, potentially influencing nutrient recycling (McLachlan & Illenberger, 1986; Montagna & Yoon, 1991; Millham & Howes, 1994).

There have been few studies to date of salinity fluctuations within sandy beaches during tidal inundation, with one example being Heiss & Michael (2014). Most published data that exist for salinity variations in sandy beaches (e.g. Jansson, 1966, 1967) have been derived at low tide. Of more than merely academic interest, such a study on Kames Bay would also assist in the formulation of soundly based advice to policy makers responsible for management and conservation decision-making, especially on sandy beach SSSIs. I hope that some enterprising marine scientist might be intrigued enough to research this topic locally.

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