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Nutrients and Phytoplankton of the Loch of Cliff, Unst, Shetland

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NUTRIENTS AND PHYTOPLANKTON OF THE LOCH OF CLIFF, UNST, SHETLAND

Introduction and rationale

This note outlines information on nutrient chemistry and plankton of the Loch of Cliff (Unst, Shetland). It is based on analyses of samples collected in late July and early September 1989 from both the cage site in the main basin of the loch, and a site in the Arm of Quoys. The work stems from initial discussions with the above Company which wanted information on water quality. The main focus is on nutrients such as phosphorus (P) and on planktonic organisms including the plant component (phytoplankton) consisting primarily of algae, and animals (zooplankton) - mainly micro-Crustacea (e.g. Daphnia) but also rotifers (Rotifera or 'wheel animals'). The work reflects an increasing interest in the potential impacts of the expanding fish-farm industry on the freshwater environment. Data on P can indicate the impact of the introduction of P-rich fishfood; this may be deposited in the lake in the form of waste (or 'missed') feed, and in the faeces of fish. The degree to, and timescale over which the P in these particulates is rendered soluble - and thus easily available to algae - varies according to a number of factors; these include the type of feed and the nature of the fish faeces, and conditions such as the temperature and the dissolved oxygen content of the water. Over and above these, are factors which determine to what extent algae capitalise on the added nutrients and, indeed, which types of algae will do so; here, the following are important: mean depth of loch, penetration of light into the water, temperature and mixing regimes, and the rate at which water is passing through the basin (i.e. the 'flushing rate'). In any event, however, in many lakes in the North Temperate zone of the world, and for much of the year in such lakes, P is the nutrient limiting phytoplankton growth. Thus, if P alone is added to these waters, it can stimulate algal growth - although again, the actual response is determined by some of the factors listed above, and also, for example, the concentrations of other nutrients (e.g. nitrogen and, for diatoms in particular, silica). In this connection, qualitative features of the response i.e. what species of algae become prominent, may be as important as, if not more important than, the quantitative consequences. As an example, some species of blue-green algae (also now known as cyanobacteria) often capitalise on warm, calm conditions under which they can aggregate at the water surface as 'blooms' and scums, and constitute a particular nuisance - even when their lake-wide concentration (biomass) is low relative to other species.

The rest of this document summarises firstly the results of the analytical and microscopical investigations; secondly, the results are interpreted in the context of fish-farm impacts, and in relation to some Loch of Cliff data obtained by the Edinburgh team as part of its Shetland freshwater survey in 1974. Finally, some recommendations are made on future sampling programmes. No details of field laboratory methods are presented at this stage, but they can be supplied, and will be incorporated in any final report. In summary, the samples were collected by the fish-farm operators, and procedures for nutrient analysis and the microscopic examination of planktonic organisms for information on species, sizes and numbers (population densities), are outlined in our own research papers and other contract reports, which are available on request.

Results

Nutrient chemistry - Levels of total phosphorus (TP) differed little between the two sampling occasions - with ca 25 µg in the Arm of Quoys, although only approximately half this concentration in the main basin of the Loch. The soluble reactive component (SRP or ortho-phosphate) which represents the fraction most immediately available to algae, however, was present in concentrations of < 5 µg P l^{-1} in each of the samples on both occasions (i.e. in those of 31 July analysed by the Clyde River Purification Board and those of 8 September analysed by IFE). According to the CRPB records, the concentrations of nitrate and ammonia were < 100 µg N l^{-1} and < 20 µg N l^{-1} respectively. IFE nitrogen results are not yet available.

Phytoplankton - Some 30 species of planktonic algae have already been recorded. In summary, in the July samples the numerically dominant forms consisted of very small unicellular green coccoid cells (ca 2 µm in diameter) at approx. 5.5 x 10^3 ml^{-1}), the diatom Rhizosolenia (150-200 µm in length of the siliceous 'frustule' but containing chloroplasts and other cell material occupying only about one-tenth of this length) and chrysophycean ('yellow-green') flagellates each at approximately 4 x 10^3 individuals ml^{-1}. Somewhat larger (ie in terms of cell volume) cryptophycean flagellates and other diatoms, were present in numbers of a few hundreds per millilitre, while even larger algae including Ceratium - representing yet another class of flagellates (the Dinophyceae) - numbered not more than a few tens of cells per millilitre. Still rarer than these, but prominent by virtue of some of its colonies which are millimetres in size, and found in the zooplankton net hauls, was Anabaena flos-aquae - a fairly cosmopolitan blue-green alga.

