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ECOLOGICAL REVIEW OF

HYDROELECTRIC RESERVOIRS

IN PUERTO RICO.

William R. Jobin, Frederick F. Ferguson,

and Raymond Brown

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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POOLOGICAL REVIEW OF WrDROELEETRIC RESERVOTAS

1 PUERTO RIOD

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---Page Break---

smaary

A veview of published Literature and avatlable data on the ecology

of hydroelectric reservotre and other lakes in Puerto Rico, ytelded various

studies on unrelated elenents in the aquatic ecology, but very fev compre:

hensive investigations. The majority of the island-vide studtes pertained

fo surveys on snails related to the parasitic dis

bithareta, A survey

of 28 major lakes in 1976 showed that Btonphalaria glabrate had gradvally

been at

?laced from most of the lakes by Marisa cornuarietis and Tarebia

?xanifera, two foreign snatle vhich do not transmit bilhareia, Of the17

Jakes containing 3. glabrata in 1956, only 8 renained infested in 1966

and only 5 in 1976, twenty years after the introduction of Maries cornua~

is. Although the trend indicates that the lak

ay be safe fron trans~

fon a monitoring systen is necessary before the lakes could be used

for recreation.

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take this cooperative study,

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ECOLOGICAL REVIEW OF HYDROELECTRIC RESERVOIRS 1 PUERTO RICO

Willian R, Jobin, Frederick F. Ferguson

and Raymond A. Brom

1. INTRODUCTION

?An increase in construction of hydroelectric reservotrs has occurred

{nthe troptes and the large ecological changes caused by these reservoirs

have often affected the ecolosy of local populations, including increases

tn the parasitic at

Schietosonta

5 also known as bithersia. The

Anerensed trend in hydroelectric projects has been typified by the Aswan

Dan in Egypt, Kariba Dam on the Zambesi River and lake Volta in Chana (Table 1).

Recently, additional emphasis in Latin Anerica was outlined by Mr. Antonio

Ortts Mena, President of the Interanerican Bank on May 19, 1975 in Santo

Domingo:

zie sectoral distribution of the loans authorized in 197% reflected

@ trend determined by the vorld fuel and food ertets. Th

hydroelectric capacity and food production within

connected to the utilization of a coumon elenent essential to both secx

fors~water. For that reason, in financing projects and prograne of this

type, the Bank {8 particularly concerned vith promoting the fattonal ise

of Latin America's vast water resources,

The total of $384.1 méllion of the Bank's 1974 loan portfolto helped

increase pover production in the region, making electric power the pare

largest individual sector. Loans approved vere distributed as follove

$162.5 mtliton to help finance hydroelectric projecte that will prosste

Power development, irrigation and other farm inprovenent facilities ie

Costa Rica, Chile and Ecuador; $93 million to tncrease hydroelectric por

Eonttal, including rural electrification cooperative provtans in Angee

tina and Ecuador; $95 million tn binattonal credit to assist tn Cinencing the second stage of construction of the Salto crande plant on the Urusine River that vill supply onerzy to Uruguay and to the coastal provinces of

Argentina, and $33.6 million to build pover distrivution systens in Paraguay.

?These bring the cumlative value of loans granted {n this sector to $1,570 tition, Such resources are helping to finance the installation of 19-1 af llion kilowatts of power, of which 12.5 million kiloustea represent hydroelectric plants. Tie energy produced by these plants would require the consumption of 69 million barrels of oll @ year with a value equal to 3623 million. Authorized loans at

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rant 1

YDROELECTRIC RESERVOIRS WLIW POTENTIAL,

IMPACT OM NUMAN HEALTH AFRICA

lake Area

Country take Das tocation ilealth Problems When Full

in i? 4

Enypt Aswan on Wile Increased stthar= 5000 EleSayed 1

River ela dowetrean, ELxtoly,,

potential tn lake 1964.

