VI.5b. Introduced species
1. *Salmo gairdneri* (Rainbow trout)

GÉRARD LOUBENS*

History of introduction and exploitation

Four species of Salmonidae were introduced into Lake Titicaca from 1939 onwards: *Salvelinus namaycush*, *Salvelinus fontinalis*, *Salmo trutta* and *Salmo gairdneri*. It appears that only small numbers of *Salvelinus* were released on few occasions. In any event, these species did not adapt to their new environment. *Salmo trutta* was common in the River Llave in 1970 (Everett, 1973), but at the present time only *Salmo gairdneri*, which was also successfully introduced into many other Andean lakes, still occurs in Lake Titicaca.

The first rainbow trout were brought to the fish farm at Chucuito near to Puno (Peru) in 1941 or 1942, probably from the United States, although Bustamante and Treviño (1977) say that they originated from the Lautaro fish farm in Chile. 19 million fingerlings were released between 1941 and 1969 (Coutts, 1983). The stocking then continued at a rate of 700 000 per year (Laba, 1979).

Fishing by trolling began from 1948, at first for sport and later commercially, throughout the lake. Specimens of more than 10 kg were captured (Gilson, 1964), the largest individual being 122 cm long and weighing 22.7 kg (Matsui, 1962). Gill-nets came into use as from 1952. The nets quickly replaced trolling, which is now no longer employed.

The trout were at first sold fresh in the regional markets as far away as La Paz, Arequipa and Cuzco. From 1961, canneries were set up and their products exported to the United States and Europe. There were up to 5 plants which processed 500 tonnes of trout in 1965. Very soon after, the production of these plants declined and all were closed by 1970 (Everett, 1973).

Exploitation using surface gill-nets continues at present almost entirely in Peruvian waters. The produce is sent fresh or smoked to the local markets. Annual production in Peru was estimated at 889 tonnes over a one-year

*This chapter is an extract of Loubens G. (1989) *Rev. Hydrobiol. Trop.* 22 (2): 157–177.

C. Dejoux and A. Iltis (eds.), Lake Titicaca, 420–426.

period 1979 to 1980 (Hanek, 1982). The total production is therefore about 1000 tonnes if the small Bolivian contribution is included.

The most recent period of exploitation shows that the situation is less pessimistic than suggested by the works of Everett which gave a sustainable annual yield of 350 tonnes. This author only studied the fishing effort and production destined for processing plants (as opposed to fishing intended for self consumption or for sale fresh or smoked) as the only data available were from the trips made by lorries collecting trout for the processing plants and the output figures for these plants. His estimate for the annual sustainable yield was therefore founded on partial data, the total production of rainbow trout in the 1960s being unknown. The decline in production of the processing plants and their final closure could have been due to overfishing. Another and perhaps main cause, was a change in the world market for trout, since it was during the 1960s that fish farming of *Salmo gairdneri* developed enormously. In France, for example, it quadrupled between 1960 and 1970, increasing from 2500 to 10 000 tonnes. In the face of such competition, the processing plants at Lake Titicaca found themselves confronted with a insoluble price problem compared to the fresh product, which is usually preferred by the consumer.

Biology

This summary of the biology of *Salmo gairdneri* in Lake Titicaca is based on the works of Everett (1971, 1973), Bustamante and Treviño (1977) and of Hanek (1982), who reviewed the studies of Peruvian researchers, and on some personal observations made between November 1979 and February 1981 in the Bolivian part of the lake. Additional information comes from Lauzanne and Franc (1980) who studied an isolated population of rainbow trout occurring since 1975 in Lake Khara Kkota in the Eastern Cordillera. On the whole, the biology of the species remains poorly known, especially in quantitative terms. The relationships derived from our results, between the various measurements of length generally used (in mm) and between length and weight (in g) are as follows:

$$\text{total length} = 1.150\ \text{standard length} + 6.6;\ r = 1.000$$
$$\text{fork length} = 1.110\ \text{standard length} + 1.7;\ r = 1.000$$
$$\log \text{fresh weight} = 3.217 \log \text{standard length} - 5.223;\ r = 0.995$$

Salmo gairdneri inhabits all of the Lago Grande and a small part of the Lago Pequeño (Chua and Calata regions). This species of fish occupies coastal areas, except for the totora belt, and all of the pelagic zone. It lives in the surface waters as indicated by the fishing method (fixed or drifting surface gill-nets), but it is not known to what depth it penetrates. The size of individuals taken in the lake is very variable: 166 to 555 mm in our observations and from about 160 to 750 mm in those of Everett (*op. cit.*). The

youngest individuals live in the rivers, where they have frequently been caught, particularly in the Rio Ramis.

