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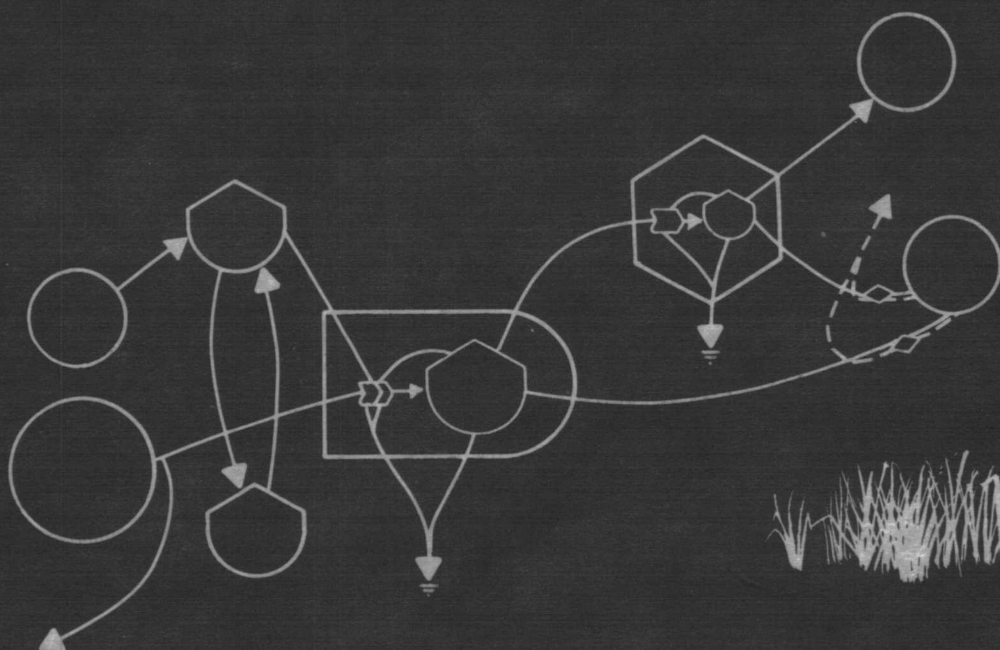

ECOLOGICAL MODELS OF THE MISSISSIPPI DELTAIC PLAIN REGION:

Data Collection and Presentation

Fish and Wildlife Service Minerals Management Service
U.S. Department of the Interior

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ECOLOGICAL MODELS OF THE MISSISSIPPI DELTAIC PLAIN REGION: DATA COLLECTION AND PRESENTATION

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DISCLAIMER

The opinions, findings, conclusions, or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the Division of Biological Services, Fish and Wildlife Service, U. S. Department of the Interior.

Library of Congress Card Number: 83-600527

This report should be cited as:

Costanza, R., C. Neill, S. G. Leibowitz, J. R. Fruci, L. M. Bahr, Jr., and J. W. Day, Jr. 1983. Ecological models of the Mississippi Deltaic Plain Region: data collection and presentation. U. S. Fish and Wildlife Service, Division of Biological Services, Washington, D. C. FWS/OBS-82/68. 342 pp.

PREFACE

The purpose of this technical report is to compile existing information about the biology, hydrology, geology, and socioeconomics of the Mississippi Deltaic Plain Region (MDPR) in a quantitative framework that will both characterize the region and provide a data base for future ecological models. The habitats modeled are aggregated from those previously identified in the MDPR by Wicker et al. (1980b) according to the classifification system of Cowardin et al. (1979) (see Table 3).

Detailed descriptions of the biological, physical, and socioeconomic interconnections within this coastal ecosystem allow coastal managers and decision makers to better assess the impacts of human activity on the region's natural resources. It is hoped that future modeling attempts based on the data collected in this report will help predict human impacts on coastal ecosystems and aid in the arduous task of assessing tradeoffs between nonrenewable resource development and renewable resource preservation.

This technical report was designed to supplement the companion narrative description of the Mississippi Deltaic Plain Region as the final products in the Mississippi Deltaic Plain Region Characterization Study. Together these two volumes provide both general descriptions and detailed data on the region.

Any questions or comments about or requests for this publication should be directed to:

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ACKNOWLEDGMENTS

The authors thank the following researchers at the Louisiana State University (LSU) Center for Wetland Resources, who provided data and guidance during this project: S. E. Bayley, W. H. Conner, R. DeLaune, D. Fuller, J. G. Gosselink, B. Johnson, I. Mendelssohn, C. Sasser, F. Sklar, and R. E. Turner.

In addition, D. Culpepper, R. Lean, P. Mather, and D. Wilson from LSU and K. Limburg from the University of Florida provided invaluable aid in literature review, data coding and entry. J. Bagur, E. Coleman, and J. Donley from LSU, and G. Farris and R. Smith from Fish and Wildlife Service (FWS) assisted in editing. K. Westphal patiently and carefully drafted the figures with the help of D. Baker, C. Duran, and P. Gremillion. Typing was done by B. Grayson, J. P. Lantier, and C. McLean from LSU and E. Krebs from FWS. S. Lauritzen of FWS handled overall layout and preparation of the manuscript for printing.

We gratefully acknowledge the expertise of Kate Benkert, whose diligent reviews of the manuscript greatly improved the quality of the report.

K. Adams, R. Ader, N. Benson, and W. Kitchens of FWS contributed to the conceptualization and data analysis phases of the report.

We also thank G. Auble, S. Batie, W. Boynton, M. Brinson, J. Browder, D. Dow, R. Fluck, M. Gilliland, B. Hannon, W. Mitsch, D. Mulholland, H. T. Odum, B. Patten, D. Pimentel, D. Rapport, P. Risser, W. Rudd, W. Schlesinger, L. Schwartz, D. Swaney, and J. Zucchetto for their review comments.

This study (FWS contract 14-16-0009-80-073) was conducted in cooperation with Minerals Management Service. Contracting Officer's Authorized Representative was R. Rogers, Minerals Management Service, P. O. Box 7944, Metairie, Louisiana 70010.

INTRODUCTION

Increasing human pressure on coastal ecological resources has resulted in the need for a more thorough understanding of ecosystem interrelationships. The ultimate management goal is a comprehensive understanding of coastal systems and the ability to utilize and preserve coastal ecological resources more effectively. Effective management depends upon knowledge of functional interdependencies, both within coastal ecological systems and between human and natural systems. This report attempts to document the current level of knowledge of ecological interdependencies in the Mississippi Deltaic Plain Region (MDPR) of coastal Louisiana and Mississippi.

BACKGROUND

The National Coastal Ecosystems Team of the U.S. Fish and Wildlife Service, Department of the Interior has produced several ecological studies concerning aspects of the Mississippi Deltaic Plain Region (Larson et al. 1980; Wicker 1980). This group has also completed ecological characterizations and syntheses of other coastal regions (e.g., Gosselink et al. 1979; Procter et al. 1980). This report is a portion of the characterization and synthesis of the MDPR. The overall intent of the Fish and Wildlife Service project is to summarize and synthesize all relevant existing information on the coastal ecological systems of the regions under study. This report contains the technical narrative and data presentation of the MDPR study. A companion nontechnical narrative is published separately.

PURPOSES OF THE TECHNICAL REPORT

The purpose of the overall project is to develop ecosystem models and a narrative report summarizing existing data for the MDPR. In a form useful to scientists and coastal managers, it integrates information on the ecology, hydrology, climatology, and socioeconomics of the 20 ecological and economic habitats and 7 hydrologic units into which the MDPR has been divided.

DESCRIPTION OF THE STUDY AREA

The Mississippi Deltaic Plain Region of the Louisiana and Mississippi coastal zones consists of the broad area that includes the largest active delta system in North America. The region's dynamic nature, acknowledged biological productivity, and intense level of economic activity have combined to create resource management problems of enormous magnitude.

Figure 1 shows the geographical limits of the study area, which consists of the following hydrologic units: I-Mississippi Sound, II-Pontchartrain, III-Mississippi River Delta, IV-Barataria, V-Terrebonne, VI-Atchafalaya, and VII-Vermilion. The study area extends from the western side of Vermilion Bay in Louisiana to the Mississippi-Alabama state line. The inland boundary is determined by the Coastal Zone Management boundary in Louisiana and the 15-foot contour in Mississippi. The offshore boundary is the three mile limit.

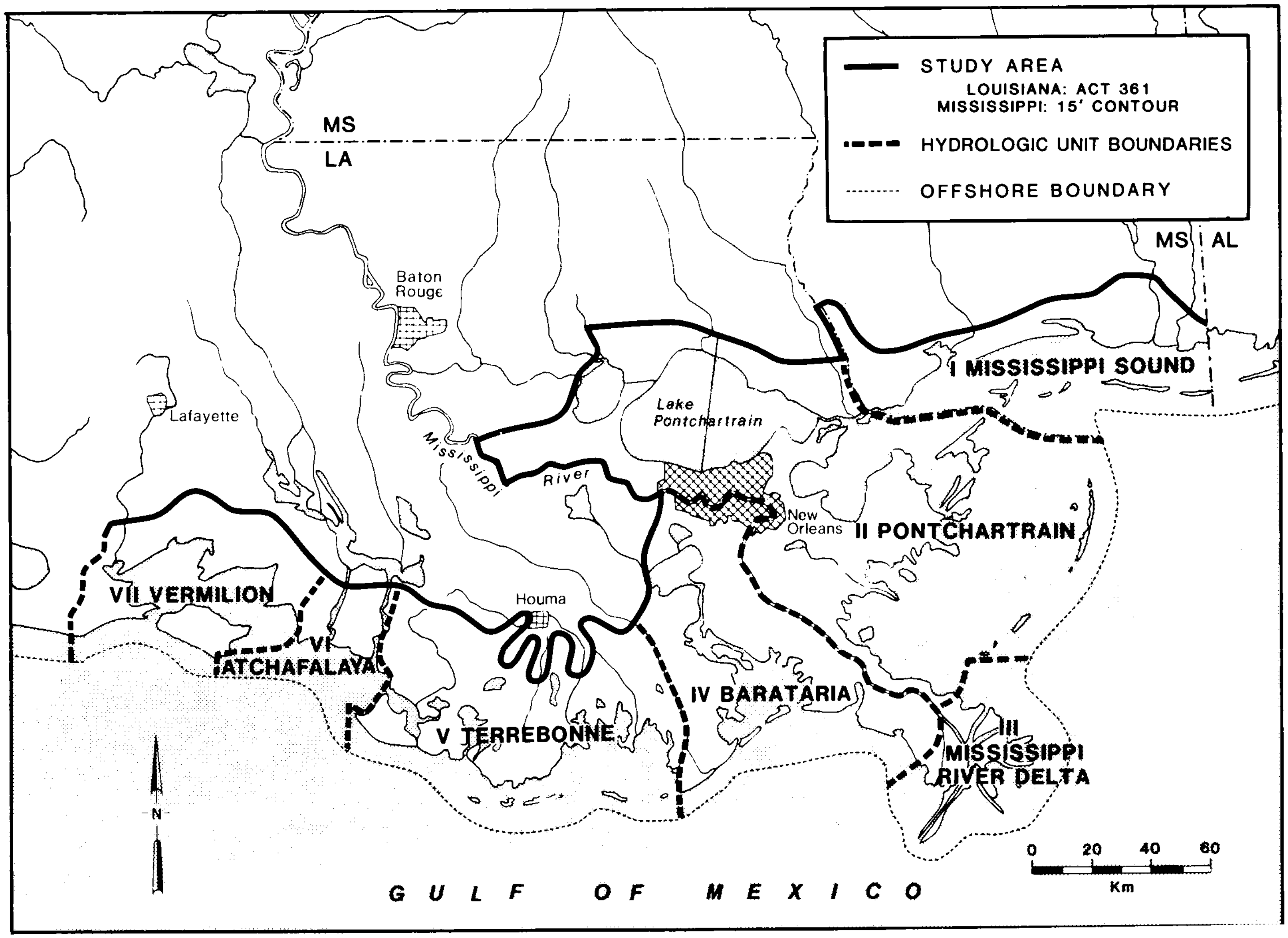


Figure 1. Map of the Mississippi Deltaic Plain region.

The hydrologic units employed in this study are the coastal portions of their respective drainage basins. The complete drainage basins sometimes extend far inland from the politically determined coastal zone boundary that forms the inland boundary of the study area. For example, the drainage basin for the Mississippi River Delta hydrologic unit (III) and the Atchafalaya hydrologic unit (VI) is the entire midsection of the North American continent. The other five drainage basins are more coastal in nature, but all are affected in important ways by upstream influences inland of the coastal zone boundary.

METHODS

GENERAL APPROACH

A general framework for ecological data was constructed for this technical report to summarize existing information, direct the emphasis of the narrative report, and point out areas in need of further research. The framework categorizes information according to its functional significance and serves as a compendium of data and as a "model" of the structure of the ecosystems involved. The framework is hierarchical, as data at various levels of space and time resolution can be conveniently and efficiently stored and collected, and is open ended so that additional data can be added as they become available.

As shown in Figure 2, the three levels considered in order of increasing size are habitats, hydrologic units, and the entire MDPR. These levels are hierarchical, in that the habitats make up the hydrologic units and the hydrologic units form the MDPR. For the purposes of this study, 20 habitat types have been defined. The 20 types are aggregations of the more than 100 habitat types that have been mapped in the MDPR (Wicker et al. 1980b) using the Cowardin et al. (1979) classification system. The region is divided into seven hydrologic units (Figure 1), each of which has a characteristic habitat distribution that is determined by both external influences and internal interactions among the habitats.

The emphasis of this technical report is on the habitats, both because they are the building blocks for the higher levels in the hierarchy and because the majority of the existing relevant data have been collected at this level of resolution. Eight of the 20 habitats identified have been studied sufficiently to allow detailed quantification, with these eight making up more than 90% of the total land area of the MDPR.

MODELING LANGUAGES AND APPROACHES

To meet the objectives of this technical portion of the study, two intertranslatable systems description formats were employed:

(1) the flow diagram language of H. T. Odum (1971), called "energy circuit language," which has been widely used in other ecological characterization studies,

(2) input-output matrices, which are used by some ecological systems modelers and are often employed in economic-ecologic analyses (i.e., Isard 1972).

These particular formats were chosen partially because of the uses to which the completed (i.e., mathematically formulated and manipulated) ecological models based on them can be put. These uses include the estimation of the direct and indirect impacts of human activities on the ecological systems of the MDPR as a basis for management. It is important to note that this technical report includes only the data collection phase of the modeling study, and the models presented here are purely descriptive. The potential analytical uses of the models are, however, a major justification for undertaking this data collection effort (see "Other Potential Uses of Input-Output Data").

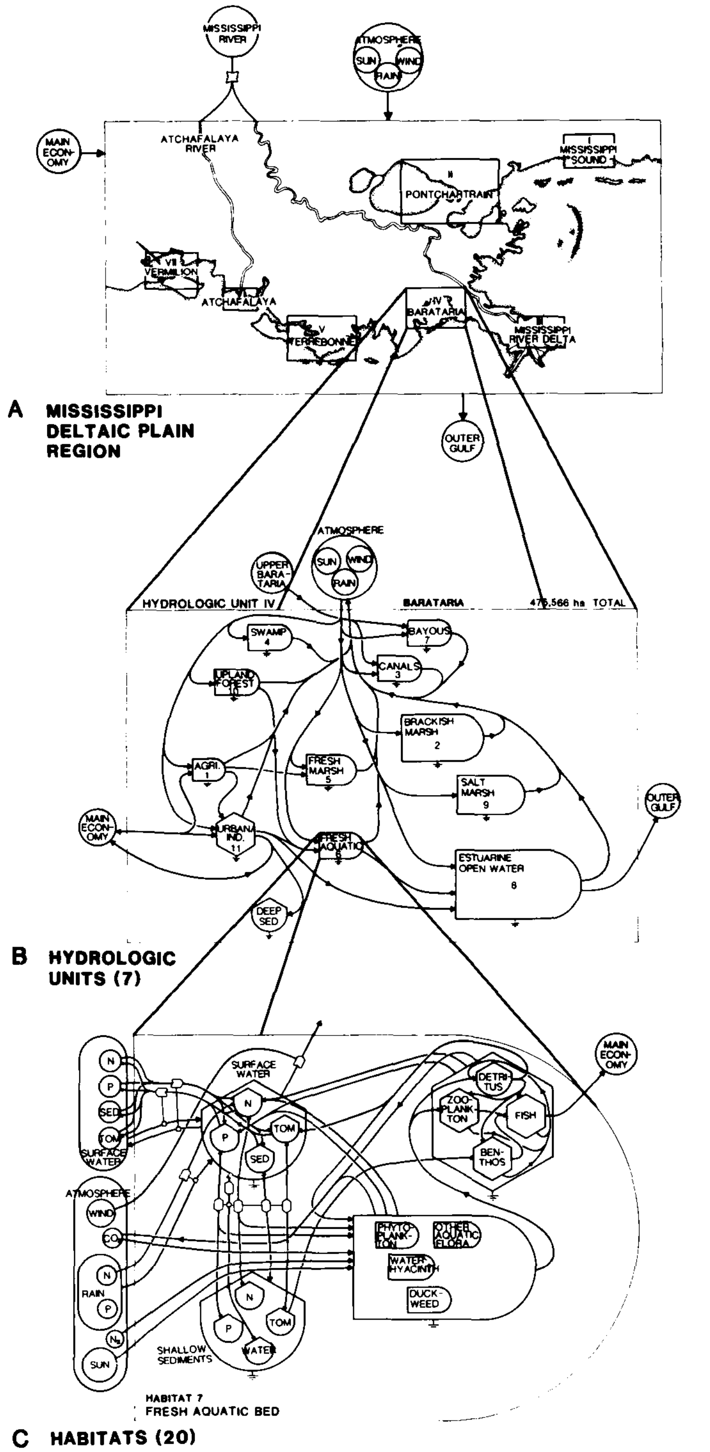


Figure 2. Hierarchical structure of the models.

ENERGY CIRCUIT LANGUAGE

This diagrammatic language was developed by H. T. Odum (1971, 1972) specifically for ecological modeling applications, but with an eye toward general applicability. The main features that differentiate it from other types of flow diagrams (i.e., Forrester 1968) are (1) it attempts to explicitly indicate thermodynamic constraints; and (2) it has a relatively large vocabulary of symbols, each of which has an implicit mathematical meaning. This allows a conversion of the diagram into sets of equations suitable for computer simulation.

Figure 3 shows the symbols used in the models in this report. Lines between symbols represent flows of material, energy, or information. H. T. Odum (1971, 1972) and Odum and Odum (1976) contain more complete descriptions. The following symbols are used in this study:

(1) Source or sink of material, energy, or information from outside the system boundary. Sources are called "exogenous variables" or "forcing functions" in modeling terminology. Sources can be of several types. Constant flow sources (such as sunlight) provide material or energy at constant rates set exogenously (from outside the system). Constant force sources provide an exogenously set force, but the flow rate may be affected by internal components. Mathematically, sources are exogenous functions and can take any form. Frequently this form is a time series function measured or projected for the system of interest.

(2) Storage or stock of material, information, or energy. Storages are also called "state variables." The level of all the storages in a system can be thought of as indicating the state of the system at a point in time. The first and second laws of thermodynamics are embodied in this symbol and its attendant mathematics. The first law requires conservation of matter and energy; thus the sum of all the inflows to a storage is equal to the sum of the outflows plus any change in the level of storage. This is the mathematical basis for the description of system dynamics. In describing a system, one can write a differential equation for each storage in the system. For the single storage shown in Figure 3, one would write:

$$dQ/dt = J_{in} - J_{out} - kQ \qquad (1)$$

where Q = the level of the storage; dQ/dt = the rate of change of the level, Q; J_{in} = inflows; J_{out} = outflows; and k = a constant.

In general the J's (inflows and outflows) will be functions of the other storages in the system and the external sources of the system.

The second law of thermodynamics is indicated by the "heat sink" symbol at the bottom of the storage. All storages tend to disperse, decay, depreciate, and otherwise increase their disorder. The rate of depreciation is usually some function of the level of the storage, and is given by the third term in Equation 1.

(3) Work gate, interaction, or transformation. These symbols are called "functions" in modeling terminology and are, in general, all processes that require the interaction of internal storages and/or external sources. The process could be a transformation of the inputs into a different output (such as the interaction of sunlight and nutrients to produce biomass) or the regulation of the flow of one substance by another (such as the control of evapotranspiration by leaves). Notice also the heat sink symbol indicating losses required by the second law for all real, irreversible processes.

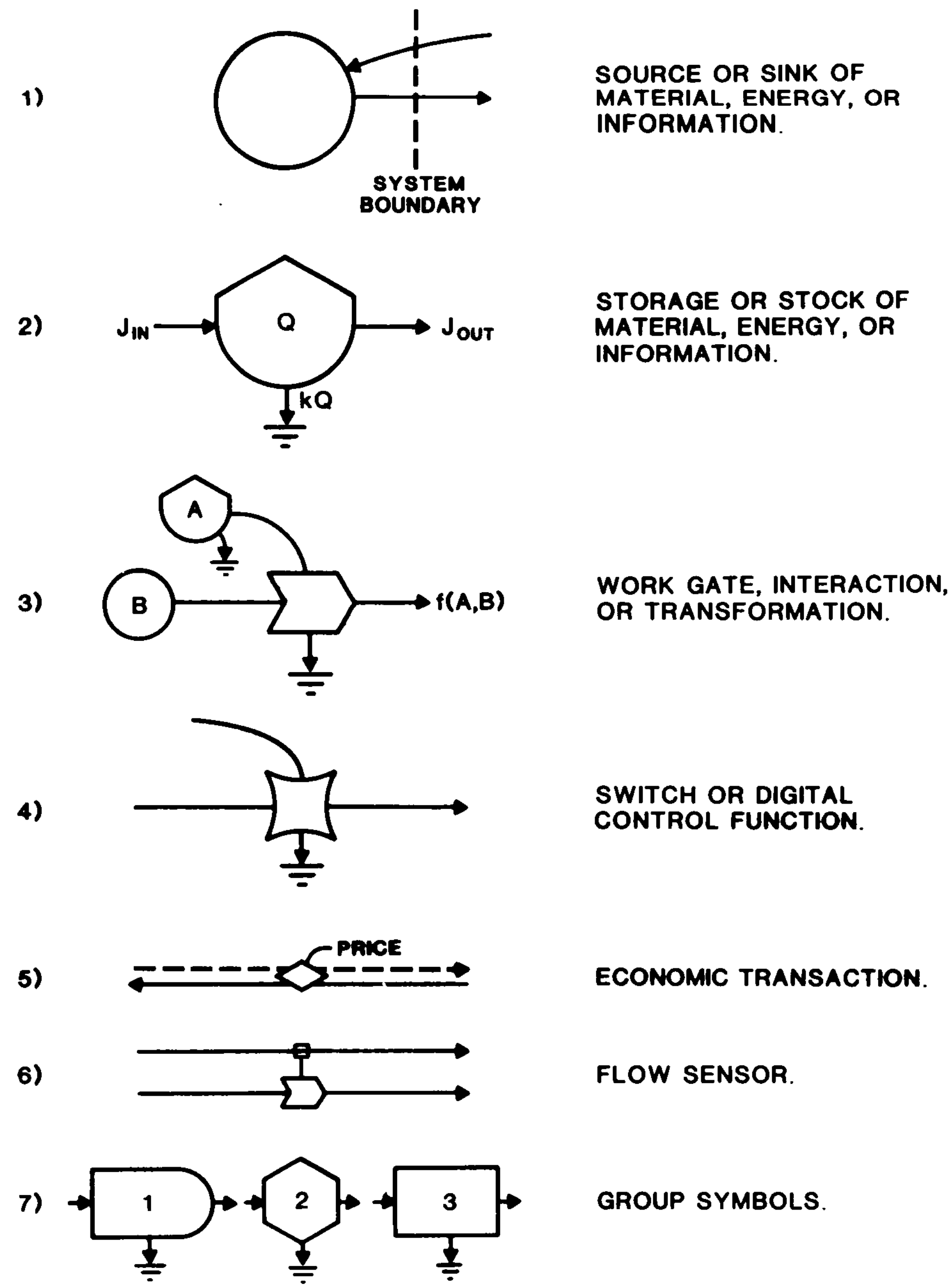


Figure 3. Energy circuit language symbols.

The mathematical form of the function can be made explicit by writing it inside the work gate symbol. For example, two common and simple forms are the multiplier and divider interaction shown in Figure 4(a). If nothing is written inside the symbol, the functional form is not specified, only the fact that there is some interaction.

Interactions that require physical inputs of the "reactants" imply that the rate of formation of the products is proportional to the rate of consumption of the inputs. For example, a chemical reaction that requires A and B to produce C with a multiplicative functional form would look like Figure 4(b), which implies that the rate of consumption of B is proportional to the amount of B present and the amount of A present (as are the rate of consumption of A, production of C and process losses). The first law constraint implies that in Figure 4(b): $k_2 + k_3 = k_1 + k_4$.

If, on the other hand, B were a catalyst required for the production of C, but not consumed at a rate proportional to the rate of production of C, the diagram would look like Figure 4(c). The small box around the flow line leaving B is a sensor that denotes that there is no consumption of B in the process.

(4) Switch or digital control function. The work gate symbol implies continuous interaction over a range of values. The switch symbol is similar but implies a digital, on or off, form of interaction. For example, flows that require some threshold value to be reached before being switched on are best indicated by the switch symbol. Note the heat sink, indicating that even digital control actions have attendant losses.

(5) Economic transaction symbol. This symbol indicates flows of material, energy, or information (solid line) that have attendant dollar transactions (dashed line). Price regulates the exchange ratio.

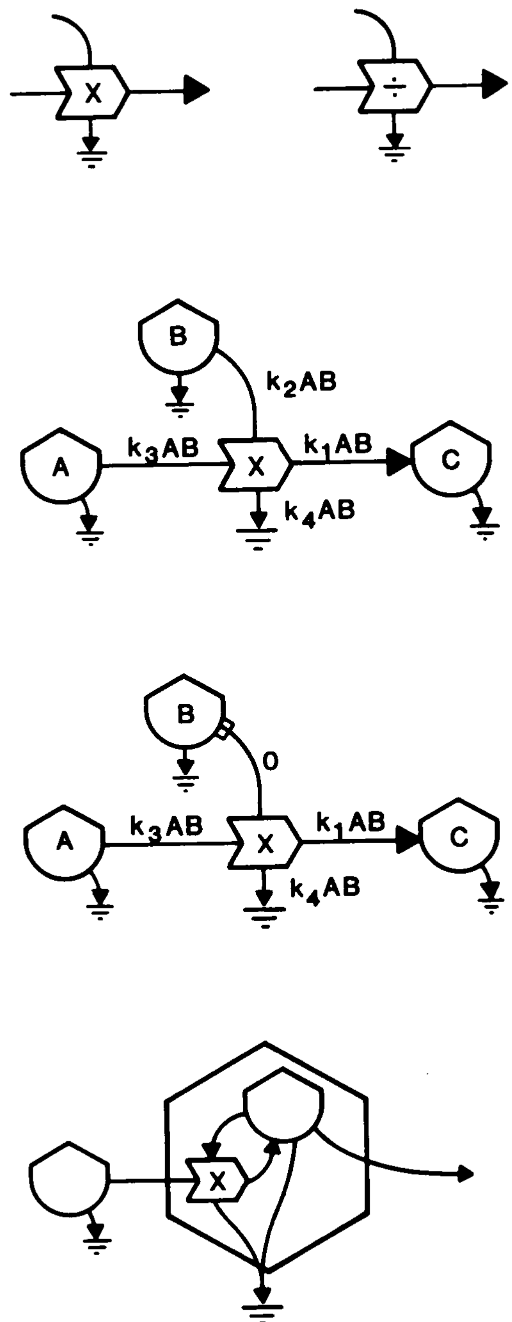
(6) Flow sensor symbol. This symbol indicates flows of material, energy, or information in proportion to the flow of some other material, energy, or information. The small box around the sensed flow indicates that the sensed material is not consumed in the process.

(7) Group symbols. These symbols indicate groupings of internal storages and interactions with special meanings. The bullet shaped symbol is used to indicate groupings that contain primary producers. These are any subsystems that convert sunlight directly into biomass. The hexagon symbol indicates a consumer or group of consumers.

The mathematical form of these symbols is nonspecific and is related to their internal structure. For example, the simplest form of internal structure for a consumer group is shown in Figure 4(d). This implies that the rate of production of the internal storage depends on the level of that storage. The box symbol is for general purpose groupings.

FLOW DIAGRAM FORMAT

When reading flow diagrams, one tends to assign meaning or significance to the layout or placement of components on the page. All of the models within each level of organization (habitat, hydrologic unit, and MDPR) were laid out similarly to try to avoid this problem. This prevents purely "semantic" differences between models from taking on any significance, and allows information about the general trophic structure of ecosystems to be expressed.



(a)

(b)

(c)

(d)

Figure 4. Some combinations of energy symbols.

INPUT-OUTPUT MODELS

Input-output (I-O) models have become very popular in the analysis of economic systems since their development by Wassily Leontief (1941). I-O models are concerned with the problem of comprehensive description and analysis of interdependence, and the modeling format is general enough to be useful in any field that deals with the analysis of interdependence. There is an enormous amount of literature on economic applications, as well as on several applications to ecological and combined ecological-economic systems (Daly 1968; Isard 1972; Victor 1972; Hargrave and Burford 1973; Hannon 1973, 1976, 1979; Richey et al. 1978; Costanza 1979, 1980; Costanza and Neill 1981a, 1981b).

An input-output model is based on a comprehensive accounting of transactions in a system as displayed in an "input-output table." An input-output table can be thought of as a tabular depiction of the same data that might be displayed on a matter and energy flow diagram.

An I-O table is a compact depiction of the quantitative interconnections among system components. Flow diagrams quickly reach an upper limit of complexity, above which they are almost impossible to read. I-O tables may be enormously complex and still be readable (some are published with 456 compartments or "sectors"), but they lack the visual impact of a flow diagram.

The following example describes the general I-O table format, its relation to the energy circuit diagrams presented earlier, and a brief treatment of the mathematics associated with it. Recent work in input-output analysis has addressed the problem of "joint products," which occurs when an ecological or economic sector produces more than one type of output (Victor 1972; Ritz 1979; Costanza and Neill 1981a, 1981b). This problem is critical when dealing with combined economic-ecologic systems, since waste or by-products are important considerations and must be treated as joint products. This explanation of input-output models focuses on the more recent "commodity-by-process" format (which allows joint products and which is used in this report), noting correspondence, when appropriate, with the earlier "standard" format.

Table 1 is an example of a commodity-by-process input-output table for the entire biosphere (from Costanza and Neill 1981a). This table illustrates the format used in all the input-output tables in this study. In the table, "processes" are listed along the top, and "commodities" are listed along the side. Commodities are actual goods or services produced or consumed in the system and correspond to a flow or storage in the energy circuit diagram. A process is a transformation of a group of commodity inputs into different commodity outputs. This corresponds to the work gate symbol in the energy circuit diagram.

Table 1 shows the consumption and the production of each commodity by each process in the system. At each intersection of a process and a commodity in the table, three values may appear: (1) the use (or input) of that commodity by that process is listed on the top line; (2) the production (or output) of that commodity by that process is listed on the center line; and (3) the storage of that commodity in that process is listed on the bottom line. For example, the global urban economy process in Table 1 consumes 2.71 E12 \$/yr[1] worth of manufactured goods and services in the process of producing 3.98 E12 \$/yr worth of the same commodity. Reading down a column in the table, one can quickly see the inputs, outputs, and storages to and from the process listed in

---

[1]Throughout this report "E format" was used for scientific notation as a convenience in writing and editing. 2.71 E12 is read: 2.71 times 10 to the 12th power.

Table 1. Input-output table for the biosphere.

BIOSPHERE

COMMODITIES		PROCESSES: URBAN ECONOMY 1	AGRICULTURE 2	NATURAL PLANTS 3	ANIMALS 4	SOIL 5	DEEP OCEAN 6	SURFACE OCEAN 7	ATMOSPHERE 8	DEEP GEOLOGY 9	IMPORTS & EXPORTS	TOTAL	UNITS
MANUFACTURED GOODS AND SERVICES	1	2.71	0.08								1.19	3.98	10^{12}\$/yr
		3.98										3.98	10^{12}\$/yr
AGRICULTURAL PRODUCTS	2	1.28	4.55		3.27							9.1	10^{15}gdw/yr
			9.1									9.1	10^{15}gdw/yr
NATURAL PRODUCTS	3	1.18			27.9	103.4	34.6			0.16		167.3	10^{15}gdw/yr
				163.4	3.9							167.3	10^{15}gdw/yr
INORGANIC NITROGEN	4	55.0	62.4	208.0		493.6		168.0	389.5			1,376.5	10^{12}g/yr
		60.0	31.0		295.0	340.5		182.0	448.0			1,376.5	10^{12}g/yr
CARBON DIOXIDE	5		8.2	147.0			15.6	37.2	110.3			318.3	10^{15}gC/yr
		5.0	6.1	73.6	14.0	46.5	15.6	49.5	108.0			318.3	10^{15}gC/yr
INORGANIC PHOSPHOROUS	6	12.6	28.5	1,345.7		8.4		21.0	9.5	13.0		1,438.7	10^{12}g/yr
		14.2				241.3	1,161.1		9.5	12.6		1,438.7	10^{12}g/yr
WATER VAPOR	7								496,100			496,100	Km^3/yr
		79	5,931	50,740		14,650		424,700				496,100	Km^3/yr
FRESH WATER	8	1,008	15,490	51,226		111,419		424,700			2,000	605,843	Km^3/yr
		929	9,829			96,985			496,100			605,843	Km^3/yr
FOSSIL FUEL	9	5										5.00	10^{15}gC/yr
										0.07	4.93	5.00	10^{15}gC/yr
SUNLIGHT	10		23	227				606				856	10^{18}Kcal/yr

the column headings. Reading across a row, one can quickly see the distribution of each commodity as input, output, and storage to and from the various processes. Thus, the input-output table is a concise listing of the interconnections among system components over a particular time interval. In Table 1 no storage values were estimated, so the bottom line at each intersection is blank.

In the standard input-output format each process produces only one commodity, and output entries (the center line of each process-commodity intersection) occur only along the diagonal in the table. Notice that in the "totals" column, the total input (or "demand" or "use") of each commodity to all internal processes (plus exports) must equal the total output (or "supply" or "production") of that commodity from all internal processes plus imports. This equality is a restatement of the first law of thermodynamics in the I-O format.

Note the unique position of sunlight in this table. When modeling the biosphere as a whole, sunlight is the only commodity that is required by internal processes that is not also produced internally. This makes it the primary resource in this model, a distinction of some importance in applications of this model as will be discussed later.

Since this technical report is concerned only with the descriptive data collection and formatting phase of the MDPR study, no additional detail of the manipulation of I-O tables is necessary to understand and use the results presented in this report. The data in I-O table format, however, have proved to be useful as the basis for a wide variety of mathematical modeling and analysis studies (Hannon 1979; Ritz 1979; Costanza and Neill 1981b). This was part of the reason for choosing this particular format for this study. Below, one example of the mathematical formulation of I-O data for a particular purpose is outlined. This is intended only as an example to give the reader an idea of the potential uses of I-O data in model building, and is not meant to be an exhaustive list of all the possibilities. Readers unfamiliar with linear algebra can skip to the next section where other potential applications are discussed. A mathematical formulation is not necessary to the goal of quantitative characterization (the table itself is sufficient for that purpose), but it is necessary if the I-O data are to be used to make summary statements about interdependence in the system, to estimate impacts, or as the basis for simulation studies.

LINEAR, STATIC INPUT-OUTPUT MODELS

The simplest and most often used mathematical formulation of input-output data and the one used in this report is the static, linear, material and energy accounting model. This formulation assumes linear relationships between the inputs and outputs of each process, and considers the system only for the time interval covered by the data. Models based on these assumptions are useful mainly to determine the degree of indirect interconnection among components and to estimate the indirect impacts of selected changes (direct impacts) in the system, assuming that the "structure" of the system does not change.

The mathematical theory behind the linear, static input-output model, and the more general but related linear programming model is well developed and is an important tool in many fields, such as industrial management, economics, ecology, strategic analysis, forest management, and energy analysis. It is beyond the scope of this report to reconstruct this material in any but the most abbreviated form. What follows is a brief model formulation specifically adapted to a particular potential use of the data. This presentation is intended only to illustrate one potential use of the data.

"Embodied" energy balance equations can be written for each process as shown below:

$$E_j + \sum_{i=1}^{n} \varepsilon_i U_{ij} = \sum_{i=1}^{n} \varepsilon_i V_{ji} \qquad (2)$$

where

E_j is the direct primary resource input to process j (direct solar energy in the global model);
U_{ij} is the input of commodity i to process j;
V_{ji} is the output of commodity i by process j;
ε_i is the weighting factor or "energy intensity" or "shadow price" associated with commodity i.

All inputs and outputs are the total flux over a particular time interval (i.e., g/yr).

This is a generalization of the single product energy balance model developed by Herendeen and Bullard (1974) and Hannon (1973). The system contains n commodities and m processes. Interest in modeling the biosphere as a whole stems partly from the fact that, at this level, the system has essentially one primary resource--sunlight. Thus, the weighting factors can all be stated as "embodied solar energy" intensities.

In matrix notation for all processes we have

$$\mathbf{E} = \boldsymbol{\varepsilon}\mathbf{U} - \boldsymbol{\varepsilon}\mathbf{V}^T \qquad (3)$$

where

$\mathbf{E}$ is an m dimensional column vector of direct energy inputs;
$\mathbf{U}$ is an m x n matrix of commodity inputs by process;
$\mathbf{V}^T$ is an m x n matrix of commodity outputs by process;
$\boldsymbol{\varepsilon}$ is an n dimensional vector of weighting factors or energy intensities.

The system of linear algebraic equations indicated in Equation 3 can be solved simultaneously for the embodied energy intensity vector, $\boldsymbol{\varepsilon}$. The details of the methods used for obtaining this solution are best left to a linear algebra text (cf., Searle 1966).

The embodied energy intensity factors that solve Equation 3 can be interpreted as the total amount of direct primary resource ($\mathbf{E}$) required directly and indirectly to produce a unit of each commodity in a system with input and output matrices A and B respectively. For example, Table 2 shows the energy intensity factors that result from solving Equation 3 for the biosphere input-output data in Table 1 (see Costanza and Neill 1981, for details of this application).

The "embodied energy intensities" presented in Table 2 can be interpreted in several complementary ways and may be useful as a method for estimating the value of non-marketed natural resources (such as fresh water, nutrients, natural plant and animal biomass). In any management decision, conflicting interests and goals must be weighed against each other. The analysis of these trade-offs can be aided if there is a common denominator by which dissimilar items can be evaluated and compared. Embodied energy calculations based on ecological-economic input-output models are one way of using detailed ecological data to provide embodied energy values that can be used as such a common denominator (Hannon 1976; Costanza 1980; Costanza and Neill 1981a, 1981b). The valuation of nonmarketed resources should be incorporated into management decisions. The specific application of the I-O data presented above can help incorporate all the available information on ecological structure and function into a calculation of resource value. These valuations would be very useful to resource

Table 2. Embodied energy intensities from the global model in various units (Costanza and Neill 1981a).

Commodity	Embodied energy intensity[a]
1. Manufactured goods and services	191.2 E6 kcal solar/$ =17,850 kcal FF/$
2. Agricultural products	13.9 E3 kcal solar/g =6.2 E6 kcal solar/lb =$.03/lb
3. Natural products	39.2 E3 kcal solar/g =17.7 E6 kcal solar/lb =$.09/lb
4. Nitrogen	0.63 E6 kcal solar/gN =$1.49/lbN
5. Carbon dioxide	57.1 E3 kcal solar/gc =$.13/lbC
6. Phosphorus	1.17 E6 kcal solar/gP =$2.75/lbP
7. Water vapor	0.55 E18 kcal solar/cu km =$2.87/cu m =$ .01/gal
8. Liquid water	0.55 E18 kcal solar/cu km =$2.87/cu m =$ .01/gal
9. Fossil fuel	96.4 E3 kcal solar/g FF =10,711 kcal solar/kcal FF

[a]The values above were calculated using standard conversion factors (i.e., 454 g/lb, 264.2 gal/cu m) and the intensities calculated by the model for the other commodities (i.e., 191.2 E6 kcal solar/$1970). Fossil fuel was converted to kcal using 9 kcal FF/g FF.

managers because they would allow environmental costs to be compared with economic benefits on an equal footing, which would form the basis for more rational, objective, environmental decision making.

Once these valuations are performed, input-output tables in consistent units (i.e., dollars or kilocalories of solar energy) can be constructed for the ecological habitats of the region and manipulated in much the same way as standard economic I-O models (cf. Hargrave and Burford 1973; Ritz 1979). A useful product of these manipulations is the estimation of summary "multipliers" of various kinds. Multipliers quantify the total (direct and indirect) change expected to result from a unit change in a particular variable. For example, an "income multiplier" in economic applications is an estimate of the direct and indirect change in total income expected to result from a unit change in the output of a particular sector of the economy. Ecological input-output models in consistent units could be used to estimate "impact multipliers" that quantify the direct and indirect impact of a particular proposed alteration of the ecosystem. Having a model in consistent units is necessary so that the various kinds of impacts can be added to produce a summary total.