Ethtopta Tana Condar on tue Ferguson, Rutz

Mile, 1970,

Chana, volta Akosonbo on Severe outbreak $500 Paperna, 1969

Volta River of Bilharzia on

be! Share,

Iwory Coast Kos Nandana Potenctal for 197%

bilharata,

Morocco tefttater 1972

Motanbique __Cabora Rossa Above Tete on 2700 1972

Zanbeot River,

Nigerta Kainji New Bossa on Bt lhareta 1300 Webbe, 1972

Niger River

Rhodonta MetIvaine Salisbury Barntsh and

shite, 1970

Sudan, Jebel Aultya on Wite 600 Abdet-Matek

Rosetres River wo 1972

Senna 200

Uganda Vietorta ovens Falla oachoceretasis addy, 1975

Zacbta Kariba on Zanbest, Bttharela 5250 tra, 1969

River ton on

Zanbian Shore.

Kafue Kafue 3100

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failes of transmission and dtateibutton Lines and t° improve dtstribue

tion systems tn 2,392 communities.?

Our purpose in this report 1s to review existing data on hydroelectric

Feservotrs in the tropics, espectally those in Puerto Rieo, to highlight

current problens and to identify fut

concerns, Our data frou Puerto Rico

derives from surveys on ecology of bitharsia and from records of Puerto Rican

Water Authorities.

|A, HYDROELECTRIC RESERVOIRS IW THE TROPICS

?The tropical region which has experienced the greatest problens with

bithareta in new hydroelectric impoundsents 1s Africa. (TABLE 1).The bLIhareia snails found most comonly in these African lakes have been of the genus Buli-?ua. Shallow papyrus swamps bordering Lake Victoria pose particular snatl con-trol problems. Sennar Reservoir has clear vara water vith adequate vegetation for support of Bulinus vitch was then regularly seeded into the Gertra Irriga-Hon District (Sharaf 21 Din,1955; Rahman and Sharaf E1 Din, 1961). AE Lake Kartba, the problens of massive floating fern, Salvinta auriculta, threatened ?navigation and was a sultable habitat for snatl vectors (Holm et al, 1969). Btharzta posed a threat at Stavonga, an area des{gnated for recreation and tourist development on Lake Kartba (iiira,1965). The Volta Reservotr hes a roving problen of urinary bithareia in fishing villages (Paperna, 1969).

?The same potential exists at Lake Nasser behind the Aswan Dan (Webbe, 1972).

The transmission of bithareia on these lakes is concentrated at local

watering points and village shores;

this simplifies control possibilities to

soue extent but leaves « clouded future because of the vast Lengths of shore=

Une in lakes such as Volta.

1m the Western Heaisphere the ecology of Blonphalasia glabrata has recei-

ved considerable study in the natural lak

of Venezuela and Brazil (table 2).

Im lake Valenciana near Maracay, Venezuela,

Alabrata 1s not comon although

there ta

?massive colonization of Biowhalarta prona, a laboratory host of

the schistosomes (Ferguson and Chrosetechowsk!, 1975). A conservatton program

---Page Break---

country

TaBuE 2

MAJOR RESERVOIRS IN LATUN AMERICA

WITH POTENTIAL HEALTH PRONLENS..

Reservoir Name and Purpose of

locality Reservoirs

Source of

Information

araztt

Domiatesn

Republic

Paraguay

Uruguay

Venezuela

Furnas in Minas Corals; tydroelecteic

Pamputha {x Delo Recreation

Horizonte, M.6.

Tres Yarias in 'N.c. lydroetectric

Jupfa-tiha Sotteira 4.6 Megawatt

Complex tm Sao Paulo iiydroeteetrie

Paulo Afonso on Sao 3.8 Megavatt

Praneteco River Hydroelectric

Taveras on Yaque det _iydroetectete

Norte River and (ertgation

Bao tn Ctbao Valley yeroelectete

Aearay Hydroelectric

Salto Crande Regtonat

Hydroelecerte

Valenciana in Yaracay) Natural

Dey E. Pautint

Des Es Pauling

De, B. Paulint

Interameriean

Development

Bank, 1975

rs, 1975

Speech by President

Joaquin Balaguer

wos, 1975

ws, 1975,

we, 1975

Dr. H. Ferrer Farta

??