Adults or pre-adults start to congregate at the mouths of the major rivers at the start of the rainy season in December. They run up the rivers throughout the rainy season with a maximum seeming to occur in February when the water level is at its highest. The nets are obstructing during this period the areas near the river mouths, as was apparent in the case of the Rio Suchez (Escoma Bay) in 1980. It appears that all the large trout are captured on their passage, because samples taken from the river only contained a total of 12 trout measuring more than 24 cm (Everett, 1973).

Spawning starts in gravelly sites in the middle and upper reaches of the rivers in April, and reaches a peak in June and July. During these two months adults of small size – about 15 cm for the males and 22 for the females – have been seen in the act of spawning. In October, small trout 3 to 4 cm long are caught in the Peruvian rivers. Nothing is known of the proportion of individuals which succeed in reaching the spawning grounds and even less so about the proportion that returns to the lake after breeding.

The cycle of development of the gonads shows that they start to mature in December, followed by a progressive increase in the gonado-somatic index, which reaches a maximum of about 16% for females and 9% for males for mature individuals captured in the littoral zone. The maximum occurs in June in the case of females and in April for males. In contrast, our observations show that individuals taken in the pelagic zone in the Lago Grande from June to November are sexually quiescent, although this is based on few observations (fifteen individuals). The size at sexual maturity is not known with precision. Adults in the advanced stages of maturation occur as from 13 cm in the case of males and from 18 cm for females. The number of mature eggs varies between 1600 and 8000 for females of between 30 and 60 cm length. Lauzanne and Franc (*op. cit.*) gave very similar results for both gonado-somatic index and fecundity.

Growth was estimated by Everett (1973) from catches made with gill-nets (meshes of 38, 50, 63.5 and 76 mm knot-to-knot), using Petersen's method. Rainbow trout reached 342 mm in 2 years, 474 mm in 3 years, 553 mm in 4 years, 613 mm in 5 years and 658 mm in 6 years (standard lengths). These results should be considered as preliminary because of the sampling method (selectivity of gill-nets and small range of meshes used) and the restricted sampling area confined to a band 3 km wide along the shore, whereas trout occupy all of the lake. In addition, the results were obtained from a series of rather indistinct modal lengths, using a method for distinguishing separate age-classes, whose correspondence with reality is unknown. The examinations of scales and otoliths made by Everett did not produce any results.

Lauzanne and Franc (*op. cit.*) provided a good estimate of growth during the first year for rainbow trout in Lake Khara Kkota. Their captures, made at the height of the spawning season in June and July, demonstrated the

existence of a group of young trout of between 8 and 20 cm length (N = 124, mean standard length 14.7 cm) with a mean age of 1 year. The growth of young trout in Lake Titicaca is probably very similar.

It is known that after the first year, the growth of *Salmo gairdneri* can be very rapid in the sea or in large lakes. Laurent (1965) showed by marking that individuals released at a mean length of 16.6 cm grew by more than 18 cm and by more than 500 g in Lake Léman in 7 months. The mean surface water temperature In Lake Léman is 12.5°C, the same value as for Lake Titicaca. Thousands of marked rainbow trout with an average length of 21 cm were introduced into Lake Vättern (Sweden) between 1964 and 1968 and several hundred were recaptured. Their mean size reached 55 cm after two years spent in the lake, despite a long period of no growth in the winter (Grimås *et al.*, 1972a). The *Salmo gairdneri* in Lake Titicaca enjoy excellent living conditions (stable temperature at 11–14°C, well oxygenated water, abundant food, reduced competition), so their growth should be as rapid as the excellent condition of all the individuals captured would tend to indicate.