OTHER POTENTIAL USES OF INPUT-OUTPUT DATA

Besides purely descriptive and accounting uses, ecosystem data in I-O format can be useful as the basis for more elaborate non-linear, dynamic modeling efforts. Non-linear, dynamic I-O models would require additional data on the time variability of the ecosystems, but the description of the average conditions provided by static input-output tables would be a necessary adjunct. This descriptive format of static I-O models is a useful as a way of organizing and presenting data.

DATA AND MEASUREMENT

This project develops and presents quantitative information on the flows of matter and energy in the ecological systems of the MDPR. Thousands of measurements made by hundreds of independent researchers at different times, using different techniques, and at different levels of accuracy and completeness have been synthesized and recorded. These measurements vary widely in their degree of precision and applicability to the purposes of this study. Detailed notes supporting and qualifying each of the calculations and estimates employed in this study are included after each detailed habitat model. The reader should be aware that the quantitative estimates presented in this study vary from reasonably precise measurements to rough guesses. In all cases, the guiding principle in this study was to choose the best estimate for the variable under consideration. Ignoring a particular variable in construction of an ecosystem model is functionally equivalent to estimating its value as zero. Even a rough guess may be a better estimate of a particular quantity than an implicit estimate of zero, if the degree of precision of the estimate is kept in mind. Thus, the numerical estimates presented in this study must be used carefully and in light of the qualifications included in the report.

The reader should also be aware that the data collection format used in this study represents a particular paradigm for viewing ecosystems. This view uses energy and material flows to characterize ecosystems. There are several alternative paradigms, none of which can claim to be all-encompassing. The particular paradigm used in this study was thought to be the most appropriate for the task at hand, but (like any paradigm) it also limits and colors the resulting picture in a particular way.

HABITAT MODELS

HABITATS USED IN THIS STUDY

Detailed habitat categories measured from MDPR habitat maps (Wicker et al. 1980b) were aggregated into 20 habitat types for consideration in this report. Detailed habitats were aggregated according to functional similarity, allowing each habitat to be general enough to permit data collection and model construction. Correspondence of the 20 habitat types to the Cowardin et al. (1979) categories and the areas of the habitats in the region measured from the detailed habitat maps are shown in Table 3.

For each of the 20 habitats used in this study, a matter and energy flow diagram and a brief narrative description were prepared. In addition, eight of the habitats were selected for detailed study and quantification: agriculture, brackish marsh, cypress-tupelo swamp, fresh marsh, fresh open water, estuarine open water, salt marsh, and urban/industrial. These eight habitats encompass more than 90% of the total area of the MDPR, and were those for which sufficient data were available for preparation of quantified flow diagrams and input-output tables. Notes supporting the quantification of these eight habitats follow each model in the text.

HABITAT MAPS

A map of the 1978 distribution of each habitat in the MDPR by 7½ minute quad sheet is included in the report. These maps were constructed using data from aerial photographs (see Wicker 1980). Data were aggregated into the 20 habitat types used in this study, since the original data base made use of the Cowardin et al. (1979) classification (Table 3). Data were mapped using a computer software program developed at the Center for Wetland Resources at Louisiana State University. This software makes use of the CALFORM mapping program (Latham and White 1978).

Although most of the aerial photographs used in the mapping study were from 1978, a number of the Mississippi photos were taken in 1976. For convenience, maps are labeled 1978, since the majority of the photos are from this date.

The maps included in this report are conformant maps. This type of map divides the region into different zones (7½ minute quads), with each zone stipled according to the area of the each habitat in that zone. Caution should be used in interpreting these maps, since they do not give any information about the location of a habitat within a zone but only give the relative area of a habitat for each quad within the MDPR.

DATA COLLECTION METHODS

The construction of the I-O tables entailed the collection and manipulation of a large volume of data from the ecological literature. The goal throughout was to describe all flows of materials and energy within each habitat as completely as possible. The data were intended to represent average temporal and spatial conditions in that habitat. Because of data constraints, however, this ideal was rarely met. Thus, data were often manipulated so that they would be more representative of those average conditions. This section describes the methods used to collect data for the I-O tables.

The first law of thermodynamics requires a balance of inputs and outputs within a process. This has important practical implications in the construction of an I-O table, since missing data can often be calculated by difference.

Table 3. Composition and land area of the aggregate habitats used in this study in terms of the Cowardin et al. (1979) classification system for the MDPR.

Aggregate habitat No.	Aggregate habitat Description	Habitats included	1955 area ha	1955 area % of Total	1978 area ha	1978 area % of Total
1	Agriculture	UDV12	1859	0.05	0	0
		UDV2	121958	3.53	82775	2.40
		UDV2e	7879	0.23	14756	0.43
		UDV2x	229	0.01	0	0
	Subtotal		131925	3.82	97531	2.83
2	Beach and dune	E1BB2	0	0	9	0
		E2BB2	3471	0.10	2539	0.07
		E2RS2	1	0	0	0
		E2RS2h	0	0	2	0
		E2RS2r	8	0	3	0
		M2BB2	2437	0.07	1600	0.05
		R1BB2	57	0	37	0
		R1RS2h	0	0	2	0
		R1RS2r	0	0	2	0
		R2BB2	201	0.01	25	0
		UGR5b	0	0	20	0
	Subtotal		6174	0.18	4239	0.12
3	Bottomland hardwood	PF01	14600	0.42	19291	0.56
		PF013	37525	1.10	24410	0.71
		PF034	2263	0.07	1852	0.05
		PF05	0	0	575	0.02
	Subtotal		54388	1.59	46128	1.34
4	Brackish marsh	E2EM3P5d	0	0	3	0
		E2EM5N5	0	0	6502	0.19
		E2EM5P5	0	0	280500	8.10
		E2EM5P5d	0	0	6754	0.20
		E2EM5P6	0	0	107609	3.12
		E2EM5P6d	0	0	2601	0.07
	Subtotal		0	0	403969	11.68
5	Canal	E1AB5o	0	0	37	0
		E1AB5x	0	0	1	0
		E1OWo	5158	0.15	10854	0.31
		E1OWx	3342	0.10	9879	0.29
		R1AB2x	0	0	2	0
		R1AB5o	0	0	395	0.01
		R1AB5x	0	0	221	0.01
		R1OWo	1771	0.05	1882	0.05
		R1OWx	3285	0.10	5273	0.15
		R2AB5x	0	0	4	0
		R2OWo	11	0	9	0
		R2OWx	977	0.03	890	0.03
		R4OWx	3	0	0	0
	Subtotal		14547	0.43	29447	0.85

(continued)

Table 3. Continued

Aggregate habitat No.	Description	Habitats included	1955 area ha	1955 area % of Total	1978 area ha	1978 area % of Total
6	Cypress-	PF012	181628	5.27	154207	4.47
	Tupelo	PF024	4071	0.12	4257	0.12
	Subtotal		185699	5.39	158464	4.59
7	Fresh aquatic	L2AB	0	0	1003	0.02
	bed	L2AB2	0	0	1107	0.03
		L2AB2h	0	0	229	0.01
		L2AB5	88	0	169	0
		L2AB5h	0	0	4	0
		L2AB5x	0	0	2	0
		PAB	0	0	22	0
		PAB2	0	0	924	0.03
		PAB2h	0	0	11	0
		PAB2x	0	0	2	0
		PAB5	0	0	133	0
		PAB5x	0	0	4	0
		PDV	457	0.01	1895	0.05
		PFL2	7	0	0	0
		R1AB	0	0.02	30	0
		R1AB2	0	0	21	0
		R1AB5	0	0	690	0.02
		R2AB5	0	0	32	0
	Subtotal		552	0.03	6278	0.16
8	Fresh marsh	PEM	356051	10.33	154812	4.49
		PEMd	8426	0.24	10423	0.30
		PEM5	0	0	10	0
	Subtotal		364477	10.57	165245	4.79
9	Fresh open	L1OW	29409	0.85	111	0
	water	L1OWh	0	0	90	0
		L2OW	29917	0.86	29711	0.86
		L2OWh	2188	0.06	1448	0.04
		L2OWx	11	0	376	0.01
		POW	1905	0.06	3138	0.09
		POWh	127	0	285	0.01
		POWo	0	0	5	0
		POWx	177	0.01	618	0.02
		POW4	0	0	41	0
	Subtotal		63734	1.84	35823	1.03
10	Fresh scrub	PSS	0	0	13	0
	shrub	PSS1	1616	0.05	7549	0.22
		PSS12	0	0	19	0
		PSS13	4760	0.13	5607	0.16
	Subtotal		6376	0.18	13188	0.38
11	Mangrove	E2SS3	63	0	2955	0.09
	Subtotal		63	0	2955	0.09

(continued)

Table 3. Continued.

Aggregate habitat No.	Aggregate habitat Description	Habitats included	1955 area ha	1955 area % of Total	1978 area ha	1978 area % of Total
12	Mud flat	E1FL	81	0	0	0
		E2FL	1791	0.05	0	0
		E2FL2	1011	0.03	70	0
		E2FL23	0	0	5	0
		E2FL24	0	0	82	0
		E2FL3	719	0.02	1428	0.04
		E2FL34	0	0	1029	0.03
		E2RF2	485	0.01	305	0.01
		E2UB34	276	0.01	7	0
		L2FL3	0	0	71	0
		L2FL34	0	0	1927	0.06
		M1UB2	136	0	0	0
		M2FL2	0	0	17	0
		R1FL	494	0.01	28	0
		R1FL3	963	0.03	190	0.01
		R2FL	34	0	0	0
	Subtotal		5990	0.16	5159	0.15
13	Nearshore gulf	M1OW	119279	3.38	116569	3.38
	Subtotal		119279	3.38	116569	3.38
14	River, stream, bayou	R1OW	35317	1.02	36968	1.07
		R2OW	846	0.02	525	0.02
		R4OW	31	0	10	0
	Subtotal		36194	1.04	37503	1.09
15	Estuarine aquatic bed	E1AB	0	0	302	0.01
		E1AB1	0	0	2470	0.07
		E1AB12	537	0.02	2923	0.08
		E1AB2	0	0	8434	0.24
		E1AB5	4	0	189	0.01
		E1AB5H	0	0	1	0
	Subtotal		541	0.02	14319	0.41
16	Estuarine open water	E1OW	1728653	50.15	1883064	54.62
		E1OWh	4147	0.12	5442	0.16
		E1OWt	26455	0.77	33502	0.97
		E1OW4	0	0	115	0.33
		E1UB2	364	0.01	0	0
		E2OW	2687	0.08	0	0
	Subtotal		1762306	51.13	1922123	56.08
17	Salt marsh	EEM	0	0	1622	0.05
		E2EM	570515	16.55	154	0
		E2EMd	2422	0.07	0	0
		E2EM5N4	0	0	178843	5.19
		E2EM5N4d	0	0	1836	0.05
	Subtotal		572937	16.62	182455	5.29

(continued)

Table 3. Concluded.

Aggregate habitat No.	Aggregate habitat Description	Habitats included	1955 area ha	1955 area % of Total	1978 area ha	1978 area % of Total
18	Spoil	E2EM5N4s	0	0	160	0
		UDV3	4432	0.13	5483	0.16
		UDV3o	1	0	0	0
		UDV3x	0	0	19	0
		UFO1s	1962	0.06	3855	0.11
		UFO13s	12	0	102	0
		UFO34s	0	0	1	0
		USS1s	2509	0.07	23670	0.69
		USS13s	1623	0.05	286	0.01
	Subtotal		10539	0.31	33576	0.97
19	Upland forest	UDV	153	0	580	0.01
		UFO	58	0	3	0
		UFO1	19	0	0	0
		UFO12	0	0	4	0
		UFO13	23104	0.67	23829	0.69
		UFO3	304	0.01	243	0.01
		UFO34	36584	1.06	44269	1.28
		UFO4	92	0	0	0
		USS1	161	0	157	0
		USS1o	0	0	72	0
		USS13	2453	0.07	1533	0.04
	Subtotal		62928	1.81	70690	2.03
20	Urban industrial	UDVo	10	0	2	0
		UDV1	47534	1.40	98712	2.80
		UDV1o	1101	0.03	3389	0.09
	Subtotal		48645	1.43	102103	2.89
	TOTAL		3447294	100.	3447764	100.

Equation 4 holds for any primary producer (autotroph):

$$GPP = R + NPP \qquad (4)$$

where GPP is equal to gross primary production (the total amount of chemical energy assimilated), R is equal to respiration (energy cost of maintenance and depreciation, as required by the second law of thermodynamics), and NPP is equal to net primary production, or the total amount of new material produced. This net primary production may be consumed by other organisms or added to the already existent biomass, giving an increase in storage. Ultimately, however, this material is broken down by decomposers and either recycled or lost to the system.

For consumers (heterotrophs), a similar balance can be constructed:

$$C = E + R + P \qquad (5)$$

where C is equal to consumption, E is equal to egestion (non-digestible food plus secretions, gamete production, etc.), R is the rate of respiration, and P is the secondary production. From Equations 4 and 5 it can be seen that it is often possible to calculate values for missing data if the other terms in the equation are known. These calculations are made easier by assuming a steady state system.

When a habitat is first colonized by an organism, the rate of production of that organism (either NPP or P) exceeds its mortality. Thus there is an accumulation (increase in storage) in the biomass of that organism. Ultimately, however, the rate of decomposition increases over time until it is equal to the rate of new production; this is a natural process in the succession of ecological communities. When this happens there is no net change in storage and that organism is said to have reached a steady state.[2]

Since it is difficult to measure net change in biomass in real ecosystems, ecologists often assume that the system is at steady state in order to simplify the calculations (for example, assuming no net growth would allow one to estimate mortality as equal to new production). When the habitat in question is not accumulating or losing biomass, this assumption probably will not lead to gross errors. This assumption can lead to greater errors, however, if it is applied to a system that is experiencing rapid change. For example, assuming a steady state for newly deposited spoil would be misleading because many new species would still be colonizing this habitat. Another case in which the steady state assumption could lead to errors would be in a system that had been disturbed, either by man or by a natural catastrophe such as a hurricane.

The steady state was often assumed even for growing or disturbed systems. It was reasoned that the estimates of particular values obtained from this assumption, though of debatable quality, were better than no estimate at all--because no estimate in the model is by default an estimate of zero. Such estimates are undoubtedly poor, but they do incorporate the information that does exist.

The ideal data for this study are data gathered over a long period of time and over a large area so they could be said to represent statistically average conditions. When this type of information was not found, data from a more restricted area within the MDPR or from an area outside the MDPR were used. To better approximate the actual conditions, these data were often adjusted to some parameter, such as biomass, NPP, or

[2] In reality, an organism may never reach a constant steady state, since there are always fluctuations over time. When we speak of steady state, we generally are considering an average condition over time where periodic oscillations and noise have been filtered out.

GPP. For example, consumption of a macrophyte might be estimated by using its consumption in a different area and adjusting it by the ratio of biomass in the MDPR to the biomass in that area. It is felt that the error caused by assuming such a linear relationship is less than the error that would be caused by not accounting for the difference in such a value. It is hoped that taking such an approach results in more precise estimates.

Another area in which linear relations were assumed was in the calculation of different foods consumed by particular organisms. For example, it might be known that three different plants made up the diet of a heterotroph and that the animal consumed a total of 100 g dry wt/sq m/yr. The mixture of the consumed plants, however, might not be known (i.e., how much of each of the three plants was consumed). In such instances, the rate of consumption of each of these plants was assumed to be proportional to its NPP rate. If plant A produced 50% of all NPP, it was assumed that 50% of the food consumed by the heterotroph was plant A.

When data for a particular organism could not be found, information from a similar organism was used in its place. For example, if data on the chemical makeup of a crab were not available, information from a closely related organism or group of organisms was substituted. An analysis of the average chemical makeup of invertebrates might be used instead. If data on invertebrates were not available, the chemical makeup of a generalized "animal" (see E. P. Odum 1971) might be used. When all else failed, a "standard ecological conversion," such as 1 gram C/2.2 grams dry wt (Whittaker 1975), was employed. Our intent here was to always use data from the most closely related organism.

Uptake and release of nutrients was another area in which poor data existed and simplifying assumptions had to be made. Where data were not available, uptake was estimated by multiplying the concentration of that nutrient in the biomass of the organism by either GPP (for producers) or consumption (for consumers). Similarly, release was calculated as the nutrient concentration multiplied by the rate of respiration.

In constructing the I-O tables, several conventions were consistently followed. Values representing physical units were always calculated in grams of that commodity (e.g., g N, g P, g dry wt), and energy values are presented as kilocalories. In all cases, storages were calculated on a per square meter basis, and flows were calculated on a per square meter per year basis.

A commodity was entered in the I-O table only if it existed in the habitat in that form. For example, inorganic nitrogen is explicitly considered since it is found in the system as such. Organic nitrogen was not considered explicitly, however, since it is implicitly included as a constituent of organic matter or biomass.

Since a habitat may contain thousands of different species, it is obvious that these could not all be included in the analyses. It was necessary to group functionally similar organisms into aggregated categories (Bahr 1982 discusses the use of functional taxonomy). In other words, a model might include consumers, decomposers, and producers as aggregated categories. When calculating values for these functional groups, only a limited number of the more functionally significant organisms could be considered. For example, only four major macrophytes were used in the salt marsh analysis. Estimates based solely on these four plants undoubtedly contain errors since there are other plants in the marsh, but these four plants account for more than 90% of the vegetated area, so the error should be small.

The preceding discussion is not meant to be an exhaustive accounting of how data were prepared for the habitat I-O tables. The purpose is to give an idea of the general way in which data were handled.

HABITAT MODEL NOTES

The notes to the habitat models are coded to the habitat model I-O tables in the following way: each note is labeled with a 2-number, 1-character code. The first number denotes the commodity, the second number the process, and the character (I, O, or S) denotes whether the estimate is an input, output, or storage. For example, the note labeled "1,2,I" in the agricultural notes explains how the input (I) of nitrogen (commodity 1) into sugarcane (process 2) was calculated. The notes are separated into groups by commodity.

Flows of materials are recorded in the standard units of g/sq m/yr, while energy flows are presented as kcal/sq m/yr. Storages are recorded as the annual average standing crop in g/sq m. Flows and storages of a material are recorded explicitly as grams of that material. For example, a flow of inorganic nitrogen is listed as gN/sq m/yr, and flows of biomass are recorded as g dry wt of organic matter /sq m/yr.

1. AGRICULTURE

Agriculture is an important activity in the MDPR. Although it uses only 2.8% of all MDPR land and ranks eighth in area (Table 3), it provides numerous jobs as well as resources. A map of the distribution of agriculture habitat is shown in Figure 5.

The region's major crop, sugarcane, has an average annual harvest of 957.9 g for an average square meter of farm.[3] Hay, silage, and pasture produce an estimated 252.0 g/sq m/yr (note 10,3,0). Soybeans, another economically important crop, has a smaller harvest of 24.4 g/sq m/yr (note 11,4,0).

Livestock products that are of economic importance in the deltaic plain are cattle and calves (6.01 g/sq m/yr) and hogs (0.93 g/sq m/yr) (Table 4). Sheep, lamb, and wool are also produced, along with dairy and poultry products.

Deltaic plain farmers apply an average of 28.6 g/sq m/yr of nitrogen, phosphorus, potassium, and lime (Table 6). Pesticide applications (herbicide, insecticide, and fungicide) amount to 0.58 g/sq m/yr (notes 7,6,I and 7,9,I). Even with these chemicals, pests consume an estimated 35.3 g/sq m/yr (Table 12).

Labor is another service used in farming. Total labor input to all crops and livestock is estimated at 3.15 E-3 hrs/sq m/yr (Table 18). Of this, 61% comes from hired labor, with the remaining 39% coming directly from farm households (Notes 18,11,O and 18,12,0). The largest users of labor are sugarcane and other crops, which require 2.04 E-3 and 4.76 E-4 hrs/sq m/yr, respectively (Table 18).

On an average MDPR farm, 246.5 kcal/sq m/yr of fossil fuels are applied (Note 19,12,0). Soybeans require a large percentage of this, using 60.4 kcal/sq m/yr (Note 19,4,I). Such a large energy input allows farm production to take place with relatively small inputs of labor.

In addition to fertilizers, pesticides, labor, and fossil fuels, farming requires other goods and services: veterinary care, feed, machinery, and government services such as extension programs. Total input of other goods and services to MDPR farms is equal to 2.36 E-2 dollars/sq m/yr (note 20,12,0). The two main users of these goods and services are sugarcane and livestock farmers.

The data used in the agricultural model are generally reliable, coming from U.S. Agricultural Statistics and the U.S. Census of Agriculture. Where possible, data used were for 1978 since this is the year of the most recent Census of Agriculture. Some problems should be mentioned.

In this report, the area classified as agricultural, based on work by Wicker (1980), is not synonymous with areas defined as agricultural by the U.S. Department of Agriculture. For example, forested areas used as pasture are considered here as forest

[3] In this report, farm production was not calculated in the standard fashion, and thus production values are lower than those normally reported. Farm production is usually calculated by dividing the total weight of harvest crop by the farm area of that crop. As an example, 6.4 E12 g of sugarcane was harvested from 2.8 E9 sq m of sugarcane farms in Louisiana in 1978 (U.S. Bureau of Census 1981), giving a yield of 2.3 E3 g/sq m. For this report, it was necessary to calculate the yield from an average farm; sugarcane yield was therefore divided by the area of all Louisiana farms, and not just the area of sugarcane farms. Thus sugarcane harvest for an average farm in the MDPR is only 960 g/sq m (note 9,2,0).

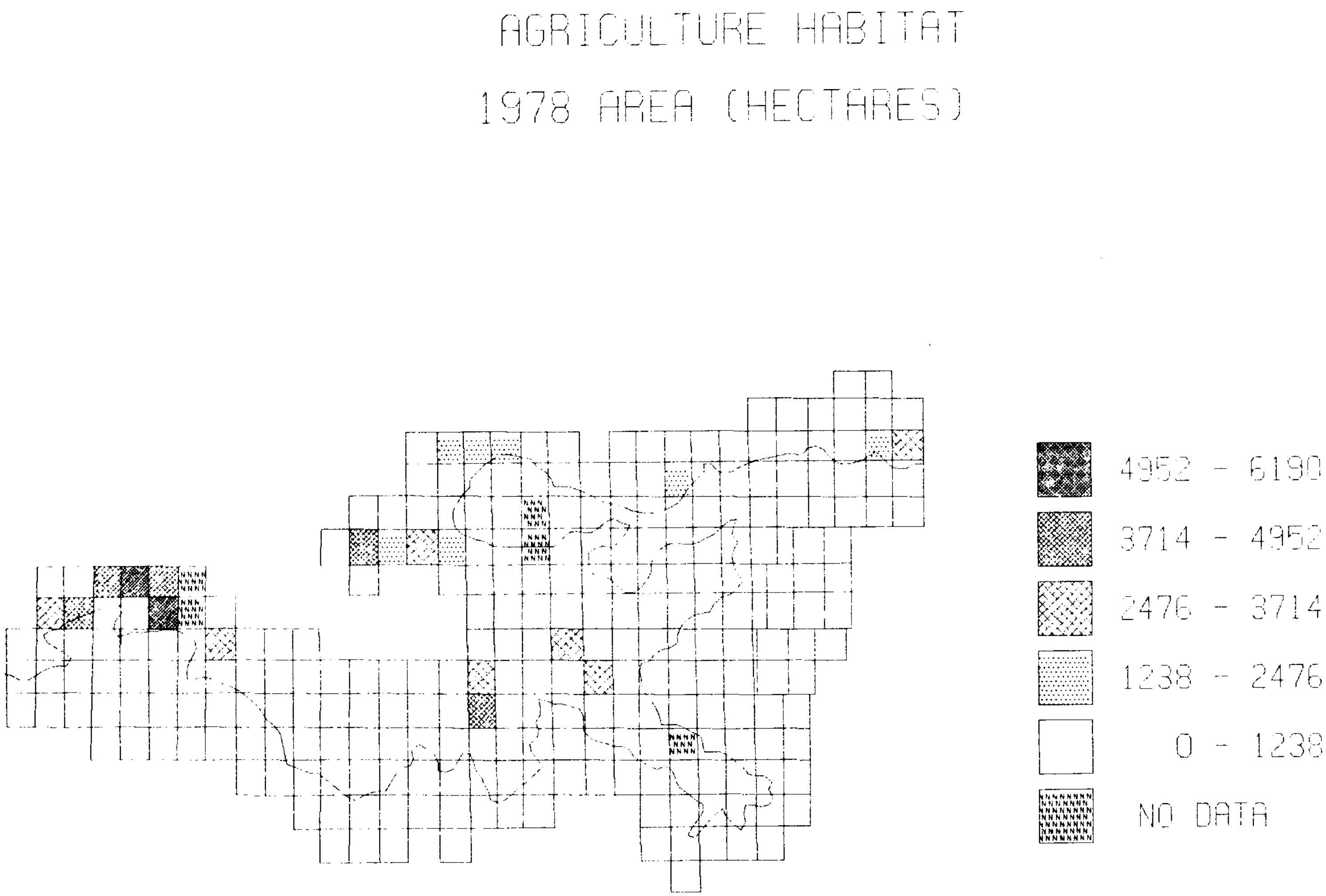


Figure 5. The distribution of MDPR agriculture habitat.

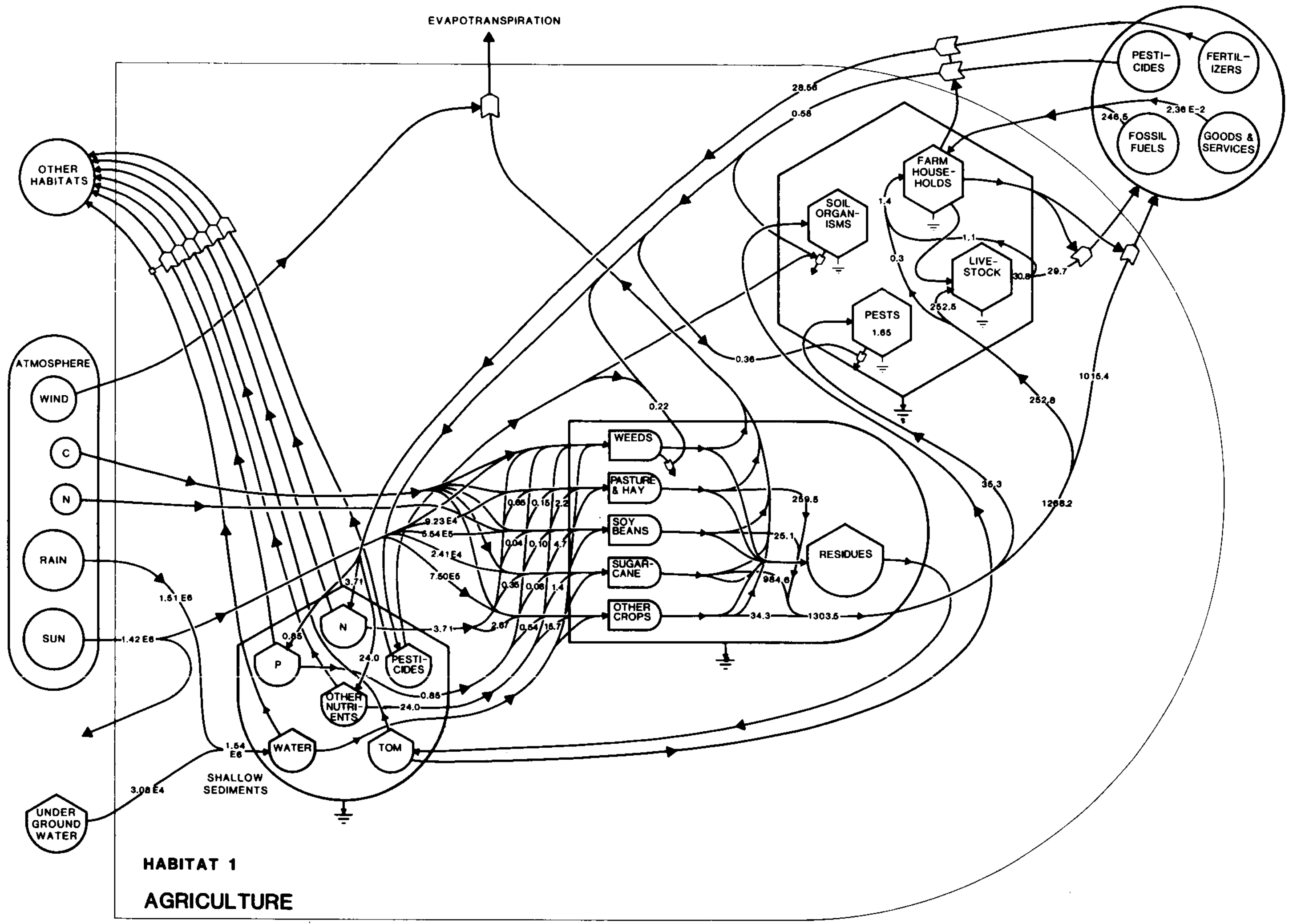


Figure 6. Agriculture habitat flow diagram.

Table 4. Input-output table for agriculture habitat.

HABITAT 1
AGRICULTURE

COMMODITIES		SOIL 1	SUGARCANE 2	PASTURE & HAY 3	SOYBEANS 4	OTHER CROPS 5	WEEDS 6	CROP RESIDUES 7	SOIL ORGANISMS 8	PEST ORGANISMS 9	LIVESTOCK 10	FARM HOUSEHOLDS 11	IMPORTS & EXPORTS 12	TOTAL	UNITS
		PROCESSES													
INORGANIC NITROGEN	1		0.35	0.65	0.04	2.67								3.71	g N/m^2/yr
													3.71	3.71	g N/m^2/yr
INORGANIC PHOSPHORUS	2		0.06	0.15	0.10	0.54								0.85	g P/m^2/yr
													0.85	0.85	g P/m^2/yr
INORGANIC CARBON	3														
OTHER NUTRIENTS	4		1.4	2.2	4.7	15.7								24.0	g/m^2/yr
													24.0	24.0	g/m^2/yr
TOTAL ORGANIC MATTER	5														
WATER	6	1.54 E6												1.54 E6	g/m^2/yr
													1.54 E6	1.54 E6	g/m^2/yr
PESTICIDES	7						0.22			0.36				0.58	g/m^2/yr
													0.58	0.58	g/m^2/yr
SHALLOW SEDIMENTS	8														
SUGARCANE BIOMASS	9									26.7			957.9	984.6	g/m^2/yr
			984.6											984.6	g/m^2/yr
PASTURE & HAY BIOMASS	10									7.0	252.5			259.5	g/m^2/yr
				259.5										259.5	g/m^2/yr
SOYBEAN BIOMASS	11									0.7			24.4	25.1	g/m^2/yr
					25.1									25.1	g/m^2/yr
OTHER CROPS BIOMASS	12									0.9		0.3	33.1	34.3	g/m^2/yr
						34.3								34.3	g/m^2/yr
WEED BIOMASS	13														
CROP RESIDUE BIOMASS	14														
SOIL ORGANISM BIOMASS	15														
PEST BIOMASS	16									1.65				1.65	g/m^2
LIVESTOCK BIOMASS	17											1.1	29.7	30.8	g/m^2/yr
											30.8			30.8	g/m^2/yr
LABOR SERVICES	18		2.04 E-3	4.98 E-5	1.16 E-4	4.76 E-4					4.71 E-4			3.15 E-3	hrs/m^2/yr
												1.24 E-3	1.91 E-3	3.15 E-3	hrs/m^2/yr
FOSSIL FUELS	19		32.7	3.1	60.4	121.5					28.7			246.4	kcal/m^2/yr
													246.5	246.5	kcal/m^2/yr
OTHER GOODS & SERVICES	20		1.33 E-3	3.50 E-4	3.34 E-5	4.58 E-5					9.55 E-3	1.23 E-2		2.36 E-2	\$/m^2/yr
													2.36 E-2	2.36 E-2	\$/m^2/yr
FARM CAPITAL	21											0.45		0.45	\$/m^2
SUNLIGHT	22		2.41 E4	9.23 E4	5.54 E5	7.50 E5								1.42 E6	kcal/m^2/yr
													1.42 E6	1.42 E6	kcal/m^2/yr

considered here as forest and not agriculture. Thus, when calculating agricultural area from USDA data, only the "cropland" and "other pastureland and rangeland" categories were included; "woodland" and "land in house lots, ponds, roads, wasteland, etc." were excluded.

When possible, the data used were from parishes and counties within the MDPR. Average per area values were then calculated by dividing by the total farm area in those parishes and counties. When data were not available on the parish/county level, state-wide data were used. Per area values were then calculated by dividing by the total farm area in Louisiana and Mississippi. This method introduces a source of error since it does not include any local deviations from the state-wide averages.

Another problem that was encountered is that agricultural data are usually collected for economic, and not ecological, purposes. For example, agricultural information on primary production only includes the harvested portion of the plant. Nonharvest portions (e.g., crop residues, belowground production) are not considered, with the result that estimates in this section are all underestimates.

In addition, information on agricultural pests, such as insects and weeds, is sparse. An insect biomass value of 1.65 g/sq m was estimated by assuming that all farms have pest populations similar to soybean farms (Table 12). Information on insect-pest energetics is scarce. Even fewer data exist on weed biomass and energetics. While we include weeds as a commodity and process in this model, we are not now able to fill in any of the quantitative detail, and a complete understanding of the agricultural ecosystem is not possible at this time.

The energy and material flow diagram for the agriculture habitat is shown in Figure 6. Table 4 is the I-O table for agriculture.

Notes to Agriculture Habitat Model

Inorganic nitrogen.

1,2,I Input of inorganic nitrogen to sugarcane. 0.35 g/sq m/yr. Total application of nitrogen fertilizer in Louisiana for 1978 was 1.05 E11 g (Table 6). In 1974, 23.0% of all nitrogen applied in Louisiana went to sugarcane (Table 7). Assuming a similar percentage for 1978, 2.42 E10 g of nitrogen were applied to sugarcane in Louisiana (sugarcane production in Mississippi is negligible). Total farm area of Louisiana and Mississippi is 6.95 E 10 sq m (Table 6, Note a). Thus the average input of nitrogen to sugarcane is equal to 0.35 g/sq m/yr.

1,3,I Input of inorganic nitrogen to pasture and hay. 0.65 g/sq m/yr. Total application of nitrogen fertilizer in Louisiana and Mississippi for 1978 was 1.05 E11 and 1.53 E11 g, respectively (Table 6). In 1974, 15.1 and 19.4% of all nitrogen applied in Louisiana and Mississippi went to pasture and hay, respectively (Table 7). Assuming similar percentages for 1978, 1.58 E10 and 2.97 E10 g of nitrogen were applied to pasture and hay in Louisiana and Mississippi, respectively, for a total of 4.55 E10 g. Total farm area of Louisiana and Mississippi is 6.95 E10 sq m (Table 6, Note a). Thus the average input of nitrogen to pasture and hay is equal to 0.65 g/sq m/yr.

1,4,I Input of inorganic nitrogen to soybeans. 0.04 g/sq m/yr. Total application of nitrogen fertilizer in Louisiana and Mississippi for 1978 was 1.05 E11 and 1.53 E11 g, respectively (Table 6). In 1974, 1.1 and 0.9% of all nitrogen applied in Louisiana and Mississippi went to soybeans, respectively (Table 7). Assuming similar percentages for 1978, 1.16 E9 and 1.38 E9 g of nitrogen were applied to soybeans in Louisiana and Mississippi, respectively, for a total of 2.54 E9 g. Total farm area of Louisiana and Mississippi is 6.95 E10 sq m (Table 6, note a). Thus the average input of nitrogen to soybeans is equal to 0.04 g/sq m/yr.

1,5,I Input of inorganic nitrogen to other crops. 2.67 g/sq m/yr. Total application of nitrogen fertilizer in Louisiana and Mississippi for 1978 was 1.05 E11 and 1.53 E11 g, respectively (Table 6). In 1974, 60.8 and 79.7% of all nitrogen applied in Louisiana and Mississippi went to other crops, respectively (Table 7). Assuming similar percentages for 1978, 6.38 E10 and 1.22 E11 g of nitrogen were applied to other crops in Louisiana and Mississippi, respectively, for a total of 1.86 E11 g. Total farm area of Louisiana and Mississippi is 6.95 E10 sq m (Table 6, note a). Thus the average input of nitrogen to other crops is equal to 2.67 g/sq m/yr.

1,12,O Output of inorganic nitrogen from exports/imports. 3.71 g/sq m/yr. Table 6.

Inorganic phosphorus.

2,2,I Input of inorganic phosphorus to sugarcane. 0.06 g/sq m/yr. Total application of phosphorus fertilizer in Louisiana for 1978 was 2.83 E10 g (Table 6). In 1974, 14.7% of all phosphorus applied in Louisiana went to sugarcane (Table 7). Assuming a similar percentage for 1978, 4.16 E9 g of phosphorus were applied to sugarcane in Louisiana (sugarcane production in Mississippi is negligible). Total farm area of Louisiana and Mississippi is 6.95 E 10 sq m (Table 6, note a). Thus the average input of phosphorus to sugarcane is equal to 0.06 g/sq m/yr.

2,3,I Input of inorganic phosphorus to pasture and hay. 0.15 g/sq m/yr. Total application of phosphorus fertilizer in Louisiana and Mississippi for 1978 was 2.83 E10 and 3.08 E10 g, respectively (Table 6). In 1974, 7.0 and 27.5% of all phosphorus applied in Louisiana and Mississippi went to pasture and hay, respectively (Table 7). Assuming similar percentages for 1978, 1.98 E9 and 8.47 E9 g of phosphorus were applied to pasture and hay in Louisiana and Mississippi, respectively, for a total of 1.04 E10 g. Total farm area of Louisiana and Mississippi is 6.95 E10 sq m (Table 6, note a). Thus the average input of phosphorus to pasture and hay is equal to 0.15 g/sq m/yr.

2,4,I Input of inorganic phosphorus to soybeans. 0.10 g/sq m/yr. Total application of phosphorus fertilizer in Louisiana and Mississippi for 1978 was 2.83 E10 and 3.08 E10 g, respectively (Table 6). In 1974, 6.4 and 17.4% of all phosphorus applied in Louisiana and Mississippi went to soybeans, respectively (Table 7). Assuming similar percentages for 1978, 1.81 E9 and 5.36 E9 g of phosphorus were applied to soybeans in Louisiana and Mississippi, respectively, for a total of 7.17 E9 g. Total farm area of Louisiana and Mississippi is 6.95 E10 sq m (Table 6, note a). Thus the average input of phosphorus to soybeans is equal to 0.10 g/sq m/yr.

2,5,I Input of inorganic phosphorus to other crops. 0.54 g/sq m/yr. Total application of phosphorus fertilizer in Louisiana and Mississippi for 1978 was 2.83 E10 and 3.08 E10 g, respectively (Table 6). In 1974, 71.9 and 55.1% of all phosphorus applied in Louisiana and Mississippi went to other crops, respectively (Table 7). Assuming similar percentages for 1978, 2.03 E10 and 1.70 E10 g of phosphorus were applied to other crops in Louisiana and Mississippi, respectively, for a total of 3.73 E10 g. Total farm area of Louisiana and Mississippi is 6.95 E10 sq m (Table 6, note a). Thus the average input of phosphorus to other crops is equal to 0.54 g/sq m/yr.

2,12,O Output of inorganic phosphorus from exports/imports. 0.85 g/sq m/yr. Table 6.

Other nutrients.

4,2,I Input of other nutrients to sugarcane. 1.4 g/sq m/yr. Total application of other nutrients (potassium and lime) in Louisiana for 1978 was 4.30 E11 g (Table 6). In 1974, 22.6% of all potassium applied in Louisiana went to sugarcane (Table 7). Assuming a similar percentage for 1978 and using this percentage for lime also, 9.72 E10 g of other nutrients were applied to sugarcane in Louisiana (sugarcane production in Mississippi is negligible). Total farm area of Louisiana and Mississippi is 6.95 E 10 sq m (Table 6, note a). Thus the average input of other nutrients to sugarcane is equal to 1.4 g/sq m/yr.

4,3,I Input of other nutrients to pasture and hay. 2.2 g/sq m/yr. Total application of other nutrients in Louisiana and Mississippi for 1978 was 4.30 E11 and 1.24 E12 g, respectively (Table 6). In 1974, 2.7 and 11.6% of all potassium applied in Louisiana and Mississippi went to pasture and hay, respectively (Table 7). Assuming similar percentages for 1978 and using this percentage for lime also, 1.16 E10 and 1.44 E11 g of other nutrients were applied to pasture and hay in Louisiana and Mississippi, respectively, for a total of 1.56 E11 g. Total farm area of Louisiana and Mississippi is 6.95 E10 sq m (Table 6, note a). Thus the average input of other nutrients to pasture and hay is equal to 2.2 g/sq m/yr.