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protects this lake from pollutton, The ecology of lake Paspulha at Belo

Hortzonte, Braz{l has been studled vith regard to posttble blologtcal

control of B. glabrata. In the Dominican Republic (tyes and Maldonado, 1969) there 4s spectal interest in the tw hydroelectric reservoirs under construction at Tavares and Ctbao. During the past decade, B. gla~

be

appeared to be absent from lakes of crater origia in Grenada},

Montserrate, St. Kitts* and St. Vincent? cures

Reservoir hag been free of B. glabrata in mmerous surveys of St, Croix waterbodies since 19535, ?The mumicipal water supply reservoir of St. Kitts contained B. glabrata prior to molluseieidal elimination durtng 1958 (Sebastian et al., 1960). Several similar units in Crenada lacked the bitharstal snail during 1970 studies but contained large populations of 3, stranines (Ferguson and Buclire, 1974) which is a natural host for achistosones in parte of Brazil

and has proven to be a potential host in Grenada (Richards 1973).

Bopservations of F.F, Ferguson and K.W. Buckmire;

46.8. Richards; 5scotchman; author's observations

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B, General Heology of Lakes In Puerto Rico

In Puerto Rteo there are 28 reservoirs which vere constructed during 1913-1975 (Figure 2). Seventeen of these impoundnents presently provide hydroelectrte pover (Table 3 and Figure 3), and some ecological information 1 available for each take, generally rulated to the studies on bilharsia.

There are no natural lakes in Puerto Rico, excopt for the brackish

Angoons of San Jose, Torrecillas, Pinon

sand the fresh vater Lagoons of Castegena and Tortuguero (Reyes de Ruiz; 1971; Cendelas and Candelas, 1964; Marry end Aldrich, 1958; Harry and Cumbie, 1956). In addition to the major lakes there are many snall ?epoundments constructed for agricultural and ftahing purposes, More than 800 standard USDA-SCS fara ponds are situated 1m the drought-prone central portion of the sland. About 30 untte have

been surveyed for 2. glabrata, and although the snail ves found in about

hal? of the ponds, they are not usually important transmission atte

bitharet

for

Spectally constructed night-storage ponds are used on the South

coast for irrigation and 8. glabrata hi

been controlled in 100 of these

Ponds using Marisa cornuarietis (Rutz Tibeh et al, 1969). Tn comparing

?ecology of such small inpoundnents with large man-made reservotra, extrs

polations of ecological parameters must be nade with caution.

Te ts tmportant to undera

nd why bilharzia snails are present oF

?absent from watersheds contributory to hydroelectric impowdaents, but

Perusal of more than 300 titles of various reports on freshevater bodies

tn Puerto Rico indtcates that ecological considerations affecting molluscan

tbe ha

been neglected (Cordero, 1969; Bogart et al, 1964). The most rele-

vant reports

fe the study on lacustrine plankton (Candelas and Candelas,

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o Rice

eu

ON of Lakes mw

FIGURE 2

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Saga ge ow as pee i ar

sae x ?

(ace 5 wv

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WALSAS Y3MOd 91NL9F1FONGAH ONY

NOLLVOINY! ASTIVA S¥PV1 4O ONIMVYG SILVW3HOS

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1964) and that on hydrography of schistosoats

's (Crooks, 1967). other

reports make general references to richness of the aquatic biota inclu=

Ging tnsects (Garcia, 1938; Klots, 1932; Martorell, 1945; Woleott, 1948), birds (Biaggi, 1970; Danforth, 1925; Leopold, 1963) and fish (Erdman, 1972; and Ferguson, 1975). Terrestrial plants have been vell studied

