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Februay 1979

STRATEGIES FOR BILHARZIA CONTROL

1 PUERTO RICO, 1978

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(rue Maria Nanvio

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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STRATEGIES FoR BILIARZTA CONTROL TH

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coparea Hegtghts Station

Puerto Rico 00935

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Strategies for Bilhareta Control in Puerto Rico

Secaure of the relatively high coats of current nethode for

determine che optinun strategies and combination of methods, usta

Puerto Rico

4 cane study. The control methods evaluat

chemotherapy, email control and satercupcion of water contact by

proviss

for safe water, The parameter used to measure effectiveness

Of the control effort was the calculated decrease $\{x$ number of

intestinal worms in the endemic area

multiplied by the number of years

?Over which these worms were eliminated

This parameter, worm-years

?4 probably proportional to the amount of disease $\{n$ an individual,

?The analysis of four strategies (or the endemic zone of Puerto Rico

showed that an annual budget of US \$1,500,000 would best be spent

Primarily on chemotherapy, with secondary allocations for snail control

and water supply, Dependence on chemotherapy would be much more costly

?effective than the present straveuy in Puerto Rico which Ls based on

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ACKNONE rDeWENTS,

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1633.

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Temowecrion

1, Simple ways are needed co

sist in choosing between alternate

serateaten of bilnerata control viteh include various coubinattons of

?control methods, Most of the field studies conducted on bitharsta

control have evaluated the cost and effectiveness of one control method

under a single prescribed level of treatment, it has thus been

satisfactorily established that several methods

have been determined, Unfortunately the costs are generally 40

MURAs that one cannot expect to apply the methods to every

infected person in an endemic area, Consequently

therefore

4 to evaluate the cost and effectiveness of judicious

combinations of th at degrees oF Levels below couplace

Uraatnent of che endemic zone, For example ££ Lt {8 too expensive to
sive oxamniouine, che nev single-dose drug to all infected people in an

endente area, the cos

effectiveness should be evaluated for treating

?only infected children or only tnfecte excretion

rates, Another possibility ts Co evaluate the cont-effectivenees of

wcictding 75% of che snail nabicats and giving chenotherapy to the
29% ont heavily infected people, compared with mollesctetding 25% of the
nail nabicats and treatiog the 75% wort heavily tafected persons.

Before attempting field studies to compare various Levels and

expenses

© conduct, should be made to determine the amount of expensive

and Long range field studies required, This report presents the necessary

theoretical analyses for Puerto Rico as a basis for planning such operational

and activities,

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The methodology is simple; calculations can be performed with a

simple hand calculator and mathematical procedures involved are limited

The amount of data involved in &

single case study 49 analyses

ing Ledger.

vues, thus they can easily be done

11 be recorded on one terse page fom « Bookk

A computer was not seeded £08 th

by most technical personal in the headquarters of « bitharsia control

of control evaluated by this theoretical approuch ware

the drug omanatquine, snail control by ditching end bayluscide and

provision of water supply with adequate health education to interrupt

The parameter used to measure effectiveness of control was the

calculated decrease

by the number of years over which they were eliminated

To be more precise, effectiveness in a theoretical community was calculated

in terms of the reduction in area under the worm population curve during

after initiation of control, assuming a stable, equilibrium

worm population at the start of control (Figure 0)

What is somewhat arbitrary the use of "number of worm-years prevented?"

ves an improve neat over the ure of the ausber of infections prevented in

?persons since St included 4 seasure of the intensity of the infeettons.

Recent unpub Lint ndteated thar ene

nd communications from Bs Ps

parameter was proportionsl to che severity of 4

ne, thus Ae use to

easure effectiveness is probably 4 rough cuantitative neanure of the

fount of disease prevented. Woru-years of tnfecion Ls also probably

?proportional to the sunber of achatonones esas embedied {n an infected

| thus proportional to the Damage caused by the Infection.