4,4,I Input of other nutrients to soybeans. 4.7 g/sq m/yr. Total application of other nutrients in Louisiana and Mississippi for 1978 was 4.30 E11 and 1.24 E12 g, respectively (Table 6). In 1974, 12.1 and 22.3% of all potassium applied in Louisiana and Mississippi went to soybeans, respectively (Table 7). Assuming similar percentages for 1978 and using this percentage for lime also, 5.20 E10 and 2.76 E11 g of other nutrients were applied to soybeans in Louisiana and Mississippi, respectively, for a total of 3.28 E11 g. Total farm area of Louisiana and Mississippi is 6.95 E10 sq m (Table 6, note a). Thus the average input of other nutrients to soybeans is equal to 4.7 g/sq m/yr.

4,5,I Input of other nutrients to other crops. 15.7 g/sq m/yr. Total application of other nutrients in Louisiana and Mississippi for 1978 was 4.30 E11 and 1.24 E12 g, respectively (Table 6). In 1974, 62.6 and 66.1% of all potassium applied in Louisiana and Mississippi went to other crops, respectively (Table 7). Assuming similar percentages for 1978 and using this percentage for lime also, 2.69 E11 and 8.20 E11 g of other nutrients were applied to other crops in Louisiana and Mississippi, respectively, for a total of 1.09 E12 g. Total farm area of Louisiana and Mississippi is 6.95 E10 sq m (Table 6, note a). Thus the average input of other nutrients to other crops is equal to 15.7 g/sq m/yr.

4,12,O Output of other nutrients from exports/imports. 24.0 g/sq m/yr. Total other nutrients (potassium and lime) applied in Louisiana and Mississippi in 1978 equaled 24.0 g/sq m/yr (Table 6).

Water.

6,1,I Input of water to soil. 1.54 E6 g/sq m/yr. The average precipitation in New Orleans over a 40 year period was 59.64 in/yr (NOAA 1981), or 1.51 cu m/sq m/yr. The density of water is 1 E6 g/cu m, and thus input of rain water to farmland is equal to 1.51 E6 g/sq m/yr. In addition, 3.09 E-2 cu m/sq m/yr (3.09 E4 g/sq m/yr) are applied through irrigation (Table 8). Total input of water is therefore equal to 1.54 E6 g/sq m/yr.

6,12,O Output of water from export/import. 1.54 E6 g/sq m/yr. Total amount of water imported into the system is equal to 1.51 E6 g/sq m/yr of rain, and 3.09 E4 g/sq m/yr of irrigation (6,1,I). This gives a total import of 1.54 E6 g/sq m/yr.

Pesticides.

7,6,I Input of pesticide to weeds. 0.22 g/sq m/yr. Total herbicide application in Louisiana and Mississippi in 1974 was 1.55 E10 g (Table 9). Total farm area of Louisiana and Mississippi in 1974 was 6.92 E10 sq m (Table 8, note b). Thus the average input of herbicide to weeds is equal to 0.22 g/sq m/yr.

7,9,I Input of pesticide to pests. 0.36 g/sq m/yr. Total insecticide and fungicide application in Louisiana and Mississippi in 1974 was 2.46 E10 g (Table 9). Total farm area of Louisiana and Mississippi in 1974 was 6.92 E10 sq m (Table 8, note b). Thus the average input of pesticide to pests is equal to 0.36 g/sq m/yr.

7,12,0 Output of pesticides from exports/imports. 0.58 g/sq m/yr. Total pesticides (herbicide, insecticide, and fungicide) applied in Louisiana and Mississippi in 1978 was 4.01 E10 g (Table 9). Total farm area of Louisiana and Mississippi in 1974 was 6.92 E10 sq m (Table 8, note b). Thus the average input of pesticide is equal to 0.58 g/sq m/yr.

Sugarcane biomass.

9,2,0 Output of sugarcane biomass. 984.6 g/sq m/yr. Total 1978 sugarcane harvest for MDPR parishes/counties was 3.87 E12 g (Table 10). Total farm area of MDPR parishes/counties is 4.04 E9 sq m (Table 5). Average harvest is therefore 957.9 g/sq m/yr. Total sugarcane consumption by pests is equal to 26.7 g/sq m/yr (9,9,I). Thus total production is equal to 984.6 g/sq m/yr.

9,9,I Input of sugarcane to pests. 26.7 g/sq m/yr. Using stinkbugs as an indicator, total crop consumption by pests is equal to 35.3 g/sq m/yr (Table 12). Harvests of sugarcane, pasture and hay, soybeans, and other crops are equal to 957.9 (9,2,0), 252.5 (10,3,0), 24.4 (11,4,0), and 33.4 (12,5,0) g/sq m/yr, respectively. Thus sugarcane accounts for 75.6% of all harvest. Assuming consumption of crops by pests is in proportion to the percent of harvest, sugarcane consumption is equal to the product of 35.3 and 0.756, or 26.7 g/sq m/yr.

9,12,I Input of sugarcane to export/import. 957.9 g/sq m/yr. Total 1978 sugarcane harvest for MDPR parishes/counties is 957.9 g/sq m/yr (9,2,0).

Pasture and hay biomass.

10,3,0 Output of pasture and hay biomass. 259.5 g/sq m/yr. Total 1978 pasture and hay harvest for MDPR parishes/counties was 1.02 E12 g (Table 10). Total farm area of MDPR parishes/counties is 4.04 E9 sq m (Table 5). Average harvest is therefore 252.5 g/sq m/yr. Total pasture and hay consumption by pests is equal to 7.0 g/sq m/yr (10,9,I). Thus total production is equal to 259.5 g/sq m/yr.

10,9,I Input of pasture and hay to pests. 7.0 g/sq m/yr. Using stinkbugs as an indicator, total crop consumption by pests is equal to 35.3 g/sq m/yr (Table 12). Harvests of sugarcane, pasture and hay, soybeans, and other crops are equal to 957.9 (9,2,0), 252.5 (10,3,0), 24.4 (11,4,0), and 33.4 (12,5,0) g/sq m/yr, respectively. Thus pasture and hay accounts for 19.9% of all harvest. Assuming consumption of crops by pests is in proportion to the percent of harvest, pasture and hay consumption is equal to the product of 35.3 and 0.199, or 7.0 g/sq m/yr.

10,10,I Input of pasture and hay to livestock. 252.5 g/sq m/yr. Total 1978 pasture and hay harvest for MDPR parishes/counties was 252.5 g/sq m/yr (10,3,0). It is assumed that all of this is consumed on local farms.

Soybean biomass.

11,4,0 Output of soybean biomass. 25.1 g/sq m/yr. Total 1978 soybean harvest for MDPR parishes/counties was 9.84 E10 g (Table 10). Total farm area of MDPR parishes/counties is 4.04 E9 sq m (Table 5). Average harvest is therefore 24.4 g/sq m/yr. Total soybean consumption by pests is equal to 0.7 g/sq m/yr (11,9,I). Thus total production is equal to 25.1 g/sq m/yr.

11,9,I Input of soybeans to pests. 0.7 g/sq m/yr. Using stinkbugs as an indicator, total crop consumption by pests is equal to 35.3 g/sq m/yr (Table 12). Harvests of sugarcane, pasture and hay, soybeans, and other crops are equal to 957.9 (9,2,0), 252.5 (10,3,0), 24.4 (11,4,0), and 33.4 (12,5,0) g/sq m/yr, respectively. Thus soybeans account for 1.9% of all harvest. Assuming consumption of crops by pests is in proportion to the percent of harvest, soybean consumption is equal to the product of 35.3 and 0.019, or 0.7 g/sq m/yr.

11,12,I Input of soybeans to export/import. 24.4 g/sq m/yr. Total 1978 soybean harvest for MDPR parishes/counties was 24.4 g/sq m/yr (11,4,0).

Other crops biomass.

12,5,0 Output of other crops biomass. 34.3 g/sq m/yr. Total 1978 harvest of other crops for Louisiana and Mississippi was 2.32 E12 g (Table 11). Total farm area of Louisiana and Mississippi is 6.95 E10 sq m (Table 6, note a). Average harvest is therefore 33.4 g/sq m/yr. Total other crops consumption by pests is equal to 0.9 g/sq m/yr (12,9,I). Thus total production is equal to 34.3 g/sq m/yr.

12,9,I Input of other crops to pests. 0.9 g/sq m/yr. Using stinkbugs as an indicator, total crop consumption by pests is equal to 35.3 g/sq m/yr (Table 12). Harvests of sugarcane, pasture and hay, soybeans, and other crops are equal to 957.9 (9,2,0), 252.5 (10,3,0), 24.4 (11,4,0), and 33.4 (12,5,0) g/sq m/yr, respectively. Thus other crops account for 2.6% of all harvest. Assuming consumption of crops by pests is in proportion to the percent of harvest, soybean consumption is equal to the product of 35.3 and 0.026, or 0.9 g/sq m/yr.

12,11,I Input of other crops to households. 0.3 g/sq m/yr. Harvest of other crops in Louisiana and Mississippi is 1.29 E12 and 1.03 E12 g, respectively (Table 11). Value of all crops consumed at the farm in Louisiana and Mississippi is equal to 5,850 and 17,385 thousand dollars, respectively (USDA 1979). Total value of all crops was 986,819 and 1,109,168 thousand dollars (USDA 1979). Thus 0.6 and 1.6% of all crops were consumed at the farm in Louisiana and Mississippi. On-farm consumption is therefore equal to 7.74 E9 and 1.65 E10 g, for a total of 2.42 E10 g. Total farm area of Louisiana and Mississippi is 6.95 E10 sq m (Table 6, note a). Thus average on-farm consumption is equal to 0.3 g/sq m/yr.

12,12,I Input of other crops to export/import. 33.1 g/sq m/yr. Total 1978 other crops harvest for Louisiana and Mississippi was 33.4 g/sq m/yr (11,4,0), 0.3 of which is consumed on the farm (12,11,I). Thus the remaining 33.1 g/sq m/yr are exported.

Pest biomass.

16,9,S Pest biomass. 1.65 g/sq m. Using stinkbugs as an indicator, pest biomass is equal to 1.65 g/sq m (Table 12).

Livestock biomass.

17,10,0 Output of livestock biomass. 30.8 g/sq m/yr. Total production of livestock and dairy products in Louisiana and Mississippi was 2.14 E12 g in 1978 (Table 16). Total farm area of Louisiana and Mississippi is 6.95 E10 sq m (Table 6, note a). Average production is therefore equal to 30.8 g/sq m/yr.

17,11,I Input of livestock to households. 1.1 g/sq m/yr. Total on-farm consumption of livestock and dairy products in Louisiana and Mississippi was 7.37 E10 g in 1978 (Table 16). Total farm area of Louisiana and Mississippi is 6.95 E10 sq m (Table 6, note a). Average on-farm consumption is therefore equal to 1.1 g/sq m/yr.

17,12,I Input of livestock to export/import. 29.7 g/sq m/yr. Total production of livestock and dairy products in Louisiana and Mississippi is 30.8 g/sq m/yr (17,10,0), 1.1 of which is consumed on-farm (17,11,I). The remaining 29.7 g/sq m/yr are exported.

Labor services.

18,2,I Input of labor to sugarcane. 2.04 E-3 hr/sq m/yr. Table 18.
18,3,I Input of labor to pasture and hay. 4.98 E-5 hr/sq m/yr. Table 18.
18,4,I Input of labor to soybeans. 1.16 E-4 hr/sq m/yr. Table 18.
18,5,I Input of labor to other crops. 4.76 E-4 hr/sq m/yr. Table 18.
18,10,I Input of labor to livestock. 4.71 E-4 hr/sq m/yr. Table 18.
18,11,0 Output of labor from households. 1.24 E-3 hr/sq m/yr. Total labor input to crops and animals is equal to 3.15 E-3 hr/sq m/yr (Table 18). Of this, 1.91 E-3 hr/sq m/yr come from hired labor (18,12,0). The remaining 1.24 E-3 hr/sq m/yr come from farm households.
18,12,0 Output of labor from export/import. 1.91 E-3 hr/sq m/yr. Total input of hired labor to farms in MDPR parishes/counties was 7.73 E6 hrs for 1978 (Table 19). Total area of MDPR parishes/counties is 4.04 E9 sq m (Table 5). Average import of labor is therefore 1.91 E-3 hr/sq m/yr.

Fossil fuels.

19,2,I Input of fossil fuels to sugarcane. 32.7 kcal/sq m/yr. Total input of fossil fuels to farms in MDPR parishes for 1978 was 9.59 E11 kcal (Table 20). In 1974, 13.8% of all energy used in Louisiana agriculture went to sugarcane (Table 21). Assuming a similar percentage for 1978, 1.32 E11 kcal were used for sugarcane in MDPR parishes (sugarcane production in Mississippi is negligible). Total farm area of MDPR parishes/counties is 4.04 E9 sq m (Table 5). Thus the average input of fossil fuels to sugarcane is equal to 32.7 kcal/sq m/yr.
19,3,I Input of fossil fuels to pasture and hay. 3.1 kcal/sq m/yr. Total input of fossil fuels to farms in MDPR parishes/counties for 1978 was 9.59 E11 and 3.66 E10 kcal, respectively (Table 20). In 1974, 1.2 and 2.5% of all energy used in Louisiana and Mississippi went to pasture and hay, respectively (Table 21). Assuming similar percentages for 1978, 1.15 E10 and 9.15 E8 kcal were used for pasture and hay in MDPR parishes/counties, for a total of 1.24 E10 kcal. Total farm area of MDPR parishes/counties is 4.04 E9 sq m (Table 5). Thus the average input of fossil fuels to pasture and hay is equal to 3.1 kcal/sq m/yr.
19,4,I Input of fossil fuels to soybeans. 60.4 kcal/sq m/yr. Total input of fossil fuels to farms in MDPR parishes/counties for 1978 was 9.59 E11 and 3.66 E10 kcal, respectively (Table 20). In 1974, 24.5 and 25.4% of all energy used in Louisiana and Mississippi went to soybeans, respectively (Table 21). Assuming similar percentages for 1978, 2.35 E11 and 9.30 E9 kcal were used for soybeans in MDPR parishes/counties, for a total of 2.44 E11 kcal. Total farm area of MDPR parishes/counties is 4.04 E9 sq m (Table 5). Thus the average input of fossil fuels to soybeans is equal to 60.4 kcal/sq m/yr.
19,5,I Input of fossil fuels to other crops. 121.5 kcal/sq m/yr. Total input of fossil fuels to farms in MDPR parishes/counties for 1978 was 9.59 E11 and 3.66 E10 kcal, respectively (Table 20). In 1974, 49.2 and 51.6% of all energy used in Louisiana and Mississippi went to other crops, respectively (Table 21). Assuming similar percentages for 1978, 4.72 E11 and 1.89 E10 kcal were used for other crops in MDPR parishes/counties, for a total of 4.91 E11 kcal. Total farm area of MDPR parishes/counties is 4.04 E9 sq m (Table 5). Thus the average input of fossil fuels to other crops is equal to 121.5 kcal/sq m/yr.

19,10,I Input of fossil fuels to livestock. 28.7 kcal/sq m/yr. Total input of fossil fuels to farms in MDPR parishes/counties for 1978 was 9.59 E11 and 3.66 E10 kcal, respectively (Table 20). In 1974, 11.3 and 20.5% of all energy used in Louisiana and Mississippi went to livestock, respectively (Table 21). Assuming similar percentages for 1978, 1.08 E11 and 7.50 E9 kcal were used for livestock in MDPR parish counties, for a total of 1.16 E11 kcal. Total farm area of MDPR parishes/counties is 4.04 E9 sq m (Table 5). Thus the average input of fossil fuels to livestock is equal to 28.7 kcal/sq m/yr.

19,12,0 Output of fossil fuels from exports/imports. 246.5 kcal/sq m/yr. Total input of fossil fuels to farms in MDPR parishes/counties for 1978 was 9.96 E11 kcal (Table 20). Total farm area of MDPR parishes/counties is 4.04 E9 sq m (Table 5). Thus import of fossil fuels is equal to 246.5 kcal/sq m/yr.

Other goods and services.

20,2,I Input of other goods and services to sugarcane. 1.33 E-3 dollars/sq m/yr. Dollar value of seeds, bulbs, plants, and trees for MDPR parishes/counties is 7.11 E6 dollars (Table 22). Total farm area of MDPR parishes/counties is 4.04 E9 sq m (Table 5). Average input to all crops is therefore 1.76 E-3 dollars/sq m/yr. Assuming that input into sugarcane is proportional to its percentage of the total crop harvest, input of other goods and services into sugarcane is equal to the product of 1.76 E-3 and 0.756, the percent of total harvest coming from sugarcane (9,9,I). This is equal to 1.33 E-3 dollars/sq m/yr.

20,3,I Input of other goods and services to pasture and hay. 3.50 E-4 dollars/sq m/yr. Average input of other goods and services to all crops is 1.76 E-3 dollars/sq m/yr (20,2,I). Assuming that input into pasture and hay is proportional to its percentage of the total crop harvest, input of other goods and services into pasture and hay is equal to the product of 1.76 E-3 and 0.199, the percent of total harvest coming from pasture and hay (10,9,I). This is equal to 3.50 E-4 dollars/sq m/yr.

20,4,I Input of other goods and services to soybeans. 3.34 E-5 dollars/sq m/yr. Average input of other goods and services to all crops is 1.76 E-3 dollars/sq m/yr (20,2,I). Assuming that input into soybeans is proportional to its percentage of the total crop harvest, input of other goods and services into soybeans is equal to the product of 1.76 E-3 and 0.019, the percent of total harvest coming from soybeans (11,9,I). This is equal to 3.34 E-5 dollars/sq m/yr.

20,5,I Input of other goods and services to other crops. 4.58 E-5 dollars/sq m/yr. Average input of other goods and services to all crops is 1.76 E-3 dollars/sq m/yr (20,2,I). Assuming that input into other crops is proportional to their percentage of the total crop harvest, input of other goods and services into other crops is equal to the product of 1.76 E-3 and 0.026, the percent of total harvest coming from other crops (12,9,I). This is equal to 4.58 E-5 dollars/sq m/yr.

20,10,I Input of other goods and services to livestock. 9.55 E-3 dollars/sq m/yr. Dollar value of livestock and poultry purchased, feed, and animal health costs for MDPR parishes/counties is equal to 9.65 E6, 2.79 E7, and 1.04 E6 dollars (Table 22), for a total of 3.86 E7 dollars. Total farm area of MDPR parishes/counties is 4.04 E9 sq m (Table 5). Average input to livestock is therefore 9.55 E-3 dollars/sq m/yr.

20,11,I Input of other goods and services to farm households. 1.23 E-2 dollars/sq m/yr. Dollar value of machinery and equipment for MDPR parishes/counties is equal to 3.36 E6 dollars (Table 22). Total farm area of MDPR parishes/counties is 4.04 E9 sq m (Table 5). Average input to farm households is therefore 8.32 E-4 dollars/sq m/yr. Dollar value for other expenses for U.S. farms is equal to 4.16 E10 dollars (Table 23). Total area of U.S. farms ("total cropland" plus "other pastureland and rangeland") is 3.63 E12 sq m (U.S. Bureau of Census 1981). Average input to farm households is therefore 1.15 E-2 dollars/sq m/yr. Total input of other goods and services to farm households is equal to the sum, or 1.23 E-2 dollars/sq m/yr.

20,12,O Output of other goods and services from export/import. 2.36 E-2 dollars/sq m/yr. Import of other goods and services is equal to the sum of goods and services used for crops, livestock, and households. These equal 1.76 E-3 (20,2,I), 9.55 E-3 (20,10,I), and 1.23 E-2 (20,11,I) dollars/sq m/yr. This gives a total of 2.36 E-2 dollars/sq m/yr.

Farm capital.

21,11,S Capital assets of farms. 0.45 dollars/sq m. Total capital assets of farms in MDPR parishes/counties are 1.82 E9 dollars (Table 24). Total farm area of MDPR parishes/counties is 4.04 E9 sq m (Table 5). Average farm assets is therefore equal to 0.45 dollars/sq m.

Sunlight.

22,2,I Input of sunlight to sugarcane. 2.41 E4 kcal/sq m/yr. Average solar insolation at New Orleans, Louisiana, from 1952-1975 was 389.8 cal/sq cm/day (Knapp et al. 1980), or 1.42 E6 kcal/sq m/yr. Assuming input of sunlight to sugarcane is proportional to its percent of total farm area, input is equal to the product of 1.42 E6 and 0.017, the percent of area in sugarcane (Table 25). This is equal to 2.41 E4 kcal/sq m/yr.

22,3,I Input of sunlight to pasture and hay. 9.23 E4 kcal/sq m/yr. Solar insolation in southern Louisiana is equal to 1.42 E6 kcal/sq m/yr (23,2,I). Assuming input of sunlight to pasture and hay is proportional to its percent of total farm area, input is equal to the product of 1.42 E6 and 0.065, the percent of area in pasture and hay (Table 25). This is equal to 9.23 E4 kcal/sq m/yr.

22,4,I Input of sunlight to soybeans. 5.54 E5 kcal/sq m/yr. Solar insolation in southern Louisiana is equal to 1.42 E6 kcal/sq m/yr (23,2,I). Assuming input of sunlight to soybeans is proportional to its percent of total farm area, input is equal to the product of 1.42 E6 and 0.390, the percent of area in soybeans (Table 25). This is equal to 5.54 E5 kcal/sq m/yr.

22,5,I Input of sunlight to other crops. 7.50 E5 kcal/sq m/yr. Solar insolation in southern Louisiana is equal to 1.42 E6 kcal/sq m/yr (23,2,I). Assuming input of sunlight to other crops is proportional to their percent of total farm area, input is equal to the product of 1.42 E6 and 0.528, the percent of area in other crops (Table 25). This is equal to 7.50 E5 kcal/sq m/yr.

22,12,O Output of sunlight from export/import. 1.42 E6 kcal/sq m/yr. Import of energy to MDPR farms is equal to the average solar insolation for southern Louisiana, which is 1.42 E6 kcal/sq m/yr (23,2,I).

Table 5. Farm area in MDPR parishes/counties, 1978.[a]

Parish/county	Area (sq m)
Louisiana	
Iberia	4.44 E8
Jefferson	1.29 E7
Lafourche	4.80 E8
Orleans	3.68 E5
Plaquemines	1.54 E8
St. Bernard	5.80 E6
St. Charles	3.59 E7
St. James	1.75 E8
St. John	5.53 E7
St. Mary	2.79 E8
St. Tammany	1.78 E8
Tangipahoa	4.34 E8
Terrebonne	1.63 E8
Vermilion	1.36 E9
Total	3.78 E9
Mississippi	
Hancock	1.16 E8
Harrison	8.00 E7
Jackson	6.77 E7
Total	7.64 E8
TOTAL	4.04 E9

[a]Data from U.S. Bureau of Census (1981). Farm area included here is "cropland" and "other pastureland and rangeland." Other farm area is excluded to maintain comparability with habitat classification used in this study (see text).

Table 6. Fertilizer use on Louisiana and Mississippi farms, 1978.[a]

	Louisiana	Mississippi	TOTAL	
	g	g	g	g/sq m
Nitrogen	1.05 E11	1.53 E11	2.58 E11	3.71
Phosphorus	2.83 E10	3.08 E10	5.91 E10	0.85
Potassium	5.98 E10	6.93 E10	1.29 E11	1.86
Lime	3.70 E11	1.17 E12	1.54 E12	22.16

[a]Weights of nitrogen, phosphorus, and potassium (as N, P, and K) are taken from USDA (1979). Lime data and farm areas taken from U.S. Bureau of Census (1981). Areas of Louisiana and Mississippi farmland ("cropland" and "other pastureland and rangeland") are 3.06 E10 and 3.89 E10 sq m, respectively, for a total of 6.95 E10 sq m.

Table 7. Fertilizer use by crop for Louisiana and Mississippi, 1974.[a]

Location	Nitrogen		Phosphorus		Potassium	
	g	%	g	%	g	%
Louisiana						
Sugarcane	2.07 E10	23.0	9.33 E 9	14.7	1.04 E10	22.6
Pasture and hay[b]	1.36 E10	15.1	4.42 E 9	7.0	1.27 E 9	2.7
Soybeans	9.52 E 8	1.1	4.02 E 9	6.4	5.56 E 9	12.1
Other crops	5.48 E10	60.8	4.55 E10	71.9	2.88 E10	62.6
Total	9.00 E10		6.33 E10		4.60 E10	
Mississippi						
Pasture and hay[b]	2.63 E10	19.4	8.68 E 9	27.5	2.91 E 9	11.6
Soybeans	1.26 E 9	0.9	5.51 E 9	17.4	5.60 E 9	22.3
Other crops	1.08 E11	79.7	1.74 E10	55.1	1.66 E10	66.1
Total	1.36 E11		3.16 E10		2.51 E10	

[a]Data from USDA (1976). Phosphorus and potassium are as P_2O_5 and K_2O, respectively. Percent is the percent of that fertilizer applied for that state.
[b]Corn silage, sorghum silage, alfalfa, and "other hay."

Table 8. Water applied through irrigation in Louisiana and Mississippi, 1974.[a]

Location	Total applied cu m	Application rate[b] cu m/sq m
Louisiana	1.52 E9	-
Mississippi	6.24 E8	-
TOTAL	2.14 E9	3.09 E-2

[a]Data from USDA (1976).
[b]In 1978, farm area in Louisiana and Mississippi was equal to 3.89 E10 and 5.61 E10 sq m, respectively (U.S. Bureau of Census 1981). Of this, 3.06 E10 (78.7%) and 3.89 E10 (69.3%) sq m was "cropland" and "other pastureland and rangeland." Total area of Louisiana and Mississippi farmland in 1974 was 3.70 E10 and 5.79 E10 sq m, respectively (U.S. Bureau of Census 1981). Assuming similar distributions of land, area of "cropland" and "other pastureland and rangeland" is equal to 2.91 E10 and 4.01 E10 sq m in 1974 for Louisiana and Mississippi, respectively. This gives a total of 6.92 E10 sq m. Other farm area is excluded to maintain comparability with habitat classification used in this study (see text).

Table 9. Pesticide use on Louisiana and Mississippi farms, 1974.[a]

Location	Herbicide	Insecticide	Fungicide	Total
Louisiana	6.00 E 9	8.00 E 9	3.79 E7	1.40 E10
Mississippi	9.46 E 9	1.63 E10	2.76 E8	2.60 E10
Total	1.55 E10	2.43 E10	3.14 E8	4.01 E10

[a]In grams. Data from USDA (1976).

Table 10. Production of selected crops in MDPR parishes/counties, 1978.[a]

Location	Sugar-cane[b]	Hay and silage[c]	Pasture[d]	Soybean[e]
Louisiana				
Iberia	1.04 E12	8.94 E 9	5.12 E10	9.47 E 9
Jefferson	-	3.27 E 8	4.97 E 9	-
Lafourche	9.69 E11	8.90 E 9	1.34 E11	8.08 E 8
Orleans	-	-	-	-
Plaquemines	-	-	7.64 E10	-
St. Bernard	-	4.92 E 8	1.89 E 9	-
St. Charles	-	1.41 E 9	1.15 E10	-
St. James	4.74 E11	1.77 E 8	7.61 E 9	6.95 E 9
St. John	1.69 E11	6.56 E 8	2.41 E 9	1.83 E 9
St. Mary	8.30 E11	1.12 E 8	7.85 E 9	4.25 E 9
St. Tammany	-	1.47 E10	7.15 E10	6.99 E 8
Tangipahoa	-	5.49 E10	1.85 E11	3.37 E 9
Terrebonne	3.26 E11	2.17 E 9	1.97 E10	4.92 E 9
Vermilion	6.22 E10	1.22 E10	2.56 E11	5.31 E10
Total	3.87 E12	1.05 E11	8.30 E11	8.54 E10
Mississippi				
Hancock	-	5.90 E 9	4.22 E10	3.91 E 9
Harrison	-	2.01 E 9	2.06 E10	4.45 E 9
Jackson	-	1.12 E 9	1.14 E10	4.63 E 9
Total	-	9.03 E 9	7.42 E10	1.30 E10
TOTAL	3.87 E12	1.14 E11	9.04 E11	9.84 E10

[a]In g of harvested crop. Data from U.S. Bureau of Census (1981).

[b]Sugarcane for sugar and for seed.

[c]Hay crops (alfalfa hay, small grain hay, other tame dry hay, wild hay, grass silage and haylage, and hay crops cut and fed green), corn for silage or green chop, and sorghum for silage or green chop. Green weight for latter two categories converted to dry weight by dividing by three.

[d]Acreage of pastureland ("cropland used only as pasture" and "other pastureland and rangeland") converted to production by using a yield value of 3 tons dry wt/acre of pasture (pers. comm., Dr. O. D. Curtis, La. Cooperative Extension Service, LSU).

[e]Bushels converted to grams by using the conversion 1 bu = 27,216 g (U.S. Dept. of Agr. 1979).

Table 11. Production of miscellaneous crops in Louisiana and Mississippi, 1978.[a]

	Louisiana	Mississippi	Total
Corn[b]	6.69 E10	1.68 E11	2.35 E11
Sorghum[c]	1.09 E10	1.86 E10	2.95 E10
Wheat[d]	1.09 E10	5.04 E10	6.13 E10
Barley[e]	5.21 E 7	-	5.21 E 7
Oats[f]	6.16 E 9	5.67 E 9	1.18 E10
Millet[g]	-	3.34 E 7	3.34 E 7
Rice	1.02 E12	4.16 E11	1.44 E12
Rye[h]	3.64 E 7	-	3.64 E 7
Sunflower Seed	-	1.32 E 9	1.32 E 9
Cotton[i]	1.03 E11	2.92 E11	3.95 E11
Tobacco	3.99 E 7	-	3.99 E 7
Field Peas[j]	2.93 E 7	1.67 E 8	1.96 E 8
Irish Potatoes	6.66 E 9	1.74 E 9	8.40 E 9
Sweet Potatoes[k]	5.64 E10	1.35 E10	6.99 E10
Peanuts	8.09 E 8	4.98 E 9	5.79 E 9
Vegetables[l]	4.58 E 9	5.79 E10	6.25 E10
Total	1.29 E12	1.03 E12	2.32 E12

[a] All quantities reported as grams. Data from U.S. Bureau of Census (1981). All conversions from USDA (1979).

[b] Corn for grain or seed. Bushels converted to grams by using the conversion 1 bu = 31,752 g.

[c] Sorghum for grain or seed. Bushels converted to grams by using the conversion 1 bu = 25,402 g.

[d] Wheat for grain. Bushels converted to grams by using the conversion 1 bu = 27,216 g.

[e] Barley for grain. Bushels converted to grams by using the conversion 1 bu = 21,773 g.

[f] Oats for grain. Bushels converted to grams by using the conversion 1 bu = 14,515 g.

[g] Proso millet. Bushels converted to grams by using the conversion 1 bu = 22,226 g.

[h] Rye for grain. Bushels converted to grams by using the conversion 1 bu = 25,402 g.

[i] Net weight. Bales converted to grams by using the conversion 1 bale = 217,728 g.

[j] Dry field and seed peas, and cowpeas for dry peas. Bushels of cowpeas converted to grams by using the conversion 1 bu = 27,216 g.

[k] Bushels converted to grams by using the conversion 1 bu = 24,948 g.

[l] Data for vegetables ("for fresh markets and for processing") are from USDA (1979).

Table 12. Biomass and consumption rates of southern green stinkbug (*Nezara viridula* (L.)) and brown stinkbug (*Euschistus serrus* (Say)) on soybeans in Louisiana.

Organism	Density[a]	Biomass[b]	Consumption[c]
Nezara viridula			
Nymph	2.45	0.56	10.9
Adult	3.38	0.78	17.6
Euschistus serrus			
Nymph	0.58	0.13	2.6
Adult	0.80	0.18	4.2
TOTAL	7.21	1.65	35.3

[a] In individuals/sq m. Densities of *E. serrus* nymphs and adults and *N. viridula* adults estimated from a graph in Gandour (1977). A row width of 42 inches (1.07 m) was assumed in calculating density. Density of *N. viridula* nymphs was calculated by multiplying adult density by 0.725, the ratio of nymph to adult densities for *E. serrus*.

[b] In g/sq m. Laboratory-reared *N. viridula* have an average weight of 0.23 g/individual (pers. comm., K. M. Kester, Dept. Entomology, LSU). This value is used to convert all densities to biomass.

[c] In g/sq m/yr. Average feeding rate for *N. viridula* is 0.074 and 0.087 g/individual/day for nymphs and adults, respectively (Marsolan 1976). A feeding season of 60 days/yr is used.

Table 13. Livestock and wool production in Louisiana and Mississippi, 1978.[a]

	Louisiana	Mississippi	Total
Cattle and calves[b]			
Total production	1.73 E11	2.45 E11	4.18 E11
On-farm consumption			
Percent[c]	4.05	2.15	
Quantity	7.01 E 9	5.27 E 9	1.23 E10
Hogs[b]			
Total production	1.85 E10	4.63 E10	6.48 E10
On-farm consumption			
Percent[c]	21.3	13.4	
Quantity	3.94 E 9	6.20 E 9	1.01 E10
Sheep and lambs[b]			
Total production	1.93 E 8	-	1.93 E 8
On-farm consumption			
Percent[c]	32.8	-	
Quantity	6.33 E 7	-	6.33 E 7
Wool[d]			
Total production[e]	3.72 E 7	1.13 E 7	4.85 E 7
TOTAL			
Total production	1.92 E11	2.91 E11	4.83 E11
On-farm consumption			
Quantity	1.10 E10	1.15 E10	2.25 E10

[a]Production and consumption in grams. Data from USDA (1979).
[b]Quantity produced on farms, in live weight.
[c]Percent of total production consumed on farm is the ratio of value of animals slaughtered for home consumption to the gross income (cash receipts from livestock sales plus value of animals slaughtered for home use), multiplied by one hundred. This ratio is multiplied by total production to give the amount consumed at the farm.
[d]Production of shorn wool.
[e]Data for Mississippi are from 1977.

Table 14. Dairy production in Louisiana and Mississippi, 1978.[a]

	Louisiana	Mississippi	Total
Milk and milkfat			
Total production	5.00 E11	3.93 E11	8.93 E11
On-farm consumption	1.18 E10	8.62 E 9	2.04 E10
Eggs[b]			
Total production	3.45 E10	1.00 E11	1.34 E11
On-farm consumption	5.31 E 8	4.72 E 8	1.00 E 9
TOTAL			
Total production	5.34 E11	4.93 E11	1.03 E12
On-farm consumption	1.23 E10	9.09 E 9	2.14 E10

[a]Production and consumption are in grams. Data from USDA (1979).
[b]Hens and pullets. Cases of eggs converted to grams by using the conversions 1 case = 30 dozen eggs and 1 egg = 59 g (USDA 1979).

Table 15. Poultry production in Louisiana and Mississippi, 1978[a]

	Louisiana	Mississippi	Total
Chickens[b]			
Total production	6.85 E 9	1.74 E10	2.42 E10
On-farm consumption	4.63 E 8	7.26 E 8	1.19 E 9
Broilers[c]			
Total production	1.30 E11	4.76 E11	6.06 E11
On-farm consumption	8.79 E 9	1.98 E10	2.86 E10
TOTAL			
Total production	1.37 E11	4.93 E11	6.30 E11
On-farm consumption	9.25 E 9	2.05 E10	2.98 E10

[a]Production and consumption in grams live weight. Data from USDA (1979).
[b]Excluding broilers.
[c]In Louisiana and Mississippi, 6.76 and 4.17% of chicken production is consumed at the farm. These ratios are used to calculate on-farm consumption of broilers.

Table 16. Production of animal products in Louisiana and Mississippi, 1978.[a]

	Louisiana	Mississippi	Total
Livestock and wool[b]			
Total production	1.92 E11	2.91 E11	4.83 E11
On-farm consumption	1.10 E10	1.15 E10	2.25 E10
Dairy[c]			
Total production	5.34 E11	4.93 E11	1.03 E12
On-farm consumption	1.23 E10	9.09 E 9	2.14 E10
Poultry[d]			
Total production	1.37 E11	4.93 E11	6.30 E11
On-farm consumption	9.25 E 9	2.05 E10	2.98 E10
TOTAL			
Total production	8.63 E11	1.28 E12	2.14 E12
On-farm consumption	3.26 E10	4.11 E10	7.37 E10

[a]Production and consumption in grams.
[b]From Table 13.
[c]From Table 14.
[d]From Table 15.

Table 17. Labor costs of sugarcane in Louisiana, 1982.[a]

Operation	Three row machinery	One row machinery	Average
Fallow and plant	2.96 E-3	4.35 E-3	3.66 E-3
Cultivation and harvest	2.17 E-3	2.54 E-3	2.36 E-3
Heat treatment	5.04 E-3	5.04 E-3	5.04 E-3
TOTAL			1.11 E-2

[a]Projected labor costs (hours/sq m) for parishes in the River, Teche, and Western areas. Data from Heagler et al. (1982).

Table 18. Labor requirements for selected crops and livestock, 1974-1978.

Commodity	Labor input[a]	Production[b]	Total labor[c]	
			hr	hr/sq m
Crops				
Sugarcane[d]	-	-	8.24 E6	2.04 E-3
Hay and silage[e]	1.76 E-6	1.14 E11	2.01 E5	4.98 E-5
Soybeans	4.78 E-6	9.84 E10	4.70 E5	1.16 E-4
Other crops				
Corn	1.26 E-6	2.35 E11	2.96 E5	4.26 E-6
Sorghum	3.15 E-6	2.95 E10	9.29 E4	1.34 E-6
Wheat	3.67 E-6	6.13 E10	2.25 E5	3.24 E-6
Rice[f]	-	-	8.61 E6	1.24 E-4
Other grains[g]	2.69 E-6	1.77 E10	4.76 E4	6.85 E-7
Cotton	5.05 E-5	3.95 E11	1.99 E7	2.86 E-4
Tobacco	2.87 E-4	3.99 E 7	1.14 E4	1.64 E-7
Potatoes[h]	3.31 E-6	7.83 E10	2.59 E5	3.73 E-6
Vegetables[i]	-	-	3.62 E6	5.21 E-5
Total other crops				4.76 E-4
Total all crops				2.68 E-3
Livestock[j]				
Cattle	3.09 E-5	4.18 E11	1.29 E7	1.86 E-4
Hogs	1.32 E-5	6.48 E10	8.55 E5	1.23 E-5
Milk	8.82 E-6	8.93 E11	7.88 E6	1.13 E-4
Eggs	5.07 E-5	1.34 E11	6.79 E6	9.78 E-5
Chickens	6.61 E-5	2.42 E10	1.60 E6	2.30 E-5
Broilers	4.41 E-6	6.06 E11	2.67 E6	3.85 E-5
Total				4.71 E-4

[a]Average labor requirement for the U.S. From USDA (1979).

[b]Production data from Tables 10, 11, 13, 14, and 15. Production for hay and silage and soybeans are for MDPR parishes/counties, only, whereas production for other crops and for livestock are for all of Louisiana and Mississippi.

[c]Total labor (hours) is equal to the product of labor input and production. Areal labor input is calculated by dividing total hours of labor by the total farm area. For hay and silage and soybeans, total farm area is for MDPR parishes/counties, and is equal to 4.04 E9 sq m (Table 5). For other crops and livestock, total farm area is for all of Louisiana and Mississippi, and is equal to 6.95 E10 sq m (Table 6, note a).

(continued)

Table 18. Concluded.

[d]The estimated labor costs of sugarcane in Louisiana for 1982 are 1.11 E-2 hr/sq m of sugarcane farm (Table 17). In 1978 there were 7.42 E8 sq m of sugarcane farms in MDPR parishes/counties (U.S. Bureau of Census 1981). Total hours of labor are equal to the product of these two, or 8.24 E6 hr. Areal input of labor for an average MDPR farm is calculated by dividing the total hours by the total area of farms in MDPR parishes/counties, which is 4.04 E9 sq m (Table 5).

[e]Labor requirement listed is for hay, but is also used for silage. It is assumed that pasturage requires no labor, and is therefore omitted.

[f]The estimated labor costs of rice in Louisiana for 1982 (average of water and dry planted) are 2.61 E-3 hr/sq m of rice farm (Musick 1982). In 1978 there were 3.30 E9 sq m of rice farms in Louisiana and Mississippi (U.S. Bureau of Census 1981). Total hours of labor are equal to the product of these two, or 8.61 E6 hr. Areal input of labor for an average Louisiana/Mississippi farm is calculated by dividing the total hours by the total area of farms in Louisiana and Mississippi, which is 6.95 E10 sq m (Table 6, Note a).

[g]Barley, oats, rye, millet, and peanuts. Labor requirement is the average of corn, sorghum, and wheat values.

[h]Irish potatoes and sweet potatoes.

[i]The average estimated labor costs of selected vegetables in Louisiana for 1982 are 4.15 E-2 hr/sq m of vegetable farm (Ellerman and Law 1982). In 1978 there were 8.73 E7 sq m of vegetable farms in Louisiana and Mississippi (U.S. Bureau of Census 1981). Total hours of labor are equal to the product of these two, or 3.62 E6 hr. Areal input of labor for an average Louisiana/Mississippi farm is calculated by dividing the total hours by the total area of farms in Louisiana and Mississippi, which is 6.95 E10 sq m (Table 6, note a).

