Introduction

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At the latitude of 14° S, the Andes chain divides into two Cordilleras which enclose a high plateau, the Altiplano, covering about 200,000 square kilometres and with an altitude varying between 3700 and 4600 metres above sea level.

Lake Titicaca occupies the northern part of this plateau. It is both vast and deep and is designated as the highest navigable lake in the world.

It is divided into two lake basins: the Lago Pequeño (or Huiñaimarca) and the Lago Grande, more rarely known as the Chucuito. These two parts are connected by the approximately 800 metres wide Tiquina Strait. The maximum depth of the Lago Grande is 285 metres whereas that of the Lago Pequeño is only 40 metres. More than two-thirds of the former has a depth greater than 150 metres whereas the latter is only 5 to 10 metres deep over most of its area.

Because of its geographical location, the lake is subject to the climatic conditions belonging to the tropical zone, especially insofar as insolation remains relatively stable throughout the year. Because of its high-altitude situation, it is influenced by conditions belonging to montane climates (high luminous intensity, low temperatures, low air humidity) which interfere with those factors related to its tropical nature. To this is added the unusual morphometry of the lake basin, in which coexist, often poorly connected to one another, large shallow areas (Lago Pequeño, and the large Puno, Ramis and Achacachi Bays) and deep areas, more typical of alpine type lakes.

The entire hydrological system of the Altiplano is endorheic, with all the consequences that such a system can have on the biological components of the habitat. The lake itself functions almost as a closed system; its only outflow river under the present hydrological situation accounts for less than 5 % of the total water losses. The lake water is subject to strong evaporation, has a retention time of the order of 63 years and has a total dissolved salt content of close to one gram per litre, which distinguishes it from the much fresher waters of the majority of the Andean mountain lakes.

It should finally be noted that it stands at the transition point between two very distinct geographical regions: the desert fringe of the Pacific coast to the west and the great Amazonian forest extending to the Atlantic coast to the east.

In addition to its unusual limnological features, it is, according to Indian mythology, one of the birthplaces of mankind. The sun, the moon and the stars were born within its bounds according to the wishes of Viraçocha, creator of the world. Here, after the Great Flood that destroyed the world, mankind took its first steps. The lake was a sacred site for the Incas, who saw it as the end of the earth and a point of fusion where the two concepts of time and space came to be expressed.

Although the Spaniards had for a long time roamed over the Altiplano, it was probably a Frenchman, Alcide D'Orbigny, who was the first scientist to take an interest in Lake Titicaca and he brought back biological collections to Europe following one of his expeditions to South America from 1826 to 1833. The first descriptions of the molluscs came from these samples.

At about the same period, another scientist, J.B. Pentland, at the time British Consul in Bolivia, studied the unusual aquatic habitat during two expeditions undertaken at ten years' interval (1827–28 and 1837–38). As a geographer he made the first precise maps of the lake and its region and also collected biological specimens, which he sent back to Europe. Among these were fish which were used by Cuvier and Valenciennes to describe the first species of *Orestias*. Other collections of biological specimens arrived in Europe following the visits of Castelnau and Weddel (1843–47). Further visitors (Squier, 1870; Orton, 1873; Marcoy, 1877; Puente, 1892; Tovar, 1892 and Basadre, 1894) only paid scant attention to the true study of the lake. But in 1875, over a period of less than two months, Agassiz and Garman carried out the first coordinated study of this environment, including bathymetric, hydrographic and biological surveys, which were published in 1876 and 1877.

It was not before the start of the twentieth century that more structured expeditions were organised, and particularly that of Créqui-Montfort and Sénéchal De La Grange (1903), in which the zoologist Neveu-Lemaire participated. It is to him that we owe the first extensive faunal inventory, which, after all the species collected had been identified, confirmed the low species diversity already reported by Agassiz and Garman (1876).

The first expedition whose aim wasn't simply to bring back further collections of specimens, but rather to study the relationships existing between the flora and fauna, was organised under the direction of H.C. Gilson in 1937. The publications resulting from the collections made by this British expedition did not however provide a very detailed ecological description of the various ecosytems studied – in particular that of Lake Titicaca. In many cases the publications were restricted to species lists with brief descriptions of the sampling locations. This 'Percy Sladen Trust Expedition to Lake Titicaca' did nevertheless have the merit of including a hydrologist, a chemist, three zoologists, an entomologist and a botanist and their full and detailed publications are still authoritative to the present day; in many fields they represent one of the main sources of reference for this synthesis.

After a hiatus of ten years because of the Second World War, a number of specialised studies were carried out providing further information to that already acquired on the biology of the lake (Vellard, 1951 to 1954; Niethammer, 1953; Brundin, 1956; Ueno, 1967) and on its geology, physicochemistry and general limnology (Newell, 1945; Schindler, 1955; Monheim, 1956; Löffler, 1960; Derkosch and Löffler, 1961).

It was not until 1972, the year of the setting up of the laboratory of the Instituto del Mar del Perú (IMARPE) at Puno, that coordinated studies started to be carried out again. From 1973 the University of Davis (California) carried out a regular programme of observations in Puno Bay and in the Peruvian part of the Lago Grande, in liaison with this institute. In 1974, the Universidad Mayor de San Andrés (UMSA) at La Paz and ORSTOM (then known as the Office de la Recherche Scientifique et Technique Outre-Mer, but later to become the Institut Français de Recherche Scientifique et Technique pour le Développement en Coopération) started a joint limnological research programme on the Bolivian part of the lake, firstly on the Huiñaimarca and then on the Lago Grande. This began with morphometric and sedimentological studies before going on to cover biological subjects.

