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?AN ECOSYSTEMS FRAMEWORK FOR ENERGY-RELATED.

ENVIRONMENTAL RESEARCH PLANNING IN PUERTO RICO

by

?Michael A. Chertock

May 1980

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§ 3 CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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Mayaguez, Puerto Rico 00708

1.0. Introduction

1.1 context

?This report sumarizes one systems ecology approach to develop a strategic energy-related environmental rescarch planning capability for tho Center for Energy and Environnent Research, University of Puerto Rico. The Center is one of the principal energy and environment research ams of the Puerto Rico Commonwealth goverment and conducts research for the federal governsent. The near term and long term research plans and approaches for the Center are important for an adequately informed government to respond to the serious energy challenges that Puerto Rico addresses. This report describes one conceptual basis for gathering critical informa tion needed to examine energy related environmental probless of the near future. It is a document that describes the challenges to the Puerto Rico Island System, and outlines a framework for developing a general strategy for addressing societies environent-related information needs.

4.2 organization and objectives

This report firet briefly provides an overview of selected char~ acteristics of the man-nature island system. Tt then describes one basis for developing research priorities, and an approach for predicting large scale system changes. The last two sections sunmarize potential Puerto

Rico environmental consequences. In the conclusion, the paper describes how shifts in potential pollutants provide an example to inform planning and research priorities.

"pormanent address:

Department of Zoology and Science and Public Policy Program
University of oklahoma

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Oak Ridge Associated Universities, Oak Ridge, Tennessee

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1.3 Approach and Limitations

systens ecology onphasizes the behavior of indicators of total system function and stresses the interrelationships among component parts. ?This paper places enghasis on energy flows and materials cycles in the inked natural and man-dominated Puerto Rico ecosysten. In part it asounss that understanding or predicting changes in the hierarchical structure of systens components provides a basis for energy and envizon~

ental re

woh planning. sy incluaing both technological or harduare components and institutional or social components, research plans can provide the basis for gathering information that affects the future behavior of the Commonveslth and its natural environment.

[A systems approach has the capability to include 6 ful) range of natural and social components and processes. This paper only sumarizes several types of interrelationships as examples. While a systems approach ?can suffer from substituting an understandable model for the complexity of a poorly understood and unpredictable reality, it offers a rational franework to predict, plan, and evaluate policy. ?This paper is also briefs it describes selected major assumptions and a general framework for developing eh planning and management to the future tangible problems that Puerto Rico will face.

2.0 The Coupled Man-Nature Island system

2.1 Bierarchical structure

fa research plan. Its purpose is Limited, however, to tying re

systems have a hierarchical arrangement of parts that structure
the flow of energy and channel the cycle of materials. This sturcture is
maintained and developed by renewable and/or exhaustable sources of energy.
?the temporal ?progran" of these energy sources control the size, distri-
bution and flows among component parts. For example,
vided for the Sispersed, pre-Columbian economy. The use of horses, oxen
land human labor energized Puerto Rico's dispersed agricultural economy,
peior to the 20th Century. Wood, water power and coal provided a more
industrial society during the early part of the 20th Century contributing
to fixed transportation paths ané strong central cities. Liguid and

?gaseous fuels account for the mobile and energy intensive Puerto Rican

solar energy pro-

society of today, nore dispersed along the coastal zone.

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?These major periods of energy use are summarized in Table 1,
Four general periods are indicated along with summary reference to transportation, urbanization and environnental change, These data provide a broad picture and are intended only to indicate the major transitions that occurred at the termination of the pre-Columbian era, about the davn of the 20th Century and during the post world war 12 periods when Puerto Rico experienced dramatic changes in the form and intensity of energy use. Figure 1 chows some of the patterns of hunan settlenent during these periods of enersy use. (Department of Natural Resources, 1977).

With any large scale energy flow soving in one Airection, a counter flow of energy in the opposite direction exists that exerts a feedback control (Odun and Odua, 1976). Consumers control the flow of enersy to their hones with overt decisions supplying in the opposite Girection to energy, a controlling flow of money. ?The Commonwealth and federal government control energy flow with purchases, taxation, regulation and other policies. the form, distribution, and activity of flows upeards through the hierarchy of Puerto Rico and the countercurrent control flows are diagraned in Figure 2. As indicated in the figure, all energy flow is ultimately dispersed as heat, although enersy may be stored for varying periods of time.