[j]Sheep's and lamb's wool are not included due to negligible production values.

Table 19. Input of hired labor to MDPR farms, 1978.

Location	Total wages[a] (thousand dollars)	Total labor[b] (thousand hours)
Louisiana		
Iberia	2900	1007
Jefferson	243	84
Lafourche	3360	1167
Orleans	-	-
Plaquemines	195	68
St. Bernard	213	74
St. Charles	136	47
St. James	1446	502
St. John	736	256
St. Mary	3640	1264
St. Tammany	2148	746
Tangipahoa	3360	1167
Terrebonne	1572	546
Vermilion	1893	657
Total	21842	7589
Mississippi		
Hancock	137	49
Harrison	163	58
Jackson	117	42
Total	417	149
TOTAL	22259	7738

[a]Total wages paid for hired farm labor and contract labor (U.S. Bureau of Census 1981).
[b]The reciprocal of the wage rate for all hired farm workers is 1 hr/$2.88 and 1 hr/$2.81 for Louisiana and Mississippi, respectively (USDA 1979). Total labor is the product of total wages and the reciprocal wage rate.

Table 20. Fossil fuel consumption in MDPR parishes/counties, 1978.[a]

Location	Gasoline[b] gal (E3)	Gasoline[b] kcal (E9)	Diesel fuel[c] gal (E3)	Diesel fuel[c] kcal (E9)	Bottled gas[d] gal (E3)	Bottled gas[d] kcal (E9)	Fuel oil[e] gal (E3)	Fuel oil[e] kcal (E9)	Natural gas[f] $ (E3)	Natural gas[f] kcal (E9)	Kerosene[g] $ (E3)	Kerosene[g] kcal (E9)	Electricity[h] $ (E3)	Electricity[h] kcal (E9)	TOTAL kcal (E9)
Louisiana															
Iberia	820	25.8	2030	69.1	362	9.0	93	3.2	15	1.6	151	13.1	135	11.5	133.3
Jefferson	57	1.8	-	-	3	0.1	-	-	8	0.9	6	0.5	11	0.9	4.2
Lafourche	800	25.2	1612	54.8	43	1.1	121	4.2	3	0.3	109	9.4	53	4.5	99.5
Orleans	4	0.1	-	-	-	-	-	-	-	-	1	0.1	-	-	0.2
Plaquemines	105	3.3	216	7.3	11	0.3	-	-	-	-	25	2.2	-	-	13.1
St. Bernard	36	1.1	4	0.1	-	-	-	-	21	2.3	3	0.3	9	0.8	4.6
St. Charles	47	1.5	79	2.7	-	-	-	-	-	-	5	0.4	4	0.3	4.9
St. James	457	14.4	918	31.2	57	1.4	12	0.4	10	1.1	94	8.1	34	2.9	59.5
St. John	104	3.3	167	5.7	30	0.7	-	-	-	-	21	1.8	7	0.6	12.1
St. Mary	519	16.4	1442	49.1	166	4.1	16	0.6	7	0.8	97	8.4	50	4.2	83.6
St. Tammany	495	15.6	314	10.7	151	3.7	6	0.2	29	3.2	40	3.5	161	13.7	50.6
Tangipahoa	1325	41.8	874	29.7	187	4.6	23	0.8	47	5.1	109	9.4	583	49.6	141.0
Terrebonne	376	11.8	634	21.6	50	1.2	43	1.5	4	0.4	63	5.4	56	4.8	46.7
Vermilion	2166	68.3	4814	163.8	1228	30.4	235	8.2	62	6.8	331	28.6	-	-	306.1
Total		230.4		445.8		56.6		19.1		22.5		91.2		93.8	959.4
Mississippi															
Hancock	114	3.6	159	5.4	6	0.1	1	0.0	1	0.1	19	1.6	-	-	10.8
Harrison	128	4.0	113	3.8	22	0.5	-	-	4	0.4	15	1.3	32	2.7	12.7
Jackson	109	3.4	145	4.9	37	0.9	1	0.0	-	-	15	1.3	30	2.6	13.1
Total		11.0		14.1		1.5		0.0		0.5		4.2		5.3	36.6
TOTAL		241.4		459.9		58.1		19.1		23.0		95.4		99.1	996.0

[a] Data from U.S. Bureau of Census (1981). In calculating kcal, the conversions 42 gal/bbl and 0.252 kcal/BTU were used. Heat content of various fuels (BTU/bbl or BTU/cu ft) taken from U.S. Dept. of Energy (1978).
[b] 31,518 kcal/gal.
[c] 34,020 kcal/gal. The heat content of kerosene is used for diesel fuel.
[d] LP gas, butane, and propane. 24,780 kcal/gal. The heat content of a 60% butane/40% propane mixture is used.
[e] 34,950 kcal/gal. The heat content of distillate fuel oil is used.
[f] 109,533 kcal/$. The 1978 price of $2.349/thousand cu ft for residential users of natural gas is used to convert cubic feet to dollars (U.S. Dept. of Energy 1978).
[g] Includes motor oil and grease. 86,565 kcal/$. The 1978 wholesale price of kerosene ($0.393/gal) is used to convert gallons to dollars (U.S. Dept. of Energy 1978).
[h] 85,082 kcal/$. The average 1978 price of electricity in Louisiana was 3.327¢/kwh for residential users and 2.997¢/kwh for commercial users (pers. comm., Ms. Janice Burbank, Gulf States Utilities, Baton Rouge, La.). The average of these two (3.16¢/kwh) is used for making this calculation. 10,669 BTU of fossil fuel energy are required to produce 1 kwh of electricity (U.S. Dept. of Energy 1978).

Table 21. Energy use by crop for Louisiana and Mississippi, 1974.[a]

Location	Energy use	
	Quantity	Percent
Louisiana		
Sugarcane	674	13.8
Pasture and hay[b]	58	1.2
Soybeans	1202	24.5
Other crops	2411	49.2
Livestock	554	11.3
Mississippi		
Pasture and hay (b)	126	2.5
Soybeans	1274	25.4
Other crops	2589	51.6
Livestock	1031	20.5

[a]Quantity of energy is in billions of kcal, and is energy consumed directly. This was calculated as total energy minus indirect energy. Percent is the percent of all direct energy consumed in that state. Data from USDA (1976).

[b]Corn silage, sorghum silage, alfalfa, and "other hay."

Table 22. Selected farm expenses in MDPR parishes/counties, 1978.[a]

Location	Livestock and poultry purchased	Feed[b]	Animal health costs	Seeds, bulbs, plants, and trees	Machinery and equipment[c]	Total
Louisiana						
Iberia	143	948	45	327	437	1900
Jefferson	51	121	11	22	38	243
Lafourche	549	316	47	226	420	1558
Orleans	-	3	-	17	-	20
Plaquemines	1068	78	27	44	83	1300
St. Bernard	-	27	-	171	1	199
St. Charles	88	67	29	6	9	199
St. James	17	25	3	136	109	290
St. John	13	32	4	38	41	128
St. Mary	101	34	20	133	163	451
St. Tammany	950	2110	105	691	69	3925
Tangipahoa	4904	21,586	572	372	399	27,833
Terrebonne	152	139	18	29	136	474
Vermilion	594	1244	106	4593	1248	7785
Mississippi						
Hancock	324	677	18	71	80	1170
Harrison	541	269	15	103	64	992
Jackson	154	199	18	134	68	573
TOTAL	9649	27,875	1038	7113	3365	49,040

[a]In thousand dollars. Data from U.S. Bureau of Census (1981).
[b]Feed for livestock and poultry, including commercially mixed formula feed.
[c]Custom work and rental of machinery and equipment.

Table. 23. Selected expenses for U.S. farms, 1978.[a]

Operation	Cost
Repairs and operation of capital items	10,835
Depreciation and other consumption of farm capital	16,648
Taxes on farm property	4,226
Interest on farm mortgage debt	5,232
Net rent to non-operator landlords	4,713
TOTAL	41,654

[a]Cost in millions of dollars. Data from U.S. Dept. of Agr. (1979).

Table 24. Capital assets of farms in MDPR parishes/counties, 1978.[a]

Location	Land and buildings[b]	Machinery and equipment	Total
Louisiana			
Iberia	1.76 E8	2.32 E7	1.99 E8
Jefferson	2.35 E7	1.01 E6	2.45 E7
Lafourche	1.65 E8	1.62 E7	1.81 E8
Orleans	4.92 E5	6.30 E4	5.55 E5
Plaquemines	4.30 E7	2.34 E6	4.53 E7
St. Bernard	4.31 E6	4.94 E5	4.80 E6
St. Charles	3.17 E7	1.50 E6	3.32 E7
St. James	9.70 E7	1.07 E7	1.08 E8
St. John	4.06 E7	2.80 E6	4.34 E7
St. Mary	1.02 E8	1.32 E7	1.15 E8
St. Tammany	1.23 E8	9.77 E6	1.33 E8
Tangipahoa	2.12 E8	2.88 E7	2.41 E8
Terrebonne	7.77 E7	6.96 E6	8.47 E7
Vermilion	4.25 E8	6.56 E7	4.91 E8
Mississippi			
Hancock	4.18 E7	4.12 E6	4.59 E7
Harrison	3.22 E7	3.23 E6	3.54 E7
Jackson	3.51 E7	3.79 E6	3.89 E7
TOTAL			1.82 E9

[a]In dollars. Data from U.S. Bureau of Census (1981).
[b]Calculated by multiplying the average value of land and buildings per farm times the number of farms.

Table 25. Farm area by crop for Louisiana and Mississippi.[a]

Crop	Louisiana	Mississippi	Total	Percent
Sugarcane	0.12 E10	-	0.12 E10	1.7
Pasture and hay	0.17 E10	0.28 E10	0.45 E10	6.5
Soybeans	1.22 E10	1.49 E10	2.71 E10	39.0
Other crops[b]	1.55 E10	2.12 E10	3.67 E10	52.8
TOTAL	3.06 E10	3.89 E10	6.95 E10	100.0

[a]Area in sq m. Data from U.S. Bureau of Census (1981).
[b]Calculated by subtracting sugarcane and pasture and hay area from total area.

2. BEACH AND DUNE

The beach areas in Louisiana are characterized by gently sloping fine sand that extends several meters from the shoreline giving way to dunes varying in height from 0.5 to 4 m. Some beaches are located on barrier islands and some line the mainland in areas unprotected by islands. In general, barrier islands in the MDPR are long and narrow, with very low elevation (approximately 5 m) and are separated from the mainland by shallow bays.

Beach and dune habitat represents a very small portion of the MDPR (4328 ha in 1978, or 0.12%) (Wicker et al. 1980a). Figure 7 is a map of the distribution of beach and dune habitat.

This habitat serves as a barrier to storms. Sand is stored in beach dunes between major storm events and eroded during storms, thus absorbing storm energy and protecting landward marshlands.

The geologic aspects of these areas have been closely studied (Morgan and Larimore 1957; Adams et al. 1978; Penland and Boyd 1981) because most of the barrier islands in Louisiana are rapidly eroding and moving shoreward. Ecological aspects of beaches and dunes in the MDPR have been little examined.

The rooted vegetation closest to the edge of the Gulf of Mexico is found in the dunes. Plants here include dog tooth grass (_Panicum repens_), beach morning glory (_Ipomoea stolonifera_), frogbit (_Erigeron repens_), _Heterotheca subaxilaris_, evening primrose (_Oenothera_ sp.) sandspur (_Cenchrus_ sp.), and sea rocket (_Cakile_ sp.).

Behind the foredunes there may be a meadow zone inhabited by beardgrass (_Andropogon_ sp.), fingergrass (_Chloris petraea_), saltmarsh fimbristylis (_Lippea lanciolata_), frogbit, pennywort (_Hydrocotyl bonariensis_), black rush (_Juncus roemerianus_), three cornered grass (_Scirpus olneyi_), softstem bulrush (_Scirpus validus_), widgeon grass (_Ruppia maritima_), sandspur, morning glory, heterotheca, sabbatia (_Sabbatia_ sp.), wiregrass, dog tooth grass, and Bermuda grass (_Cynodon dactylon_).

Old dunes that have been stranded inland from the meadow zone and that have achieved sufficient elevation are typically colonized by trees and shrubs, including live oak (_Quercus virginiana_), hackberry (_Celtis laevigata_), Hercules-club (_Zanthoxylum clava-herculis_), wax myrtle (_Myrica cerifera_), and St. Augustine grass (_Stenotophrum secundatum_). A further description of the vegetation characteristic of beach and dune habitat can be found in Bahr and Hebrard (1976).

Although the rate of primary production in dune areas is considerably lower than that of marsh habitats, the role of dune plants in stabilizing and accumulating sediments is critical. The plants trap wind-blown sand that would otherwise be lost to the beach system. The vegetation in the beach habitat supports populations of rabbits and other small mammals, birds, and reptiles.

There is little known about nutrient cycling in the beach and dune habitat. Plants adapted to the dune areas must be able to tolerate xeric conditions and low nutrient concentrations. Preliminary studies by Mendelssohn et al. (in preparation) revealed an average total nitrogen concentration of 1.82 ppm for foredune and middune regions and 3.07 ppm for beaches in the MDPR compared with 12.00 ppt for cypress swamp soils (Table 73) and 15.00 ppt for fresh marsh soils (Table 76). The average phosphorus concentrations are 70.75 ppm and 70.25 ppm for dune and beach areas, respectively. Wullstein and Pratt (1980) found that grasses adapted to survival on sand dunes have rhizosheaths on their roots. These sheaths are enriched in organic carbon and are associated with nitrogen fixation. They may also serve as storage areas for moisture.

The intertidal portion of the beach habitat is the focus of active energy flux, much of it hidden from view. A characteristic community of burrowing organisms feeds on organic matter that is pumped through beach sands by tidal and wave energy. These organisms are eaten by predatory burrowers and by shorebirds that are specialized to feed in the swash zone. An excellent description of the dynamics of this community can be found in Peterson and Peterson (1979). The intertidal beach community includes meiobenthic fauna, especially the so-called interstitial fauna: tiny crustaceans that live in the spaces between sand grains. The most conspicuous of the larger animals that occupy the lower beach habitat are the molluscs (including bivalves such as clams), cockles, gastropods, and decapod crustaceans (e.g., Orchestoidea sp., Emerita sp., Ocypode quadrata). Some benthic beach inhabitants are deeply burrowing forms that are rarely seen without sampling the sediments. These include polychaetes such as Diopatra sp. and hemichordates (Balanoglossus sp.). Burrowing forms are important food sources for specialized shorebirds, including plovers, willets, sandpipers, and turnstones that forage in the swash zone during low tide. During times of inundation, the benthic fauna in the beach habitat serve as a rich food source for marine demersal nekton. The functional partitioning of this intertidal food source by various fish and bird groups is described in detail by Peterson and Peterson (1979).

In addition to the intertidal sand flat feeding areas, the higher beach and dune areas are stopover, resting, and staging points for migrating birds such as warblers and as nesting grounds for shorebirds. In a study carried out in 1972 in dune ridges inland from Caminada Bay (Barataria hydrologic unit), 69 species of migrating birds used the dune habitat during the spring migration period (Hebrard, unpublished data cited in Bahr and Hebrard 1976). Nesting colonies of black skimmers, sandwich terns, royal terns, least terns, Caspian terns, gull-billed terns, Forster's terns, laughing gulls, and oystercatchers are all found in the barrier island beach and dune habitats in the MDPR.

Because of the vulnerability of the beach and dune habitat to storm erosion and because of the lack of sediment enrichment in many parts of the MDPR caused by the entrainment of the Mississippi, the erosion of barrier islands and retreat of shore lines is a serious problem. Penland and Boyd (1981) estimated that the Chandeleur Islands have been receding at rates of from 1 to 20 m per year (averaging 7 m/yr) during the past 60 years. It is likely that this island chain will totally disappear during the next century, causing increased marsh erosion in the Pontchartrain hydrologic unit (Baumann et al., in preparation).

Although there has been some oil and gas industry activity on Timbalier Island, the only barrier island in Louisiana that has been extensively developed is Grand Isle. As of 1970, more than one-third of the island was in residential, commercial, or industrial use. In addition to the oil and gas industry activities, Grand Isle is a widely used recreational area.

Although the beach and dune habitat is not a dominant one in terms of area, it is an important habitat ecologically and economically. Further study of the ecological relationships and methods for slowing the erosion of these areas is warranted.

The beach and dune habitat was not selected for detailed modeling. Figure 8 shows an unquantified material and energy diagram for the beach and dune habitat.

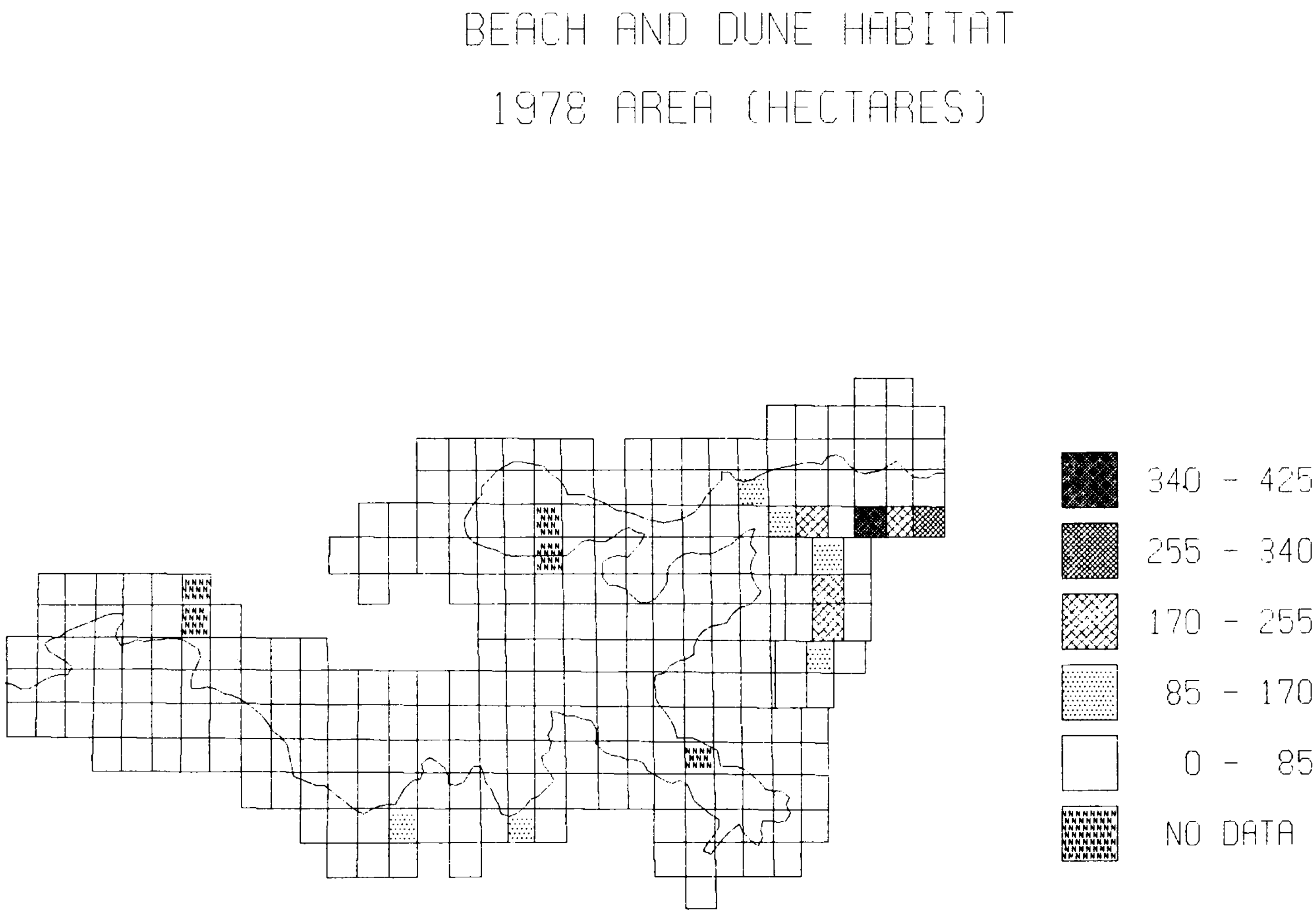


Figure 7. The distribution of MDPR beach and dune habitat.

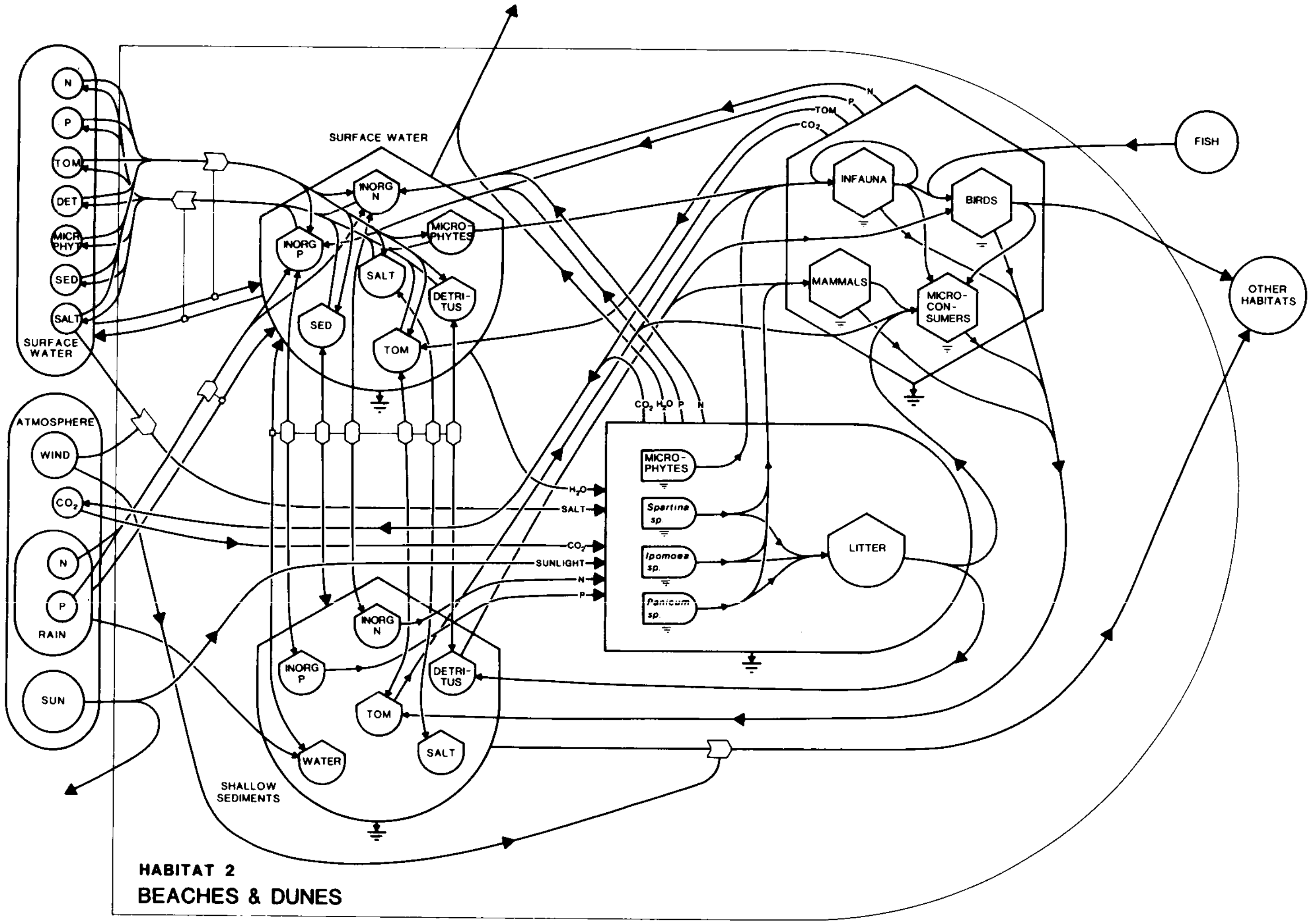


Figure 8. Beach and dune habitat flow diagram.

3. BOTTOMLAND HARDWOOD

The forested wetlands of the MDPR contain two types of plant communities--bottomland hardwoods and the baldcypress-water tupelo swamps. Bottomland hardwood forests covered 46,127 ha in the MDPR in 1978 (Wicker et al. 1980a). They are found in better drained areas of swampland with moist soil and brief, occasional floodings. A map of the distribution of bottomland hardwood habitat is shown in Figure 9.

In the upper Barataria Basin the bottomland hardwood forest and cypress-tupelo swamp lie below 1.5 m in elevation (Conner and Day 1976). Elevation on natural levees of the Mississippi River in the upper basin may reach 9 m above mean sea level (Day et al. 1981). Small changes in elevation in the swamp can have major effects on vegetative composition. Brown (1972) called a 15-cm change in elevation in the swamp as important as a 30-m change in mountainous regions.

The character of bottomland hardwood forests is determined by hydrological conditions. Such factors as the rate, seasonality, and amount of water flow are crucial in determining community structure, composition, and chemical cycling (Day et al. 1981).

Bottomland hardwood sites are flooded each year for a period of several weeks to a few months. The rest of the time the water table is near or just below the soil surface (Conner and Day, 1982). A bottomland hardwood site in the des Allemands swamp where primary productivity was measured experienced 15 to 30 cm of flooding for a period of 2 to 3 months (Conner and Day 1976). Net sediment deposition occurs as flood waters spread out and slow down over the forest floor. Most sediment movement occurrs during relatively brief periods of high flooding (Wharton et al. 1982). Leaf litter and organic matter are carried out of the bottomland hardwood forest during high-water periods.

The bottomland hardwood swamp community includes more plant species than the cypress-tupelo swamp. Conner and Day (1976) reported 23 tree species in a hardwood site in the des Allemands swamp, compared with nine species in a nearby deep baldcypress-water tupelo swamp. Bell (1974) found that as flooding frequency in a floodplain forest decreased, the number of herbaceous species increased.

Bottomland hardwood forest sites with a hydrological regime unaltered by man appear to be slightly more productive than unaltered cypress-tupelo swamp sites. Production in a MDPR bottomland hardwood community measured by Conner and Day (1976) was 1574 g/sq m/yr, compared with 1140 g/sq m/yr for a nearby undisturbed baldcypress-water tupelo community.

Bottomland hardwood habitats contain a variety of woody plant species. Oak (*Quercus* spp.), willow (*Salix nigra*), elm (*Ulmus americana*), boxelder (*Acer negundo*), cottonwood (*Populus* spp.), dogwood (*Cornus drummondii*), persimmon (*Diospyros virginiana*), hackberry (*Celtis laevigata*), ash (*Fraxinus* spp.), and privet (*Forestiera acuminata*) are found along with baldcypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*). Red maple (*Acer rubrum* var. *drummondii*), the most abundant tree in the bottomland hardwood forest, is generally small (average diameter at breast height = 5.8 cm); its high density is responsible for its high importance value (a measure of relative frequency, density, and dominance). Herbs and vines are common along bayou banks and in any open spaces where light penetrates the canopy. Poison ivy (*Rhus radicans*), evening trumpet flower (*Gelsemium sempervirens*), green briar (*Smilax* spp.), peppervine (*Ampelopsis* spp.), and Virginia creeper (*Parthenocissus quinquefolia*) are the most prevalent vines in this area (Day et al. 1981). A complete list of species found in both Louisiana bottomland hardwood and deep swamp communities is found in Conner et al. (1975).

Figure 9. The distribution of MDPR bottomland hardwood habitat.

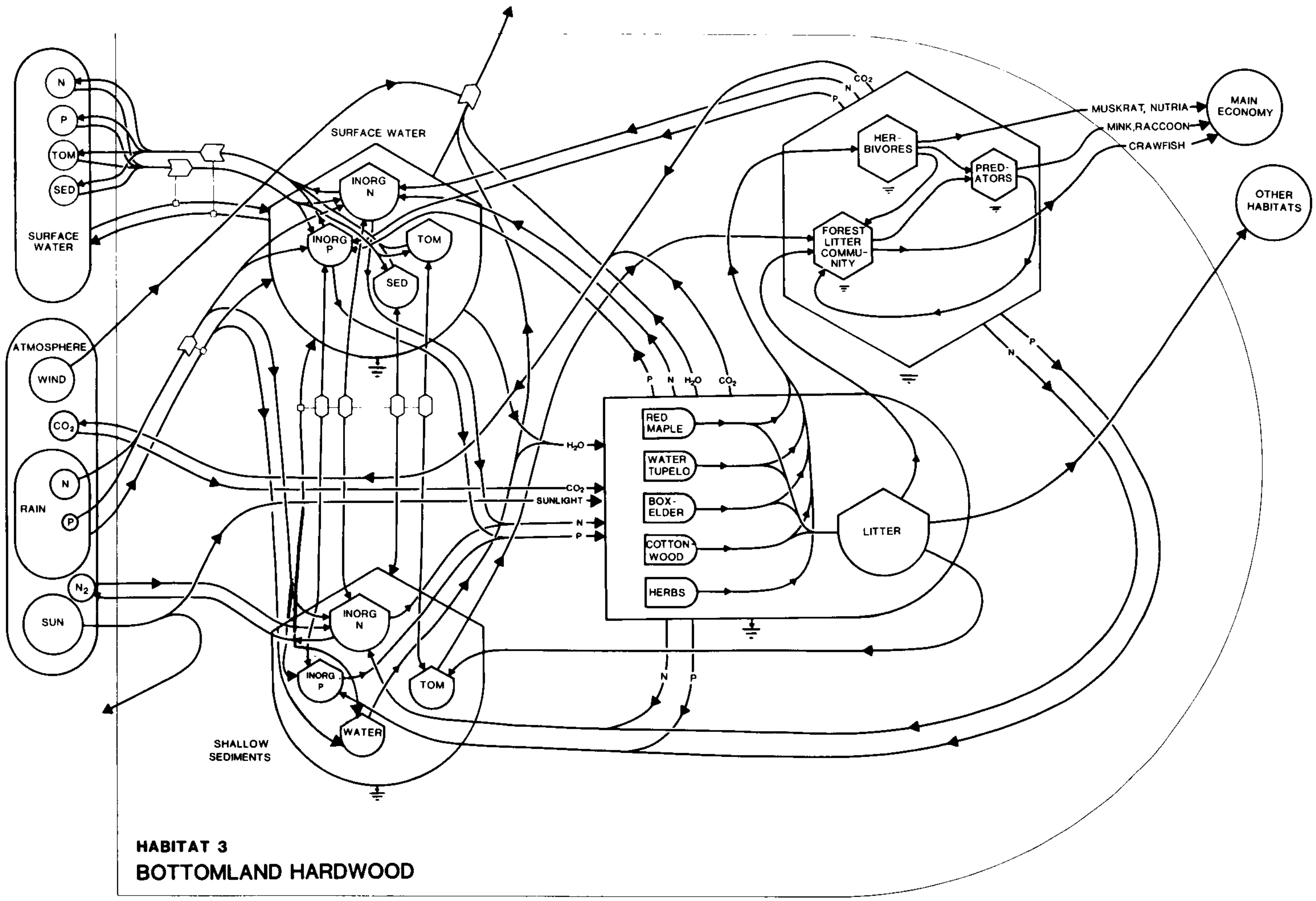


Figure 10. Bottomland hardwood habitat flow diagram.

Insects, rabbits, and deer are major bottomland hardwood forest herbivores. Raccoons, snakes, songbirds, wading birds, and raptors are common predators. Crawfish, furbearers such as nutria and mink, and game animals such as deer and waterfowl are harvested by man from bottomland hardwood forests.

Bottomland hardwood habitat was not selected for detailed modeling. It is similar to cypress-tupelo swamp habitat, and a general idea of interconnections in this habitat can be obtained from that model.

The unquantified energy and matter flow diagram for bottomland hardwoods is shown in Figure 10.

4. BRACKISH MARSH

The brackish marsh is the second largest habitat in the MDPR, containing 404,000 ha, or 11.7% of the entire area (Table 3). While the range of salinity values for MDPR salt marshes is 16 to 19 parts per thousand (ppt), the brackish marsh is found in less saline waters, with values ranging from 7 to 9 ppt (Rainey 1979). Since brackish marsh is defined here to also include those marshes classified as intermediate by Chabreck (1972), the total salinity range is 2 to 9 ppt. A map of the distribution of MDPR brackish marsh habitat is shown in Figure 11.

The brackish marsh includes plants with lower salt tolerances than those found in the salt marsh. The dominant macrophyte, *Spartina patens*, grows in waters with an average salinity of 8.6 ppt, compared with 15.2 ppt for the dominant salt marsh macrophyte, *Spartina alterniflora* (Chabreck 1972). The brackish marsh supports a higher diversity of plant life than the salt marsh: whereas only 17 plant species are found in the salt marshes of coastal Louisiana, 63 species have been identified in brackish and intermediate marshes (Chabreck 1972).

Spartina patens is the most abundant macrophyte in the brackish marsh. It occupies 220,000 of the 404,000 ha of MDPR brackish marsh (Table 40), or 54% of the area. *Spartina alterniflora* accounts for only 17,000 ha, or 4% of the area. *Distichlis spicata*, *Juncus roemerianus*, and *Scirpus* sp. are also abundant.

The biomass and productivity of brackish marsh marcrophytes have been studied in the MDPR by de la Cruz (1974), Payonk (1975), Hopkinson et al. (1978b), White et al. (1978), and Cramer et al. (1981). It is calculated that an average MDPR brackish marsh has an aboveground productivity of 3375 g dry wt/sq m/yr (Table 41), compared with a value of 2459 for the salt marsh (Table 114). This higher value is a result of the greater productivity of *S. patens* (Table 110). Including belowground production, it is estimated that total net primary production of brackish marshes is equal to 6545 g dry wt/sq m/yr (Tables 37 and 38). This estimate is high compared with values usually cited for marshes, and it is imprecise because of the uncertainty associated with belowground production. More research is needed to quantify this important value.

It is estimated here that detrital export from the brackish marsh may exceed 3300 g dry wt/sq m/yr (Table 27). This value is dependent on the value for microconsumer respiration, however (Table 27, note d), which is itself poorly understood (Table 33, note a). Understanding the magnitude of this flow is necessary for an understanding of the impact of the marsh on nearby estuaries. Thus this estimate requires field verification.

Other biological research conducted in the brackish marsh has examined birds (Mabie 1976), insects (Farlow et al. 1978), and furbearers (Palmisano 1972; Fleming 1975; Robicheaux 1978; and Linscombe as reported in Sasser et al. 1981). While bird biomass in the brackish marsh is only 60% as great as that in the salt marsh (Table

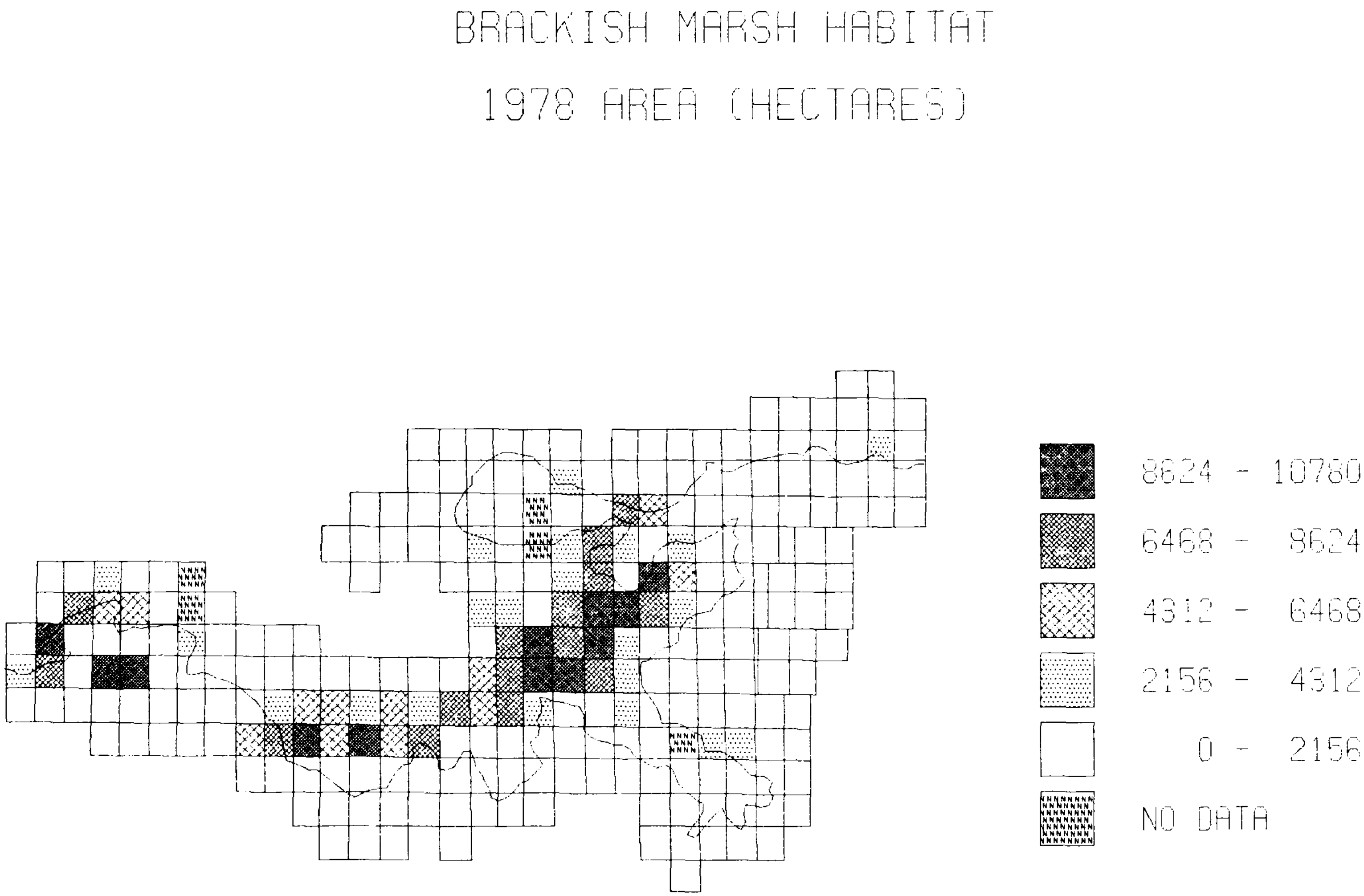


Figure 11. The distribution of MDPR brackish marsh habitat.

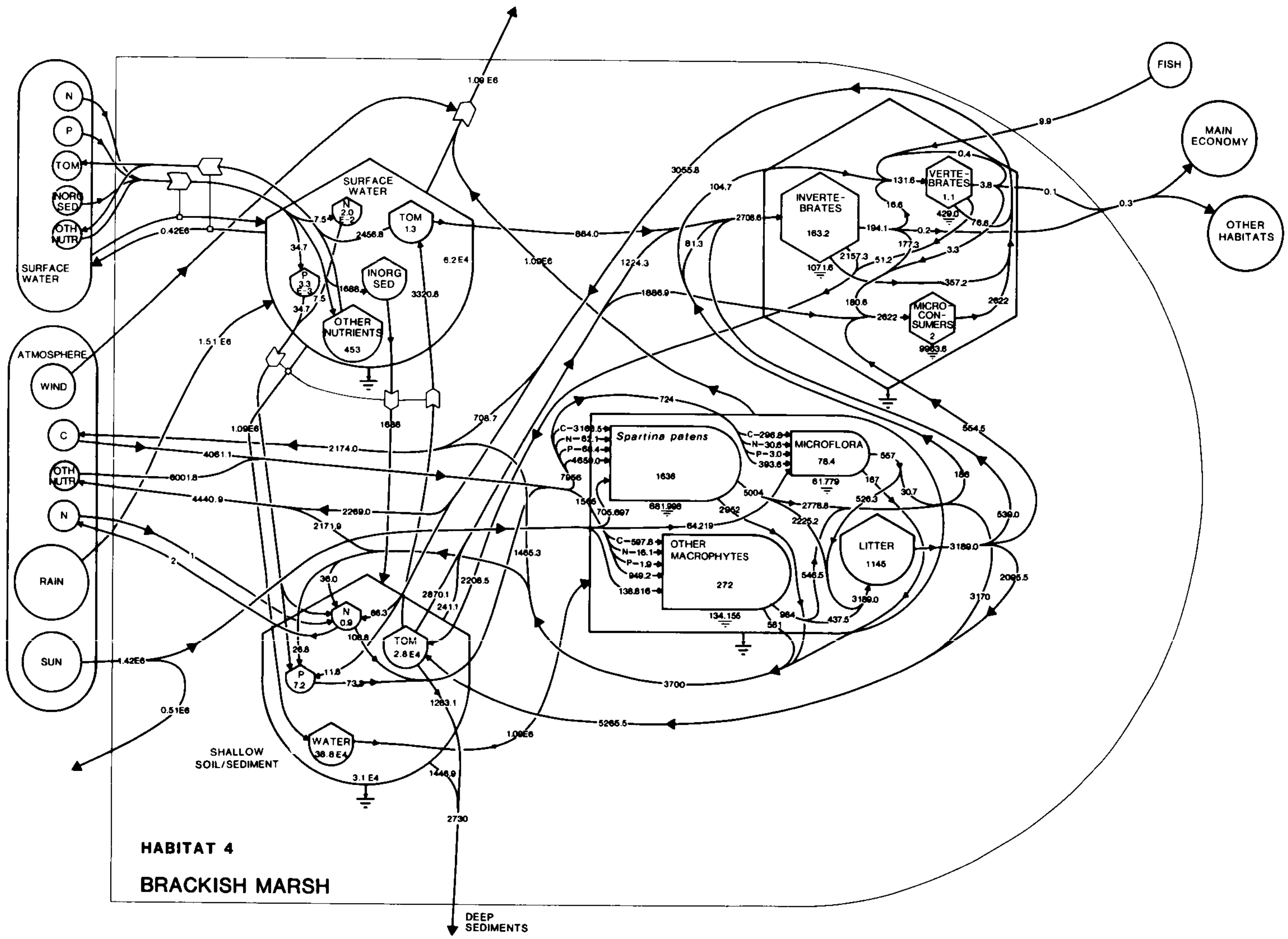


Figure 12. Brackish marsh habitat flow diagram.