In spite of the setting up of cooperative research arrangements and the relative ease of access to the Andes and its aquatic habitats, scientific expeditions have not yet become a thing of the past. In June-July 1978, North American scientists organised a scientific expedition known as the 'Catherwood Bolivian-Peruvian Altiplano Expedition' involving two invertebrate specialists, an entomologist, an algologist and a botanist. Their main results were published a few years later (Roback *et al.*, 1980; Roback and Coffman, 1983) and represent a major contribution to our knowledge of the aquatic insects of this region of Latin America.

A Peruvian-Bolivian programme of assessment of Lake Titicaca's resources was carried out from 1983 to 1985, under the auspices of SELA (Sistema Economico Latino-Americano) and OLDEPESCA (Organización Latino-americana de Desarollo Pesquero). The University of La Paz then developed research on the spatio-temporal variations in physico-chemical variables and on the plankton during 1984–1985. The Instituto del Mar del Perú at Puno turned its work towards estimating the present fish stocks.

We should also mention the setting up in 1988 of an experimental pisciculture station on the edges of Lago Pequeño near the Tiquina Strait, as part of the economic cooperation programme between Japan and Bolivia. This is particularly aimed at the production of trout fry and at the study of the biology of this species in the lake.

It is certain that increasingly extensive understanding of Titicaca will be required in the forthcoming years, especially as this area is the subject of several present and future regional development projects. For this reason, it seemed to us essential in this work to take stock of the data accumulated from over a century of work on this lake basin, as the results of the numerous studies carried out up until now were very disconnected, fragmentary and scattered over several countries.

We have therefore attempted to make an exhaustive as possible review of current knowledge from the existing literature and from the results of more recent observations, the aim being to produce a sort of database on this unusual ecosystem. This synthesis, which highlights gaps and imperfections in existing knowledge, should help in guiding future research. Future work should aim at filling in the gaps of the descriptive part of this work and then go on to study the dynamics of the relationships between the various communities and their habitat, an aspect that has scarcely been touched up until now.

The following chapters describe the lake's animal and plant populations and their high degree of endemism which has frequently been reported in the literature. This concept of endemism needs to be qualified and used with a certain amount of discretion, as it only in fact concerns certain groups. It shows itself to its fullest extent in the molluscs, of which the majority of specics (*Taphius montanus* excluded) are only known from Lake Titicaca. The same is true for the amphipods among which only *Hyalella inermis* is found in other habitats on the Altiplano. The fish occurring in the lake also have a high degree of endemism, with only a few species of *Orestias* and *Trichomycterus* being recorded in other aquatic habitats neighbouring the lake.

For the majority of other taxonomic groups the flora and fauna consist of species that are widespread either throughout the Andes or South America, or are even cosmopolitan. Although some newly named species are only currently known from Lake Titicaca, it is highly likely that more intensive and extensive surveys will widen their distribution range.

The more motile species occurring in Lake Titicaca have often colonised other habitats around the lake, but in contrast, animal species living in neighbouring aquatic habitats are not always capable of adapting to the slightly saline waters of the lake, this being particularly the case with the insect fauna.

In terms of population dynamics, the older data are too short-term and too scanty to provide a description of the temporal changes and especially long-term changes that have occurred to the flora and fauna of the lake. However, some species previously recorded as dominant are now only recorded sporadically (certain molluscs and amphipods) and other taxa have not been found recently. In the last case, insufficient sampling may be the cause, but it is certain that the changes in dominance have more complex causes. With the exception of the fish fauna which has been and continues to be highly influenced by fishing pressure and species introductions, it is unlikely that human activities are the direct cause of the radical changes that have occurred to the species composition.

Perhaps internal rhythms belonging to Lake Titicaca itself could be cited, although for many groups it is difficult to demonstrate marked intra-annual seasonal cycles. At the interannual level, the few studies covering at least two years demonstrate frequently acyclical variations which seem to be the direct consequence of the variability of abiotic factors rather than major rhythms of a biological nature.

In the applied field, three subjects appear to have been given particular attention, the study of the beginnings of pollution being the most important. Although the closure for economic reasons of most of the mining operations in the catchment is a positive factor on this front, the increase in the human population along the shoreline recorded in recent years is already leading to contamination in certain almost enclosed bays.

The second applied subject to be studied with great attention is the long-term changes to the lake's hydrology. Several development projects envisage the taking of sometimes large quantities of water from this environment, and it is important to know with precision the variations in the potential available water resources caused by meteorological variability.

Finally, estimates of the overall fish production and its variability are still, if not quite non-existent, at least very approximate for a system which contributes greatly to feeding the population of the neighbouring areas. The population dynamics of trout and pejerrey (since they were introduced into the lake more than forty years ago) are still practically unknown over the lake as a whole and knowledge of the indigenous fish species is scarcely better. Information needed for a rational management of the fish resources should be collected as soon as possible.

Publicising the value of further developing research on this very special lake is also one of the aims of this book, and we sincerely hope that this objective will be fulfilled.

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