(Odum and Pigeon, 1970; Britten and Hilson, 1930; De Otero et al, 1945;

vel

sz and Van Overbeek, 1950; Little and Wadsworth, 1964), and much te

known about aquatic and semi-aquatic plants (Pratt, 1947, 1948; Reyes de

Rutz, 1971). Both verre

trial snails (Aguayo, 1961, 1966; Van der Schalee,

1948) and freshwater snails have received definitive study (Abbott, 1952;

Baker, 1945; Ferguson, 195% Ferguson and Gerhardt, 195

Ferguson and

Richa

1963; Harry and Hubendich, 1964; ilubendich, 1955; PARO=i0, 196:

Reyes de Ruiz, 1971; Richarda, 1965; Richards, 1964; Richards and Ferguson,

1962; Watlington, 1955).

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table &

(ING OF HYDROELECTRIC RESERVOIRS IN PUERTO RICO BY POWER PRODUCTION

Fover Production Present Volume in Length of Shoreline

?Kilowatts illon cubse Kilometers

Yahueca: 1.60 7

cuayo 20,000 161 228

Prieto 0:60 4.0

?oro Diversion to Prieto 0.12 2.0

Lechates 14.65 21.2

Dot Bocas 18,000 39.47

Ceont tas 17,600 60.46

Cerzas 12,240 5.80

Macrutlas 8,640 3.58

Carraizo 2,600 24.67

Gutnes 1,920 222

Rio Blanco

loco 0.79 68

Jordan Diverston to Caonitlas

Adjuntas 0.57

Pellejas ous

vive 0.36

16

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TT. IMPACT OF RESERVOIRS ON BILHARZIA SKALLS

In an attempt to

sess the role of the major reservoirs in transmission

of bilharzia, a complete survey vas made of all lakes on the island between

July 1975 and June 1976, tm cooperation vith the Department of Health. A five

?man crew with @ boat inspected the

satire shoreline of eact lake and identified

all Live anatla, In addition water samples were taken at ecch tributary and tn

the main body of the lake near the dam. The

wmples were avalyzed by standard

methods (APHA, 1973).

?The survey showed that only 5 lakes contained Hlonghalaria glabrata, vhile

18 Lakes harbored Marisa cornuarietis and 14 lakes contained

eb

grani fers

(Table 5). Four other species of aquatic snails vere scattered throughout the

lakes but in such fewer mmbers than the firet 3 species mentioned. Seven of

the lakes harbored floating water hyacinth and generally Large anounts of vege~

tation, but the other 23 had rather sparse quantities of vegetation.

Although the lakes had fairly high curbidity and color, only 7 of chen had

signi fteant Leve:

of phosphates, indicative of sevage pollution or eutrophication

(table 6).

A, Previous Snail Surveys

Tm previous studi

only nominal attention vas paid to the presence of B. gla

in reservoirs during 1952-1954 (larry and Cumbie, 195

Harry and Aldrich,

1958; Marry et al, 1957; Pimentel and vhite, 1957, 19594, 1959). Cursory searches

of Lakes Guajata:

Guineo, Dos Bocas, Patillas, Guayabal and Coamo at a few poin-

te failed to locate B. glabrata during 1952-1954. In order to clearly define the

presence or absence of the anail in all r

srvolrs, a comprehensive survey was

completed during 1956-58, A two-man team valked accessible shorelines and used a

uv

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TABLES MAJOR LAKES OF PUERTO RICO