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NUMBER OF SCHISTOSOME WORMS IN A COMMUNITY

AFTER INITIATION OF CONTROL

NUMBER OF WORMS IN THOUSANDS

YEARS OF CONTROL EFFORT

Figure 2

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THE TWO METHODS FOR CALCULATING NUMBER OF SCHISTOSOME WORMS

A simple control scheme was developed (0 or 1)

scheme was used in which worn deaths were subtracted from the estimate

of transmission. The assumptions used in the calculation scheme were:

half-life of 5 e0 6 years,

?0 cercarial population and this in the number of new worms

from 1 to 10 without affecting the comparative effectiveness

of the control strategies evaluated.

?4. Normal populations are strongly clumped in people so single-ex infections are neglected.

rate of worms in a single transient

reductions in acquisition of new worms,

---Page Break---

?Based on the above

Assumption, the following rationale was used in

estimating the yearly changes in the worm population. The reduction in worms was due to natural death at the rate of 10K per year, and deaths

?

0 drugs at the expected mortality rate of the drug, assuming 4

clumped distribution of worms in pear

Worm deaths due to death of

4m the number of worms were due to transmission which occurred

only in areas outside of « designated email control zone, The pre-control

transmission rate was equal to the pre-control death rate of the worm

(20%), assuming « stable worm population, During control efforts the

original transmission rate was reduced

result of the taproved water

supply by 0.9, a

to reduction in water contact and by the proportion of

people

led with piped vater. Ay the total worm population decreas

?the tranuniseton rate alan decres

ed in direct proportion, due to loved

sniractdtal and cercarial populations.

The number of vorns killed by drugs was $E \times W$ where E was the drug

?efftetency (proportional reduction {n worm population in treated comunity)

and W van che minber of worms in the treaced people, the W wan calculated

from the number of infected people given the drug, assuming the clumped
distribution of worms, The initial clumped worm burden was assumed to
exist in people until the entire population was treated, then a new uniform
worm distribution was calculated for subsequent cycles of treatment, These
calculations were carried out separately for the zone with sand control

and for 1

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The initial worm population in the endemic zone of Puerto Rico was

estimated from data supplied by the USPHS-CDT from the study in

which were indicated as follows

6 worms per gram of

feces of infected persons (COC Hansen Report 1975 page 8). It was

arbitrarily assumed that this corresponds to a mean worm load of 3

?or pairs per infected person, an equivalent of 1 egg per person per worm,

?This assumption agrees with autopsy data from Brazil (Cheever, 1968).

?Since 189,000 infected people thus harbored 6 worms each, the number of
seventy-nine worms in Puerto Rico before starting the control program was
1,134,000, and it was assumed that 752 (142,000 people) were in the endemic

?area (Figure 2). More recent estimates give a turnover of infected

People in

?The conclusions are not sensitive to small changes in population sizes,

to Rico but the example reported here was not changed since

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{TTT, REGIMEN FOR APPLICATION OF VARIOUS cowToL, ETHODS

The control methods a

janeg 19 eK anelyeia are well known bet the

concept of reduced Levels or degrees of control te sonevhat new and {x

deca

?herein. Snatl control vas assumed to be based on the technique

?currently ured in Puerto Rico of ditching and drainage to atrintse the

?mount of snail habitat then application of Bayluscide to the renaining

luabteate at a Level of treatment adequate to interrupt transnteston, end

wae of Sological control afterwards, in those habitate where {ç (a

?ettictent. Although reduced Levels of treatuent were not considered far

rol, in some cases the budget restraints required that only

portion of the endemic areas could be placed under snail control, The

average amount of snail habitat in the endemic areas in Puerto Rico is

about 700 cubic meters per square kilometer and the annual rainfall is
about 2 meters in the endemic zone (Figure 3), At a revised 1976 cost
of US \$46 per 100 cubic meters, \$100,000 per year would be adequate to
control only 925 square kilometers of endemic areas (Table 1). From
these figures reductions in budgets for snail control were calculated in
terms of reduced areas in which snails were kept at minimal levels,

The chemotherapy analyzed was

on the use of oxymetazoline

stonevhat arbitrary drug prices, since the market price Ls not yet established.

ceaveny of welective trestnent was evaluated vherein « quantitative
stool exam is made on the entire population and only the persons with the
heaviest infections are treated. Diagnosis coat US §1 per parson in 1976

prices and treatment was assumed to cont US°F10 per person treated. An

effectiveness of 90% wae asuned for oxanniquine trettment meaning then

Un of the worms were killed tn a population, Af avery person was treated,

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a

Stee the majority of achistosone vorms in Puerto Rico appear to be
found ts

4 small proportion of

needed people selective chemotherapy

should

subtle convective (Figure 4). The same clumping of worms

has been demonstrated for other rodent areas. (Lehman et al., 1976).