Table 26. Input-output table for brackish marsh habitat.

HABITAT 4
BRACKISH MARSH

COMMODITIES		SURFACE WATER 1	SHALLOW SOIL/SEDIMENT 2	MICROFLORA 3	*S. patens* 4	OTHER MACROPHYTES 5	LITTER 6	MICROCONSUMERS 7	INVERTEBRATES 8	VERTEBRATES 9	IMPORTS & EXPORTS 10	TOTAL	UNITS
		PROCESSES											
INORGANIC NITROGEN	1	7.5 7.5 2.0 E-2	110.8 110.8 0.9	30.6 7.0	62.1 23.0	16.1 6.0		15.7	41.1	9.5	2.0 8.5	229.1 229.1 0.9	g N/m²/yr g N/m²/yr g N/m²
INORGANIC PHOSPHORUS	2	34.7 34.7 3.3 E-3	73.3 73.3 7.2	3.0 0.7	68.4 25.4	1.9 0.7		5.2	5.4	1.2	34.7	181.3 181.3 7.2	g P/m²/yr g P/m²/yr g P/m²
INORGANIC CARBON	3			296.8 68.5	3166.5 1174.9	597.8 221.9		435.2	236.8	36.7	2174.0 4061.1	6235.1 6235.1	g C/m²/yr g C/m²/yr
OTHER NUTRIENTS	4	453		393.6 90.8	4659.0 1728.7	949.2 352.4		2165.9	73.9	29.2	4440.9 6001.8	10,442.7 10,442.7 453	g/m²/yr g/m²/yr g/m²
TOTAL ORGANIC MATTER	5	3320.8 3320.8 1.3	2208.5 7474 2.8E4					1886.9	1847.2 2167.3	51.2	3739.9	13003.3 13003.3 2.8E4	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
INORGANIC SEDIMENTS	6	1688.0 1688.0	1688.0 1688.0 3.1E4						241.1		1446.9 1688.0	5064 5064 3.1E4	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
WATER	7	1.51E6 1.51E6 6.2E4	1.1E6 1.1E6 38.8E4	0.1E6 0.1E6	0.9E6 0.9E6	0.1E6 0.1E6					1.51 E6 1.51 E6	5.22E6 5.22E6 46.0E4	g/m²/yr g/m²/yr g/m²
MICROFLORA BIOMASS	8			557 78.4			526.3		13.4	17.3		557 557 78.4	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
S. patens BIOMASS	9		2649		5004 1636		2226.2		56.8	73.0		5004 5004 1636	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
OTHER MACROPHYTIC BIOMASS	10		521			984 272	437.5		11.1	14.4		984 984 272	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
LITTER BIOMASS	11		2095.5				3189 1145	554.5	539.0			3189 3189 2433	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
MICROCONSUMER BIOMASS	12							2.0				2.0	g dry wt/m²
INVERTEBRATE BIOMASS	13							177.3	194.1 163.2	16.6	0.2	194.1 194.1 163.2	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
VERTEBRATE BIOMASS	14							3.3		0.4 3.8 1.1	0.1	3.8 3.8 1.1	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
FISH BIOMASS	15									9.9	9.9	9.9 9.9	g dry wt/m²/yr g dry wt/m²/yr
HEAT	16			61,779	661,996	134,155		9963.6	1071.6	429.0	889,396	889,396 889,396	kcal/m²/yr kcal/m²/yr
SUNLIGHT	17			64,219	706,697	136,816					0.51E6 1.42E6	1.42E6 1.42E6	kcal/m²/yr kcal/m²/yr

134), furbearer biomass (muskrat, nutria, and raccoon) is more than twice that in the salt marsh (Table 137). To develop a habitat model, it has been assumed that brackish marsh dynamics are similar to those of the salt marsh. For example, invertebrate consumption in the brackish marsh is calculated by multiplying invertebrate consumption in the salt marsh by a correction factor which takes into account the greater aboveground production in the brackish marsh (Table 50). By doing this, it is implicitly assumed that primary production and plant biomass are the main driving forces of the brackish marsh system. Another assumption made here is that the hydrology of the brackish marsh is similar to that of the salt marsh. Because of these simplifying assumptions, significant ecological differences between these habitats are lost. Future studies must be aimed at filling in these data gaps.

The energy and material flow diagram for brackish marsh habitat is shown in Figure 12. The brackish marsh I-O table is given in Table 26. The diagram and table show that the main export from the brackish marsh is organic matter, which is lost through subsidence and through transport to surrounding waters. The importance of detritus to the dynamics of this system can be seen by the large contribution that soil organic matter makes to microconsumers; in addition, organic matter from the soil and surface water is the major source of food for invertebrates.

Notes to Brackish Marsh Habitat Model

Inorganic nitrogen.

1,1,I Input of inorganic nitrogen to surface water. 7.5 g N/sq m/yr. Table 27.
1,1,O Output of inorganic nitrogen from surface water. 7.5 g N/sq m/yr. Table 27.
1,1,S Storage of inorganic nitrogen in surface water. 2.0 E-2 g N/sq m. Table 28.
1,2,I Input of inorganic nitrogen to soil. 110.8 g N/sq m/yr. Table 29.
1,2,O Output of inorganic nitrogen from soil. 110.8 g N/sq m/yr. Table 29.
1,2,S Storage of inorganic nitrogen in soil. 0.9 g N/sq m. Table 30.
1,3,I Uptake of inorganic nitrogen by microflora. 30.6 g N/sq m/yr. Table 32.
1,3,O Release of inorganic nitrogen by microflora. 7.0 g N/sq m/yr. Table 32.
1,4,I Uptake of inorganic nitrogen by *Spartina patens*. 62.1 g N/sq m/yr. Table 32.
1,4,O Release of inorganic nitrogen by *Spartina patens*. 23.0 g N/sq m/yr. Table 32.
1,5,I Uptake of inorganic nitrogen by other macrophytes. 16.1 g N/sq m/yr. Table 32.
1,5,O Release of inorganic nitrogen by other macrophytes. 6.0 g N/sq m/yr. Table 32.
1,7,O Release of inorganic nitrogen by microconsumers. 15.7 g N/sq m/yr. Table 33.
1,8,O Release of inorganic nitrogen by invertebrates. 41.1 g N/sq m/yr. Table 34.
1,9,O Release of inorganic nitrogen by vertebrates. 9.5 g N/sq m/yr. Table 35.
1,10,I Input of inorganic nitrogen to import/export. 2.0 g N/sq m/yr. Total export of inorganic nitrogen from the system, assumed equal to the rate of denitrification in the salt marsh (DeLaune et al. 1976).
1,10,O Output of inorganic nitrogen from import/export. 8.5 g N/sq m/yr. Total import of inorganic nitrogen to the system, equal to input to surface water (Table 27) plus an estimated atmospheric input of 1 g N/sq m/yr through nitrogen fixation, based on the salt marsh (DeLaune et al. 1976).

Inorganic phosphorus.

2,1,I Input of inorganic phosphorus to surface water. 34.7 g P/sq m/yr. Table 27.
2,1,O Output of inorganic phosphorus from surface water. 34.7 g P/sq m/yr. Table 27.
2,1,S Storage of inorganic phosphorus in surface water. 3.3 E-3 g P/sq m. Table 28.
2,2,I Input of inorganic phosphorus to soil. 73.3 g P/sq m/yr. Table 29.

2,2,O Output of inorganic phosphorus from soil. 73.3 g P/sq m/yr. Table 29.

2,2,S Storage of inorganic phosphorus in soil. 7.2 g P/sq m. Table 30.

2,3,I Uptake of inorganic phosphorus by microflora. 3.0 g P/sq m/yr. Table 32.

2,3,O Release of inorganic phosphorus by microflora. 0.7 g P/sq m/yr. Table 32.

2,4,I Uptake of inorganic phosphorus by _Spartina patens_. 68.4 g P/sq m/yr. Table 32.

2,4,O Release of inorganic phosphorus by _Spartina patens_. 25.4 g P/sq m/yr. Table 32.

2,5,I Uptake of inorganic phosphorus by other macrophytes. 1.9 g P/sq m/yr. Table 32.

2,5,O Release of inorganic phosphorus by other macrophytes. 0.7 g P/sq m/yr. Table 32.

2,7,O Release of inorganic phosphorus by microconsumers. 5.2 g P/sq m/yr. Table 33.

2,8,O Release of inorganic phosphorus by invertebrates. 5.4 g P/sq m/yr. Table 34.

2,9,O Release of inorganic phosphorus by vertebrates. 1.2 g P/sq m/yr. Table 35.

2,10,O Output of inorganic phosphorus from import/export. 34.7 g P/sq m/yr. Total import of inorganic phosphorus to the system, equal to input to surface water (Table 27).

Inorganic carbon.

3,3,I Uptake of inorganic carbon by microflora. 296.8 g C/sq m/yr. Table 32.

3,3,O Release of inorganic carbon by microflora. 68.5 g C/sq m/yr. Table 32.

3,4,I Uptake of inorganic carbon by _Spartina patens_. 3166.5 g C/sq m/yr. Table 32.

3,4,O Release of inorganic carbon by _Spartina patens_. 1174.9 g C/sq m/yr. Table 32.

3,5,I Uptake of inorganic carbon by other macrophytes. 597.8 g C/sq m/yr. Table 32.

3,5,O Release of inorganic carbon by other macrophytes. 221.9 g C/sq m/yr. Table 32.

3,7,O Release of inorganic carbon by microconsumers. 435.2 g C/sq m/yr. Table 33.

3,8,O Release of inorganic carbon by invertebrates. 236.8 g C/sq m/yr. Table 34.

3,9,O Release of inorganic carbon by vertebrates. 36.7 g C/sq m/yr. Table 35.

3,10,I Input of inorganic carbon to import/export. 2174.0 g C/sq m/yr. Total export of inorganic carbon from the system, equal to the sum of all respired carbon (Tables 32-35).

3,10,O Output of inorganic carbon from import/export. 4061.1 g C/sq m/yr. Total import of inorganic carbon to the system, equal to the sum of carbon assimilation by producers (Table 32).

Other nutrients.

4,1,S Storage of other nutrients (salts) in surface water. 453 g/sq m. Table 28.

4,3,I Uptake of other nutrients by microflora. 393.6 g/sq m/yr. Table 32.

4,3,O Release of other nutrients by microflora. 90.8 g/sq m/yr. Table 32.

4,4,I Uptake of other nutrients by _Spartina patens_. 4659.0 g/sq m/yr. Table 32.

4,4,O Release of other nutrients by _Spartina patens_. 1728.7 g/sq m/yr. Table 32.

4,5,I Uptake of other nutrients by other macrophytes. 949.2 g/sq m/yr. Table 32.

4,5,O Release of other nutrients by other macrophytes. 352.4 g/sq m/yr. Table 32.

4,7,O Release of other nutrients by microconsumers. 2165.9 g/sq m/yr. Table 33.

4,8,O Release of other nutrients by invertebrates. 73.9 g/sq m/yr. Table 34.

4,9,O Release of other nutrients by vertebrates. 29.2 g/sq m/yr. Table 35.

4,10,I Input of other nutrients to import/export. 4440.9 g/sq m/yr. Total export of other nutrients from the system, equal to the release of all other nutrients (Tables 32-35). It is assumed that other nutrients are mostly hydrogen and oxygen and thus are lost through the atmosphere.

4,10,0 Output of other nutrients from import/export. 6001.8 g/sq m/yr. Total import of other nutrients to the system, equal to the sum of all other nutrients assimilated (Table 32). It is assumed that other nutrients are mostly hydrogen and oxygen and thus are assimilated through the atmosphere.

Organic matter.

5,1,I Input of organic matter to surface water. 3320.8 g dry wt/sq m/yr. Table 27.
5,1,0 Output of organic matter from surface water. 3320.8 g dry wt/sq m/yr. Table 27.
5,1,S Storage of organic matter in surface water. 1.3 g dry wt/sq m. Table 28.
5,2,I Input of organic matter (egesta) to soil. 2208.5 g dry wt/sq m/yr. Table 29, note d.
5,2,0 Output of organic matter from soil. 7474 g dry wt/sq m/yr. Table 29.
5,2,S Storage of organic matter in soil. 2.8 E4 g dry wt/sq m. Table 30. 5,7,I Input of soil organic matter to microconsumers. 1886.9 g dry wt/sq m/yr. Table 48.
5,8,I Uptake of organic matter by invertebrates. 1847.2 g dry wt/sq m/yr. Table 51.
5,8,0 Release of organic matter by invertebrates (egestion). 2157.3 g dry wt/sq m/yr. Table 50.
5,9,0 Release of organic matter by vertebrates (egestion). 51.2 g dry wt/sq m/yr. Table 53.
5,10,I Input of organic matter to import/export. 3739.9 g dry wt/sq m/yr. Total export of organic matter from the system, equal to losses of organic matter from the deep sediments due to subsidence (Table 27, note d) plus loss from surface water. Surface water losses are equal to input to surface water (Table 27) minus uptake by invertebrates (Table 51), or 2456.8 g dry wt/sq m/yr.

Inorganic sediments.

6,1,I Input of inorganic sediments to surface water. 1688.0 g/sq m/yr. Table 27.
6,1,0 Output of inorganic sediments from surface water. 1688.0 g/sq m/yr. Table 27.
6,2,I, Input of inorganic sediments to soil. 1688.0 g/sq m/yr. Table 29.
6,2,0 Output of inorganic sediments from soil. 1688.0 g/sq m/yr. Table 29.
6,2,S Storage of inorganic sediments in soil. 3.1 E4 g/sq m. Table 30.
6,8,I Uptake of inorganic sediments by invertebrates. 241.1 g dry wt/sq m/yr. Table 51.
6,10,I Input of inorganic sediments to import/export. 1446.9 g/sq m/yr. Total export of inorganic sediments from the system, equal to loss to the deep sediments due to subsidence (Table 29, note e).
6,10,0 Output of inorganic sediments from import/export. 1688.0 g/sq m/yr. Total import of inorganic sediments to the system, equal to input to surface waters (Table 27).

Water.

7,1,I Input of water to surface water. 1.51 E6 g water/sq m/yr. Table 27.
7,1,0 Output of water from surface water. 1.51 E6 g water/sq m/yr. Table 27.
7,1,S Storage of water in surface water. 6.2 E4 g water/sq m. Table 28.
7,2,I Input of water to soil. 1,090,639 g water/sq m/yr. Table 29.
7,2,0 Output of water from soil. 1,090,639 g water/sq m/yr. Table 29.
7,2,S Storage of water in soil. 38.8 E4 g water/sq m. Table 30.
7,3,I Uptake of water by microflora. 87,573 g water/sq m/yr. Assumed equal to release (transpiration). Table 36.

7,3,0 Release of water by microflora (transpiration). 87,573 g water/sq m/yr. Table 36.

7,4,I Uptake of water by Spartina patens. 860,090 g water/sq m/yr. Assumed equal to release (transpiration). Table 36.

7,4,0 Release of water by Spartina patens (transpiration). 860,090 g water/sq m/yr. Table 36.

7,5,I Uptake of water by other macrophytes. 142,976 g water/sq m/yr. Assumed equal to release (transpiration). Table 36.

7,5,0 Release of water by other macrophytes (transpiration). 142,976 g water/sq m/yr. Table 36.

7,10,I Input of water to import/export. 1.51 E6 g water/sq m/yr. Total export of water from the system, assumed equal to total import (Table 27).

7,10,0 Output of water from import/export. 1.51 E6 g water/sq m/yr. Total import of water to the system, equal to annual rainfall (Table 27).

Microflora.

8,3,0 Output of microflora biomass (net primary production). 557 g dry wt/sq m/yr. Table 37.

8,3,S Storage of microflora biomass. 78.4 g dry wt/sq m. Table 37.

8,6,I Input of microflora to litter. 526.3 g dry wt/sq m/yr. Table 47.

8,8,I Uptake of microflora by invertebrates. 13.4 g dry wt/sq m/yr. Table 51.

8,9,I Uptake of microflora by vertebrates. 17.3 g dry wt/sq m/yr. Table 54.

Spartina patens.

9,2,I Input of Spartina patens to soil. 2649 g dry wt/sq m/yr. Equal to belowground NPP (Table 38).

9,4,0 Output of Spartina patens biomass (net primary production). 5004 g dry wt/sq m/yr. Table 38.

9,4,S Storage of living Spartina patens biomass. 1636 g dry wt/sq m. Table 43.

9,6,I Input of Spartina patens to litter. 2225.2 g dry wt/sq m/yr. Table 47.

9,8,I Uptake of Spartina patens by invertebrates. 56.8 g dry wt/sq m/yr. Table 51.

9,9,I Uptake of Spartina patens by vertebrates. 73.0 g dry wt/sq m/yr. Table 54.

Other macrophytes.

10,2,I Input of other macrophytes to soil. 521 g dry wt/sq m/yr. Equal to belowground NPP (Table 38).

10,5,0 Output of other macrophytes biomass (net primary production). 984 g dry wt/sq m/yr. Table 38.

10,5,S Storage of living other macrophytes biomass. 272 g dry wt/sq m. Table 43.

10,6,I Input of other macrophytes to litter. 437.5 g dry wt/sq m/yr. Table 47.

10,8,I Uptake of other macrophytes by invertebrates. 11.1 g dry wt/sq m/yr. Table 51.

10,9,I Uptake of other macrophytes by vertebrates. 14.4 g dry wt/sq m/yr. Table 54.

Litter.

11,2,I Input of litter to soil. 2095.5 g dry wt/sq m/yr. Table 29, note d.

11,6,0 Output of litter biomass. 3189.0 g dry wt/sq m/yr. Assumed equal to total input (Table 47).

11,6,S Storage of litter. 1145 g dry wt/sq m. Equal to aboveground portions of dead Spartina patens and other macrophytes (Table 43).

11,7,I Input of litter to microconsumers. 554.5 g dry wt/sq m/yr. Table 48.

11,8,I Uptake of litter by invertebrates. 539.0 g dry wt/sq m/yr. Table 51.

Microconsumers.

12,7,S Storage of microconsumer biomass. 2.0 g dry wt/sq m. Based on the standing crop of meiobenthos in the salt marsh (Day et al. 1973). It is assumed that these organisms make up the major bulk of microconsumer biomass.

Invertebrates.

13,7,I Input of invertebrates to microconsumers. 177.3 g dry wt/sq m/yr. Table 49.

13,8,0 Output of invertebrate biomass (production). 194.1 g dry wt/sq m/yr. Table 50.

13,8,S Storage of invertebrate biomass. 163.2 g dry wt/sq m. Table 50.

13,9,I Uptake of invertebrates by vertebrates. 16.6 g dry wt/sq m/yr. Table 54.

13,10,I Input of invertebrates to import/export. 0.2 g dry wt/sq m/yr. Total export of invertebrates from the system, equal to crab harvest (Table 126).

Vertebrates.

14,7,I Input of vertebrates to microconsumers. 3.3 g dry wt/sq m/yr. Table 49.

14,9,I Uptake of vertebrates by vertebrates. 0.4 g dry wt/sq m/yr. Table 54.

14,9,0 Output of vertebrate biomass (production). 3.8 g dry wt/sq m/yr. Table 53.

14,9,S Storage of vertebrate biomass. 1.1 g dry wt/sq m. Table 53.

14,10,I Input of vertebrates to import/export. 0.1 g dry wt/sq m/yr. Total export of vertebrates from the system, equal to harvest (Tables 136 and 141).

Fish.

15,9,I Uptake of fish by vertebrates. 9.9 g dry wt/sq m/yr. Table 54.

15,10,0 Output of fish from import/export. 9.9 g dry wt/sq m/yr. Total import of fish into the system, equal to consumption by vertebrates (Table 54).

Heat.

16,3,0 Release of heat by microflora. 61,779 kcal/sq m/yr. Table 57.

16,4,0 Release of heat by *Spartina patens*. 681,998 kcal/sq m/yr. Table 57.

16,5,0 Release of heat by other macrophytes. 134,155 kcal/sq m/yr. Table 57.

16,7,0 Release of heat by microconsumers. 9963.6 kcal/sq m/yr. Table 57.

16,8,0 Release of heat by invertebrates. 1071.6 kcal/sq m/yr. Table 57.

16,9,0 Release of heat by vertebrates. 429.0 kcal/sq m/yr. Table 57.

16,14,I Input of heat to import/export. 889,396 kcal/sq m/yr. Total export of heat from the system (Table 57).

Sunlight.

17,3,I Uptake of sunlight by microflora. 64,219 kcal/sq m/yr. Table 58.

17,4,I Uptake of sunlight by *Spartina patens*. 705,697 kcal/sq m/yr. Table 58.

17,5,I Uptake of sunlight by other macrophytes. 138,816 kcal/sq m/yr. Table 58.

17,10,I Input of sunlight to import/export. 0.51 E6 kcal/sq m/yr. Total export of sunlight from the system, equal to albedo (Table 59).

17,10,0 Output of sunlight from import/export. 1.42 E6 kcal/sq m/yr. Total import of sunlight from the system, equal to insolation (Table 59).

Table 27. Nutrient movement in MDPR brackish marsh surface waters.[a]

Nutrient	Value
N[b]	7.5
P[c]	34.7
Organic matter[d]	3320.8
Inorganic sediments[e]	1688.0
Water[f]	1.51 E6

[a]Values as g/sq m/yr. It is assumed that there is no net change in the storage of a nutrient and that flow in is equal to flow out.

[b]Uptake of inorganic nitrogen from soils is equal to 110.8 g N/sq m/yr (Table 29). Inputs to the soil by plants, microconsumers, invertebrates, and vertebrates are 36.0 (Table 32), 15.7 (Table 33), 41.1 (Table 34), and 9.5 (Table 35) g N/sq m/yr, respectively. Based on the salt marsh, nitrogen fixation returns an additional 1 g N/sq m/yr (DeLaune et al. 1976). This gives a total of 103.3 g N/sq m/yr. Assuming a steady state, input of the remaining 7.5 g N/sq m/yr are from the surface water.

[c]Uptake of inorganic phosphorus from soils is equal to 73.3 g P/sq m/yr (Table 29). Inputs to the soil by plants, microconsumers, invertebrates, and vertebrates are 26.8 (Table 32), 5.2 (Table 33), 5.4 (Table 34), and 1.2 (Table 35) g P/sq m/yr, respectively, giving a total of 38.6. Assuming a steady state, input of the remaining 34.7 g P/sq m/yr are from the surface water.

[d]The total input of organic matter to soils is equal to 7474.0 g dry wt/sq m/yr (Table 29). Microconsumers and invertebrates consume 1886.9 (Table 48) and 983.2 (Table 51) g dry wt/sq m/yr, respectively, for a total of 2870.1. In addition, 1283.1 g dry wt/sq m/yr of organic matter are lost to deep sediments (total soil loss to deep sediments is 2730 g soil/sq m/yr, 1446.9 of which are inorganic sediments; Table 29, note e). This gives a total of 4153.2 g dry wt/sq m/yr. Assuming a steady state, the remaining 3320.8 g dry wt/sq m/yr enter the surface water.

[e]Total output of inorganic sediments from the soil is 1688.0 g/sq m/yr (Table 29). Assuming a steady state, this same amount enters the soil from the surface water.

[f]Calculated as total input of rain. The 40 year average rate of precipitation for New Orleans, Louisiana was 59.64 in/yr (NOAA 1981), or 1.51 cu m/sq m/yr. This is equivalent to 1.51 E6 g/sq m/yr.

Table 28. Storage of nutrients and organic matter in brackish marsh surface water.[a]

Component	Storage
N[b]	2.0 E-2
P[c]	3.3 E-3
Other nutrients[d]	452.6
Organic matter[e]	1.3
Total water[f]	6.2 E4

[a]Values as g/sq m. Storages of nutrients and organic matter calculated by multiplying the total amount of water by the concentration of that nutrient.

[b]The concentration of inorganic nitrogen in the surface water of the marsh is 3.2 E-4 g/l (Table 99).

[c]The concentration of inorganic phosphorus in the surface water of the marsh is 5.4 E-5 g/l (Table 99).

[d]The concentration of salts in the surface water of the marsh is 7.3 parts per thousand, or 7.3 g/1000 g (Table 99).

[e]An organic matter value of 2.1 E-2 g/l is assumed, based on the salt marsh (Table 98, note e).

[f]A water value of 6.2 E4 g/sq m (62 l/sq m) is assumed, based on the salt marsh (Table 98, note f).

Table 29. Nutrient movement in MDPR brackish marsh soils.[a]

Nutrient	Value
N[b]	110.8
P[c]	73.3
Organic matter[d]	7474.0
Inorganic sediments[e]	1688.0
Water[f]	1,090,639

[a]Values as g/sq m/yr. It is assumed that there is no net change in the storage of a nutrient and that flow in is equal to flow out.

[b]Calculated as the sum of soil loss through plant uptake and denitrification. Plant uptake is equal to 108.8 g N/sq m/yr (Table 32). A denitrification rate of 2.0 g N/sq m/yr is used, based on the salt marsh (DeLaune et al. 1976).

[c]Calculated as soil loss through plant uptake (Table 32).

[d]Calculated as the sum of inputs from belowground NPP, litter, and egesta. Total belowground NPP is equal to 3170 g dry wt/sq m/yr (Table 38). The total amount of litter produced is 3189.0 g dry wt/sq m/yr (Table 47), with consumption of litter by invertebrates and microconsumers equal to 539.0 (Table 51) and 554.5 (Table 48) g dry wt/sq m/yr. Thus input of litter to soil is equal to the remaining 2095.5 g dry wt/sq m/yr. Egestion rates for invertebrates and vertebrates are 2157.3 (Table 50) and 51.2 (Table 53) g dry wt/sq m/yr, respectively, for a total of 2208.5.

[e]Calculated as soil loss through uptake by consumers and loss to the deep sediments. Uptake of sediments by invertebrates is equal to 241.1 g dry wt/sq m/yr (Table 51). The subsidence rate of MDPR soils is 1.3 cm/yr (Baumann 1980), and the bulk density of brackish marsh soils is estimated as 0.21 g soil/cu cm (Table 30, note f). Loss of soil to deep sediments is therefore 0.273 g/sq cm, or 2730 g/sq m. The percent organic matter of brackish marsh soils is 47% (Table 30, note d) with inorganic sediments making up the other 53%. Loss of inorganic sediments to the deep sediments is therefore equal to 1446.9 g/sq m/yr.

[f]Calculated as soil loss through plant uptake, which is assumed equal to transpiration (Table 36).

Table 30. Storage of nutrients, organic matter, and moisture in brackish marsh soils.[a]

Component	Storage
Soil	
N[b]	0.9
P[c]	7.2
Organic matter[d]	2.8 E4
Inorganic sediments[e]	3.1 E4
TOTAL[f]	5.9 E4
Moisture[g]	38.8 E4

[a]Values as g/sq m.

[b]An N concentration of 14.5 ug N/g soil is assumed, based on the salt marsh (Table 101, note b). Soil N is calculated by multiplying this by the total storage of soil.

[c]A P concentration of 121.3 ug P/g soil is assumed, based on the salt marsh (Table 101, note c). Soil P is calculated by multiplying this by the total storage of soil.

[d]The carbon content of brackish marsh soils is 27.3% (Table 31). Using a conversion factor of 1.724 to convert soil carbon to soil organic matter (DeLaune et al. 1979) gives a value of 47.1% for soil organic matter.

[e]Calculated as total minus organic matter.

[f]Because brackish marsh soils have such high organic contents (see note d above), the bulk density of salt marsh soils -- 0.21 g soil/cu cm(Table 101, note f) -- is used. Assuming a rooting depth of 28 cm (Table 101, note f) gives a soil density of 5.9 E4 g dry soil/sq m.

[g]The moisture content of brackish marsh soil is 86.8% (Table 31); thus the dry portion represents 13.2% of the total weight of a wet soil. The wet to dry ratio is therefore 86.8/13.2 = 6.58. Soil moisture is calculated by multiplying this by the total dry weight of the soil.

Table 31. Percent water and organic carbon of sediments from a Louisiana brackish marsh.[a]

Date	Water	Organic Carbon
June 1973	85.3	23.6
Aug. 1973	94.0	28.5
Oct. 1973	84.7	22.9
Dec. 1973	90.9	24.8
Feb. 1974	73.5	33.6
Apr. 1974	92.1	30.5
Avg.	86.8	27.3

[a]Percent water is based on wet sample weight, and percent organic carbon is based on dry weight. Brackish marsh values are from station 7 of the Louisiana Offshore Oil Port study (Ho and Schneider 1976).

Table 32. Nutrient uptake and release by MDPR brackish marsh flora.[a]

Nutrient	Microflora[b]	*Spartina patens*[c]	Other macrophytes[d]
Uptake			
N	30.6	62.1	16.1
P	3.0	68.4	1.9
C	296.8	3166.5	597.8
Other[e]	393.6	4659.0	949.2
Release			
N	7.0	23.0	6.0
P	0.7	25.4	0.7
C	68.5	1174.9	221.9
Other[f]	90.8	1728.7	352.4

[a]Values are g/sq m/yr. Uptake is calculated as gross primary production multiplied by the percent composition of each nutrient, and release is calculated as respiration multiplied by the percent composition. GPP and respiration for microflora are from Table 37, and from Table 38 for *S. patens* and other macrophytes.

[b]The average %N, %P, and %C of algae from ponds and lakes in the southeastern U.S. was 4.22, 0.42, and 41.0%, respectively (Jorgensen 1979). This was based on analyses of 15, 15, and 14 species, respectively.

[c]The average %N and %P for *S. patens* is 0.78 and 0.86%, respectively, and the %C is estimated as 39.8% (see Table 102, note d).

[d]The %N for *Distichlis spicata*, *Juncus roemerianus*, and *Spartina alterniflora* is 1.04, 0.98, and 1.02%, respectively (Gosselink et al. 1977). The relative proportions of net production by these producers is 0.622, 0.134, and 0.244, respectively (Table 42). The weighted %N for other macrophytes is therefore 1.03%. The %P of *D. spicata*, *J. roemerianus*, and *S. alterniflora* is 0.12, 0.12, and 0.13, respectively (Gosselink et al. 1977), giving a weighted average of 0.12%. The %C for *D. spicata*, *J. roemerianus*, and *S. alterniflora* is 36.6, 42.6, and 39.8%, respectively (de la Cruz 1973), giving a weighted average of 38.2%.

[e]Uptake of other nutrients (primarily oxygen and hydrogen) is calculated as gross primary production minus uptake of N, P, and C.

[f]Release of other nutrients (primarily oxygen and N, P, and C.

Table 33. Release of nutrients by microconsumers in MDPR brackish marshes.[a]

Nutrient	Value
N[b]	15.7
P[c]	5.2
C[d]	435.2
Other[e]	2165.9

[a]Values as g/sq m/yr. Calculated by multiplying the respiration rate of microconsumers by the nutrient concentrations of detritus. The rate of respiration for microconsumers in MDPR salt marshes is 1914 g dry wt/sq m/yr (Table 103, note a). This value is multiplied by the ratio of brackish marsh NPP to salt marsh NPP to give a brackish marsh microconsumer respiration. Total NPP in the brackish marsh is 6545 g dry wt/sq m/yr (Tables 37 and 38), and 4769 in the salt marsh (Tables 107 and 109). This gives a ratio of 1.37, and therefore a respiration rate of 2622 g dry wt/sq m/yr. Nutrient concentrations are based on analyses of *Juncus roemerianus* which included partially decayed pieces, decomposed, fragments, and particulate detritus (de la Cruz and Gabriel 1974).

[b]%N in detritus equal to 0.6%.

[c]%P in detritus equal to 0.2%.

[d]%C in detritus equal to 16.6%.

[e]Calculated as respiration minus release of N, P, and C.

Table 34. Nutrient release by MDPR brackish marsh invertebrates.[a]

Nutrient	Value[b]
Release	
N	41.1
P	5.4
C	236.8
Other[c]	73.9

[a] Values are g/sq m/yr. Release is calculated as respiration multiplied by the percent composition of each nutrient. Respiration for invertebrates (crabs, mussels, *Littorina irrorata*, and insects) is taken from Table 50.

[b] The N to biomass (ash free dry weight) ratio for invertebrates is 0.090, based on an analysis of 19 species (Jorgensen 1979). The ratio of dry weight to ash free dry weight is 1.28, based on crabs (Table 124, note b), giving an N to biomass ratio of 0.115. There is one mole of P (30.1 g) incorporated with every 16 mole of N (224 g) in protoplasm (E. P. Odum 1971), giving a P to N ratio of 0.13. Using this to convert the N to biomass ratio gives a P to biomass ratio of 0.015. The C to biomass (ash free dry weight) ratio for invertebrates is 0.518, based on an analysis of 19 species (Jorgensen 1979). This gives a ratio of 0.663 on a dry weight basis.

[c] Release of other nutrients (primarily oxygen and hydrogen) is calculated as respiration minus uptake of N, P, and C.

Table 35. Nutrient release by MDPR brackish marsh vertebrates.[a]

Nutrient	Birds[b]	Mammals[c]	Total
Release			
N	0.9	8.6	9.5
P	0.1	1.1	1.2
C	4.1	32.6	36.7
Other[d]	4.1	25.1	29.2

[a]Values are g/sq m/yr. Release is calculated as respiration multiplied by the percent composition of each nutrient. Respiration for birds and furbearers are taken from Tables 133 and 137, respectively.
[b]The mean %N for all animals is 10% (Jorgensen 1979). Using a P to N ratio of 0.13 (Table 34, note b), gives a %P of 1.3%. The mean %C for all animals is 45% (Jorgensen 1979).
[c]The mean %N for mammals is 12.8% (Jorgensen 1979). Using a P to N ratio of 0.13 (Table 34, note b) gives a %P of 1.7%. The mean %C for mammals is 48.4% (Jorgensen 1979).
[d]Release of other nutrients (primarily oxygen and hydrogen) is calculated as respiration minus uptake of N, P, and C.

Table 36. Transpiration by producers in MDPR brackish marshes.[a]

Process	Value
Microflora[b]	87,573
Spartina patens[c]	860,090
Other macrophytes[d]	142,976
TOTAL	1,090,639

[a]Values as g water/sq m/yr. Calculated by multiplying aboveground biomass by a transpiration to biomass ratio. Transpiration ratios in Florida marshes range from 414-1820 g water/g dry wt (Lugo et al. 1979 as cited in Brown 1981). The middle value, 1117 g water/g dry wt, is used.
[b]Biomass equal to 78.4 g dry wt/sq m (Table 37).
[c]Biomass equal to 770 g dry wt/sq m (Table 43).
[d]Biomass equal to 128 g dry wt/sq m (Table 43).

Table 37. Gross primary production, net primary production, respiration, and biomass of microflora in MDPR brackish marshes.[a]

Process	Value
Gross primary Production[b]	724
Net primary Production[c]	557
Respiration[d]	167
Biomass[e]	78.4

[a]Biomass as g dry wt/sq m. All other values as g dry wt/sq m/yr.

[b]Gross primary production of microflora is calculated by multiplying total gross primary production of macrophytes (9521 g dry wt/sq m/yr; Table 38) by a microflora GPP to macrophyte GPP ratio of 0.076 (Table 108).

[c]Ricklefs (1979) cites net to gross production ratios of 0.79 and 0.75 for algae and phytoplankton, respectively. The average of these two, 0.77, is used to calculate net primary production from gross primary production.

[d]Gross primary production minus net primary production.

[e]The average NPP to biomass ratio of three algae (*Agarum cribrosum*, *Laminaria digitata*, and *L. longicruris*) is 7.1 (Jorgensen 1979). Biomass is calculated by dividing NPP by this value.

Table 38. Net primary production, respiration, and gross primary production of brackish marsh macrophytes in the MDPR.[a]

	Spartina patens	Other macrophytes[b]	Total
Aboveground NPP[c]	2355	463	2818
Belowground NPP[d]	2649	521	3170
TOTAL NPP	5004	984	5988
Respiration[e]	2952	581	3533
Gross primary production[f]	7956	1565	9521

[a]Values are g dry wt/sq m/yr.
[b]*Distichlis spicata*, *Juncus roemerianus*, *Spartina alterniflora*.
[c]From Table 39.
[d]The ratio of belowground net production to aboveground net production is 2310/2053 = 1.125 for MDPR salt marshes (Table 109). This value is used to convert aboveground NPP to belowground NPP for brackish marsh macrophytes.
[e]Respiration is calculated by multiplying total NPP by a respiration to NPP ratio of 0.59 (Table 113).
[f]Gross primary production is equal to the sum of NPP and respiration.

Table 39. Aboveground net primary production of MDPR brackish marsh macrophytes.

Plant	Production[a]
Distichlis spicata	
Mean[b]	1961
Weighted avg.[c]	288
Juncus roemerianus	
Mean	2499
Weighted avg.	62
Spartina alterniflora[d]	
Mean	1853
Weighted avg.	113
Spartina patens	
Mean	3066
Weighted avg.	2355
Total, *Spartina patens*	2355
Total, other macrophytes	463
Total, All	2818

[a]Listed as g dry wt/sq m/yr.
[b]Means are taken from Table 110.
[c]The weighted average is the product of the mean production and a weighting factor. Weighting factors are from Table 40 and are 0.147, 0.025, 0.061, and 0.768 for *D. spicata*, *J. roemerianus*, *S. alterniflora*, and *S. patens*, respectively.
[d]*Spartina alterniflora* mean is a weighted average of streamside and inland values. The average streamside *S. alterniflora* value was weighted by multiplying by 0.254, and the inland value was multiplied by 0.746 (Table 110, note e). These values were then summed.

Table 40. Vegetative composition of MDPR brackish marshes.

Plant	Hydrologic unit[a] 1	2	3	4	5	7	Total
Distichlis spicata							
Percent[b]	9.2	6.2	2.7	25.4	10.7	3.1	14.7
Area[c]	1353	8028	280	20189	9845	2415	42110
Juncus roemerianus							
Percent	2.9	3.4	-	2.8	-	-	2.5
Area	426	4403	-	2226	-	-	7055
Spartina alterniflora							
Percent	3.5	5.3	22.8	7.8	1.6	-	6.1
Area	515	6863	2368	6200	1472	-	17418
Spartina patens							
Percent	48.5	67.8	3.1	45.3	57.1	46.5	76.8
Area	7130	87792	322	36006	52538	36224	220012
Total							
Percent[d]	64.1	82.7	28.6	81.3	69.4	49.6	100.1[e]
Area[f]	9424	107086	2970	64621	63855	38639	286595[g]

[a]Hydrologic units are: Mississippi Sound I, Pontchartrain II, Mississippi Delta III, Barataria IV, Terrebone V, and Vermilion VII. Atchafalaya VI is not included since it does not contain brackish marsh.

[b]The percent coverage of each of the four major brackish marsh macrophytes is taken from Chabreck (1972). Brackish marsh as used here is equivalent to Chabreck's brackish and intermediate marsh. Percentages are a weighted average of brackish and intermediate marsh values, using the proportions of the two marsh types in each hydrologic unit as weighting factors. Since data for hydrologic unit I could not be found, percentages based on the mean values of Chabreck's units I-IX are used. Hydrologic unit II as used here is equivalent to Chabreck's units I and II. To calculate percent coverage for this unit, the percent coverage of Chabreck's units I and II were weighted by the area of brackish marsh in those units. The total percentage of the MDPR covered by each of the four major macrophytes was calculated by dividing the total area of each of these four plants by the sum of those four totals, e.g., (42110/286595)*100 = 14.7 for *D. spicata*.

(continued)

Table 40. Concluded.

[c]The area of each hydrologic unit covered by each of the four major macrophytes (ha) is calculated by multiplying percent coverage by the total amount of brackish marsh in a particular hydrologic unit. The area of brackish marsh in units I, II, III, IV, V, and VII is 14,702, 129,487, 10,386, 79,483, 92,010, and 77,902 ha, respectively (Tables 13, 14, 16, 18, 20, and 23). Total area of each plant for the entire MDPR is the sum of the areas in the six hydrologic units.

