An integrated approach to hydropower impact assessment

II. Submerged macrophytes in some Norwegian hydro-electric lakes

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Received 29 June 1987; in revised form 16 October 1987; accepted 21 March 1988

Key words: submerged macrophytes, spatial niches, vertical distribution, environmental impact assessment, hydropower, disturbance, stress, water-level fluctuation, reservoirs, hydrolakes, Norway

Abstract

The submerged aquatic vegetation of 17 Norwegian lakes is described and related to the environmental impacts that result from hydro-electric power (HEP) use of these lakes. Largely based upon physiognomical features, three main community types are discerned. These are denoted as (a) shallow-water, (b) mid-depth, and (c) deep-water community, respectively. The aquatic macrophytes are classified into a plant strategy framework. This classification suggests that these macrophytes frequently exhibit combined traits of the 'S' (stress-tolerating), 'R' (ruderal), and 'C' (competitive) strategies. A plant-strategy index for the lakes is derived from the species classification and related to their HEP use.

Broadly, the response features of hydrolake vegetation are: (1) a decline in species richness; (2) the gradual disappearance of the shallow-water and mid-depth communities; (3) a conspicuous absence of vascular submerged macrophytes in storage hydrolakes when lake levels change more than 7 m annually, and; (4) an increased incidence of species possessing plant strategies of the ruderal (R) type. The implications of these results for an environmental impact assessment of hydropower schemes are discussed.

Introduction

Norwegian rivers and lakes have been used for generating hydro-electric power (HEP) for more than one century. Today, Norway annually generates some 100 TWh of hydropower from her renewable water resources. This makes Norway a clear world leader in per capita hydro-electricity consumption (= 25 MWh yr⁻¹). The number of developed hydropower projects such as generating installations, hydro-electric reservoirs, impounded river reaches, river diversions, and river abstractions, is believed to run into the thousands (no official statistics exist, however). Yet the environmental impacts from this comprehensive and nation-wide scheme are often not assessed within a proper, scientific framework (Rørslett, 1988b).

This paper is the second in a series which aims to provide an insight into the ecology of hydro-electric lakes. To this end, I attempt to generalize environmental features and biological response patterns found in a number of Norwegian lakes. In this study I concentrated on submerged macrophytes. These species are well suited as indicators for hydropower impacts because they mainly are perennial, rooted plants and have a number of ecophysiological adaptations for their aquatic habitat (Hutchinson, 1975; Davis & Brinson, 1980; Henriques, 1987; Rørslett, 1987b). Relationships
observed for this group of lake biota could also have important bearings on other ecological forms (Smith et al., 1987) when a hydropower scheme is developed.

The following specific objectives are addressed; (i) to characterize hydrological and physical features of hydrolakes in biological and conceptual respect, including their relationship to non-managed water bodies; (ii) to determine how aquatic vegetation relates to the physical impact of lake regulation or an altered water-level regime, and in particular, to predict whether critical thresholds for regulation extent can be developed such that ecosystem response meets some preset criteria; (iii) to determine if the regulated lake system is resilient to impact on an integrated community level, i.e., are community measures apart from species composition, such as spatial structure and productivity, influenced less than species diversity, and; (iv) to predict how the species can lessen adverse regulation impacts by selection of alternative life strategies.

Objectives (ii) through (iv) are within the scope of the present paper, while a previous paper (Rsrslett, 1988b) addressed the first issue (i) listed above. Forthcoming papers shall attempt a synthesis of this approach to environmental impact assessment (EIA).

Material and methods

**Studied lakes**
Vegetation data from 17 lakes, spanning a wide range of areas, altitudes, and nominal extent of regulation, are presented here. Their geographical locations are indicated on Fig. 1. Some lakes with a naturally extensive range of water-level fluctuation are also included. Throughout this series of papers, the term 'hydrolake' is applied to any water body, the water levels of which are operated for generating hydro-electric power (HEP). A hydrolake classification scheme is suggested in Tab. 1. Ten of the 17 lakes are operated for HEP. Additionally, three lakes are indirectly influenced by HEP use. Some basic morphometric and hydrological data are collated in Tab. 2. Further limnological details are found in Rørslett (1988b).

![Fig. 1. Location of the studied lakes in Norway. The 'Setesdal' lakes comprise lake nos. 1–8.](image)

**Macrophytes and photographic analysis**
The aquatic species present in a lake were assessed mainly by examination of drift material in near-shore areas, and floristic inventory of an 100 m shoreline. For each lake, 1–29 sites were investigated. Sites were randomly located on maps prior to field work according to Jensen (1977).

A SCUBA diver-operated photographic device was employed for quantitative sampling of submerged macrophyte communities. Using dual 35 mm cameras, this system produces stereophotographic images of a 0.25 m² quadrat (Rørslett et al., 1978). The quadrats were located using a depth-stratified random sampling procedure. The sampling density exceeded the pre-assigned minimum of 20 samples (vertical m)⁻¹ within the vegetated zone whenever possible. The maximum sampling density was up to 100 samples (vertical m)⁻¹. The divers sampled lake floors at least 2 vertical meter below the deepest observed macrophyte.

Coverage of species was determined from the stereophotographs using either a nested grid