?Although other possible approaches to reduced chemotherapy have been

1d dosages of treatment of certain

groups, only

The approach of treating the most heavily infected people was analysed

herein, The proportion of infected people to be treated depended on

budget constraints. A budget ratio

2:1 for expenditures for diagnosis:

Treatment was followed initially in these analyses, and as the prevalence

decreased, excess

funds occurred in the drug treatment budget. These

excess funds were then diverted to the diagnosis budget, Keeping the total

for chemotherapy constant,

Water supply is quite expensive and for practical reasons this analysis

assumed an even pace of construction the fleet few years. reaching 4 stable

umber of persons served when the

ation and maintenance coats aonauned

entire annus budget. øc

5 Flguren for water supply were taken from

anneal reporte of the aqueduct and sever

hority which serves both rurel

?and urban populations(Table 2). Since ite creation in 1945 the Puerto Rico

Sever Authority has constructed potable water systems which

cost \$450 million dollars and which serve 2.04 million people as of 1976

(Annual Report 1977, ASA). This includes all costs of a system which

provides chemical treatment (filtration, chlorination and fluoridation to

water supplying 11 urban areas. and partial treatment to water serving many

rural areas. The construction cost of \$180 per capita is thus much higher than

needed to simply prevent bilharzias, which can be accomplished by avoiding

the use of contaminated

surface water. Additional treatment gives protection

against typhoid and diarrheal diseases as well,

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name 2

(OTS OF ORETRUCTION, OPERATION AND MAINTENANCE POR
?PUERTO RICO AQUEDOCT AND SHER AUTHORITY AS OF
1m 30, 1977, FIOM STATISTICAL REPORT OF ASA, 1977.

ater Sewage Comes

1m Srply ?Diaporat Yee lie

?_?

construction cont of facilities in service \$438,269,867 \$191.714.540 \$26,571,536

?nanual operation Costs 1.46896 2.609.040

?Anoua Maintenance Comes 0,549,930 6,876,470

?ecsons Served 2,899,476 1,496,287

?

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»

DISTRIBUTION OF SCHISTOSOME WORM POPULATION AMONG
INFECTED PEOPLE FROM SOQUERON, PUERTO RICO, 1972
CALCULATED FROM DATA SUPPLIED BY E. RUIZ?TIBEN,
SAN JUAN LABORATORIES, USPHS- coc.

Zw

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3 rencenrase

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10% _

: 20% oe

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. ton oon

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: fox sox

3 vox %

PERCENTAGE OF INFECTED PERSONS

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?

?the Baral Aqueduct program in Puerto Rico was budgeted separately and sore closely approximates the type of system which would be sufftetent to elistnace previous dependece on polluted surtace waters, Construction conte by 1950 averaged \$14 per capita, by 1960 they were \$30 per capita and by 1966 4 toca of \$39 million hed been invented to aerve 836,000

people 4 mean construction cont

499 per person (Cuma, 1966), Te

?rine tn cost over the 20 yours reported was due co inflation and alto because the easteat ayutens were constructed first, leaving difficult eyrtene serving only & fev people to be goustructed dering the Latter years, Even this lover construction cost-encinated \$50 per capita by 1976 ean only be partially charged againat biiharsia control, operation and maintenance costs for 1976 vere \$22 million for the

2.04 million people served oF \$8 pe ct

ta per year (Annual Report ASA 1977).

