INTRODUCTION

It is well documented that aquatic sediments are sites of intensive microbial activity and that the majority of the processes which occur there involve the breakdown of organic matter and the subsequent transformations of the products of decomposition. Estuarine sediments typically have higher interstitial water concentrations of dissolved inorganic nitrogen (DIN) than in the overlying water column, suggesting that sediments are sites of active nitrogen cycling.

Biological nitrogen cycling is predominantly carried out by physiologically distinct groups of micro-organisms in a series of well defined transformations. There are two broad, fundamental processes. Firstly, the mineralisation of organic to inorganic nitrogen and secondly, interconversions between the various redox states of inorganic nitrogen resulting from the decomposition processes.

In a previous paper (Owens et al., 1979) it was shown that in the Eden Estuary, Scotland, there was a close coupling between sediment nitrogen cycling processes and primary production. It is the aim of this paper to describe, more fully, the role of the sediment nitrogen cycling bacteria and their interactions with nitrogen speciation and concentrations in interstitial water.
MATERIALS AND METHODS

The Study Area

The estuary under investigation was the Eden Estuary, Fife, Scotland (Nat. Grid Ref. NO 475195), situated approximately 10 km south of the River Tay and approximately 6 km in length from the upper limit of tidal influence to the mouth in St. Andrew's Bay. The estuary drains completely at low tide exposing extensive mud and sand flats. At approximately MHWS level there are salt marsh fringes. The study was carried out on a transect chosen to incorporate the major features of the estuary, along which eight sampling stations were established. See Owens et al., (1979) for a more detailed account of the study site.

Chemical Analyses

Sediment samples for chemical analyses were obtained by hand at low tide. Interstitial and exchangeable inorganic nitrogen species were determined spectrophotometrically after their extraction by the methods of Bremner (1965). NO$_2$-$\text{N}$ was determined by the method of Bendschneider and Robinson (1952) as was NO$_3$-$\text{N}$, after reduction to NO$_2$-$\text{N}$ by spongy-cadmium (Mackereth et al., 1978). NH$_4$-$\text{N}$ was determined according to Solorzano (1969).

Enumeration of Bacteria

This was carried out using the MPN technique by decade dilutions and five replicates. The medium of Meiklejohn (1965) was used for ammonifying bacteria, those of Alexander and Clark (1965) for NH$_4^+$ and NO$_2^-$ oxidizers. The CPS medium of Collins (1963) supplemented with 2 g l$^{-1}$ KNO$_3$ was used for total and denitrifying bacteria. The salinity of all media was 35 $^\circ$/oo. A similar relative efficiency of recovery of the particular bacteria was assumed for each medium.

$^{15}$N Analysis

$^{15}$N was determined by mass spectrometry after release of N$_2$ from NH$_4^+$ in an evacuated Rittenberg tube (see Stewart, 1967).

Inorganic Nitrogen Concentrations and Speciation

Data were obtained over a thirteen-month period between March, 1977 and March, 1978 on the DIN concentrations in the interstitial water in the top 3 cm sediment at eight sites in the Eden Estuary. The mean concentrations of NO$_3$-$\text{N}$ and NH$_4$-$\text{N}$ for the period are presented in Table 1, as are DIN data for the water column.