[d]The percent of a hydrologic unit's brackish marsh covered by the four major macrophytes is calculated by dividing the total area of these four plants by the total amount of brackish marsh in that hydrologic unit (see note c for brackish marsh areas).

[e]Percentages do not add to 100% due to rounding errors.

[f]Total area covered by the four major macrophytes is the sum of the four areas for each hydrologic unit.

[g]Area inhabited by these four plants represents 70.9% of the total MDPR brackish marsh area.

Table 41. Aboveground net primary production in MDPR brackish marshes by producer.

Producer	Aboveground NPP[a]	Percent of Total
Microflora[b]	557	16.5
Spartina patens[c]	2355	69.8
Other macrophytes[d]	463	13.7
TOTAL	3375	100.0

[a]Net primary production as g dry wt/sq m/yr.

[b]From Table 37.

[c]From Table 38.

[d]_Distichlis spicata_, _Juncus roemerianus_, and _Spartina alterniflora_. From Table 38.

Table 42. Aboveground net primary production of other macrophytes in MDPR brackish marshes.[a]

Producer	Aboveground NPP[b]	Percent of Total
Distichlis spicata	288	62.2
Juncus roemerianus	62	13.4
Spartina alterniflora	113	24.4
TOTAL	463	100.0

[a]Data are from Table 39.
[b]Net primary production as g dry wt/sq m/yr.

Table 43. Total live and dead biomass of MDPR brackish marsh macrophytes.[a]

	Spartina patens	Other macrophytes[b]	Total
Live Biomass			
Aboveground[c]	770	128	898
Belowground[d]	866	144	1010
TOTAL	1636	272	1908
Dead Biomass			
Aboveground[c]	977	168	1145
Belowground[d]	1099	189	1288
TOTAL	2076	357	2433

[a]Values are g dry wt/sq m.
[b]*Distichlis spicata*, *Juncus roemerianus*, and *Spartina alterniflora*.
[c]From Table 44.
[d]From Table 45.

Table 44. Aboveground biomass of MDPR brackish marsh macrophytes.

Plant	Biomass[a] Live	Dead
Distichlis spicata		
Mean[b]	502	689
Weighted avg.[c]	74	101
Juncus roemerianus		
Mean	941	871
Weighted avg.	24	22
Spartina alterniflora[d]		
Mean	500	743
Weighted avg.	30	45
Spartina patens		
Mean	1003	1272
Weighted avg.	770	977
Total, *Spartina patens*	770	977
Total, other macrophytes	128	168
Total, all	898	1145

[a]Listed as g dry wt/sq m.
[b]Means are taken from Table 117.
[c]The weighted average is the product of the mean biomass and a weighting factor. Weighting factors are from Table 40 and are 0.147, 0.025, 0.061, and 0.768 for *D. spicata*, *J. roemerianus*, *S. alterniflora*, and *S. patens*, respectively.
[d]*Spartina alterniflora* mean is a weighted average of streamside and inland values. The average streamside *S. alterniflora* value was weighted by multiplying by 0.254, and the inland value was multiplied by 0.746 (Table 110, note e). These values were then summed.

Table 45. Belowground biomass of brackish marsh macrophytes in the MDPR.

	Spartina patens	Other macrophytes[a]	Total
Belowground NPP[b]	2649	521	-
Ratio[c]			
Live	0.327	0.276	-
Dead	0.415	0.363	-
Belowground biomass[d]			
Live	866	144	1010
Dead	1099	189	1288

[a]*Distichlis spicata*, *Juncus roemerianus*, and *Spartina alterniflora*.
[b]Net primary production in g dry wt/sq m/yr. From Table 38.
[c]Ratio of aboveground live or dead biomass to aboveground net primary production from Table 46.
[d]Values are g dry wt/sq m. Calculated by multiplying belowground net primary production by the biomass to production ratio.

Table 46. Ratios of live and dead aboveground biomass to aboveground net primary production.

	Spartina patens	Other macrophytes[a]
Aboveground biomass[b]		
Live	770	128
Dead	977	168
Aboveground NPP[c]	2355	463
Ratio[d]		
Live	0.327	0.276
Dead	0.415	0.363

[a]*Distichlis spicata*, *Juncus roemerianus*, and *Spartina alterniflora*.
[b]Values are g dry wt/sq m. From Table 43.
[c]Values are g dry wt/sq m/yr. From Table 38.
[d]Ratio of aboveground live or dead biomass to aboveground net primary production.

Table 47. Input of plant matter into litter in MDPR brackish marshes.[a]

Source	Value
Microflora[b]	526.3
Spartina patens[c]	2225.2
Other macrophytes[d]	437.5
TOTAL	3189.0

[a]Values as g dry wt/sq m/yr. Calculated as aboveground net primary production minus consumption. NPP for each producer taken from Tables 37 and 38. Consumption values for invertebrates and vertebrates taken from Tables 51 and 54, respectively.
[b]NPP equal to 557 g dry wt/sq m/yr. Consumption by invertebrates and vertebrates equal to 13.4 and 17.3 g dry wt/sq m/yr, respectively.
[c]NPP equal to 2355 g dry wt/sq m/yr. Consumption by invertebrates and vertebrates equal to 56.8 and 73.0 g dry wt/sq m/yr, respectively.
[d]NPP equal to 463 g dry wt/sq m/yr. Consumption by invertebrates and vertebrates equal to 11.1 and 14.4 g dry wt/sq m/yr, respectively.

Table 48. Total input of organic materials to microconsumers in MDPR brackish marshes.[a]

Source	Value
Soil organic matter[b]	1886.9
Litter[c]	554.5
Animal remains[d]	180.6
TOTAL	2622.0

[a]Values as g dry wt/sq m/yr. It is assumed that total input to microconsumers is equal to respiration, or 2622 g dry wt/sq m/yr (Table 33, note a).
[b]Rate of decomposition of soil organic matter is equal to belowground production (3170 g dry wt/sq m/yr; Table 38) minus the amount of organic matter lost through sedimentation (1283.1 g dry wt/sq m/yr; Table 27, note d).
[c]Total decomposition of aboveground materials is equal to total input to microconsumers minus inputs of soil organic matter and animal remains.
[d]From Table 49.

Table 49. Input of marsh animals to microconsumers by source.[a]

Source	Value
Invertebrates[b]	177.3
Vertebrates[c]	3.3
TOTAL	180.6

[a]Values as g dry wt/sq m/yr. Calculated as secondary production minus consumption and/or harvest.
[b]Production equal to 194.1 g dry wt/sq m/yr (Table 50). Consumption by vertebrates equal to 16.6 g dry wt/sq m/yr (Table 54). Harvest by man equal to 0.2 g dry wt/sq m/yr (Table 126).
[c]Production equal to 3.8 g dry wt/sq m/yr (Table 53). Consumption by vertebrates equal to 0.4 g dry wt/sq m/yr (Table 54). Harvest by man equal to 9.5 E-2 g dry wt/sq m/yr (Tables 136 and 141).

Table 50. Biomass and energy budget for MDPR brackish marsh invertebrates.[a]

Process	Salt marsh[b]	Brackish marsh[c]
Biomass	119.1	163.2
Consumption	1977.1	2708.6
Egestion	1574.7	2157.3
Respiration	260.7	357.2
Production	141.7	194.1

[a]Biomass in g dry wt/sq m. All other values as g dry wt/sq m/yr. Invertebrates are crabs, mussels, _Littorina irrorata_, and insects.
[b]Data for salt marshes are from Tables 124, 127, 128, and 130, respectively.
[c]Total aboveground NPP for MDPR brackish marshes is 3375 g dry wt/sq m/yr, and for salt marshes is 2459 (Tables 41 and 114, respectively). Thus aboveground NPP is 1.37 times greater at MDPR brackish marshes. Values for brackish marsh invertebrates are calculated by multiplying salt marsh values by this factor.

Table 51. Dietary breakdown for brackish marsh invertebrates.[a]

Source	Value
Soil TOM	983.2
Water TOM	864.0
Litter	539.0
Inorganic sediments	241.1
Microflora[b]	13.4
Spartina patens[b]	56.8
Other macrophytes[b]	11.1
TOTAL	2708.6

[a]Values as g dry wt/sq m/yr. Values are calculated by using the percent of consumption derived from each food source for salt marsh invertebrates. Total invertebrate consumption taken from Table 50 and percentages from Table 52.

[b]Plant matter makes up 3% of the diet of salt marsh invertebrates (Table 52). Thus total plant consumption by brackish marsh invertebrates is equal to 81.3 g dry wt/sq m/yr. It is assumed that consumption of marsh flora is in proportion to their percent of aboveground NPP, which is taken from Table 41.

Table 52. Dietary breakdown for salt marsh invertebrates.[a]

Source	Value	Percent
Soil TOM		
Crabs[b]	647.1	
Littorina[c]	71.6	
Total	718.7	36.3
Water TOM		
Mussels[d]	630.5	31.9
Litter		
Littorina[c]	393.6	19.9
Inorganic sediments		
Littorina[c]	175.3	8.9
Plant matter		
Littorina[c]	26.7	
Insects[e]	32.3	
Total	59.0	3.0
TOTAL	1977.1	100.0

[a]NPP as g dry wt/sq m/yr.
[b]From Table 124. It is assumed that the only significant input to crabs is soil organic matter.
[c]From Table 129.
[d]From Table 127. It is assumed that the only significant input to mussels is organic matter from surface waters.
[e]From Table 130. It is assumed that the only significant input to insects is plant matter.

Table 53. Biomass and energy budget for MDPR brackish marsh vertebrates.[a]

Process	Birds[b]	Mammals[c]	Total
Biomass	3.8 E-2	1.1	1.1
Consumption	14.4	117.2	131.6
Egestion	5.2	46.0	51.2
Respiration	9.2	67.4	76.6
Production	4.9 E-2	3.8	3.8

[a]Biomass in g dry wt/sq m. All other values as g dry wt/sq m/yr.
[b]Biomass from Table 134. All other values from Table 133.
[c]From Table 137.

Table 54. Dietary breakdown for brackish marsh vertebrates.[a]

Source	Birds[b]	Mammals[c]	Total
Microflora	0.4	16.9	17.3
Spartina patens	1.7	71.3	73.0
Other macrophytes	0.4	14.0	14.4
Invertebrates	5.9	10.7	16.6
Vertebrates	-	0.4	0.4
Fish	6.0	3.9	9.9
TOTAL	14.4	117.2	131.6

[a]Values as g dry wt/sq m/yr.
[b]From Table 55.
[c]From Table 56.

Table 55. Dietary breakdown for brackish marsh birds.[a]

Source	Value
Microflora[b]	0.4
Spartina patens[c]	1.7
Other macrophytes[d]	0.4
Invertebrates[e]	5.9
Fish[f]	6.0
TOTAL	14.4

[a]Values as g dry wt/sq m/yr. Total consumption taken from Table 133.

[b]Plant uptake by waterfowl is estimated as 32% of dietary intake, based on data for mottled ducks (Guidry 1977). For wading birds, a value of 2.1% is assumed, based on the average consumption of plants by the great white heron and the roseate spoonbill (Cottam and Knappen 1939). Waterfowl and wading birds account for 50.7 and 49.3% of total bird biomass, respectively (Table 134). The weighted average for percent plant uptake is therefore 17.2%, giving an uptake rate of 2.5 g dry wt/sq m/yr. It is assumed that uptake of microflora, *S. patens*, and other macrophytes is proportional to their percent of NPP, which for microflora is equal to 16.5% (Table 41). Thus consumption of microflora is equal to 0.4 g dry wt/sq m/yr.

[c]Total consumption of plants is equal to 2.5 g dry wt/sq m/yr (note b above). It is assumed that uptake of microflora, *S. patens*, and other macrophytes is proportional to their percent of NPP, which for *S. patens* is equal to 69.8% (Table 41). Thus consumption of *S. patens* is equal to 1.7 g dry wt/sq m/yr.

[d]Consumption of other macrophytes equal to total plant consumption minus consumption of microflora and *S. patens* (see notes b and c).

[e]Invertebrate uptake by waterfowl is estimated as 56% of dietary intake, based on data for mottled ducks (Guidry 1977). For wading birds, a value of 25% is assumed, based on the average consumption of invertebrates by the great white heron and the roseate spoonbill (Cottam and Knappen 1939). The weighted average (note b above) for percent invertebrate uptake is therefore 40.7%, giving an invertebrate uptake rate of 5.9 g dry wt/sq m/yr.

[f]Uptake of fish equal to total consumption minus consumption of microflora, *S. patens*, other macrophytes, and invertebrates.

Table 56. Dietary breakdown for brackish marsh mammals.[a]

Source	Value
Microflora[b]	16.9
Spartina patens[c]	71.3
Other macrophytes[d]	14.0
Invertebrates[e]	10.7
Vertebrates[f]	0.4
Fish[g]	3.9
TOTAL	117.2

[a]Values as g dry wt/sq m/yr. Total consumption taken from Table 137.

[b]Plant uptake by the raccoon is equal to 6% of its dietary intake (Fleming 1975). Nutria and muskrats are herbivores and therefore 100% of the food they consume is plant matter (Love 1981, O'Neil 1949, Shirley 1979). Based on Tables 138 and 139, raccoons, nutria, and muskrats make up 13.6, 80.5, and 5.9% of total mammal biomass, respectively. The weighted average for percent plant uptake is therefore 87.2%, giving an uptake rate of 102.2 g dry wt/sq m/yr. It is assumed that uptake of microflora, *S. patens*, and other macrophytes is proportional to their percent of NPP, which for microflora is equal to 16.5% (Table 41). Thus consumption of microflora is equal to the product of 0.165 and 102.2, or 16.9 g dry wt/sq m/yr.

[c]Total consumption of plants is equal to 102.2 g dry wt/sq m/yr (note b above). It is assumed that uptake of microflora, *S. patens*, and other macrophytes is proportional to their percent of NPP, which for *S. patens* is equal to 69.8% (Table 41). Thus consumption of *S. patens* is equal to the product of 0.698 and 102.2, or 71.3 g dry wt/sq m/yr.

[d]Consumption of other macrophytes equal to total plant consumption minus consumption of microflora and *S. patens* (see notes b and c).

[e]Approximately 67% of consumption by raccoons is invertebrates (Fleming 1975), while nutria and muskratrs are herbivorous and do not consume any. The weighted average (note b above) for percent invertebrate uptake is therefore 9.1%, giving an invertebrate uptake rate of 10.7 g dry wt/sq m/yr.

[f]Approximately 2% of consumption by raccoons is vertebrates (Fleming 1975), while nutria and muskrats are herbivorous and do not consume any. The weighted average (note b above) for percent vertebrate uptake is dry wt/sq m/yr.

[g]Uptake of fish equal to total consumption minus consumption of microflora, *S. patens*, other macrophytes, invertebrates, birds, and mammals.

Table 57. Release of heat by MDPR brackish marsh organisms.[a]

Source	Value
Producers[b]	
Microflora[c]	61,779
Spartina patens[d]	681,998
Other macrophytes[e]	134,155
Consumers[f]	
Microconsumers[g]	9963.6
Invertebrates[h]	1071.6
Vertebrates[i]	429.0
TOTAL	889,396

[a]Values as kcal/sq m/yr.

[b]Producers release heat in the process of photosynthesis, since the reaction is not 100% efficient, and also in the process of catabolism when biomass is broken down for energy requirements. Heat loss by catabolism is calculated by multiplying the respired biomass by the heat content of that material. Losses due to photosynthesis were calculated by multiplying GPP by a heat to GPP ratio that was derived from H. T. Odum (1957), which reports that a heat loss of 389,190 kcal/sq m/yr was associated with a GPP rate of 20,810 kcal/sq m/yr (4624 g dry wt/sq m/yr). This gives a heat to GPP ratio of 84.2 kcal/g dry wt.

[c]GPP and respiration of microflora are equal to 724 and 167 g dry wt/sq m/yr, respectively (Table 37). The heat content of microflora is 4.9 kcal/g dry wt, based on the heat content of algae (E. P. Odum 1971).

[d]GPP and respiration of *S. patens* are equal to 7956 and 2952 g dry wt/sq m/yr, respectively (Table 38). The heat content of *S. alterniflora*, 4.1 kcal/g dry wt (Golley 1961), is used.

[e]GPP and respiration of other macrophytes are equal to 1565 and 581 g dry wt/sq m/yr, respectively (Table 38). The heat content of *S. alterniflora* is used for other macrophytes (note d above).

[f]Consumers release heat only through catabolic processes. Heat loss is calculated by mutiplying respired biomass by the heat content.

[g]Respiration of microconsumers is equal to 2622 g dry detritus is 3.8 kcal/g dry wt, based on four detritus size fractions of *Spartina alterniflora* (Gosselink and Kirby 1974).

[h]Respiration of invertebrates is equal to 357.2 g dry wt/sq m/yr (Table 50). The average heat content of invertebrates is 3.0 kcal/g dry wt (E. P. Odum 1971).

[i]Respiration of vertebrates is equal to 76.6 g dry wt/sq m/yr (Table 53). The average heat content of vertebrates is 5.6 kcal/g dry wt (E. P. Odum 1971).

Table 58. Assimilation of sunlight by MDPR brackish marsh producers.[a]

Producer	Value
Microflora	64,219
Spartina patens	705,697
Other macrophytes	138,816
TOTAL	908,732

[a]Values as kcal/sq m/yr. Studies by H. T. Odum (1957) found that a gross primary production rate of 20,810 kcal/sq m/yr (4624 g dry wt/sq m/yr) required 410,000 kcal/sq m/yr of sunlight, giving a sunlight/GPP ratio of 88.7 kcal/g dry wt. Assimilation is calculated by multiplying this ratio by GPP. GPP taken from Tables 37 and 38.

Table 59. Solar insolation and albedo in MDPR brackish marshes.[a]

Process	Value
Insolation[b]	1.42 E6
Assimilation[c]	0.91 E6
Albedo[d]	0.51 E6

[a]Values as kcal/sq m/yr.
[b]The average solar insolation at New Orleans, Louisiana for 1952-1975 was 389.8 cal/sq cm/day (Knapp et al. 1980). This is equivalent to 1.42 E6 kcal/sq m/yr.
[c]Total assimilation of sunlight by marsh producers, from Table 58.
[d]Calculated as insolation minus assimilation.

5. CANAL

Canals, dredged primarily for oil and gas extraction and navigation, are an important manmade feature of the MDPR. Inventories of canal area in coastal Louisiana (Barrett 1970; Chabreck 1972; Adams et al. 1976) reported that canals make up from 0.6 to 0.9% of total marsh plus water area. Wicker et al. (1980a) reported that canals covered 29,449 ha in the MDPR in 1978, or 0.85% of the total area. A map of the distribution of canal habitat is shown in Figure 13.

Barrett (1970) measured 7374 km of canals in a 28,632 sq km area of coastal Louisiana south of the Intracoastal Waterway. Barrett reported 11,656 km of natural channels in the same area, indicating that, although the total area of canals is not large compared with the area of other habitats, the canal area is approaching that of natural drainage channels.

The indirect effects of canals and their associated spoil banks on wetland hydrology and marsh deterioration are discussed in Bahr et al. (in preparation). (See also Craig et al. 1979; Gagliano 1973).

Canals occur in fresh, brackish, and saline regions of the MDPR. Their hydrology and ecology differ with the type of wetland, salinity, size, orientation (parallel or perpendicular to the coast), and other factors. Because of this variation, it was impractical to construct a generalized I-O model for canals. We assumed that conditions in canals in freshwater regions are approximated by the Fresh Open Water Model and those in brackish and saline regions by the Estuarine Open Water Model.

Studies show canals to be a less productive habitat for animal life than unaltered natural channels. Canal dredging disturbs benthic communities, and although recolonization and restoration of original biomass are often attained, recolonization is usually by opportunistic species of less value to the food chain (Allen and Hardy 1980). Changes in substrate character and decreased oxygen supply are considered factors for lower amphipod and demersal fish populations in dredged canals (Allen and Hardy 1980).

Adkins and Bowman (1976), in a survey of Terrebonne Parish canals, found the greatest numbers of organisms in unaltered open water areas and fewer in open and semi-open canals. Closed canals had the fewest numbers of organisms. Gilmore and Trent (1974) found benthic microinvertebrates slightly more abundant in a natural Texas marsh than in an adjacent marsh altered by channelization, bulkheading, and filling. These organisms were more than twice as abundant volumetrically in the natural marsh.

Lindstedt (1978) measured 60% fewer numbers of amphipods, total crustaceans, and total organisms in MDPR oil field canals near Leeville, Louisiana, than in undisturbed control sites. The effects of oil contamination could not be separated from those of dredging. Some canals in the MDPR are subject to chronic low-level oil contamination from drilling operations. Increased levels of dissolved organic carbon (Whelan et al. 1976) and hydrocarbon contamination (Hood et al. 1975) were found in marshes near an MDPR oil field. Milan (1978) found that benthic organisms at the Leeville site experienced greater tissue enrichment by petroleum hydrocarbons than did free swimming forms. May (1977) found no difference between petroleum hydrocarbon concentrations in killifish from contaminated and control sites in the same area.

The unquantified energy and material flow diagram for canal habitat is shown in Figure 14.

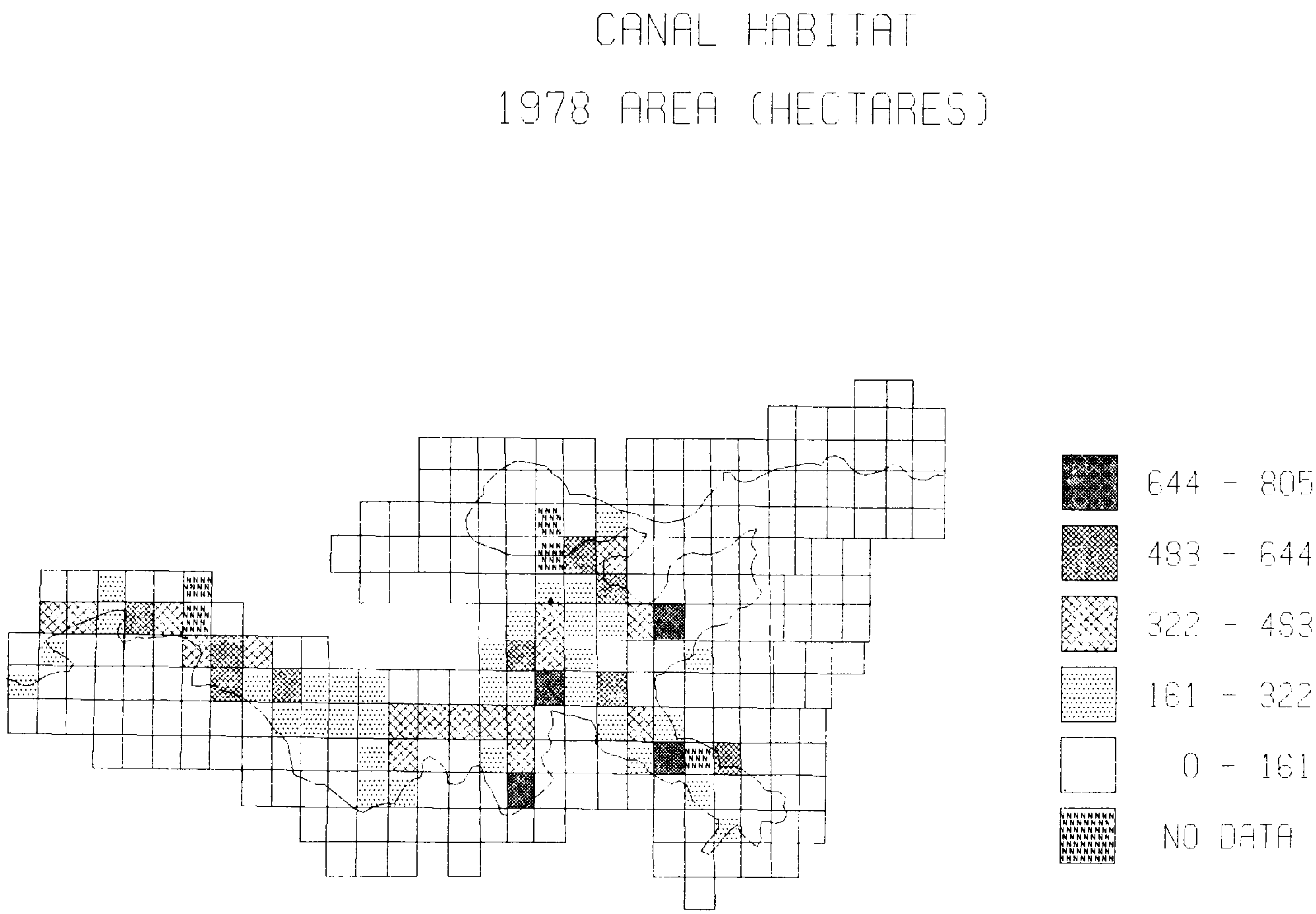


Figure 13. The distribution of MDPR canal habitat.

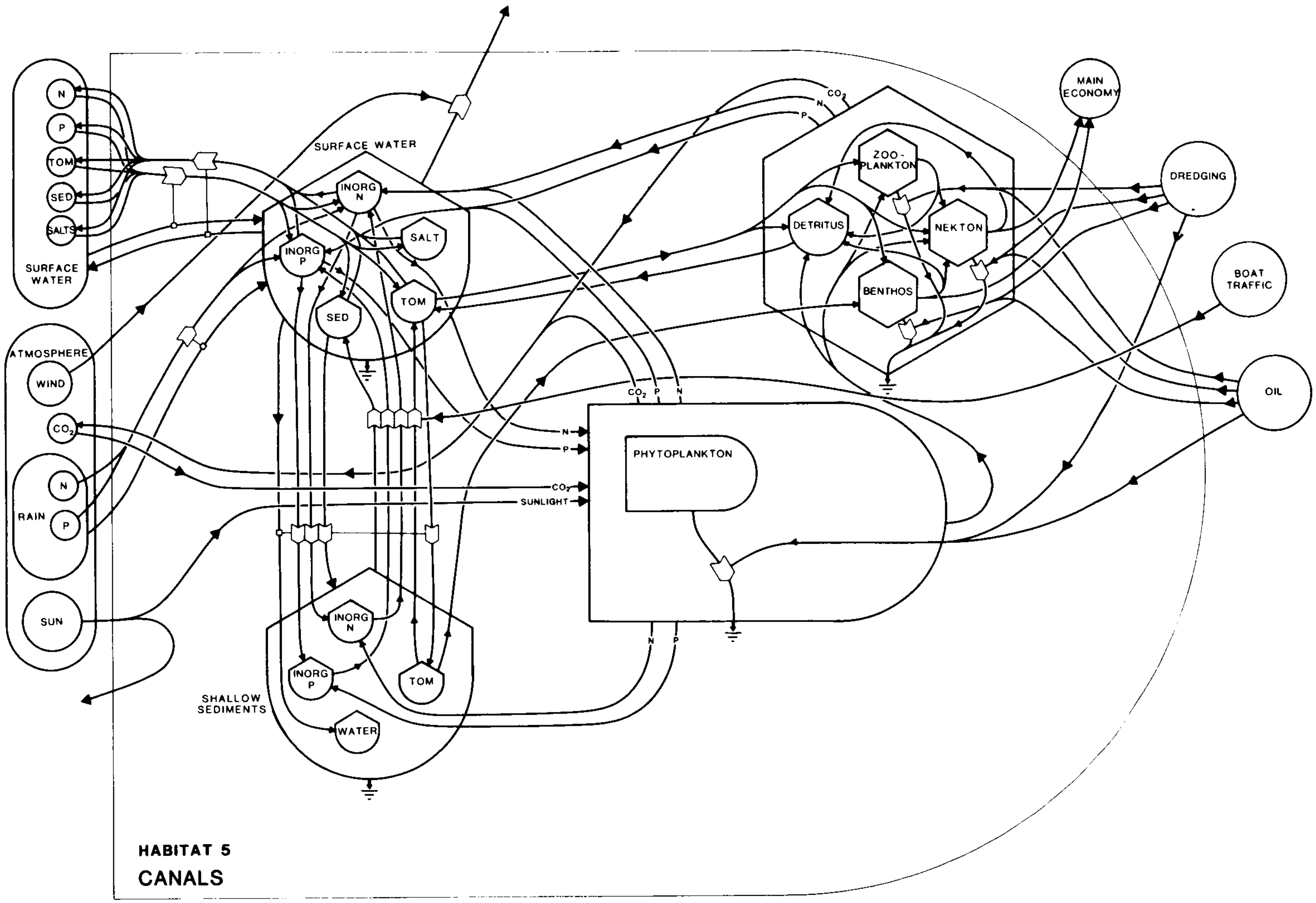


Figure 14. Canal habitat flow diagram.

6. CYPRESS-TUPELO SWAMP

Cypress-tupelo swamps comprise one of the major wetland plant associations in the MDPR. Swamps are found in backwater areas behind natural levee ridges in the freshwater regions of all of the interdistributary hydrologic basins. Cypress-tupelo swamps covered 158,465 ha in the MDPR in 1978. A much larger area of similar swampland lies north of the MDPR boundary in Louisiana and Mississippi. A map of the distribution of cypress-tupelo swamp habitat is shown in Figure 15.

Information available on the ecology of MDPR cypress-tupelo habitats has accumulated rapidly since 1970 and is now sufficient to allow construction of a generalized ecosystem model. Many aspects of the ecology of these habitats, however, have never been quantitatively measured.

Penfound (1952) gave an early description of Louisiana swamp vegetation. Coastal region swamp vegetation has been studied more recently in St. Charles Parish (Montz 1970; Montz and Cherubini 1973; Cramer 1978), St. James Parish (Conner et al. 1980), and in the upper Barataria Basin along Bayou Chevreuil (Conner and Day 1976; Conner et al. 1981). Information on consumer populations is limited. Bahr and Hebrard (1976) and Gosselink et al. (1979) provided basic qualitative descriptions of Louisiana cypress-tupelo swamp consumer populations. Day et al. (1981) provided the first quantitative attempt to detail a Louisiana swamp forest food web.

Swamp hydrology has been little studied; its relationship to riverine processes has been noted, but is poorly understood (Van Beek et al. 1978). There are some recent studies on swamplands and closely linked areas in the Atchafalaya (Wells and Demas 1977; Van Beek et al. 1978) and Barataria (Day et al. 1977; Sklar 1980) basins.

Since the number of Louisiana swamp sites studied is limited, one particular site, the des Allemands swamp in the upper Barataria Basin, was chosen for detailed modeling. The swamp covers areas in St. James, Lafourche, and St. John the Baptist parishes. The site was chosen for modeling principally for two reasons: (1) it is a riverine swamp system generally characteristic of swamps in the MDPR, and (2) it has been the site of numerous biological and hydrological studies that provide valuable information to the modeler.

Information on flows and storages directly measured for the des Allemands cypress-tupelo swamp was used in the model. When data on particular flows were unavailable, calculation based on other aspects of the des Allemands swamp system was attempted. If a flow could not be calculated for the des Allemands swamp, a flow measured for another comparable swamp ecosystem was used in the model.

An energy and material flow diagram of the cypress-tupelo swamp is shown in Figure 16, with the corresponding I-O table shown in Table 6. Details of all the calculations follow the model.

The des Allemands swamp is naturally flooded for about 11 months of the year. Spring high water occurs in April and May, followed by a dry summer period in July and August when the swamp's surface water drains off completely. Inundation generally resumes in late August or September.

Water flows into the des Allemands swamp from surrounding wooded natural levee ridges, agricultural fields, and urban areas. This water flowing into the swamp is shown in the upper left portion of the model. Standing water on the swamp floor either infiltrates the soil, evaporates, or runs off to downstream habitats, primarily bayous and freshwater lakes. These flows are shown by arrows from the swamp surface water storage tank. Runoff leaves the swamp via surface water. Although all areas outside

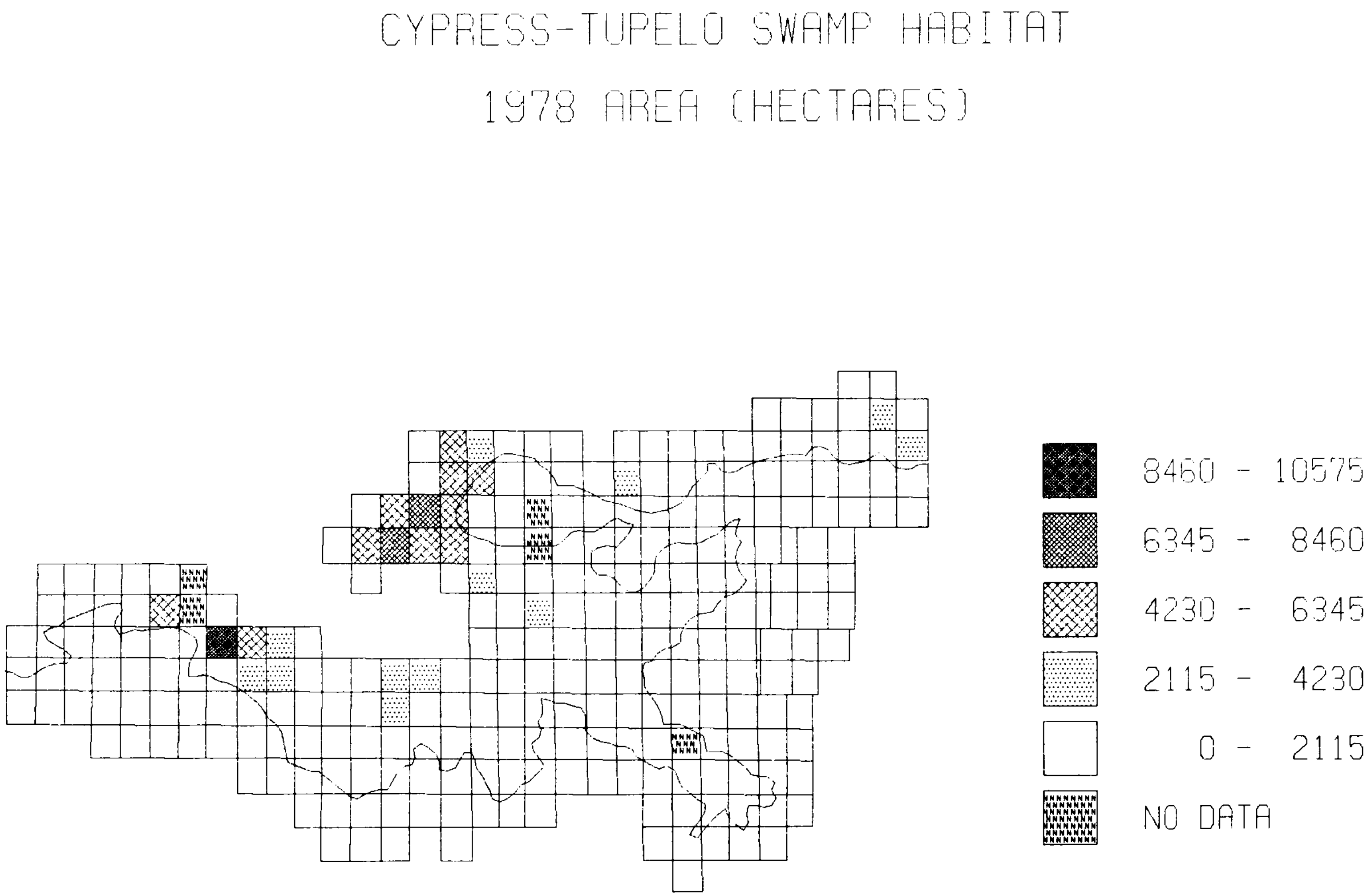


Figure 15. The distribution of MDPR cypress-tupelo swamp habitat.

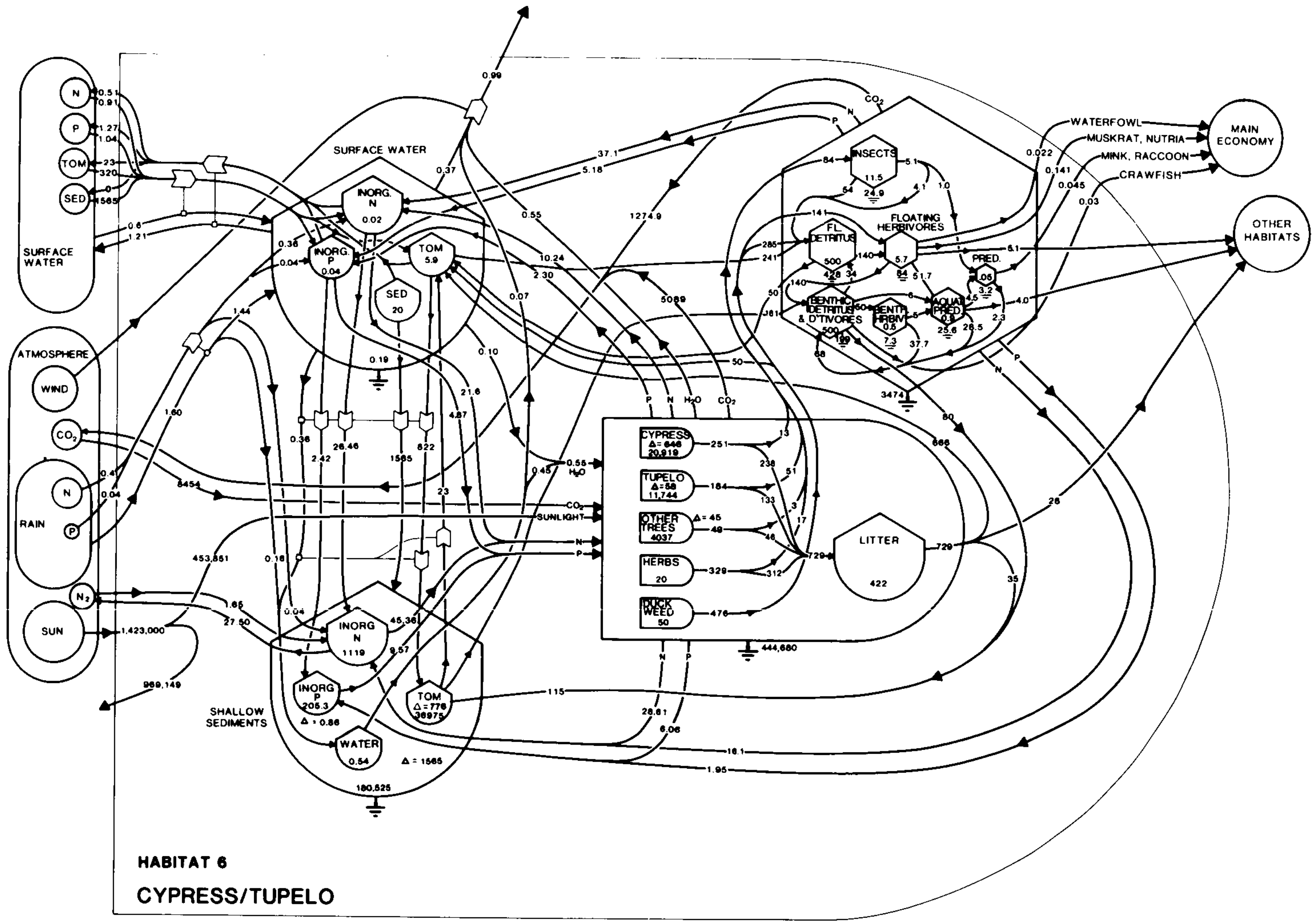


Figure 16. Cypress-tupelo swamp habitat flow diagram.

Table 60. Input-output table for cypress-tupelo swamp habitat.