Again his cove was for operating « fully developed

sn water supply

yrcent. far beyond the needs for bitherala control. The overall vater consumption figure for both urban and rural systems was 47 cuble meters

per family per month by 1976, oF 990 Liters per capita per day (Stattetical Report by the Rxecutive Director, July 1977 ASA). This is much greater han the anoune required for effective bilharata control in \$ç: tects etch was about 50 liters par person (Ouran, 1975). Thus tone than 5/39,

?of the conte should be charged to bitharsia control, about 15%,

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as

Since the provision of piped water has many benefits in addition to prevention of sehistosont

2, only part of the conta were attributed £0

the control program, Thut che construction cont used in these analyses ves U5 \$10 per capita and operation and maintenance cost vas \$1 per capita per year, The seceseary oust of health education was assumed to be netuded tn the annual \$1 per capita cont.

?he thie Level of expenditures 1 was assumed that the water systems

?vere highly effective and reduced 90% of the water contact and thus 90

cof transmission. Sanitary disposal of excreta by constrvction of latrines

or septic tanks was not avalusted here atnce Lt appears co be relatively

tnetteceive (Dhajen et al, 1978).

These strategies evaluated included 4 different budget schedules where

11 5 control methods were used simultaneously, but with 4 different

strategies compared, concentrating 80% of the money on each method in

turn, and also dividing the money equally between the three methods

(table 2). The results then show that the expenditure was divided into 2 parts,

one with snail control and one without. In the area with snail control

transmission was completely interrupted but in the area without it,

transmission was only decreased by provision of water supply in proportion

to the number of people served and the 90% reduction in chloroform water

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TABLE 3, DISTRIBUTION OF FUNDS ON VARIOUS STRATEGIES IN COMBINATION.

Sanitation Water

sanitation » REY See Bee

Drugs . 1% 10%

Snails a 10% on 10%

Water e 2% at oo

vattons > 33.8 33.9 3M

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EVALUATION OF SEVERAL STRATECICS Fo! vuEHTO RICO

son was made of several alternate ecratestes for ittares

conttel So Puerto Hes 4

4 aamutl bedget of US £1 per capiss tm the

eodesie tone IIE peteer, » cotal ef £1,509, Pande vere

beted ans the three control methods, either expla

ro (Steeteey BY, er water evspty wie! eeith

wéeeetton (Stratery ?), bet aluave inciutin, all 3 nethads ie soue deszes

oustly among the three methose. (Stratesy DY.

dn stinate of bth

hor apecstoup cerrerpords elsaly te prevalence deserrined by five fold

Prevalence cone al ages, doving there sears. Ths the water of

sons in Pocrto Rico wat estinated at $0.07 \times 2,700,000$ or

1e wee arhitrartiy

ined that about 752 of the infected persons

vente monies pets

: and a total variation of 1.5 million, Thus the mean prevalence rate of

in the endemic zone was 9.4. for 1969, The distribution of

: the number of worm loads among these infected people was assumed to follow

in the endemic community of Boqueron in Us Fiséres (Figure 4),

Obviously all of them have

changed by an or

of magnitude, the conclusions of this comparative

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w

The following scenarios were used in visualizing the xeropaphte

lovertapping of the three contro! sethots. Chenotherapy would be organized to cover the entire endenie sone fe cycles whose period war inversely

proportional to the chenotherapy bedget, Ter a

tay program budget of

41 por capita or \$1,300,000 deters and allocating 10: for chesotherapy

with o ratio of expenditures of 2:1 for dtarnosts

treateent, this allow

tor \$100,000 per year for dingnosis and \$50,000 for trestnent (Table 4).

?thos 100,000 people would be examined each year at U5 \$1 per capita and

9,400 would be found postin

?At a cost of \$10 per person treated, only

5,000 of 53% would be treated, The following year « new group of 100,000 would be examined, and the 53% most heavily infected of that group would be treated, This procedure would reach 97% of the worms in the population of 9,400 infected people diagnosed each year and would cover the entire population in 15 years.