As far as food is concerned, rainbow trout living in the rivers feed especially on aquatic insects (62% in volume) and fish (14%). In the Peruvian part of the Lago Grande, individuals of less than 27 cm length (N = 207) fed especially on amphipods (62%), insects (18%) and fish (17%); those measuring beteen 27 and 46 cm (N = 122) mostly on fish (76%) of which a third were *Orestias ispi*, the rest not having been identified (Hanek, 1982). Our own observations in the Bolivian part of the lake show the same gradual change in diet in relation to two correlated factors: size and habitat. The stomachs of 13 trout measuring 195 to 323 mm taken near the shore, contained 61 *O. ispi*, 9 *Basilichthys bonariensis* about 10 cm long, numerous insects and a few amphipods and other crustaceans; in 9 trout measuring 317 to 558 mm taken in open water in depths exceeding 25 m, we found 219 *O. ispi* of 45 to 70 mm and 3 small *B. bonariensis*. It should be noted that benthic species of *Orestias* and those living amongst macrophytes were absent from all these stomach contents, although they are very abundant in or near the vegetation belt. These species of *Orestias* probably have time to hide among the aquatic vegetation which is too dense for trout to pursue them in.

In Lake Khara Kkota *Salmo gairdneri* of 15 to 20 cm (N = 35) feed on amphipods (66% by volume) and insects (27%); those of 30 to 45 cm (N = 16) on molluscs (76%), amphipods (14%) and a few fish (6%). In this lake the fish fauna is very poor, only one other species *O. polonorum* being present.

These results show that the rainbow trout feeds on all the organisms available near the bottom or in the water column in which it lives, but that the density of aquatic vegetation prevents it from exploiting the abundant benthic fish fauna.

The only fish species which is a potential predator of the trout is *Ba-*

silichthys bonariensis, but no trout have been recorded from the stomach contents of this fish, probably because the *Salmo gairdneri* living in the lake are too large. No cannibalism has been recorded either.

Improvement of the state of stocks

The most sensitive stage in the life cycle of *Salmo gairdneri* is that spent in the river during spawning and growth of the young. Although Lake Titicaca is very large, its five main inflows are of modest size. Four of these are in Peru, The Huancané, Ramis, Coata and Llave. The smallest of the five, the Río Suchez, has its source in Peru but its lower course is in Bolivia. All five flow into the Lago Grande.

The flow regime of these rivers is very irregular (Carmouze and Aquize Jaen, 1981). Although the maximum discharges in February and March range from 19 m^3/s for the Rio Suchez to 233 m^3/s for the Río Ramis, the dry season flows are very small. In June and July, the period of peak spawning, discharges vary from 3 to 4 m^3/s (Suchez) to about 20 m^3/s (Ramis). These are the discharges recorded at the river mouths, those of the tributaries making up the middle and upper reaches where the redds are built are obviously much lower. In addition, there are strong variations between years – in August 1965 for example the discharge of the Suchez fell to 0.65 m^3/s. It can therefore be seen that the available habitat at the time of spawning is very reduced, making capture of fish running up the rivers very easy, whether this be by dynamite, as has been reported by many authors (there are numerous mines established in the region and explosives are easy to come by), or even by hand, as has been recorded by Lauzanne and Franc in the inflow of Lake Khara Kkota. Chemical pollution from washing of mineral ores or clothing in the rivers is also probably occurs. River discharges only start to increase again in December, so that the habitat available to fish fry during their first months of life is very reduced and susceptible to many forms of degradation and pollution.

A proper protection of the main rivers, with in particular the prohibition of all forms of fishing within them, is therefore essential. Large channels to allow the passage of fish should be left permanently free in the areas of the lake near river mouths as long as the periods when fish run up the rivers and when the young descend are not well known. Once these measures have been taken and are respected, detailed monitoring of the fishing is needed. It is possible that the breeding stock is already too low in some rivers and that restocking in some way or other is needed. The best results seem to be obtained by releasing young trout about 20 cm long in the coastal areas of lakes (Grimås *et al.*, 1972b; Laurent, 1972).

Conclusions

There have been several vigorous attacks against the introduction of rainbow trout into Lake Titicaca, accusing it of seriously threatening the fauna of *Orestias* and for having been responsible for the disappearance of *O. cuvieri* (Vellard, 1963; Vilwock, 1962, 1975; Lillelund, 1975; various authors cited by Laba, 1979 and Laba himself). Vellard in particular, declared that: "soon they (the trout) will have brought about the destruction of the entire indigenous fauna of *Orestias* and of *souches*." (local name of *Trichomycterus rivulatus*).

As we have seen above, this opinion is entirely without foundation as far as the benthic and plant-dwelling species of *Orestias* are concerned, and particularly the main exploited species *O. agassii* (54% of the fishery yield according to Hanek, 1982).