HABITAT 6
CYPRESS/TUPELO

COMMODITIES		PROCESSES: SURFACE WATER 1	SHALLOW SOIL/SEDIMENT 2	CYPRESS 3	TUPELO 4	OTHER TREES 5	HERBS 6	DUCKWEED 7	LITTER 8	INSECTS 9	FLOATING DETRITUS 10	FLOATING HERBIVORES 11	BENTHIC DETRITUS 12	BENTHIC HERBIVORES 13	AQUATIC PREDATORS 14	PREDATORS 15	IMPORTS & EXPORTS 16	CHANGE IN STORAGE 17	TOTAL	UNITS
WATER	1	2.04 2.04 0.19	0.52 0.52 .54	0.26 0.26	0.07 0.07	0.03 0.03	0.09 0.09	0.10 0.10									2.20 2.20		5.31 5.31 73	10^9 g $H_2O/m^2/yr$ 10^9 g $H_2O/m^2/yr$ 10^9 g H_2O/m^2
INORGANIC NITROGEN	2	48.57 48.57 0.02	72.86 72.86 1119	13.60 6.56	8.07 5.09	2.39 1.50	21.30 13.46	21.60 10.24		1.7	29.5	5.8	13.7	0.5	1.8	0.2	28.01 2.96		216.4 216.4 1119.02	g $N/m^2/yr$ g $N/m^2/yr$ g N/m^2
INORGANIC PHOSPHORUS	3	8.56 8.56 0.04	10.43 10.43 206.3	3.50 2.20	1.02 .62	.25 .21	4.80 3.03	4.87 2.30		0.02	4.13	0.80	1.89	0.01	0.25	0.03	1.27 1.06	.86	36.56 36.56 206.34	g $P/m^2/yr$ g $P/m^2/yr$ g P/m^2
CARBON DIOXIDE	4			4000 2519	1078 679	419 264	1467 923	1490 704		41.1	706.8	138.7	328.6	12.1	42.3	5.3	6363.9 8454.0		14817.9 14817.9	g $CO_2/m^2/yr$ g $CO_2/m^2/yr$
TOTAL ORGANIC MATTER	5	1066 1066 6.9	937 937 36975					50	729		241 50		161 80				51 320	776	3252 3252 36980.9	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
INORGANIC SEDIMENTS	6	1565 1565 20	1565 1565 180525														1565	1565	4695 4695 180645	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
CYPRESS BIOMASS	7			897 20919					238	13								646	897 897 20 919	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
TUPELO BIOMASS	8				242 11744				133	51								56	242 242 11 744	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
OTHER TREE BIOMASS	9					94 4037			46	3								45	94 94 4037	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
HERB BIOMASS	10						329 20		312	17									329 329 20	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
DUCKWEED BIOMASS	11	50						476 50			285	141							476 476 50	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
LITTER BIOMASS	12	666	35						729 422								28		729 729 422	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
INSECT BIOMASS	13									59.1 11.5	58.1					1.0			59.1 59.1 11.5	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
FLOATING DETRITUS	14	50									190 500	140							190 190 500	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
FLOATING HERBIVORES	15											197 5.7	140		51.7		5.3		197 197 5.7	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
BENTHIC DETRITUS	16		80								34		170.03 500	50	6		.03		170.03 170.03 500	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
BENTHIC HERBIVORES	17												37.7	42.7 0.5	5				42.7 42.7 0.5	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
AQUATIC PREDATORS	18												28.5		37.0 0.9	4.5	4.0		37 37 0.9	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
PREDATORS	19												2.3			2.345 .05	.045		2.345 2.345 .05	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
HEAT	20			210 699	56 806	22 096	77 250	77 829		112	1926	378	896	33	115	14	448 154		448 154 448 154	kcal/m^2/yr kcal/m^2/yr
SUNLIGHT	21			214 735	57 895	22 520	78 730	79 971									969 149		1 423 000 1 423 000	kcal/m^2/yr kcal/m^2/yr

the swamp are represented in the left side of the model, this does not not imply that flows in and out come from the same location, either upstream or downstream.

During the period when the soil is flooded, flows of surface water control the transport of nitrogen, phosphorus, total organic matter (TOM), and sediment in and out of the swamp, as shown by the work gates in the upper left portion of the model. Nutrients and sediment entering surface water are either taken up by duckweed or settle out and contribute to soil or sediment fertility. The amounts of nutrients carried through the swamp by the surface water during a year are much greater than the amount of nitrogen, phosphorus, or organic matter actually stored in the water, as indicated by the relative magnitudes of the storage and flow quantities in the model. The average storage of nitrogen in the surface water is only 0.02 g/sq m/yr, but the total annual inflow in runoff is 49 g/sq m/yr. The values are shown as entries 2,1,S and 2,1,I, respectively, in the I-O table (Table 6).

It was assumed that the concentrations of nitrogen, phosphorus, total organic matter, and suspended sediment in the swamp surface water are in steady state; thus, all inflows of these commodities to the surface water must be balanced by outflows or changes in storage of similar magnitude.

Rainfall also contributes nutrients to the swamp--to surface water when the swamp floor is flooded and directly to the soil during the dry period. A water budget (Table 64) for the des Allemands swamp was derived from Sklar (1980). In the model, precipitation is shown coupled with flows of nitrogen and phosphorus.

Baldcypress (Taxodium distichum) and water tupelo (Nyssa aquatica) are the dominant trees in the swamp overstory. Each is included as a separate primary producer in the model. On very poorly drained sites, baldcypress tends to predominate. On slightly raised sites within the swamp, water tupelo increases in abundance, and black willow (Salix nigra), pumpkin ash (Fraxinus caroliniana), and Drummond red maple (Acer rubrum var. drummondii) occupy part of the canopy. Willow, ash, maple, and other trees are included in the model as "other trees." Herbs such as amaryllises, ferns, pennyworts, vines, emergent macrophytes, and grasses are found growing on rotting stumps and logs and other dry substrates (Conner and Day 1976) and are all included in the herb compartment in the model. The presence of standing water on the swamp forest floor also allows the growth of floating vegetation. Duckweed (Lemna minor and Spirodela polyrhiza), riccia, water hyacinth (Eichhornia crassipes), and common frog's bit (Limnobium spongia) are common (Conner and Day 1976). All are aggregated as "duckweed" in the model.

Aboveground net plant production is divided into three categories in the model: (1) stem growth, (2) litterfall, and (3) consumption by insects. Net plant production is the sum of all three categories. Litterfall does not include treefall because no data were available. Stem growth is shown in the model and in the I-O table (Table 6) as a change in tree biomass storage. The sum of litter production and consumption by insects is shown as an output of plant biomass from each producer in the model. This flow of biomass is then divided between inputs to litter and to the insect consumer compartment of the model. Total annual net primary productivity in the model is 2,038 g dry wt/ sq m/yr (see Table 61).

It was estimated that the des Allemands swamp model site was logged between 50 and 95 years ago (Conner and Day 1976). The area is still accumulating tree biomass.

Belowground production has not been studied in Southeastern U.S. swamps and it was not considered in the model. Belowground biomass in a cypress stand in the Great Dismal Swamp, Virginia, was measured at 1531 g/sq m (peripheral roots only) (Montague and Day 1980). Aboveground biomass in the same stand was 34,527 g/sq m. Nitrogen concentration in cypress and tupelo roots is about twice as high as in stems, and phosphorus concentration is about three times higher in roots than in stems (Dickson et al. 1972).

Baldcypress and water tupelo net primary productivity in the upper Barataria Basin has been shown to be strongly linked to the hydrological regime of that drainage basin (Conner et al. 1981). Swamps that experience regular periods of inundation and drying show higher net primary productivity than those with sluggish or stagnant water. Conner et al. (1981) examined three Barataria Basin cypress-tupelo swamp sites in upper Barataria and found that an impounded area showed significantly lower net tree production (887 g dry wt/sq m/yr) than a naturally flooded site (1166 g dry wt/sq m/yr). Even higher net tree production was found in a nearby area where water levels were artificially maintained. That area was flooded from late fall to early spring and drained the rest of the year. While it was flooded, water was pumped through to ensure high oxygen levels. The net tree production of this area was found to be 1780 g dry wt/sq m/yr (Conner et al. 1981).

Direct grazing by insects accounts for a minor portion of net primary production. Consumption by other herbivores is of even lower magnitude than by insects (Gosselink et al. 1979) and was omitted from the model.

Insect consumption in the model (84 g/sq m/yr) was obtained from Conner and Day (1976). Most of this consumption is by the abundant forest tent caterpillar (Malacosoma disstria), which often defoliates large areas of deltaic plain forest (Morris 1975).

Much of the primary production enters the detritus food chain. Leaf litter provides an important source of food for detritivores and other consumers low on the food chain. Leaf litter also plays a role in sedimentation and the transfer of organic matter to downstream habitats. Export of organic matter was calculated to be 51 g/sq m/yr, 28 g of which is leaf litter. Both of these flows are shown in the model.

The swamp's consumer food web was detailed by Day et al. (1981). That model was for an impounded swamp and is used as the only available estimate of the consumer food web in MDPR swamps. Terrestrial insects, not included as a separate category in the Day et al. model, were added in this study.

Day et al. (1981) divide detritus and associated bacteria and organisms into two compartments: that floating on the water surface (floating detritus community), and that on the sediment surface (benthic detritus community). Crawfish, major swamp detritivores, are included in the benthic detritus community. Herbivore communities are similarly partitioned. The floating herbivore community includes amphipods, oligochaetes, and lepidoptera. Bivalves, snails, isopods, and crawfish make up the benthic community herbivores.

Other consumer compartments are aquatic predators, made up of aquatic insect predators like dragonflies and spiders, and predators, consisting of larger swamp predators like amphibians, snakes, turtles, alligators, raccoons, and birds.

Consumers excrete nitrogen and phosphorus and regenerate them to the water and soil/sediment, as shown by the flows of these nutrients to surface water and soil/sediment in the model.

Amphibians, reptiles, and mammals are abundant in the cypress-tupelo swamp (Gosselink et al. 1979). The swamp is used extensively by many bird species, mostly on a seasonal basis.

The cypress-tupelo swamps provide man with many important products. Crawfish are harvested for food; nutria, muskrat, mink, and raccoon are harvested for fur; and waterfowl from swamps are hunted for sport. Cypress lumbering in the MDPR was historically important (Mancil 1972), but current lumbering in the des Allemands swamp region is insignificant and was not included in the model. Estimates of the flows of mammals and waterfowl to the main economy are shown in Tables 70 and 71. The crawfish harvest from MDPR swamps was estimated at 0.03 g dry wt/sq m/yr.

Notes to Cypress/Tupelo Swamp Habitat Model

Water.

1,1,I Input of water to surface water. 2.04 E6 g/sq m/yr. Table 64.

1,1,0 Output of water from surface water. 2.04 E6 g/sq m/yr. Table 64.

1,1,S Storage of surface water. 0.19 E6 g/sq m/yr. Average water depth in swamp equals 0.19 m (Conner et al. 1981, from graph). Water volume equals 0.19 E6 g/sq m/yr.

1,2,I Input of water to soil/sediment. 0.52 E6 g/sq m/yr. Table 64.

1,2,0 Output of water from soil/sediment. 0.52 E6 g/sq m/yr. Table 64.

1,2,S Storage of water in soil/sediment. 0.54 E6 g/sq m/yr. Soil water content averages 71.3% (see Table 72). 0.713 g water/ 0.287 g dry soil x soil volume (0.75 cu m/sq m) (Kemp and Day, in press) x soil bulk density (0.29 g dry soil/cu cm) (Brown 1981) x E6 cu cm/cu m = 0.54 E6 g/sq m/yr.

1,3,I Water uptake by baldcypress. 0.26 E6 g/sq m/yr. Table 64.

1,3,0 Transpiration by baldcypress. 0.26 E6 g/sq m/yr. Table 64.

1,4,I Water uptake by water tupelo. 0.07 E6 g/sq m/yr. Table 64.

1,4,0 Transpiration by water tupelo. 0.07 E6 g/sq m/yr. Table 64.

1,5,I Water uptake by other trees. 0.03 E6 g/sq m/yr. Table 64.

1,5,0 Transpiration by other trees. 0.03 E6 g/sq m/yr. Table 64.

1,6,I Water uptake by herbs. 0.09 E6 g/sq m/yr. Table 64.

1,6,0 Transpiration by herbs. 0.09 E6 g/sq m/yr. Table 64.

1,7,I Water uptake by duckweed. 0.10 E6 g/sq m/yr. Table 64.

1,7,0 Transpiration by duckweed. 0.10 E6 g/sq m/yr. Table 64.

1,16,0 Net input of water. 2.20 E6 g/sq m/yr. Table 64, notes a, c. (1.60 E6 g/sq m/yr precipitation + 0.60 E6 g/sq m/yr runoff = 2.20 E6 g/sq m/yr.)

1,16,I Net output of water. 2.20 E6 g/sq m/yr. Table 64, notes d, f. (1.21 E6 g/sq m/yr runoff + 0.99 E6 g/sq m/yr evaporation = 2.20 E6 g/sq m/yr.)

Inorganic nitrogen.

2,1,I Input of inorganic nitrogen to surface water. 48.57 g/sq m/yr. Sum of inputs in runoff, precipitation, nutrient regeneration by plants, and nutrient regeneration by animals. Runoff accounts for 0.91 g/sq m/yr, (Table 74). Precipitation contributes nitrogen to surface water when soil is flooded and to soil/sediment when swamp is dry. Precipitation during the dry period equals 0.16 m (Table 64, note a), which is 10% of annual precipitation of 1.6 m (Sklar 1980). Assuming nitrogen concentration in precipitation remains constant year-round, 10% of the total nitrogen input in precipitation of 0.40 g/sq m/yr (Table 74) goes directly into the soil, and 90%, or 0.36 g/sq m/yr, goes into surface water. Of the swamp producers, only duckweed regenerates nitrogen to surface water, all others regenerate nitrogen to soil/sediment. Duckweed nitrogen regeneration equals 10.24 g/sq m/yr (Table 65). The floating detritus community, the floating herbivore community, and aquatic predators regenerate nitrogen to surface water. Total animal nitrogen regeneration to surface water equals 37.1 g/sq m/yr (Table 69).

2,1,0 Output of inorganic nitrogen from surface water. 48.57 g/sq m/ yr. It was assumed that the storage of nitrogen in surface water remains relatively constant over time, so average annual output equals average annual input. Total output is the sum of outputs to runoff, nutrient uptake by plants, and inorganic output to the sediments. Runoff output equals 0.51 g/sq m/yr (Table 74). Plant uptake from surface water is only by duckweed and is equal to 21.30 g/sq m/yr (Table 65). Contribution of nitrogen to the sediments was calculated by difference (48.57 g/sq m/yr total - 21.60 g/sq m/yr duckweed uptake - 0.51 g/sq m/yr runoff) and equals 26.46 g/sq m/yr.

2,1,S Storage of inorganic nitrogen in surface water. 0.02 g/sq m. Equal to product of nitrogen concentration in surface water (0.11 mg/l) (Kemp and Day, in press) and water depth (0.19 m) (1,1,S), 1000 l/cu m, and g/1000 mg.

2,2,I Input of inorganic nitrogen to soil/sediment. 72.86 g/sq m/yr. Sum of inputs from precipitation, sedimentation, nitrogen fixation, plant regeneration and animal regeneration. Input from precipitation occurs when swamp is dry and equals 10% of total nitrogen input of 0.40 g/sq m/yr (Table 74), or 0.04 g/sq m/yr (see also 2,1,I). Input by sedimentation equals 26.46 g/sq m/yr (2,1,0). Nitrogen fixation occurs in the soil/sediment bacterial community at plant roots. Fixation was estimated from fixation in flooded rice field soils in Louisiana (57 ug N fixed/g soil) (Reddy and Patrick 1979). Multiplication of fixation by soil bulk density (0.29 g soil/cu cm) (Brown 1981), a soil depth of 10 cm, and conversion to g/sq m = 1.65 g N fixed/sq m. Nitrogen regeneration by baldcypress, tupelo, other trees and herbs equals 28.61 g/sq m/yr (Table 65). Nitrogen regeneration by insects, benthic detritus, benthic herbivores and predators equals 16.1 g/sq m/yr (Table 69).

2,2,0 Output of inorganic nitrogen from soil/sediment. 72.86 g/sq m/ yr. It was assumed that the storage of nitrogen in soil/sediment remains relatively constant over time, so average annual output equals average annual input. Total output is the sum of uptake by baldcypress, tupelo, other trees, and herbs (45.36 g/sq m/yr) (Table 65) and denitrification. Denitrification was calculated by difference to balance the soil sediment compartment (72.86 g/sq m/yr - 45.36 g/sq m = 27.50 g/sq m/yr). This probably overestimates denitrification. Much of this nitrogen may be accounted for by uptake to support belowground production. (Lack of data prevented inclusion of belowground production in the model.)

2,2,S Storage of inorganic nitrogen in soil/sediment. 1119 g/sq m. Interstitial soil water inorganic nitrogen content was used as an estimate of soil inorganic nitrogen content, since most inorganic nitrogen is highly soluble. Product of average soil depth (0.75 m) (Kemp and Day, in press), soil bulk density (0.29 g dry soil/cu cm) (Brown 1981), soil water content (0.713 g water/0.287 g dry soil) (Table 72), interstitial water inorganic nitrogen/ total nitrogen ratio of 0.46 g inorganic N/g total N (Table 73), total soil nitrogen (0.45 g total N/100 g water) (Table 72), and 1 E6 cm/cu m, yields 1119 g inorganic N/sq m/yr.

2,3,I Nitrogen uptake by baldcypress. 13.60 g/sq m/yr. Table 65.

2,3,0 Nitrogen release by baldcypress. 8.56 g/sq m/yr. Table 65.

2,4,I Nitrogen uptake by water tupelo. 8.07 g/sq m/yr. Table 65.

2,4,0 Nitrogen release by water tupelo. 5.09 g/sq m/yr. Table 65.

2,5,I Nitrogen uptake by other trees. 2.39 g/sq m/yr. Table 65.

2,5,0 Nitrogen release by other trees. 1.50 g/sq m/yr. Table 65.

2,6,I Nitrogen uptake by herbs. 21.30 g/sq m/yr. Table 65.

2,6,0 Nitrogen release by herbs. 13.46 g/sq m/yr. Table 65.

2,7,I Nitrogen uptake by duckweed. 21.60 g/sq m/yr. Table 65.

2,7,0 Nitrogen release by duckweed. 10.24 g/sq m/yr. Table 65.

2,9,0 Output of inorganic nitrogen from insects. 1.7 g/sq m/yr. Table 69.

2,10,0 Output of inorganic nitrogen from floating detritus. 29.5 g/sq m/yr. Table 69.

2,11,0 Output of inorganic nitrogen from floating herbivores. 5.8 g/sq m/yr. Table 69.

2,12,O Output of inorganic nitrogen from benthic detritus. 13.7 g/sq m/yr. Table 69.

2,13,O Output of inorganic nitrogen from benthic herbivores. 0.5 g/sq m/yr. Table 69.

2,14,O Output of inorganic nitrogen from aquatic predators. 1.8 g/sq m/yr. Table 69.

2,15,O Output of inorganic nitrogen from predators. 0.2 g/sq m/yr. Table 69.

2,16,I Total export of inorganic nitrogen. 28.01 g/sq m/yr. Sum of output in runoff (0.51 g/sq m/yr) (Table 74) and denitrification (27.50 g/sq m/yr) (2,2,O).

2,16,O Total import of inorganic nitrogen. 2.96 g/sq m/yr. Sum of inputs in runoff and precipitation (0.91 g/sq m/yr and 0.40 g/sq m/yr, respectively) (Table 74) and nitrogen fixation (1.65 g/sq m/yr, 2,2,I).

Inorganic phosphorus.

3,1,I Input of inorganic phosphorus to surface water. 8.56 g/sq m/yr. Sum of inputs in precipitation and runoff (0.04 g/sq m/yr and 1.04 g/sq m/yr respectively) (Table 74), and regeneration by plants and animals. Regeneration by duckweed is contributed to surface water and equals 2.30 g/sq m/yr (Table 66). Regeneration by floating detritus, floating herbivores and aquatic predators equals 5.18 (Table 69).

3,1,O Output of inorganic phosphorus from surface water. 8.56 g/sq m/yr. It was assumed that the concentration of phosphorus in surface water remains relatively constant over time, so the average annual output of phosphorus equals the average annual input. Total output equals the sum of runoff, uptake by plants, and sedimentation. Output in runoff equals 1.27 g/sq m (Table 74). Uptake by duckweed equals 4.87 g/sq m/yr (Table 66). Sedimentation was calculated by difference (8.56 g/sq m/yr - 4.87 g/sq m/yr - 1.27 g/sq m/yr = 2.42 g/sq m/yr).

3,1,S Storage of phosphorus in surface water. 0.04 g/sq m. Equal to phosphorus concentration in surface water (0.23 mg/l) (Kemp and Day, in press) times water depth (0.19 m) (see 1,1,S), multiplied by 1000 l/cu m and g/1000 l.

3,2,I Input of inorganic phosphorus to soil/sediment. 10.43 g/sq m/yr. Sum of input in sedimentation, regeneration by plants, and regeneration by animals. Sedimentation equals 2.42 g/sq m/yr (3,1,O). Regeneration by baldcypress, tupelo, other trees, and herbs equals 6.06 g/sq m/yr (Table 66). Regeneration by insects, benthic detritus, benthic herbivores, and predators equals 1.95 g/sq m/yr (Table 69).

3,2,O Output of inorganic phosphorus from soil/sediment. 10.43 g/sq m/ yr. It was assumed that the concentration of phosphorus in soil/sediment remains relatively constant over time, so the average annual output from the compartment equals the average annual input. Output equals the sum of baldcypress, tupelo, other trees, and herb uptake (9.57 g/sq m/yr, Table 66) and change in soil/sediment phosphorus storage. Change in storage was calculated by difference (10.43 g/sq m/yr - 7.18 g/sq m/yr) and equals 0.86 g/ sq m/yr.

3,2,S Storage of inorganic phosphorus in soil/sediment. 205.3 g/sq m. Assuming swamp soil P content is equal to phosphorus content of nearby fresh marsh soils (944 ug P/g dry soil) (Hatton 1981), phosphorus storage equals product of phosphorus content, soil depth (0.75 m) (Kemp and Day, in press), soil bulk density (0.29 g dry soil /cu cm) (Brown 1981), and conversion factors of g/1 E6 ug N and 1 E6 cu cm/cu m, yields 205.3 g/sq m.

3,3,I Phosphorus uptake by baldcypress. 3.50 g/sq m /yr. Table 66.

3,3,O Phosphorus release by baldcypress. 2.20 g/sq m/yr. Table 66.

3,4,I Phosphorus uptake by water tupelo. 1.02 g/sq m/yr. Table 66.

3,4,O Phosphorus release by water tupelo. 0.62 g/sq m/yr. Table 66.

3,5,I Phosphorus uptake by other trees. 0.25 g/sq m/yr. Table 66.

3,5,O Phosphorus release by other trees. 0.21 g/sq m/yr. Table 66.
3,6,I Phosphorus uptake by herbs. 4.80 g/sq m/yr. Table 66.
3,6,O Phosphorus release by herbs. 3.03 g/sq m/yr. Table 66.
3,7,I Phosphorus uptake by duckweed. 4.87 g/sq m/yr. Table 66.
3,7,O Phosphorus release by duckweed. 2.30 g/sq m/yr. Table 66.
3,9,O Phosphorus release by insects. 0.02 g/sq m/yr. Table 69.
3,10,O Phosphorus release by floating detritivore community. 4.13 g/sq m/yr. Table 69.
3,11,O Phosphorus release by floating herbivore community. 0.80 g/sq m/yr. Table 69.
3,12,O Phosphorus release by benthic detritus community. 1.89 g/sq m/ yr. Table 69.
3,13,O Phosphorus release by benthic herbivore community. 0.01 g/sq m/ yr. Table 69.
3,14,O Phosphorus release by aquatic predators. 0.25 g/sq m/yr. Table 69.
3,15,O Phosphorus release by predators. 0.03 g/sq m/yr. Table 69.
3,16,I Net export of inorganic phosphorus. 1.27 g/sq m/yr. Equal to export in run-off. Table 74.
3,16,O Total import of phosphorus. 1.08 g/sq m/yr. Sum of phosphorus added in precipitation (0.04 g/sq m/yr) (Table 74) and phosphorus in incoming surface water (1.04 g/sq m/yr). Table 74.
3,17,I Change in phosphorus storage. 0.86 g/sq m/yr. See 3,2,O.

Carbon dioxide.

4,3,I Carbon dioxide uptake by baldcypress. 4000 g/sq m/yr. Table 63.
4,3,O Carbon dioxide release by baldcypress. 2591 g/sq m/yr. Table 63.
4,4,I Carbon dioxide uptake by water tupelo. 1078 g/sq m/yr. Table 63.
4,4,O Carbon dioxide release by water tupelo. 679 g/sq m/yr. Table 63.
4,5,I Carbon dioxide uptake by other trees. 419 g/sq m/yr. Table 63.
4,5,O Carbon dioxide release by other trees. 264 g/sq m/yr. Table 63.
4,6,I Carbon dioxide uptake by herbs. 1467 g/sq m/yr. Table 63.
4,6,O Carbon dioxide release by herbs. 923 g/sq m/yr. Table 63.
4,7,I Carbon dioxide uptake by duckweed. 1490 g/sq m/yr. Table 63.
4,7,O Carbon dioxide release by duckweed. 704 g/sq m/yr. Table 63.
4,9,O Carbon dioxide release from insects. 41.1 g/sq m/yr. Table 69.
4,10,O Carbon dioxide release from floating detritus. 706.8 g/sq m/yr. Table 69.
4,11,O Carbon dioxide release from floating herbivores. 138.7 g/sq m/yr. Table 69.
4,12,O Carbon dioxide release from benthic detritus. 328.6 g/sq m/yr. Table 69.
4,13,O Carbon dioxide release from benthic herbivores. 12.1 g/sq m/yr. Table 69.
4,14,O Carbon dioxide release from aquatic predators. 42.3 g/sq m/yr. Table 69.
4,15,O Carbon dioxide release from predators. 5.3 g/sq m/yr. Table 69.
4,16,I Net export. 6363.9 g/sq m/yr. Sum of releases from producers (5089 g/sq m/yr) (Table 63) and consumers (1274.9 g/sq m/yr) (Table 69).
4,16,O Net import. 8,454 g/sq m/yr. Sum of inputs to producers. Table 63.

Total organic matter (TOM).

5,1,I Input of TOM to surface water. 1086 g dry wt/sq m/yr. Inflow of TOM to surface water equals the sum of net inflow in sediment and contributions from leaf litter, duckweed, and the floating detritivore community. TOM inflow in sediment equals 320 g dry wt organic matter/ sq m/yr. This was calculated by multiplying sedimentation depth of 0.65 cm (measured for a nearby fresh marsh on the south shore of Lac des Allemands; Hatton 1981), soil bulk density (0.29 g/cu cm: Brown 1981), and sediment organic matter content (17%: Ho and Schneider 1976). Since measured sedimentation equals net sedimentation, resuspension was assumed to be zero. Input of TOM from litterfall equals 666 g/sq m/yr (12,9,O). The contribution of unconsumed duckweed to surface water

TOM equals 50 g/sq m/yr (Day et al. 1981). The contribution from the floating detritivore community equals 50 g/sq m/yr (Day et al. 1981).

5,1,0 Output of TOM from surface water. 1086 g dry wt/sq m/yr. Suspended TOM in water was assumed to be in steady state, so total output from surface water equals input plus change in storage. Output equals consumption by the floating detritus community (241 g/sq m/yr) (5,10,0), export, and the flow of TOM to the sediments that occurs by settling. Export of TOM in surface water was calculated for the des Allemands swamp to be 23 g/sq m/yr (12,16,0). Settling was calculated by difference (1086 g/sq m/yr - 241 g/sq m/yr - 23 g/sq m/yr = 822 g/sq m/yr).

5,1,S Storage of TOM in surface water. 5.9 g dry wt/sq m. The bayou draining Lac des Allemands swamp contained annual average of 14.1 mg C/l, or 31 mg dry wt/l. (Day et al. 1977) (2.2 g dry wt/g C ; Whittaker 1975). TOM concentration multiplied by 0.19 m water depth (1,1,S), and 1000 l/cu m, and g/1000 mg yields 5.9 g dry wt/sq m/yr.

5,2,I Input of TOM to soil/sediment. 937 g dry wt/sq m/yr. Equal to the sum of settling (822 g/sq m/yr) (5,1,0), TOM output from the benthic detritus community (80 g/sq m/yr) (5,10,0), and litterfall when the swamp is dry (35 g/sq m/yr) (12,9,0).

5,2,0 Output of TOM from soil/sediment. 937 g dry wt/sq m/yr. It was assumed that TOM in the soil/sediment is in steady state, so total inputs equal outputs plus change in storage. The benthic detritus community consumes 161 g/sq m/yr (Day et al. 1981) (see also 5,12,I). Accumulation in TOM storage in soil/sediment equals 776 g/ sq m/yr.

5,2,S Storage of TOM in soil/sediment. 36,975 g dry wt./sq m/yr. Swamp soil is highly organic (7.64% organic C, or 17.0% dry organic matter) (Ho and Schneider 1976). Bulk density of similar swamp soils equals 0.29 g/cu cm (Brown 1981). Soil depth averages 0.75 m (Kemp and Day, in press). Product of density, depth, and organic fraction yields 36,975 g dry wt/sq m.

5,7,0 Output of TOM from duckweed. 50 g/sq m/yr. Equal to unconsumed duckweed. 5,1,I.

5,8,0 Output of TOM from litter. 729 g/sq m/yr. Equal to total litter production.

5,10,I Input of TOM to floating detritus community. 241 g/sq m/yr (Day et al. 1981).

5,10,0 Output of TOM from floating detritus community. 50 g/sq m/yr (Day et al. 1981).

5,12,I Input of TOM to benthic detritus community. 161 g/sq m/yr (Day et al. 1981).

5,12,0 Output of TOM from benthic detritus community. 80 g/sq m/yr (Day et al. 1981).

5,16,I Net export of TOM. 51 g dry wt/sq m/yr. Export of TOM in surface water (23 g/sq m/yr) (5,1,0) plus export of leaf litter (28 g/sq m/ yr) (12,16,I).

5,16,0 Net import of TOM. 320 g/sq m/yr. Equal to net import in sediment. See 5,1,I.

5,17,I Change in TOM storage. 776 g/sq m/yr. See 5,2,0.

Sediment.

6,1,I Input of inorganic sediment in surface water. 1565 g/sq m/yr. Hatton (1981) records total net sedimentation on nearby fresh marsh as 0.65 cm/yr. Multiplying by soil bulk density of 0.29 g/cu cm (Brown 1981), 10,000 sq cm/sq m, and 83% inorganic matter (17% organic matter; Ho and Schneider 1976) yields 1565 g/sq m/yr.

6,1,0 Output of inorganic sediment from surface water to sediments. 1565 g/sq m/yr. Sediment recorded by Hatton (1981) is net sedimentation. The amount of resuspended inorganic sediment exported is unknown and would presumably be balanced by a gross inflow in surface water greater than the 1565 g/sq m/yr net sedimentation (6,1,I). In the model, outflow of inorganic sediment in surface water was assumed to be zero, and output of sediment from surface water includes only the settling out of sediments.

6,1,S Sediment storage in surface water. Estimated to be 20 g/sq m/yr.

6,2,I Input of sediment to sediments. 1565 g/sq m/yr. Equal to sediment inflow in surface water (6,1,I).

6,2,0 Output of sediment from soil/sediment. 1565 g/sq m/yr. The output of sediment from soil/sediment is equal to the change in storage of sediment in the soil/sediment compartment. Although resuspension of sediment occurs, it is not included because its quantity is not known. Net flux of sediment is into the soil/sediment compartment, at a rate of 1565 g/sq m/yr (6,1,0). Change in storage of sediment in soil/sediment is thus 1565 g/sq m/yr.

6,2,S Sediment storage in soil/sediment. 180,525 g/sq m/yr. Defined to be the inorganic soil fraction, or 83% (soil is 17% organic) (Ho and Schneider 1976, see also 5,2,S). Product of soil depth of 0.75 m (Kemp and Day, in press), bulk density (0.29 g/cu cm, Brown 1981), and inorganic fraction (0.83), yields inorganic sediment storage of 56,025 g/sq m/yr. (0.75 m x 0.09 g/cu cm x 0.83 E6 cu cm/cu m = 180,525 g/sq m/yr)

6,16,0 Net import of inorganic sediment. 1565 g/sq m/yr. Equal to sediment entering in surface water (6,1,I).

6,17,I Change in sediment storage. 1565 g/sq m/yr. See 6,2,0.

Baldcypress biomass.

7,3,0 Net production of baldcypress. 897 g/sq m/yr. Table 61.
7,3,S Standing crop of baldcypress. 20,919 g/sq m. Table 61.
7,8,I Litterfall of baldcypress. 238 g/sq m/yr. Table 61.
7.9.I Insect consumption of baldcypress. 13 g/sq m/yr. Table 61.
7,17,0 Stem growth of baldcypress. 646 g/sq m/yr. Table 61.

Water tupelo biomass.

8,4,0 Net production of water tupelo. 242 g/sq m/yr. Table 61.
8,4,S Standing crop of water tupelo. 11,744 g/sq m. Table 61.
8,8,I Litterfall of water tupelo. 133 g/sq m/yr. Table 61.
8,9,I Insect consumption of water tupelo. 51 g/sq m/yr. Table 61.
8,17,0 Stem growth of water tupelo. 58 g/sq m/yr. Table 61.

Other tree biomass.

9,5,0 Net production of other trees. 94 g/sq m/yr. Table 61.
9,5,S Standing crop of other trees. 4037 g/sq m. Table 61.
9,8,I Litterfall of other trees. 46 g/sq m/yr. Table 61.
9,9,I Insect consumption of other trees. 3 g/sq m /yr. Table 61.
9,17,0 Stem growth of other trees. 45 g/sq m/yr. Table 61.

Herb biomass.

10,6,0 Net production of herbs. 329 g/sq m/yr. Table 61.
10,6,S Standing crop of herbs. 20 g/sq m. Table 61.
10,8,I Litterfall of herbs. 312 g/sq m/yr. Table 61.
10,9,I Insect consumption of herbs 17 g/sq m/yr. Table 61.

Duckweed biomass

11,1,I Input of duckweed to surface water. 50 g/sq m/yr. Day et al. 1981.
11,7,0 Net production of duckweed. 476 g/sq m/yr. Table 61.

11,7,S Standing crop of duckweed. 50 g/sq m/yr. Table 61.
11,10,I Input of duckweed to floating detritus. 285 g/sq m/yr. (Day et al. 1981).
11,11,I Input of duckweed to floating herbivores. 141 g/sq m/yr. (Day et al. 1981).

Leaf litter.

12,1,I Input of leaf litter to surface water. 666 g/sq m/yr. Leaf litter contributes organic matter to surface water and soil/sediment. It is included as a separate commodity in these notes to distinguish it from allochthonous sources of TOM and production of detritus from animal production and mortality. Total leaf litterfall equals 729 g/sq m/yr (Table 61), of which 28 g/sq m/ yr are exported (12,16,I), leaving 701 g/sq m/yr. It was calculated from Conner and Day (1976) that 5% of the litterfall in the swamp occurs between July 15 and Aug. 15 when the swamp is dry. Thus 5% of 701 g/sq m/yr, or 35 g/sq m/yr, falls directly on the soil/sediment, and 666 g/sq m/yr fall on surface water.
12,2,I Input of leaf litter to sediment. 35 g/sq m/yr (12,1,I).
12,8,O Output of leaf litter from litter storage. 729 g/sq m/yr. Equals litter production by baldcypress, water tupelo, other trees, and herbs (Table 61). Outputs from litter storage go to surface water (666 g/sq m/yr), soil/ sediment (35 g/sq m/yr), and export (28 g/sq m/yr).
12,9,S Storage of leaf litter. 422 g/sq m (Conner and Day 1976).
12,16,I Export of leaf litter. 28 g/sq m/yr. Day et al. (1982) estimated that 2.5% of net aboveground production in the des Allemands swamp region of the Upper Barataria Basin is annually exported. Net production equals 2038 g/sq m/yr, making export 51 g/sq m/yr. Mulholland and Kuenzler (1979) estimated particulate and dissolved organic matter exported from the des Allemands swamp watershed to be 10.4 gC/sq m/yr, or 23 g dry wt organic matter/sq m/yr. The Mulholland and Kuenzler number refers to export from the swamp through swamp bayous to downstream habitats. The Day et al. value refers to export from the swamp proper to swamp bayous. Since swamp bayous are considered a separate habitat in this study, the latter estimate was used as a measure of total export. It was assumed that 23 g/sq m/yr was an approximation of small particulate and dissolved TOM leaving the swamp. It was assumed that all TOM that leaves the swamp makes its way out of the watershed. The remaining 28 g/sq m/yr export was assumed to be leaf litter exported from the swamp that settles to the bottom of swamp bayous.

Insect biomass.

13,9,O Output of insect biomass. Secondary production plus fecal production. 59.1 g/sq m/yr. Figure 61.
13,9,S Insect standing crop. 11.5 g/sq m. Figure 61.
13,10,I Input of insect biomass to floating detritus. 58.1 g/sq m/yr. Equal to insect biomass output minus flow to predators (1.0 g/sq m/yr) (13,15,I).
13,15,I Predation on insects. Estimated at 1 g/sq m/yr.

Floating detritus and detritivore community biomass.

14,1,I Input of floating detritus community biomass to surface water. 50 g/sq m/yr (Day et al. 1981) (5,1,I).
14,10,O Output of floating detritus community biomass. 190 g/sq m/yr. Sum of flows to herbivores (140 g/sq m/yr) and surface water (50 g/sq m/yr) (Day et al. 1981) (5,1,I).
14,10,S Storage of floating detritus community biomass. 500 g/sq m (Day et al. 1981).

14,11,I Input of floating detritus community biomass to floating herbivores. 140 g/sq m/yr (Day et al. 1981).

Floating herbivore community biomass.

15,11,O Output of floating herbivore community biomass. 197 g/sq m/yr (Day et al. 1981). Sum of outputs to benthic detritus, aquatic predators, floating detritus, and export.

15,11,S Standing crop of floating herbivore community biomass. 5.7 g/sq m/yr (Day et al. 1981).

15,12,I Input of floating herbivore community biomass to benthic detritus. 140 g/sq m/yr (Day et al. 1981).

15,14,I Input of floating herbivore community biomass to aquatic predators. 51.7 g/sq m/yr (Day et al. 1981).

15,16,I Export of floating herbivore community biomass. 5.3 g/sq m/yr. Sum of 5.1 g/sq m/yr (Day et al. 1981), nutria and muskrat harvest, (0.141 g/sq m/yr, Table 70), and waterfowl harvest (0.022 g/sq m/yr, Table 71).

Benthic detritus and detritivore community biomass.

16,2,I Input of benthic detritus to soil/sediment. 80 g/sq m/yr (Day et al. 1981) (5,2,I).

16,10,I Input of benthic detritus community biomass to floating detritus. 34 g/sq m/yr (Day et al. 1981).

16,12,O Output of benthic detritus community biomass. 170.03 g/sq m/yr (Day et al. 1981). Sum of flows to benthic herbivores, floating detritus, aquatic predators, sediment, and export.

16,12,S Benthic detritus community standing crop. 500 g/sq m (Day et al. 1981).

16,13,I Input of benthic detritus community biomass to benthic herbivores. 50 g/sq m/yr (Day et al. 1981).

16,14,I Input of benthic detritus community biomass to aquatic predators. 6 g/sq m/yr (Day et al. 1981).

16,16,I Export of benthic detritus community biomass. 0.03 g/sq m/yr. Swamp crawfish, a major benthic detritivore, is an important swamp fishery. Crawfish harvest equals 0.03 g/sq m/yr. Total harvest from Louisiana is 11 million pounds, 30% of which comes from swamps and swamp ponds (Gary 1974). Swamps and swamp ponds (forested wetlands) in Louisiana cover 2,281,000 ha (Turner and Craig 1980). Assuming the same weight of crawfish are harvested per hectare in the MDPR as statewide, crawfish harvest equals 11 E6 lb wet wt/2,281,000 ha x 0.30 (30% harvest from swamps) x 454 g/lb x ha/10,000 sq m x 0.5 g dry wt/g wet wt.

Benthic herbivore community biomass.

17,12,I Input of benthic herbivore community biomass to benthic detritus. 37.7 g/sq m/yr (Day et al. 1981).

17,13,O Output of benthic herbivore community biomass. 42.7 g/sq m/yr (Day et al. 1981). Sum of inputs to benthic detritus and aquatic predators.

17,13,S Benthic herbivore community standing crop. 0.5 g/sq m (Day et al. 1981).

17,14,I Input of benthic herbivore community biomass to aquatic predators. 5 g/sq m/yr (Day et al. 1981).

Aquatic predator biomass.

18,12,I Input of aquatic predators to benthic detritus. 28.5 g/sq m/yr (Day et al. 1981).

18,14,O Output of aquatic predators. 37.0 g/sq m/yr (Day et al. 1981). Sum of inputs to benthic detritus and predators.

18,14,S Aquatic predator standing crop. 0.9 g/sq m/yr (Day et al. 1981).
18,15,I Input of aquatic predators to predators. 4.5 g/sq m/yr (Day et al. 1981).
18,16,I Export of aquatic predators. 4.0 g/sq m/yr (Day et al. 1981).

Predator biomass.

19,12,I Input of predators to benthic detritus. 2.3 g/sq m/yr (Day et al. 1981).
19,15,O Output of predators. 2.345 g/sq m/yr. Sum of input to benthic detritus and harvest.
19,15,S Predators standing crop. 0.05 g/sq m (Day et al. 1981).
19,16,I Harvest of mink and raccoon. 0.045 g/sq m/yr. Table 70.

Heat.