?at \$1 per capita and allocating 80% of the budget for chemotherapy

\$900,000 would be available for diagnosis, then the entire population would

be examined every 2 years, Similarly with 33% of the budget on chemotherapy, \$933,000 would be available for diagnosis

requiring 5 years to complete

4 treatment cycles throughout the endemic zone,

snail control costs at \$420 per square kilometer would require

4564 000 per year to completely control the andente sone, F6

10

cenphasis on mottunetes

?only \$150,000 would

aiatiabte, thes there

?would be snail controt in 27% of the endeaie rone (400,000 people). Tor

0% eophest on snail controt (1,200,000 would be available, more then

necessary to cover the endente sone, Tn this case the excess funds

would be diverted to the chenotherapy buiget (\$636,000), aTioving # total

?of \$786,000 for chesotherapy and \$364,000 for snail control. For the

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?ASLE 4, YIROT YEAR DUCED ALLOCATION FOR OCHTORCGENCASTS COMO.

?Dr FUEEZD AICO MINH A TOTAL AMAL, BiDoeT OF UG 41 Fan

PERGOH 1H TH HOM TORE, OR UE \$1,500, 000, 1976 PRICES

(oreamaay 2).

?2oe___

8 Dingnosis Treataent sat. ater

Drugs = 1A \$800,000 \$400,000 \$150,000 \$150,000

Snatis~ 1B 524,000 262,000 s6h,000 350,000

Water = 1 100,000 50,000 150,000 3,200,000

Unitom = 3D 333,000 167,000 500,000 500,000

---Page Break---

balanced strategy about \$500,000 would be available for onatl control,

Just enough fo cover the endenic sone,

tn Strategy B when the surplus anatl control funds were diverted to

chemotherapy, « total of \$524,000 would

available each year for

agnorsa, exantatng the entire population in 3 years, According to this

bodeet

aves (\$1,500,000) the tatttal buiget distribution was caleslated (Table 0),

Jaertbuton system and allocating \$1 for each person tn che endente

?om this beste dteteibution, slight adjustnents were made for cases where
che bodget allocated to a certain nethod excended the amount needed for
that method (Tables 4 and 5).

vor the water supply program, construction would be evenly distributed

ehroughout the

Jee tone outside of the snail control aren, when the

?entire cadente sone was covered by snail control, water ruppy bad very
eete noticeable effect, This occurred for Strategies Baand D.

she water supply program vould Snclude both construction and the annual

cost of operation, maintenance and health education. The first year all

the funds would be used for construction but as more units were added the

operational cost would increase until all funds were used for operation.

The eventual, stable number of persons supplied with piped water was

calculated by assuming 411 funds were used (for operations maintenance and

health education, for each of the strategies (Table 5. In 1970 only 10%

of the population in Puerto Rico did not have piped water, thus the total

population to be served in the endemic zone (if we ignore changes occurring

from 1970 to 1976) was 150,000. Reduction in water contact due to this

water supply program is thus the fraction of this 150,000 that is supplied

with piped water (Table 9)

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oravoonx uzrvat axy sAMCLUETYH *NOLIVESIO HMA YAIAYD Ya OTG \$0 MEIK S100

NoLzOMIEEIO

ammssy ?siadns WAnyn cata 40 NOIStACAK OX ann JOVNOD WAIVR KI NOLNGRE @ zIEVE

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TABLE 6, SAMPLE CALCULATIONS FOR MODEL RAPRASING SNAIL CONTROL

(RSTORATED AS STRATEGY 18

See

?Saath control budget = \$564,000 covers entire andamic tone, thus no new
nfections after first year+

Matar avpply budget = \$130,000

Chemotherapy: Raminacion budget = \$524,000

Treatment budget = \$262,000

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vont omn2 wees ean

SOO"

{= NOG OF WOR DEATRS DUE To ORUC PROGUA

Prevalence {n examined pop, 0.096

People examined 326,000 %°824,000 596,000 524,000

Cumulative people examined 524,000 1,048,000 1,500,000

Infected peopte locates 49,000

Mean vorm load in infected

?peor 60

Worms located 296,000

People treated 26,000

Pepe int pente/ereateg

Prop. worms treated 0.97

ore created 287.000

Worm killed by drug (90%) 258000 258.000 258,000 258,000

59,000 28,000

238,000 258,000

120,000 100,000 (0)

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vu weak 2 mR aR

at ~ saree surety

ignore)

1v = mREvalENCE RATE

Initial intected perso 141,000 118,000 95,000 72,000

Number persons treated 26,000 28,000 26,000 25,000

Munber cured 23,000 23,000 23,000 22,000

?stores treated but mot K{lled (30,000 worms Left each year).

