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Biological implications of lake management with reference to lago Chungará

Consideraciones biológicas del manejo de lagos, en relación con el lago Chungará

TONY E. ANDREW

The Limnology Laboratory, The University of Ulster,
Traad Point, Drumenagh, Magherafelt, Co. Derry, N. Ireland

El lago Chungará se caracteriza por su altitud, su endorreismo, su composición y estructura de las comunidades biológicas representadas así como por su avifauna y bofedales asociados. Los niveles del espejo de agua van a modificarse a medida que se extraiga el agua. Regímenes de agua fluctuantes tendrían efectos más catastróficos que la reducción del nivel del lago. Ambas situaciones necesitan de un manejo cuidadoso para minimizar los cambios.

INTRODUCTION

Historically, many lakes have been subject to a degree of management for a variety of purposes. Such purposes include fisheries, irrigation and flood control, water supply and disposal and other functions such as transport, conservation and amenity. An example of antique management for irrigation and fisheries is Parakrama Samundra, a partially man-made lake in Sri Lanka, managed for over fifteen centuries (Schiemer, 1983). To maintain several, often conflicting, activities on one lake requires management based upon fundamental biological and hydrological understanding often enshrined in legislation or traditional practices.

Relatively recently we have seen the development of a considerable interest in all aspects of limnological research often directed towards problem solving for management purposes. Much of the international stimulation and collation of information may be attributed to international programmes such as IBP[1] and MAB[2] and the activities of SIL[3]. A summary of the recent advances in the understanding of the biological attributes of freshwaters is found in Le Cren and Lowe-McConnell (1980). Works more specifically concerned with the general aspects of lake management include those of Lowe-McConnell (1966), Edwards and Garrod (1972) and Ilmavirta, Jones and Persson (1982). There also exists a large number of works dealing with many aspects of particular lakes, *e.g.* Neusiedlersee (Löffler, 1979), Chilwa (Kalk, McLaughlan and Howar-Williams, 1979) or with catchments, *e.g.* Cruickshank and Wilcock (1982). The observation that "In recent years we have begun to understand water bodies as parts of larger systems and particularly as parts of their respective catchments" (Blazka, Backiel and Taub, 1980) still has to receive wide acceptance. Specific elements of lake ecosystems have received much attention as evidenced by many learned tomes *e.g.* fisheries (Gerkin, 1978) etc. However, it is apparent to the limnologist that although lakes with common characteristics of geography, chemistry or morphometry, are often grouped together for convenience, every lake has its own individual characteristics and, as such, needs a "personal" management programme.

Several schemes have been erected to classify lake types and these are often based on simple characteristics such as the mixing qualities of the water column (Hutchinson, 1957) or their geographical location. Although useful, these schemes do not adequately describe more than one specific lake. An equally simplistic scheme

[1] International Biological Programme.
[2] Man and Biosphere.
[3] Societas Internationalis Limnologiae.

might be initially, to identify lakes as natural, man-manipulated or man-made, perhaps more useful in a management context. Examples of each type may be found in most countries. Man-made lakes are usually constructed for a specific purpose such as hydro-electric power generation (Embalse Rapel) or water supply (Embalse El Yeso). Other functions, secondary uses are subjugated to the prime function without other uses such as amenity or fisheries being excluded. This is good management practice. At the other end of the scale, natural lakes (the majority of the southern lakes) are exploited only to a very limited extent, particularly in the area of fisheries and this only to the extent of stocking with the exotic *Salmo gairdneri* Richardson. It is the man-manipulated lakes (Laguna Negra, potentially L. Chungará) that require the most stringent management as they are usually natural lakes whose fundamental characteristics may be irrevocably altered by management practice. Occasionally such lakes may be encouraged to revert to their original state after gross perturbations to their ecology, but at great cost, for example Lake Washington (Edmondson, 1972). Unfortunately, not all lakes have the potential to accommodate such changes, particularly those with unique characteristics or isolated catchments. Careful consideration, which can only be based on sound limnological research, must be given to such lakes.

Lago Chungará

In world terms, Lago Chungará represents one of a very rare type. Distinguishing features include the isolated geographical location at extreme altitude, (4539 m), in the Altiplano, the self-contained catchment with its balanced water budget and a high ionic concentration with magnesium sulphate of major importance. These characteristics together with a well mixed water column and cold annual temperature cycle "polymictic" (Hutchinson and Löffler, 1956) – combine to create a lake of considerable limnological interest. Part of the catchment, closely associated with the lake, consists of a permanent marsh (bofedal) an important part ot the system.

Algal elements of the plankton community are dominated by the Chlorophyceae, *Botryococcus* sp. and *Sphaerocystis* spp. together with centric diatoms-indicative of a cold water assemblage. The presence of *Nostóc* sp. implies nitrate limitation, as appears to be the case from the ionic composition of the water. Phosphate limitation is unlikely. Algal production is high (Montecino *et al.*, 1982) and sufficient to support high standing crops of zooplankton dominated by copepods (Sanzana & Thomann, 1984). Although population densities of cladocerans are smaller than copepod densities, the cladoceran fauna is diverse (Domínguez, 1973).