SNAILS AND VEGETATION, 1976

Lake Water General

No. Name Bgt Me Tg Pa Ph Ly Tr Hyacinth Vegetation

1 : x - Sparse

2 = - Sparse

3 carite xX x - Sparse

4 Carraizo x x x Abundant,

5 - Sparse

6 = = x x Moderate

7 x Abundant

8 - x x x x x Moderate

9 > x x x Moderate

10 Ko ox Xx x Moderate

n Xie xi ax x - Sparse

12 Cuajataca = XX x: Sparse

13 Cusyabal = XX xO

14 Guayo > ox 5 Sparse

15 Cuneo > Xx x x ot

1 Jordan SX :

17 waPlate 2x x x Moderate

18 tas curtas = xx : Sparse

19 oeo letras -

20 © Wuchetta «= XX x

2) Mateullas = x : Sparse

2 0 Patillas, = xx : Sparse

2 Pellejas = :

% Prieto =x : sperse

25 Rio Blanco - :

2% Toa Vaca = XX x: Sparse

27 Toro =

28 © tortugero KX x x

2 vive : x

30 Yahuecas =

+ bg Btocphalarie glabrata

Me= Marten coruactetts

vin grant fers

Pas Fonaces australis

Phe Physe 9p.

tym Lamnaes sp.

Te

?Tes Tropteorbis ap.

18

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boat to survey the remainder of the shores in all unite, Prom thie firat {sland-vide survey it was determined that 17 of the Lakes contained populations of B. glabrata (Table 7).

The use of chemical solluscicides for snail control vas avoided for

the

Lakes because many of then also

eve aa drinking water supplies,

Thus attenpts were made, beginning in 1958 to enploy Yarisa cormuartetis

a0 a competitor or predator snail and thus reduce the populations of 3,

alabrata. In addition observations were nade on the encroachment of ano=

ther suspected conpetitor snail, Tarebia granifera (Ferguson, 1973; Fer-

suson, 1975). Marisa cornuartetis vas hand scattered in batch

of 50 or

ore at several points along the shore of each lake from 1958 to 1961.

The concurrent spread of Tarebia granifera was apparently dua to natural

agents uch as birds, Several other apecias of enatle were seen tn th

Feservoirs during this time in much gnaller nusbers, including Physa cu-

bensis, Helisous sp., Ferriset

sp., and Aupullarta or Zomaces, an a}

Fent foreign import (Watlington, 1955).

?Ten years after the initial island-wide survey, a second similar study

vas completed on all the lakes, a

in searching all the shorelines and lis~

ting the

esence or absence of B. glabrata, Marien cormuartetis and Zarebia

granifera,the three most coumon and profuse species. Due to the introduction

of

cormuarietie, this snail vas stable

4 15 of the lakes by 1966,

while 3. glabrata vas found in only 8 (Table 7).

Biologteal control of Btonphalaria glabrata by Mar!

dynamic proce

cormuartette ts a

» Hot an absolute change. Snails are thought to be carried

about on the muddy feet of birds and cattle, and the reservoirs

re continually

ecoming reinfested by natural meana from upstream colonies. Great losses of

a

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?snails occur with constantly shitting water levels, determined hy hydroelec-

erie power generation and irrigation usage, as well as drewdoms for urban

water supply. However the stranding does not necessarily eliminate all che

snails and they soon repopulate the habitat if conditions are favorable,

Thus the 20 year record of snatl populations, concluding with the ftnal com

prehensive survey in 1976, 18 a sumation of the biological interaction of

these snail speci

in response to the dynante nature of the lake habitate,

and the vartous means of reintroduction of the snails, By 1976 the balance

hhad shifted tn favor of M. corpusrtetis which was found tn 21 lakes, often

in very large mumbers (Table 7). At the sane tine B. glabrata was present

only in 5 lakes and in 3 of these, less than 100 snails were found after

several days of searching by a 5 nan crew (Tables 7 and 8).

Im studies on small ponda,

comusrtetie has often eliminated dartatn

types of vegetation due to the large number of snatle which ha covetapp,

However im these large lakes, although Martsa cormuarietis consumes some.of

of the types of aquatic vegetation which shelter and feed Sionphalarte glabra-

8) tn general te hy

hhad no pronounced effect on weeds {nthe lakes during

the 20 years observation. As in previous studies on farm ponda, the instances

im which Bicaphalaria glabrate and Mariea cormuartetis co-exist over a long

Period of tine are those vaterbodies which contain large quantities of vagetar

ton. This is confimed by the observations froa the Lakes tn 1976 (table 5 and

5). Te lakes harboring both spectes either had large masses of floating water

hyacinth of high Levels of nutrients which indicate extensive algae growths.