Most energy incorporated in ecosystems, moves along paths of materials flows, and ali materials flows contain some energy. The paths of

energy movement in a complex ecosysten intersect at structures where changes in form of quality occur. AS energy noves upwards, the pover to control increases along with its quality or ability to influence other Flows. Materials in turn are frequently concentrated in these process

steps. For exampl

fon the social level some wealth in most societies tends to concentrate anong the fev people in the controlling sectors of

the economy. Recognizing this problem, the government of Puerto Rico Anstitot

sone economic redistribution policies to achieve its socially Qesirable goals of enhanced equity anong citizens. In an analogous process as cities becone larger, pollutants also tend to concentrate in centers With high rates of energy input secondary industries develop in close conjunction with pri-

of activity, such as, San Juan, Ponce and Pefvel:

nary industry contributing to socially desirable economic development,

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behavior. Technolosios are guserally Aestend to increase the power (energy flow/unit time) und stability of the system or subsystem, For cxample, wiguepread veo OF automobile ?rantortation in Puerto Rico Generally increases the effoctivences and rowsr of those riding fa then land the corporations selling them, (This mutualistic situation is hose

Rogus in ecosysten developnent to exyotent ial increases in dorestic ani«

mals following the pre-Colunbian cra). he U.S. Pnvircnnental Protection

Agency (EPA) has controlled auronohtle onissicns so that people can continue

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(2) star cf coeponents, Arewralation as a haraxa may take Rony

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wnchanges or deamarieatly hice,

Thermal pollution say obiminats some specter, Eat tonal system respiration

and production may incruase, cresting 2 ncze rowerful developmental stey

(cdun, 1974), for oxunpte."

2.4 Values ang Syotens Functicn

cloncíess, sonagers, and lay perrone establish values as a par

ef their activitios co make operational Judgement or to evaluate the gu

ty of the environment and sveten funstion. Then values

?take several

generat forms. Deviation af change from 2 steady crate cnr be established

[as one value. Chars may not agree taat a stoady state exists and eel.

?that the composition of cities, forse

lakes, streams

ands has beer continually changing. Some heliove that # steady state

exists, = ound which @ pattern or

random fluctuation occure. Ta part this apparent probabilistic behavior

As due to the couplexity at all levele ef eystens structure (Kowal, 1971).

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?The relative edventage of thie dovalonmantal step je Aapondont on a range

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Vi tha senge 02 gcortensation 48 acceratble

by tracing the effwors of sew enersy s:veces,

2.0. Criteria fer Developing Research Frisrivies

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ties will be Largely influenced

by the industrial character and to: 4

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Pucrto Aico, the valiies and norms tha: influence the dizection ef policy,

and the scientific basis for accurave and effective ducisions, Pach of

these criterin ix Hikely te change, Scveras apsrowches axe possible in

attempting to develop an «

changes: (1) develop a resyoncive process oriented research framework

that is Flexible; (2) develop a syerer thet identities alternative Likely futures; and (3) identify critical existing problens and issues and associated uncursainvicr snd areas ners new information would have an effective payoff.

Sone combination of the above ox related approaches can be wreful.

The development of = ef

?sive antictpatery or predictive systes for

Puerto Rico can provide one ration

approach, ?This approach vould exe

amine critical alters

suiting factors oF forcing functions

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cxarining alternative farure-, the ressarch agenda is nog Tetked on a

echnical fix, wut can provide infcrmation about & range of ciotces oF

3.1 Alsernacive Fu

Ef an effective reveareh pl

Likely future, onty Limited zesearch ani Geveloument would acod to be

undertaken. The cor

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sumption that We now know ne ie bighly uncertain.

?he uncertainty of even Mietorie accounts provides suport for this. %

syatens approach infoune U5, towrwer, th

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and perish, but that nageituse and cou tr

rowslts in a persistence

of aystens behavior patter

Because the future de also highly uncertain, an effective rescareh

plan must be informed on the basis of alternetive futures ang their im

plications on human health and enviroorentai

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yality. A research planning

strategy is ured here to meun the ve aoployeent of Linited racearch

Resources in @ nonncr shot yxevisee an unterecanaing of che sajor risks

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or careers to the cinological

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change and identifies courses of niticating action. This stratesy must

?take into account the magnitude of risks within alcernative futures, and

prepares a consempora Jeercs infre.cruciure te mest the challenges

of the cosine decades.

WhSie alternative futures are affected by a wide range of policies

oth within the Conmonmesith, tho netic and in other countries, this

poper rests primarily on the concept that the form of society and nacural

systems is largely affected ty enersy pottey and othor resource Linteing

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factors. ficwever, for Puurio Kino, the Vinkage ?etween trade, Growth,

?energy and environment ace veitival because of Jue ingular yet interde-

pangont natura.

2.2 rodiesing systems Changes

Several critical factors inflcence and maintain the organizacion

of mecural systens, The most critica? s or driving ore

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Lopletod syetem (the boerdarios of a aystan se defines For conventence