In the plankton crop in September, a green alga Monoraphidium contortum (approximately 25 µm in greatest dimension, resembling an 'S' but curved in two dimensions) was the most numerous - 3 to 4 x 10^3 cells ml^{-1} at both sampling sites. There was also a greater variety of diatoms in the September material and, in the Arm of Quoys water at least, evidence of iron bacteria associated with suspended detritus.

While these cell concentrations are not inconsiderable, the crops are comparatively moderate. A useful index of the total photyplankton content of the water, is the concentration of the pigment chlorophyll a, which we can extract from the cells by steeping them in methanol. The pigment analyses carried out by the CRPB on the July samples were suspiciously high. This view was based on long experience of determining chlorophyll levels, and counting and measuring phytoplankton; so, even in the absence of pigment data, the microscopical investigations allow the likely chlorophyll content to be judged - albeit very roughly because different algae contain different amounts of chlorophyll, and the pigment content per cell can also vary with ambient light conditions, nutrient status etc. As far as the July samples from the Loch of Cliff are concerned, pigment concentrations of no more than one-tenth of the values indicated by the CRPB would be expected. While it is impossible to prove this case, it is notable that IFE determinations of the pigment in the September samples gave values of 7.0 and 6.1 µg chlorophyll a l^{-1} at the Arm of Quoys and Cage sites respectively.

Zooplankton - To date, we have only had zooplankton samples from July, although a standard IFE zooplankton tow-net has now (20 November 1989) been despatched to the Loch of Cliff hatchery. Detailed estimates of the

population densities (ie numbers per litre) of the different species present, have not yet been completed. However, it is plain that within the Crustacea, the calanoid copepod Diaptomus is dominant. The cylopoid copepod (Cylops) is also common, and Daphnia - representing the cladoceran group of micro-Crustacea - has been frequently recorded. Cyclops is an omnivore feeding on a range of algae and micro-fauna, while Diaptomus and Daphnia are primarily herbivorus, and obtain their food largely by means of filtering small particles from the water.

Interpretation of the findings

It will be necessary to have more information on the Loch of Cliff - of the type discussed above but for other times of the year - before any definitive statements can be made on (i) its condition and (ii) whether fish-farming activities are having an (adverse) impact, (see 'Recommendations for future work'). However, on the basis of the preliminary analyses, the loch is far from 'over-enriched'. Neither nutrient levels, nor the concentrations of total phosphorus and chlorophyll a give any cause for concern. What is more, the values obtained by the CRPB from the July 1989 samples, for pH (ca 7.5), alkalinity (32-34 mg l^{-1} as $CaCO_3$) and conductivity (290-300 µS cm^{-1}) are very similar to those measured by the IFE team in 1974. A corresponding comparison of data on nitrate, ammonia and soluble phosphorus also suggests no significant differences between these times which are 15 years apart.

Recommendations for future work

The contractor is invited to consider 3 proposals for work to improve on the present database and to enable a better assessment of the impacts of the fish hatchery and cage.

> To continue with the present sampling arrangements (apart from some minor modifications such as the use of IFE sampling bottles) - but collect the materials quarterly for 1 year - and then review accordingly. AT EACH OF THE 2 SAMPLING SITES, each set of samples would consist of 2 zooplankton net hauls (fixed with formalin) for micro-Crustacea, 2 collections of water for chlorophyll, rotifer and nutrient analysis, and 2 separate subsamples of water ('fixed' with Lugol's Iodine) for phytoplankton counts.
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> Depending on the first year's results a desk study to assess the likely impact of fish-farming, by taking account of (a) various physical and chemical features of the loch, (b) size, land-use and topographical characteristics of its catchment, and (c) the type of hatchery and cage operations including feed application and fish production; a field limnological reconnaissance may be needed to support this.

IFE charges would be approximately £300 per day; as an indication of costs incurred, the analyses and reporting of the data concerning 1 above takes 2 days per sampling occasion, and a desk study combined with a field reconnaissance would take 5 or 6 days exclusive of travel. Of course, if a site visit was required, travel and subsistence costs would be extra.


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