The pelagic species *O. pentlandii* at present lives in the areas where *Salmo gairdneri* is rare or absent. The situation would not appear to have changed much since the observations of Vellard (1963) who wrote: "La boga (*O. pentlandii*) est aussi en voie d'extinction. Devenu à peu près introuvable dans la région de Puno et le Grand Lac, il existe en petites quantités près de Guaqui."

O. cuvieri can be considered as having disappeared since Vellard (1963) and Vilwock (1962) already stated that they had no longer encountered it, and it has not been captured during the numerous fish surveys carried out throughout the lake since the 1970s. From their morphology, the adults of this species were probably piscivorous and were therefore in direct competition with rainbow trout. Nothing is known, however, about the life habits of the young, the preferred habitats, the abundance of the species or even the date of its disappearance. It was seen for the last time with certainty in 1937 (Tchernavin, 1944). The hypothesis of *O. cuvieri* being eliminated by *S. gairdneri* can therefore neither be confirmed nor disproved.

The major problem which needs to be studied in detail at the present day is that of the impact of rainbow trout on populations of *O. ispi*. This species would appear to be very abundant at the moment, but the situation could change quickly with a predator as voracious as *S. gairdneri*, if effective measures for protecting the reproduction of this latter species led to a major increase in recruitment. It would however be fairly easy to redress the unbalance between predator and prey, by starting to fish again in the areas of the lake near to the mouths of the main inflow rivers.

As far as *Salmo gairdneri* and the populations of *Basilichthys bonariensis* are concerned, the two species do not seem to interfere with one another to any great extent and are complementary in terms of their resource utilisation in Lake Titicaca. The rainbow trout breeds and its young stages grow up in the river systems, whereas these stages occur mainly in the vegetation belt in the case of pejerrey. Once they have reached 15–20 cm both species inhabit the lake, but *B. bonariensis* lives much closer to the littoral in more

surface waters than *S. gairdneri*, which occupies the entire lake down to greater depths. The abundance of young pejerreys shows that the predation exerted on them by trout is not too serious under the present conditions.

Two points should however be studied: the relationships between the two species in the lower courses of the inflow rivers, and the methods to be used for stocking with young trout.

In the lower part of the rivers, young trout and small and medium-sized pejerreys occur together. The latter could well feed in part on the former. As regards stocking, the young trout introduced into the lake in the 1940s were not subject to any predation as far as is known. The situation changed however from 1955 when the lake was invaded by *Basilichthys bonariensis*. At the present day, it is possible that any young trout released into the lake would be immediately devoured by pejerreys of a greater size. Rather large trout therefore need to be used to stock the lake, so that they can escape predation from pejerreys, or fertilised eggs could be introduced into the gravel beds of the middle or upper reaches of the inflow rivers.

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C. DEJOUX and A. ILTIS / Editors

Lake Titicaca

A Synthesis of Limnological Knowledge

Kluwer Academic Publishers

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KLUWER ACADEMIC PUBLISHERS

DORDRECHT / BOSTON / LONDON

Library of Congress Cataloging-in-Publication Data

Lake Titicaca : a synthesis of limnological knowledge / edited by C.
Dejoux and A. Iltis.
p. cm. -- (Monographiae biologicae ; v. 68)
Includes indexes.
ISBN 0-7923-1663-0 (HB : alk. paper)
1. Limnology--Titicaca Lake (Peru and Bolivia) 2. Aquatic
resources--Titicaca Lake (Peru and Bolivia) I. Dejoux, Claude.
II. Iltis, A. III. Series.
QP1.P37 vol. 68
[QH128]
574 s--dc20
[574.5'26322'098412] 92-7958

ISBN 0-7923-1663-0

Published by Kluwer Academic Publishers,
P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

Kluwer Academic Publishers incorporates
the publishing programmes of
D. Reidel, Martinus Nijhoff, Dr W. Junk and MTP Press.

Sold and distributed in the U.S.A. and Canada
by Kluwer Academic Publishers,
101 Philip Drive, Norwell, MA 02061, U.S.A.

In all other countries, sold and distributed
by Kluwer Academic Publishers Group,
P.O. Box 322, 3300 AH Dordrecht, The Netherlands.

Printed on acid-free paper

Printed in the Netherlands