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?A eacood set of stracegien was evaluated, based on an annual bedset
fof \$750,000 which wae the actual 1976 expenditure of the Health Department
on schistovontania control, This represents an annual expense of \$0.50
per perton in the endente sone, Tunds vere agate allocated according to
four poratble alternatives, sophastaing either druge, snail control, oF
?acer supply or elae a balanced division of the fends between the chree

setnode (table 2).

Spending \$1 per capita annually

serately sephartzing the use of

drugs was clearly more effective than the other three strategies (Figure 3).

Preliminary calculations showed that this was true for many other endemic

diseases as well, such as St. Lucia, Brazil, Egypt, and Tanzania. A second

set of strategies utilizing the smaller annual budget also demonstrated

the advantage of implementing chemotherapy, and snail control again ranked

second (Figure 6). A balanced approach was the Least cost-effective of

the four strategies evaluated.

A more precise evaluation of cost-effectiveness was made by calculating

the proportion cost per reduction (worm-years during the first four years

of control and dividing by the total four-year budget, again demonstrating

the ranking of drugs, snail control, water supply and a balanced program,

in that order (Table 8). Preliminary calculations for other endemic areas

showed that the cost-effectiveness (increased with increased worm burden

as one would expect. Thus priority for international programs should be

given to areas with high worm-burdens, such as northeastern Brazil or the

Mile River valley.

A reduced budget of \$0.50 per person was evaluated for Puerto Rico

and no advantage was indicated by the cost-effectiveness analysis, in

face 1¢ wan nore conteattective to ute che higher budget (Table 8).

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{ASLE 7, FIRST YEAR MIDOHT ALO:ANTON FoR SCIZETOSAKIASIS CONTRO:

Er soso nico FIVH A OTA? ARWAL MIDGED OP US \$0.50 FER

PIRSOW 18 TE HOBUE Oe, OR \$750, 000 FER YEAR, 1976

maaces (ensaronr 2).

Methods of

se a ata Sontne ater,

Drugs = 2& \$400,000 § 200,000 \$75,000 \$75,000

smite - 25 © TH,000? 57,000, 561,000 75,000

ater = 20 59,000 25,000, 75,000 600,000

Vattora - 2 167,000 63,000 250,000 250,000,

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PREDICTED EFFECTIVENESS OF SCHISTOSOMIASIS CONTROL IN

PUERTO RICO WITH AN ANNUAL BUDGET OF § 1,500,000

Nuaen OF scnisTosoMe woRME in THOUSANOS

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Fame 6

PREDICTED EFFECTIVENESS OF SCHISTOSOMIASIS CONTROL
IN PUERTO RICO WITH AN ANNUAL BUDGET OF \$750,000

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TABLE 8. COMPARISON OF COST-EFFECTIVENESS FOR SEVERAL STRATEGIES

(OF SCHIBROOOUASTS CONTROL IN PUERTO RICO, 1976 COSTS).

Cost per Yorn

Control Stestecy _-?Effeottvness in wiiton Years, Prevented

?Bepaste ors YearePrevented 1976 US § per Norm-Year

?Totes Basges for

years Srutliton

rugs - 14 238 \$252

us 3.05

eter = 10 18 3.6

Balanced = 1D 132 3.93

?Total Budget for &

years #3 milton

Drige 2 1.60 35

santas = 28 0.8 4.69

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Sow uss

A compariaon of

al posible strategies for bithersta control

4% Puerto Rico shoved that enphesis on the nev drug oxamtguine would

bbe much more

-effective chan continued efforts vith the prasent

strateny eaphasiaing snail control, The analysis

eo indented hat

intensive program of « fev years duration wuld

ram of low sntenetey,

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fansoni in a rural community in northeastern Brazil.

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