The littoral communities appear to be highly developed and include areas of rooted macrophytes *(Miriophyllum elatinoides)*. This suggests that marginal benthic communities are highly developed containing a variety of invertebrates. This is confirmed by the presence of fish populations *(Orestias* spp.) which are dependent on the littoral regions for feeding and breeding. Lago Chungará suports an internationally famous bird fauna including, among fifteen species, flamingo and tagua. Flamingoes are dependent on the shallow, marginal areas of the lake for feeding, tagua require rooted macrophytes or marshy areas to nest, both marked features of the littoral regions of the lake.

The potential effects of water abstraction

The following observations are based on the assumption that the following premises have been satisfied; (a) the project is feasible and *sustainable* in hydrobiological terms and that the abstracted water is appropriate for the purposes required, (b) that the return on investment, social and *biological*, as well as economic, have been equated with the benefits that would accrue in that the Lauca region is designated a Biosphere Reserve.

The principle effect of water abstraction, given the closed nature of the catchment, would be to alter the water level. Depending upon the abstraction demand, volume and temporal pattern, this would manifest itself as either a fluctuating water level or as a permanent fall in water level. The major areas to be affected include the littoral region and the marsh. Secondary effects will occur in the plankton community. The exact nature of the changes depend partly on the morphometry of the lake, particularly around the margins (Fig. 1).

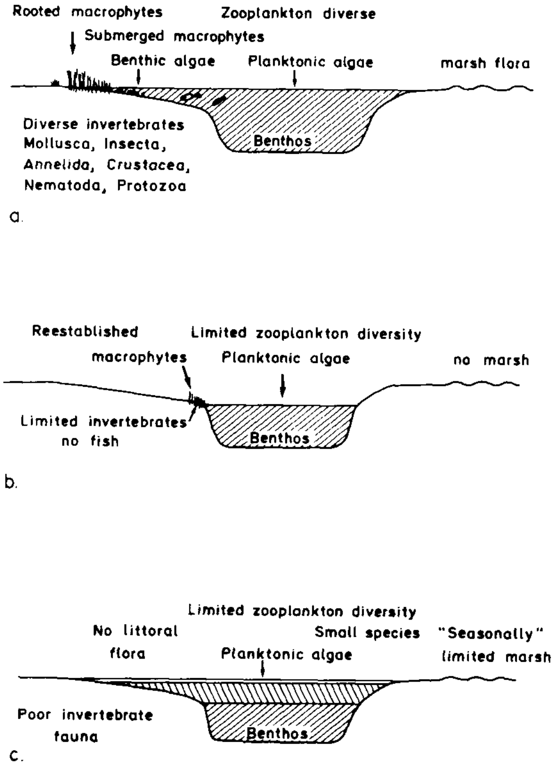

Fig. 1: Generalised effect of water level fluctuations on the communities of Lago Chungará: (a) present situation, (b) permanent fall in water level, (c) fluctuating water level.

The effect of a fluctuating water level would be catastrophic to any littoral community although some species with powerful migratory capacity or very rapid developmental times might survive. These would include "pest" species such as midges, diptera and mosquitos. The flora would be very limited in composition, a situation found in many man made lakes (*e.g.* E. Rapel). The influence on planktonic communities and benthic communities would be significant. Many zooplankton species have resting stages which find refuge in the littoral regions and these would not survive, reducing the diversity in the plankton. Insect species often lay their eggs at the margins and the developing larvae migrate into deeper waters as part of a seasonal cycle, this would become precarious. Many of the littoral species provide food for fish and birds and consequent effects would be manifest in those populations. Some lakes, particularly in tropical situations, are subject to natural or controlled fluctuations *e.g.* L. Chilwa (Kalk *et al.*, 1979) and Parakrama Samundra (Schiemer, 1983) respectively. In these cases species diversity tends to be limited and shows very slow recovery especially in numerical population density terms. Zooplankton, for example, tends to alter its composition in favour of smaller species with rapid generation times, – a strategy not common in cold, polymictic waters.

The effect of a permanent reduction in water level would also catastrophically alter the community structure of the lake margins. If morphological characteristics of the lake allow, some elements of the flora and fauna might become re-established in the new littoral and sublittoral region, but at a very much reduced level. This may take a considerable time as experience in lake control has shown. Water level reduction has been practised for example on Lough Neagh, N. Ireland for over a century. Successive lowerings have resulted in major changes in the marginal community structure reducing species diversity, reed bed areas etc. and creating a new bank structure to the shore (Wood and Smith, in press). The effect in L. Chungará, a smaller lake, would be to alter total production of all areas at each trophic level as well as reducing diversity and affecting fish populations.

The effect of either type of water level alteration on the marsh area is unpredictable but all too likely to modify the habitats of the bird and other animal populations.

CONCLUSIONS

The abstraction of water from Lago Chungará will undoubtedly result in major changes in the lake flora and fauna. Perturbations in the water chemistry will not be on the same scale. The main effects will be seen in the reduction of littoral and marsh communities including fish and bird populations. Other effects, dependent upon abstraction practice, will be seen in the planktonic and benthic communities.

In practical management terms, every effort should be made to minimise changes in water levels of the lake and, in the event of changes being necessary these should be undertaken in a manner *not* creating large, fluctuating changes in water level.

Steel (1972) argues cogently, in relation to water supply reservoirs, that "because of the complexity of interactions, the empirical approach must necessarily be abandoned for fundamentalism" and as such and as L. Chungará is part of a Biosphere Reserve, the project should include a detailed study of the lake and catchment before, during and after abstraction takes place. The sequence of limnological events and the effect of abstraction would provide valuable information for the management of this lake and as a guide for other similar schemes.

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