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and for effective policy cevelojment} except that social and

technical controls primarily ar imlinentes as Bounded by Cornonweaith

Peinteipal forcing fu

rng in Pusrte Rico are the avediaaic

unergy sources and ?he ogutpment and van uateriais which act ase gate te

use these energy souress. So many secrces are now thperted, that én

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of the Puerto Rican cabeyrtom within the wore. An cbvous exenple,

petrolout entively inported, and a> petroleum supplies a

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minished, they will act ay a Zorsing function coqaieing policy and tu

nological change in power cararation. By systonatically examining the

future availability oz energy sources and suiting factors, a generat

understanding of alternative futures can snfold

3.3. Potential Flvctsazions

A range of possible alternative futnees existe, based on potentiat

Future "ériving forsee". Ae diasroned &

cgure 2, these future pat

basically include -ontinued oxpenontiat seowen, sigmesd growth, fluctusting growth, and qrosth ang ascey, Homsver, ar indicated Sn section 2.4, it is Sifesoult to distinguish mali scale cacterns of Fluctuations to leryer

patterns of steady-state, growth or decay

Tn fact, frequently steady

states are maintained through *puisss". (osm, 2871). TH

88 pulsos

apply short texm bursts of rower, ané may be ruquired for systems function,

?Thus a system may not bo able to apply continuing high cates of eneray use

to maintain conplenity without periods of decay as wastes accumslate, par

wear ovt or congestion occurs. Svssequent periods of reduced power output

functionaMy represent timas in which the ?katteries" are recha-ged (ca~

pital accumilates) or wastes are disposed, so to speak. For Puerto Rico

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ations, policy te fouguer kosis of whether

or not rates chango: fee of casing" or "écorcueing".

Thus xeseare® and oot

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Vorae in potsed systens, doepite che reek toss she quslaty of the

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pave Matted cole putves, and policies ave often implenantead to

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cupraas them.

4.0 Consnquances fou the Faviroment

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Puerts Rica and the rasulesnt systom attributus ave described in Table 2,

?Thess selected cparucturistice are size, noxee, hunan values, and onntrol.

ovhere parimevers could be incluted, These caransters were chosen te

emphasize the underlying velationshins totween foreine fmevions and is

portant charaoterictice ist vay affece cuviscnvental research and do~

cision making. The actus? eining as to when seo of tes

chazacterietice

say predominate tn part is Copantect on the use and flow of information

about the sycten. Ruv{scusentsl rersazen tues ea anticipate chee problens,
and the widespread antictystion of those <turacteriaties ean result in
earlier policy afjuetionts oF envivoarentsl controls, Environmental atti
tudes and values are 1ikely to cone into adjustment with the foreing fune~

?ions at cone time, however.

None suppression or sulsos 1 partly aye 0 ure oF near Ferm Antormation rather
than data relating to long tern stnrslity or erowth of the total system.
This points to the Limizutions of any comprononsively rational straregy:
or plan. Facause the system structure is continually changing, either
over the ehort of lang term in respons te fossing funetions of long tem
internal change, # cotelly conprchensive ungezstanding of research stra~
tegies Le not poessble. Jt se difrleule co evaluate merits of policies
within systen, since che aysten structure le wedi fied when policies

aro in place. it shoulé 29 noted, houever, that often tundencier to sta

balize a fluctuating systom are one part of the controls that enhance

Yong term growth and output.

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4.2. Pollution piste

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quently & key factor, growth tendy to Formly in rotation to

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Aseeribution comes close to that of oncrsy availazility. as modified by

eportaticn cechadlouy and overt policy decisions. Ths combination of

Federal and Conon

th polietse for sromth have Sevelopad incentives to

y and people in Pusrto Rico. an as

jerlying Factor is also

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environment, ané the changes in

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Patterns that relate to the distripution of resources an? assinil

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capacity of the euvizonnent can provide = poliey basis that recognizes the

natural capacity of the environment to 6

arse pollutants at low cesource

cost oF Limited change in the hi

chy of system structure

4.3. Pottution sources

The criteria for evaluating environmental policies

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4.4 Pavironnental Escorageneity

As tochnolory develops, vantret loses bezone mare extensive.

However, the controls can be Suplenented veing ystems performance a8 a

principle criteria, fysceme performance criteria reccgnize heturoveneity

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milative capacity of respective goosraphic axsas: in some locations re
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concentrated in landfille, systomc partornancy elz0 recomnize the eyelic

nature of envircnmental :xoee:

Ses, and recounizos @ifforent tine Franes
Scelination periods, seasons, auotogical time and evolutionary time, ete.).

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5.0 Environvental kesvareh tians

5.1) Planning for Pactuzas of Chinas

Alternative forcing functions and the development of the Common wealth social and envirvowntal eyetom can be used to predict shifts in major economic sectors and sources of ?soniduale? (pollutants). Table 2 illustrates sone of these shifts. It Indies!

5. fer example, that cone

Einued system develornent typically roves toward areacer complexity and

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associated vith the clectruries in action may 4e-

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5.2 eveloping @ Fracnans Aye

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tive cnersy resource development policy say be a basis fer

maximizing environmental yeotaction with Limites reseacch sumport.

?The examples discussed in thi

paper are exploratory, and are in

tended to indicate tie qualitative application of thie approach ce environ=

mental research planning. Purthes quantitative develounent

f this approach

would permit and svaluation of sors utalled svsunrtions, ané an elaboracion

of the research consequences for orviconmencal protection in specific social

sectors and natural environsents under alternative con@itic

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