Fecal Contamination of Lake

It should be emphasized that snails infected vith the bitharsia parasite

?have been collected from only one lake, at two different sites on Lake Carraizo

au

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TABLES ANALYSIS OF PRESENCE OF STOMPRALARTA GIABRATA

AND MARISA CORNUARTETTS IN NAJOR RESERVOTIS OF PUERTO RICO, 1956-1976.

DMosphalacte glabrata Marte cormuartecte

ReseavorR 557-61 1962-66-19 BIS T9A2-GE 1076 succes

ee ae

2Cecntiis + + pee + te

Scartte $+ + + FF m + ye

Scarrateo fT + + fo wm Pf

Cartagena + ND - mi fF +

te Soe + Pe

+ > om ff 7

Comeeto #1 XDD MD

Comerio #2 XD XD NDS m +

bos'tecas) FS ee Pot

ok a tot

12 Guajataca + XD 2 fee Ss as

13 Cuayabat? ? ¢D > > fom om lt

16 cuaye ? © bof top PF

15 culms wD - 2 2 om wm ¢

16 Jorden xDD m 2 2 & wm Ft

Vita Plate 9D ND m > @ mm =

18 tas certs SY ee Pt we

19 toca + ee Pot oe

2tochetet + xD tt tof oye

2 Macrutias ND > ff mlm

wraciiies ee) oes Pt ve

Brellee Dm mw > fom

24 Pre a a a

25 Mo Starco xD Dm

26 Toa Vaca XD ND ND SOND

27 Toro > ow > wm om Fe

25 Tortusero ND ~ + PF wm Ff fw

2 viet om ? > » » m -

30 Yahuecas x= Epon suey + sve

Present/ VAs 57 S/S 280/25 12/13 15/17 21/28??«12/17

surveyed

= Snails absent

+ Snatis present

ND No data

2

---Page Break---

wear Yairoa and near San Antonio. At present this lake {8 probably the grea

feet potential hazard in terms of btthareia transmission since it receives

ve Capuas Treatment Plant and from several other co-

sevaye discharges feom #

wmunictes (n che watershed, In addition there are potential problens from the

Villalba sevage discharge into Lake Cusyabal, the Utuado sevage discharge into

Jake Dos Yocas, sewage from Conerio whlch enters the two Comerio reservetre wd sewage from che Cuavate prison colony which enters Lake Carite, There have also been many infected snails collected in the Jayuya river below the town,

and there is a possibility that these snails could be carried into Lake Caont lta

Thus the absence of the host snail from most of these reservoirs is e gocd indi-

cation thar the Lakes could eventually be developed for recreation, but careful

nonttoring will be required to make sure that the small and sporadic populations

of B. glabrata which appear in the lakes are not carrying the bilharzia infection.

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APPENDEX

Pigures 7-31. Maps and photos of Lakes in alphabetteal order.

Tables AL A30, Data Record of water quality samples from lakes in

alphabetical order 1975 - 1976.

SPANISH TERAINOLOGY

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Ruta = Route

Carretera = Highway

Entrada = Entrance

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Figure 7. Yap of lake Adjuntas

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Figure 15. Map of Geraas Lake

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Pigure 16. Map of Lake Cuajataca

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Figure 17. Map of Lake Cuayabal

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Figure 18, Map of Lake Cuayo

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Figure 24, Map of Lake Macrullas

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Figure 25, Map of Lake Patilles

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Figure 26.

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Figure 27. Map of Lake Prieto

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LAGO TORO

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Figure 29, Map of take Toro

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Figure 30, Map of Lake Vivi

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LAGO YAHUECAS

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Figure 31. Map of Lake Yahuecas

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