20,3,O Total heat output from cypress. 210,699 kcal/sq m/yr. Table 63.
20,4,O Total heat output from tupelo. 56,806 kcal/sq m/yr. Table 63.
20,5,O Total heat output from other trees. 22,096 kcal/sq m/yr. Table 63.
20,6,O Total heat output from herbs. 77,250 kcal/sq m/yr. Table 63.
20,7,O Total heat output from duckweed. 77,829 kcal/sq m/yr. Table 63.
20,9,O Metabolic heat output from insects. 112kcal/sq m/yr. Table 63.
20,10,O Metabolic heat output from floating detritus community. 1926 kcal/sq m/yr. Table 69.
20,11,O Metabolic heat output from floating herbivore community. 378 kcal/sq m/yr. Table 69.
20,12,O Metabolic heat output from benthic detritus community. 896 kcal/sq m/yr. Table 69.
20,13,O Metabolic heat output from benthic herbivore community. 33 kcal/sq m/yr. Table 69.
20,14,O Metabolic heat output from aquatic predator community. 115 kcal/sq m/yr. Table 69.
20,15,O Metabolic heat output from predators. 14 kcal/sq m/yr. Table 69.
20,16,I Net output of heat. 448,154 kcal/sq m/yr. Sum of heat outputs from plants (444,688 kcal/sq m/yr) (Table 63), and animals (3474 kcal/sq m/yr) (Table 69).

Sunlight.

22,3,I Sunlight absorbed by baldcypress. 214,735 kcal/sq m /yr. Table 63.
22,4,I Sunlight absorbed by water tupelo. 57,895 kcal/sq m /yr. Table 63.
22,5,I Sunlight absorbed by other trees. 22,520 kcal/sq m/yr. Table 63.
22,6,I Sunlight absorbed by herbs. 78,730 kcal/sq m /yr. Table 63.
22,7,I Sunlight absorbed by duckweed. 79,971 kcal/sq m/yr. Table 63.
22,16,I Net output of sunlight. 969,149 kcal/sq m/yr. Net output of sunlight, or albedo, equals total sunlight input (1.423 E6 kcal/sq m/yr) (see 22,16,O) minus sum of uptake by plants (453,851 kcal/sq m/yr) (Table 63).
22,16,O Net input of sunlight 1.423 E6 kcal/sq m/yr. Total insolation equals 389.8 cal/sq cm/day at New Orleans, averaged from 1952-1975 (Knapp et al. 1980).

Table 61. Cypress-tupelo swamp net primary productivity (NPP) and standing crop. All values in g/sq m/yr except standing crop, which is in g/sq m.

Species	Stem Production[a]	Litter-fall[b]	Consumption by Insects[c]	Total NPP[d]	Standing Crop[e]
Baldcypress (*Taxodium distichum*)	646	238	13	897	20,919
Water tupelo (*Nyssa aquatica*)	58	133	51	242	11,744
Other trees	45	46	3	94	4037
Herbs	--	312	17	329	20
Duckweed (*Lemna* sp., *Azolla* sp., *Spirodela* sp.)	--	476[f]	--	476	50
TOTAL	749	1205	84.0	2038	36,770

[a] Conner et al. (1981).
[b] See Table 62.
[c] See Table 67.
[d] Sum of stem production, litterfall, and insect consumption.
[e] Conner and Day (1976).
[f] Day et al. (1981). Note: Duckweed does not contribute litter to terrestrial litter compartment.

Table 62. Calculation of cypress-tupelo swamp tree litterfall. Total annual litterfall is 417 g/sq m/yr (Conner and Day 1976).

Species	Basal area (BA) (sq cm/sq m)[a]	% total BA	% total litterfall[b]	Litterfall (g/sq m/yr)[c]
Baldcypress (*Taxodium distichum*)	21	57	57	238
Water tupelo (*Nyssa aquatica*)	12	32	32	133
Other trees	4	11	11	46
TOTAL	37	100	100	417

[a] Conner et al. 1981.
[b] Each plant group was assumed to account for the same percentage of total BA and total litterfall.
[c] Conner and Day 1976.

Table 63. Inputs and outputs of biomass, water, carbon dioxide, solar energy, and respiratory heat from cypress-tupelo swamp primary producers.

Flow	Cypress	Tupelo	Other Trees	Herbs	Duckweed	TOTAL
NPP[a] (g dry wt/ sq m/yr)	897	242	94	329	476	2038
GPP[b] (g dry wt/ sq m/yr)	2422	653	254	888	902	5119
Respiration[c] (g dry wt/ sq m/yr)	1525	411	160	559	426	3081
Water input[d] (E6 g/sq m/yr)	0.26	0.07	0.03	0.09	0.10	0.55
Water output[e] (E6 g/sq m/yr)	0.26	0.07	0.03	0.09	0.10	0.55
Carbon dioxide input[f] (g/sq m/yr)	4000	1078	419	1467	1490	8454
Carbon dioxide output[g] (g/sq m/yr)	2519	679	264	923	704	5089
Solar input[h] (kcal/sq m/yr)	214,735	57,895	22,520	78,730	79,971	453,851
Heat loss due to inefficiency of photosynthesis[i] (kcal/sq m/yr)	203,836	54,956	21,376	74,734	75,912	430,814
Respiratory heat[j] (kcal/sq m/yr)	6863	1850	720	2516	1917	13,866
Total heat output[k] (kcal/sq m/yr)	210,699	56,806	22,096	77,250	77,829	444,680

(continued)

Table 63. Concluded.

[a]From Table 61.

[b]Gross primary production = 2.7 x net primary production (Whittaker 1975).

[c]Respiration = GPP - NPP.

[d]Water incorporated into biomass is 1% of water transpired (Penman 1970) and is considered negligible. Water transpired is considered equal to water absorbed.

[e]Total transpiration was calculated from data in Wetzel (1975, p. 41) to be 55% of evaporation for flooded vegetated regions. Transpiration of individual producers was calculated on the basis of their respective GPP.

[f]Carbon uptake equals 0.45 x g dry wt GPP (E. P. Odum 1971). Weight of CO_2 was calculated by multiplying g C by 3.67 (44 g CO_2/12 g C). Carbon dioxide uptake equals 0.45 x 3.67, or 1.65 x GPP.

[g]Carbon dioxide output equals 1.65 x g dry wt respired. See note f.

[h]410,000 kcal are required for every 20,810 kcal fixed in GPP (calculated from H. T. Odum 1957. See also Figure 17). Total solar energy required for GPP = 410,000 kcal/4624.4 g dry wt (4.5 kcal=1 g dry wt) (88.66 kcal/g dry wt GPP).

[i]389,190 kcal of heat are dissipated for every 4624.4 g dry wt fixed in GPP (84.16 kcal/g dry wt GPP) as a result of the inefficiency of photosynthesis.

[j]Respiratory heat lost = 4.5 kcal/g dry wt respired (Whittaker 1975).

[k]Sum of heat loss due to the inefficiency of photosynthesis and respiratory heat loss.

Table 64. Water budget for MDPR cypress-tupelo swamp[a].

From	To P	R	SW	SS	E	C	T	OT	H	D	TL
P[b]	--	--	1.44	0.16	--	--	--	--	--	--	1.60
R[c]	--	--	0.60	--	--	--	--	--	--	--	0.60
SW[d]	--	1.21	--	0.36	0.37	--	--	--	--	0.10	2.04
SS[e]	--	--	--	--	0.07	0.26	0.07	0.03	0.09	--	0.52
E[f]	--	--	--	--	--	--	--	--	--	--	--
C[g]	--	--	--	--	0.26	--	--	--	--	--	0.26
T[h]	--	--	--	--	0.07	--	--	--	--	--	0.07
OT[i]	--	--	--	--	0.03	--	--	--	--	--	0.03
H[j]	--	--	--	--	0.09	--	--	--	--	--	0.09
D[k]	--	--	--	--	0.10	--	--	--	--	--	0.10
TOTAL	--	1.21	2.04	0.52	0.99	0.26	0.07	0.03	0.09	0.10	

[a]A water depth of one meter corresponds to 1 E6 g water/sq m. Legend: P=Precipitation, R=Runoff, SW=Surface Water, SS=Soil/Sediment, E=Evaporation, C=Cypress, T=Tupelo, OT=Other Trees, H=Herbs, D=Duckweed, TL=Total.

[b]Total annual precipitation on soil and surface water = 1.6 m (63 in) (Sklar 1980). Precipitation falling between July 15 and August 15 when swamp is dry falls on soil/sediment. Remainder falls on surface water. Precipitation falling between July 15 and August 15 was obtained by averaging July and August average precipitation (7.22 in/mo (July) + 6.44 in/mo (Aug.))/2 = 6.25 in/mo (0.16 m) (Sklar 1980). 1.6 m/yr - 0.16 m/mo (for July 15 - Aug. 15) = 1.44 m/(11 wet months).

[c]Annual runoff from surrounding uplands = 23.8 in. (0.60 m) (Sklar 1980).

[d]Outflow of surface water from swamp was calculated by difference to balance surface water compartment. Surface water runoff = 1.21 = 1.44 + 0.60 - 0.10 - 0.37 - 0.36. Infiltration of surface water into soil/sediment was calculated by difference to balance soil/sediment compartment. Surface water infiltration = 0.36 = 0.07 + 0.26 + 0.07 + 0.03 + 0.09 - 0.16. Annual evaporation from surface water and soil/sediment equals total annual evapotranspiration, or 39.2 in. (0.99 m) (Sklar 1980). Total evapotranspiration - annual transpiration (0.55 m, see notes f-j) equals total annual evaporation (0.44 m). Evaporation from soil/sediment occurs only from July 15 to August 15 when the swamp is not flooded. Evaporation between July 15 and August 15 was determined by calculating the percentage of evapotranspiration that occurs

(continued)

Table 64. Concluded.

when the swamp is dry. July 15 to August 15 evapotranspiration (6.17 in/mo (July) + 5.86 in/mo (Aug))/2 = 6.0 in (0.14 m) or 15% of total annual evapotranspiration of 0.99 m. Assuming total evaporation is proportional to total evapotranspiration, 15% of total evaporation (or about 0.07 m) occurs from soil/sediment. 0.44 m - 0.07, or 0.37 m evaporates from surface water. Input of surface water into duckweed. Table 63. Duckweed is the only producer that absorbs surface water. Trees and herbs absorb water from soil/sediment.

[e] Evaporation from soil/sediment = 0.07 (note c). Input of soil/sediment water into cypress = 0.26 (Table 63). Input of soil/sediment water into tupelo = 0.07 (Table 63). Input of soil/sediment water into other trees = 0.03 (Table 63). Input of soil/sediment water into herbs = 0.09 (Table 63).

[f] Evaporated water is not an input, only an output from the swamp.

[g] Output of water from cypress. Equal to input to cypress = 0.26 (Table 63).

[h] Output of water from tupelo. Equal to input to tupelo = 0.07 (Table 63).

[i] Output of water from other trees. Equal to input to other trees = 0.03 (Table 63).

[j] Output of water from herbs. Equal to input to herbs =0.09 (Table 63).

[k] Output of water from duckweed. Equal to input to duckweed = 0.10 (Table 63).

Table 65. Nitrogen uptake and release by cypress-tupelo swamp primary producers.

Producer	Part	Source of nutrients	N content[a] (g N/g dw biomass)	GPP[b] (g/sq m/yr)	Plant resp.[c] (g/sq m/yr)	N uptake[d] (g/sq m/yr)	N released[e] (g/sq m/yr)
Bald-cypress	leaf	Soil/ Sediment	0.0216	678	427	8.54	5.38
	stem		0.0029	1744	1098	5.06	3.18
Water Tupelo	leaf	Soil/ Sediment	0.0153	497	313	7.60	4.79
	stem		0.0030	157	99	0.47	0.30
Other trees	leaf	Soil/ Sediment	0.0153	132	83	2.02	1.27
	stem		0.0030	122	77	0.37	0.23
Herbs	all	Soil/ Sediment	0.024[f]	888	561	21.30	13.46
Duckweed	all	Surface Water	0.024[f]	902	426	21.60	10.24
TOTAL						66.96	38.85

[a]From Dickson et al. (1972). Other trees assumed to be similar to tupelo.
[b]Gross primary production (GPP) equals net primary production (NPP) (Table 61) x 2.7 (Whittaker 1975).
[c]Plant respiration equals GPP - NPP.
[d]Uptake equals N content x GPP.
[e]Nitrogen released equals N content times plant respiration. Nitrogen released by baldcypress, water tupelo, and other trees is returned to the soil, that released by duckweed is returned to the water.
[f]From Mitsch (1975). Duckweed assumed to be similar to herbs.

Table 66. Phosphorus uptake and release by cypress-tupelo swamp primary producers.

Species	Part	P conc.[a] (mg P/gdw biomass)	GPP[b] (g/sq m/yr)	Respiration[c] (g/sq m/yr)	P uptake[d] (g/sq m/yr)	P released[e] (g/sq m/yr)
Bald-	leaf	3.38	678	427	2.29	1.44
cypress	stem	0.691	1744	1098	1.21	0.76
Water	leaf	1.79	497	313	0.89	0.54
tupelo	stem	0.834	157	99	0.13	0.08
Other	leaf	1.79[f]	132	83	0.24	0.15
trees	stem	0.834	122	77	0.01	0.06
Herbs	all	5.4[g]	888	561	4.80	3.03
Duckweed	all	5.4[g]	902	426	4.87	2.30
TOTAL					14.44	8.36

[a]Calculated from Dickson et al. (1972).
[b]Gross primary production (GPP) equals net primary production (NPP) (Table 61) x 2.7 (Whittaker 1975), except for duckweed, for which GPP was calculated as the sum of NPP and respiration as given by Day et al. (1981). Litterfall was used as an estimate of leaf NPP and stemgrowth as an estimate of stem NPP for all trees and herbs.
[c]Respiration equals GPP - NPP, except for duckweed, which was estimated directly by Day et al. (1981).
[d]P uptake equals average P concentration in plant part times GPP.
[e]P release equals average P concentration in plant part times plant respiration.
[f]Assumed to be equal to concentration in tupelo.
[g]Taken to be the average concentration of *Sagittaria falcata* (0.22%) and *Phragmites communis* (0.86%), two species of fresh marsh emergent macrophytes (Gosselink et al. 1977).

Table 67. Terrestrial insect consumption of cypress-tupelo swamp primary producers.

Plant species	Litterfall (g/sq m/yr)	Percent of leaf production consumed[a]	Consumption (g/sq m/yr)[b]
Baldcypress	238	5.3	13.3
Water tupelo	133	27.6	50.6
Other trees	46	5.3	2.6
Herbs	312	5.3	17.5
TOTAL	729		84.0

[a]5.3% of leaf production consumed (Table 68) for all trees but water tupelo. Consumption of water tupelo was calculated as the difference between total insect consumption of 84 g/sq m/yr (Conner and Day 1976) and consumption of baldcypress, other trees, and herbs. This value is higher than that for consumption of other species of trees. Morris (1975) reports defoliation of tupelo up to 70% in Louisiana and Alabama forests, but the 27.6% obtained here is probably a more reasonable estimate of the overall average.

[b]Insect consumption (g/sq m/yr) was calculated as the percentage of leaves consumed multiplied by leaf production, where production equals litter production plus insect consumption.

Table 68. Insect leaf consumption in woodland habitats.

Forest type	Consumption by insects	Reference
Beech (Fagus)	5%[a]	Funke 1972[b]
Yellow poplar (Liriodendron)	5.6%[c]	Reichle and Crossley 1967
Hazel (Corylus)	4% (year 1)[d] 1.3% (year 2)[d]	Smith 1972
Average of 13 collections	8.3%[e]	Bray 1961
Average of 4 collections	7.7%[b]	Bray 1964
OVERALL AVERAGE	5.3%	

[a]Percent of annual leaf fall.
[b]Cited in Schroeder 1973.
[c]Percent of leaf production.
[d]Percent of leaf energy content.
[e]Percent of canopy leaf area.

Table 69. Respiration, carbon dioxide output, inorganic nitrogen and phosphorus output, and heat output for cypress-tupelo swamp consumers.

	Respiration[a] (gdw/sq m/yr)	CO_2 output[b] (g CO_2/sq m/yr)	N output[c] (g N/sq m/yr)	P output[d] (g P/sq m/yr)	Destination of N & P output	Heat output[e] (kcal/sq m/yr)
Insects	24.9	41.1	1.7	0.02	soil	112
Floating detritus	428	706.8	29.5	4.13	water	1926
Floating herbivores	84	138.7	5.8	0.80	water	378
Benthic detritus	199	328.6	13.7	1.89	soil	896
Benthic herbivores	7.3	12.1	0.5	0.01	soil	33
Aquatic predators	25.6	42.3	1.8	0.25	water	115
Predators	3.2	5.3	0.2	0.03	soil	14
Total	772	1274.9	53.2	7.13		3474

[a]Respiration from Kemp and Day (in press) ex ept insect respiration, which was calculated from Conner and Day (1976) and Schroeder (1973) (Figure 18).

[b]Weight of CO_2 respired was calculated by multiplying dry weight respired by 0.45 to obtain carbon respired (E. P. Odum 1971) and multiplying the weight of carbon by 3.67 (44 g CO_2/12 g C) to obtain the weight of CO_2.

[c]0.069 g inorganic nitrogen releaed per gram of biomass respired (E. P. Odum 1971).

[d]Sixteen moles of nitrogen (224 g) and one mole of phosphorus (31 g) are required to produce 3258 grams of biomass (E. P. Odum 1971). The ratio of P/N in the cell is therefore 0.138 g P/g N. Assuming this is the ratio for material broken down by decomposers, phosphorus output equals 0.138 times nitrogen output.

[e]4.5 kcals are released per gram of biomass respired (Whittaker 1975).

Table 70. Mammal harvest from the Louisiana cypress-tupelo swamp.

Animal	No. harvested/ 1000 acres[a]	Avg. wet wt/ animal g	Avg. wet wt/ animal lb[b]	Total wet wt[c] (g/ac)	Wet wt (g/sq m/yr)	Dry wt (g/sq m/yr)
Muskrat	42.3	1000	2.2	42,300	0.01	0.003
Nutria	340.8	5539	12.2	1,856,678	0.46	0.138
Mink	72.6	908	2.0	65,921	0.02	0.005
Raccoon	98.4	5448	12.0	536,083	0.13	0.040

[a]From Chabreck (1978).
[b]Lowery (1974).
[c]For mammals, dry weight = 0.3 x wet wt (Day et al. 1973).

Table 71. Waterfowl harvest from the Louisiana cypress-tupelo swamp.

Species	Weight lb[a]	Weight g[b]	U.S. harvest x1000[c]	% in LA	LA harvest (birds)	% from Atch swamp[d]	Atch. swamp harvest (birds)	Total weight of Atch. harvest E6 g/yr	Total weight of Atch. harvest wet wt g/sq m /yr[e]
Mallard	2.75	1249	3474	5.1	177,174	38.12	67,539	84.36	0.0460
Gadwall	1.75	795	540	16.2	87,480	4.49	3928	3.12	0.0017
American wigeon	1.50	681	881	6.8	59,908	0.79	473	0.32	0.0002
Green-winged teal	0.60	272	1288	10.3	132,664	0.65	862	0.23	0.0001
Blue-winged teal	0.75	341	477	8.7	41,449	12.11	5026	1.71	0.0009
Shoveler	1.25	568	414	10.4	43,056	2.11	908	0.52	0.0003
Pintail	1.75	795	1268	8.3	105,244	6.07	6388	5.04	0.0030
Wood duck	1.50	681	709	13.0	92,170	18.66	17,198	11.71	0.0060
Ring-necked duck	1.50	681	360	6.1	21,960	4.14	909	0.62	0.0003
Lesser scaup	1.75	795	340	5.6	19,040	10.92	2079	1.65	0.0009
Redhead	2.00	908	169	1.3	2197	0.44	10	0.01	0
Canvasback	2.50	1135	105	3.0	3150	0.62	20	0.02	0
TOTAL					785,492		105,340	190.31	0.0594[f]

[a]From Palmer (1976).
[b]1 lb = 454 g.
[c]Percent of total U.S. waterfowl harvest taken in Louisiana (Chabreck 1978).
[d]Percent harvest in Atchafalaya (Atch.) swamp only.
[e]Atchafalaya Basin contains about 451,000 acres (1.825 E9 sq m) of swamp.
[f]Dry wt harvest = 0.022 g/sq m/yr (dry wt = 0.37 x wet wt, Day et al. 1973).

Table 72. Barataria Basin swamp sediment chemistry. Numbers are the monthly averages of two cypress-tupelo swamp sampling stations (Ho and Schneider 1976).

Month	Total N content(%)	Organic C content(%)	Water content(%)
June	0.301	5.09	62.8
August	0.690	13.91	80.5
October	0.505	6.10	54.2
December	0.443	6.08	74.7
February	0.263	5.76	76.1
April	0.493	9.09	79.4
Annual Avg.	0.449	7.67	71.3

Table 73. Barataria Basin cypress-tupelo swamp interstitial sediment water chemistry. Monthly averages of two swamp sampling stations (Ho and Schneider 1976).

Month	Ammonium N (mg/l)	Nitrate-nitrite N (mg/l)	Organic N (mg/l)	Inorganic N/ total N (%)
June	1.09	0.74	0	1.00
August	3.20	1.94	6.52	0.44
October	0.71	2.79	20.54	0.15
December[a]	2.95	0.09	13.42	0.18
February	3.31	0.12	5.21	0.40
April	2.72	1.05	5.05	0.59
Annual avg.	2.33	1.12	8.46	0.46

[a]One station only. No data for second station.

Table 74. Nutrient input and removal for the des Allemands cypress-tupelo swamp (g/sq m/yr) (Kemp and Day, in press).

Nutrient	Runoff input	Precipitation input	Outflow in runoff
Total inorganic nitrogen	0.91	0.40	0.51
Total inorganic phosphorus	1.04	0.04	1.27

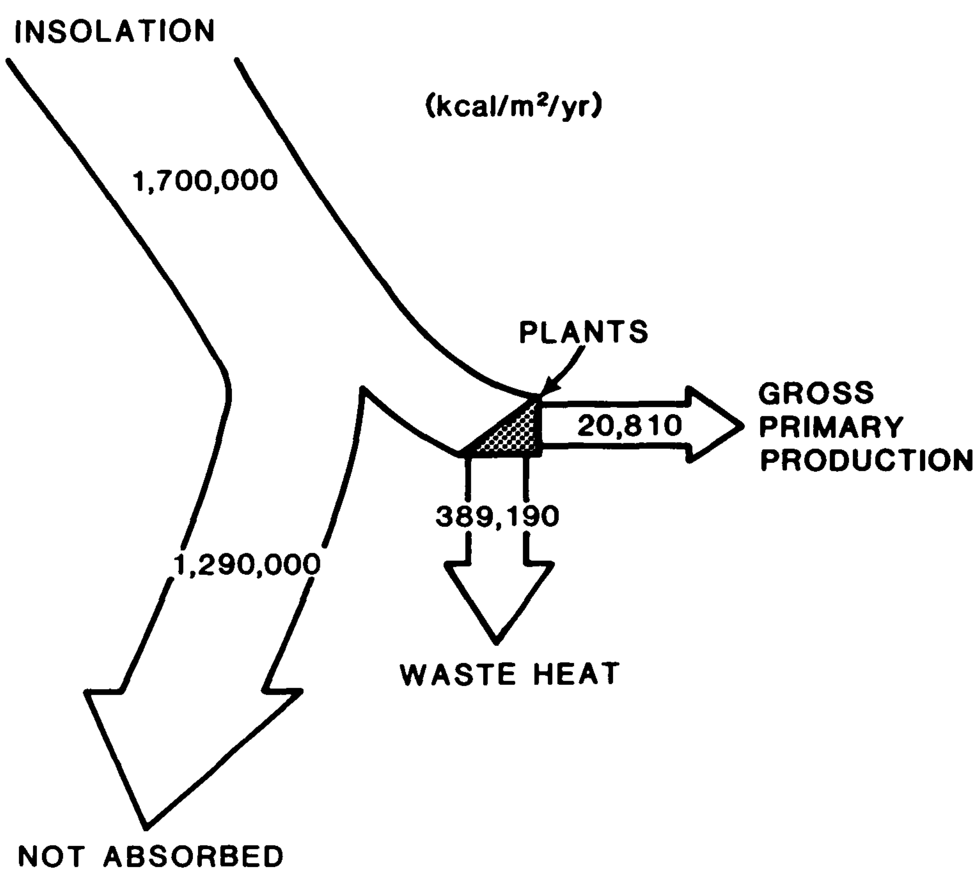


Figure 17. Energy budget for Silver Springs, Florida, ecosystem (Odum 1957).

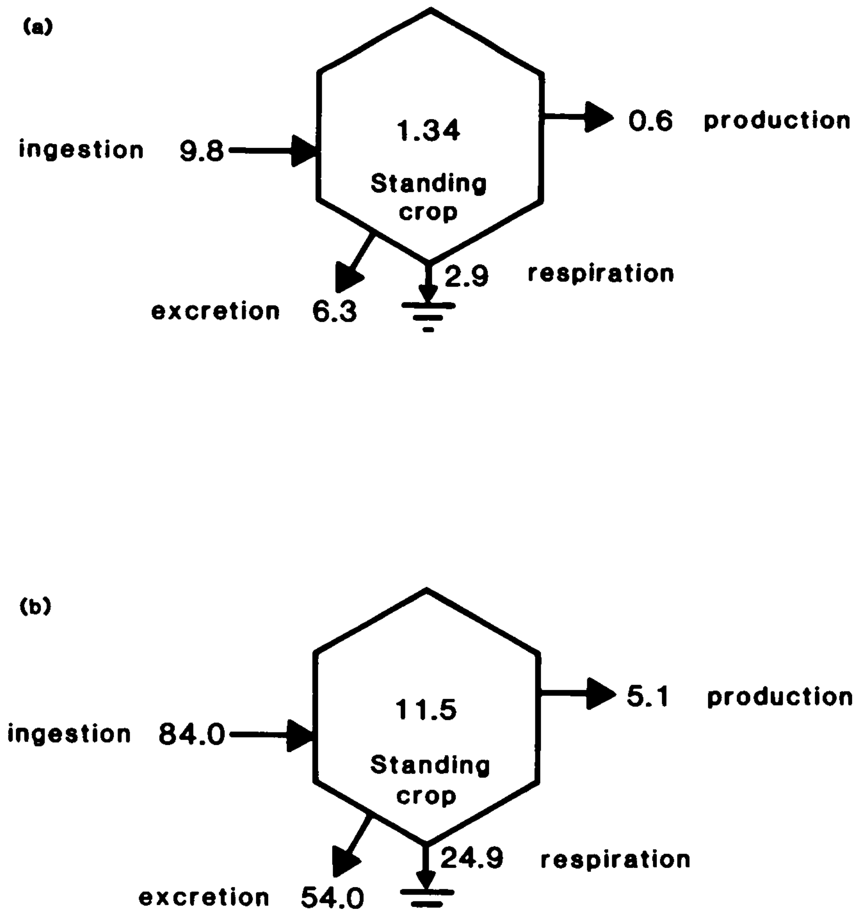


Figure 18. Insect energy budgets. Units are g dry wt/sq m/yr. (a) Energy budget for the moth, Pachysphinx modesta (Schroeder 1973). (b) Energy budget for insects in MDPR cypress-tupelo swamp habitat. Since ingestion is the only energy flow measured for swamp insects in the MDPR (Conner and Day 1976), it was assumed that the ratios of insect standing crop, excretion, respiration, and production to ingestion are the same in MDPR insects as in Pachysphinx modesta.

7. FRESH AQUATIC BED

The fresh aquatic bed habitat in the MDPR consists of submerged aquatic vegetation, floating vegetation, and floating-leaved vegetation in shallow fresh waterbodies. Its areal extent is small, covering only 6256 ha in 1978 (Wicker et al. 1980a). A map of the distribution of fresh aquatic bed habitat is shown in Figure 19.

Most of the fresh aquatic bed habitat in the study region consists of floating vegetation, usually water hyacinth (Eichhornia crassipes) or duckweed (Lemna sp., Spirodela polyrhiza), that forms dense mats on sheltered waterbodies (Wicker 1980). The distribution of these mats frequently changes in relation to physical factors such as wind direction, flooding, currents, and the biotic factors of shading, competition, grazing, or human eradication (Penfound and Earle 1948). Floating aquatic plants die and sink below the water surface every winter (Wicker 1980). Flotant freshwater marshes are not considered fresh aquatic bed but rather fresh marshes.

Submerged aquatic plants include widgeongrass (Ruppia maritima), wild celery (Vallisneria americana), pondweed (Potomogeton pusillus), and watermilfoil (Myriophyllum sp.). Light often limits the distribution of submerged aquatic flora. The Secchi depth of many large fresh waterbodies in the MDPR does not exceed 50 cm (Hopkinson and Day 1979), indicating that turbidity is too high to allow submerged plant growth in most regions of these lakes, which range in depth to about 2 m.

Little is known about the animal communities associated with submerged freshwater aquatic flora in the MDPR. The floating aquatic vegetation community is better known (Day et al. 1981) because it is similar to the floating community in many regions of swamp forest, particularly artificially impounded areas. This floating community (primarily duckweed) is discussed in greater detail in the swamp forest habitat section.

Fresh aquatic bed was not selected for detailed modeling. The unquantified energy and material flow diagram for the fresh aquatic bed habitat is shown in Figure 20.

8. FRESH MARSH

Freshwater marshes--emergent marshes and flotant marshes composed of a root mat that floats over water approximately 1 m deep--covered 165,267 ha in the MDPR in 1978 (Wicker et al. 1980a). A map of the distribution of fresh marsh habitat is shown in Figure 21.

Of the marsh types in the MDPR, the fresh marshes are the least studied. Although there have been several studies of fresh marsh plant production (Hopkinson et al. 1978b, Sasser et al. 1981) and soil chemistry (Chabreck 1972, Hatton 1981), data on other ecological features are lacking. This study includes the most current data available on the fresh marsh habitat in the MDPR. Some of the data that were unavailable for fresh marshes directly were estimated from studies of intermediate or brackish marshes in the MDPR. Figure 22 illustrates the flow of materials and energy through the fresh marsh system. The corresponding input-output table is shown in Table 75.

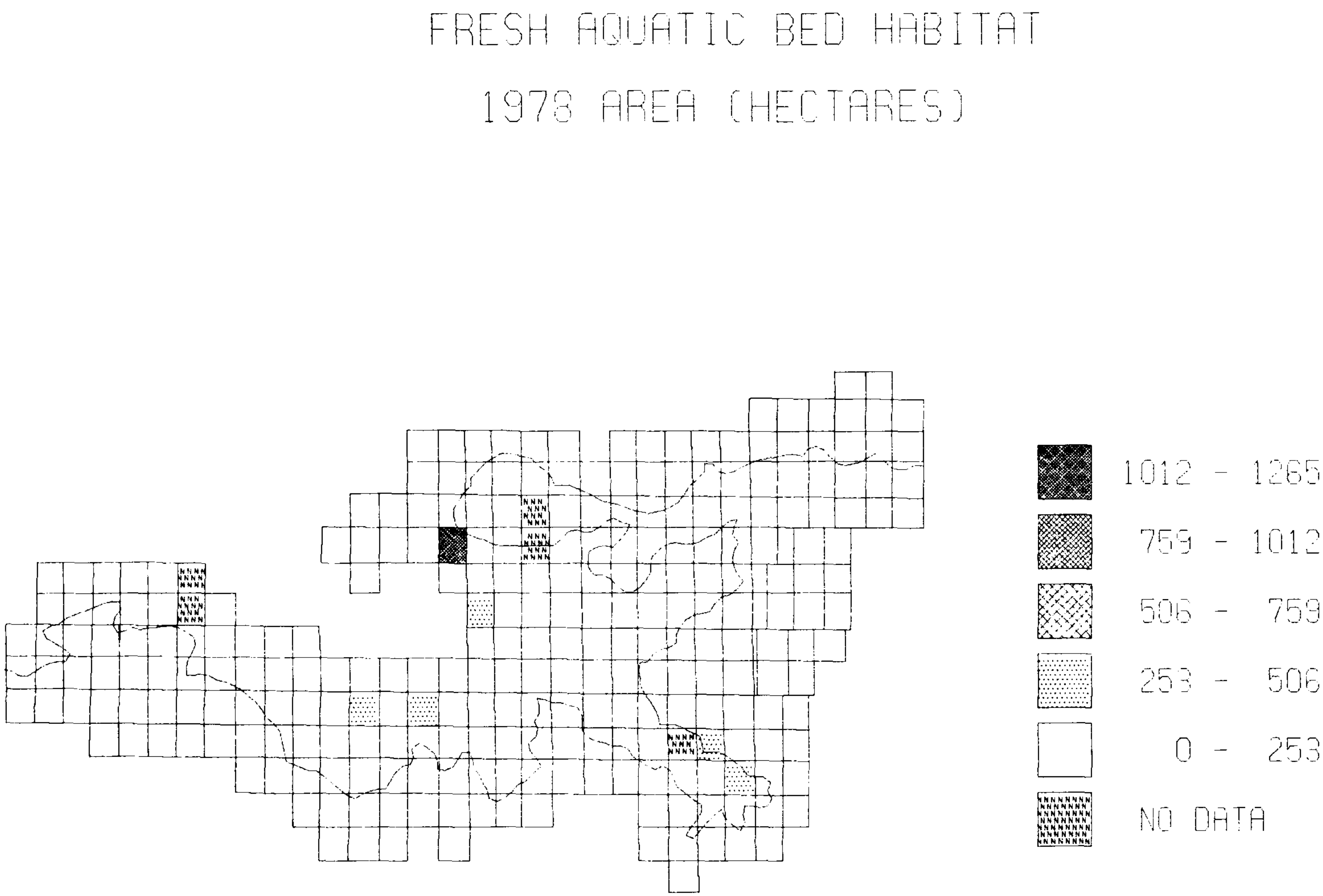


Figure 19. The distribution of MDPR fresh aquatic bed habitat.

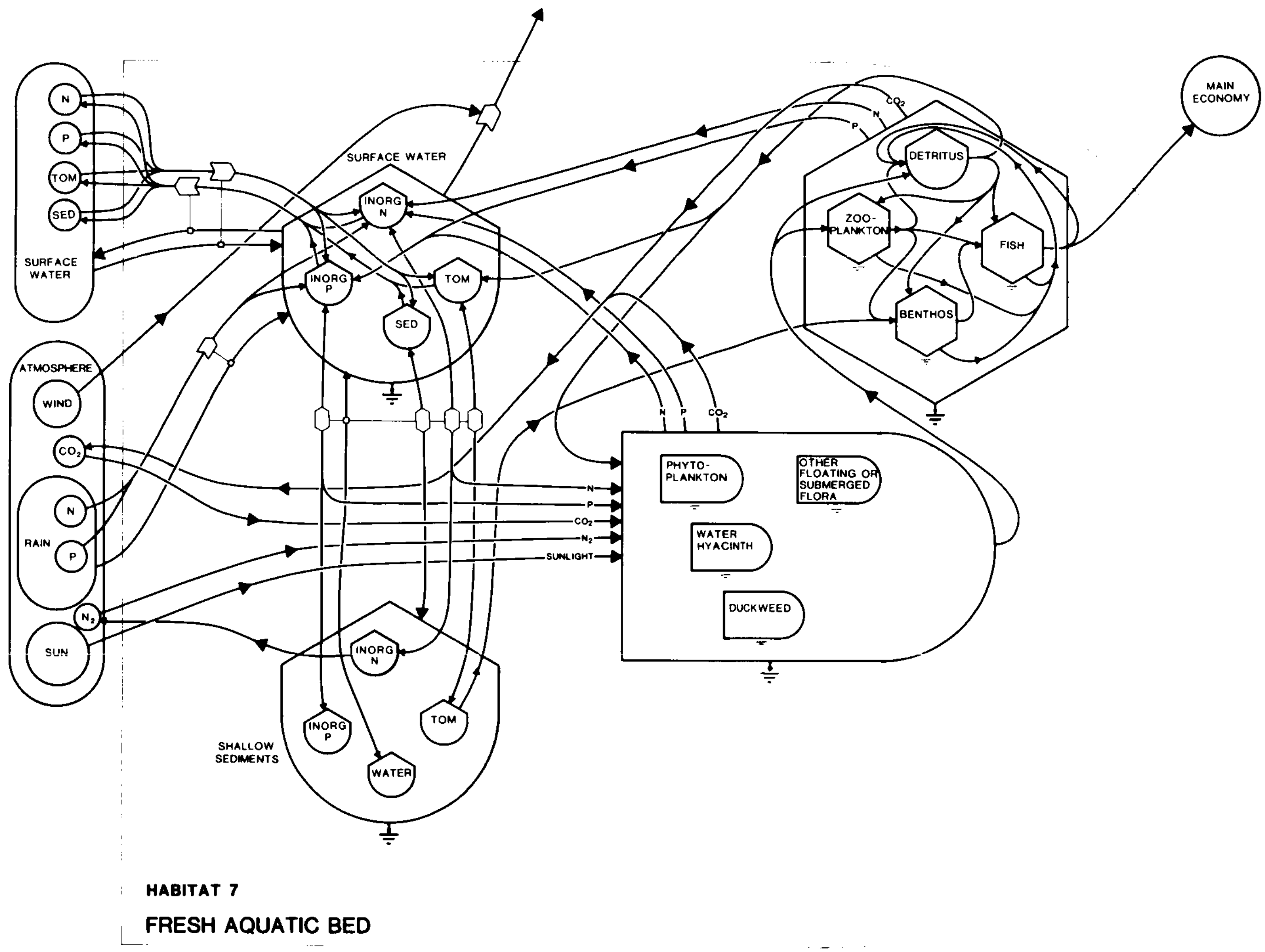


Figure 20. Fresh aquatic bed habitat flow diagram.

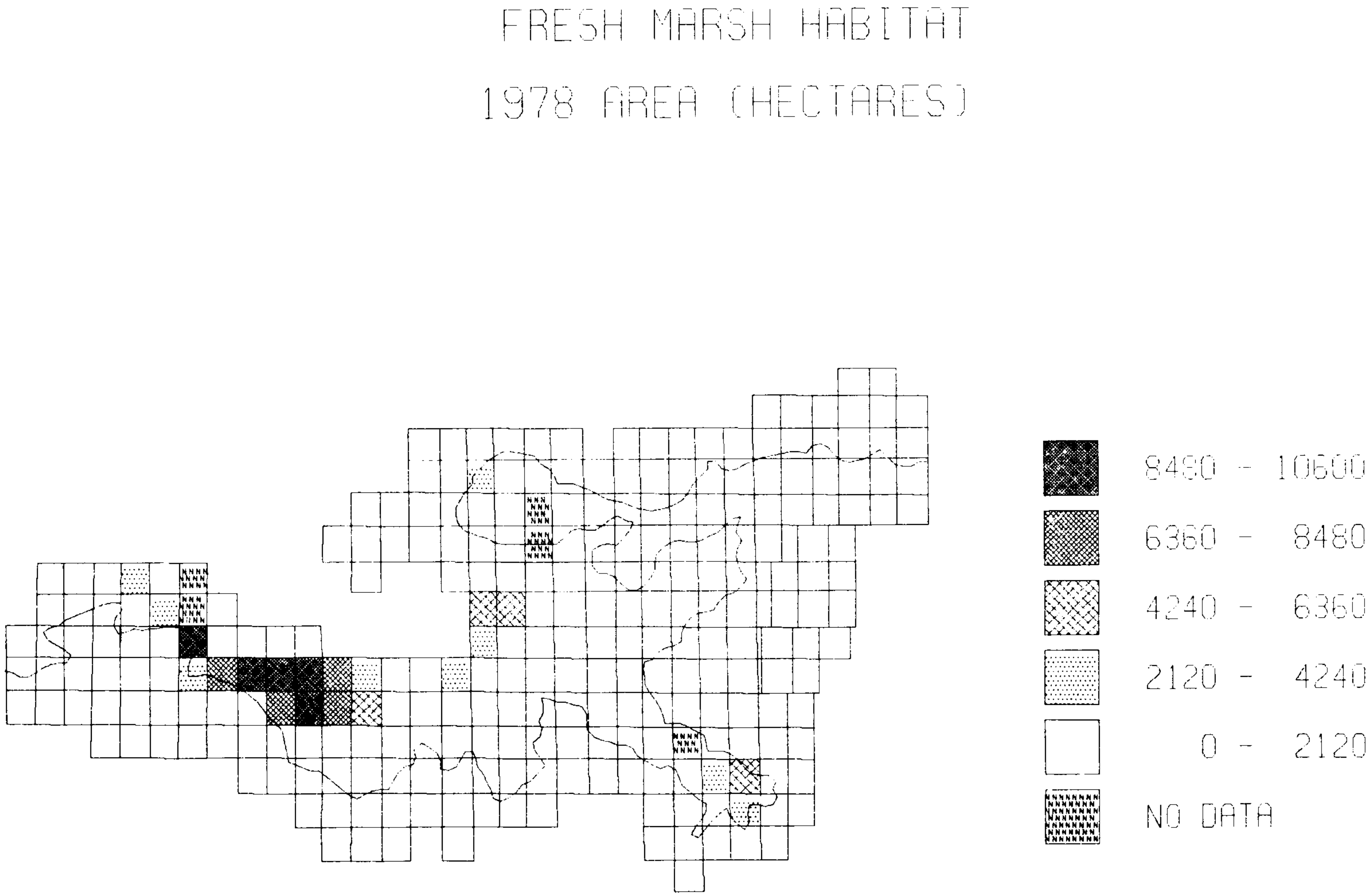


Figure 21. The distribution of MDPR fresh marsh habitat.

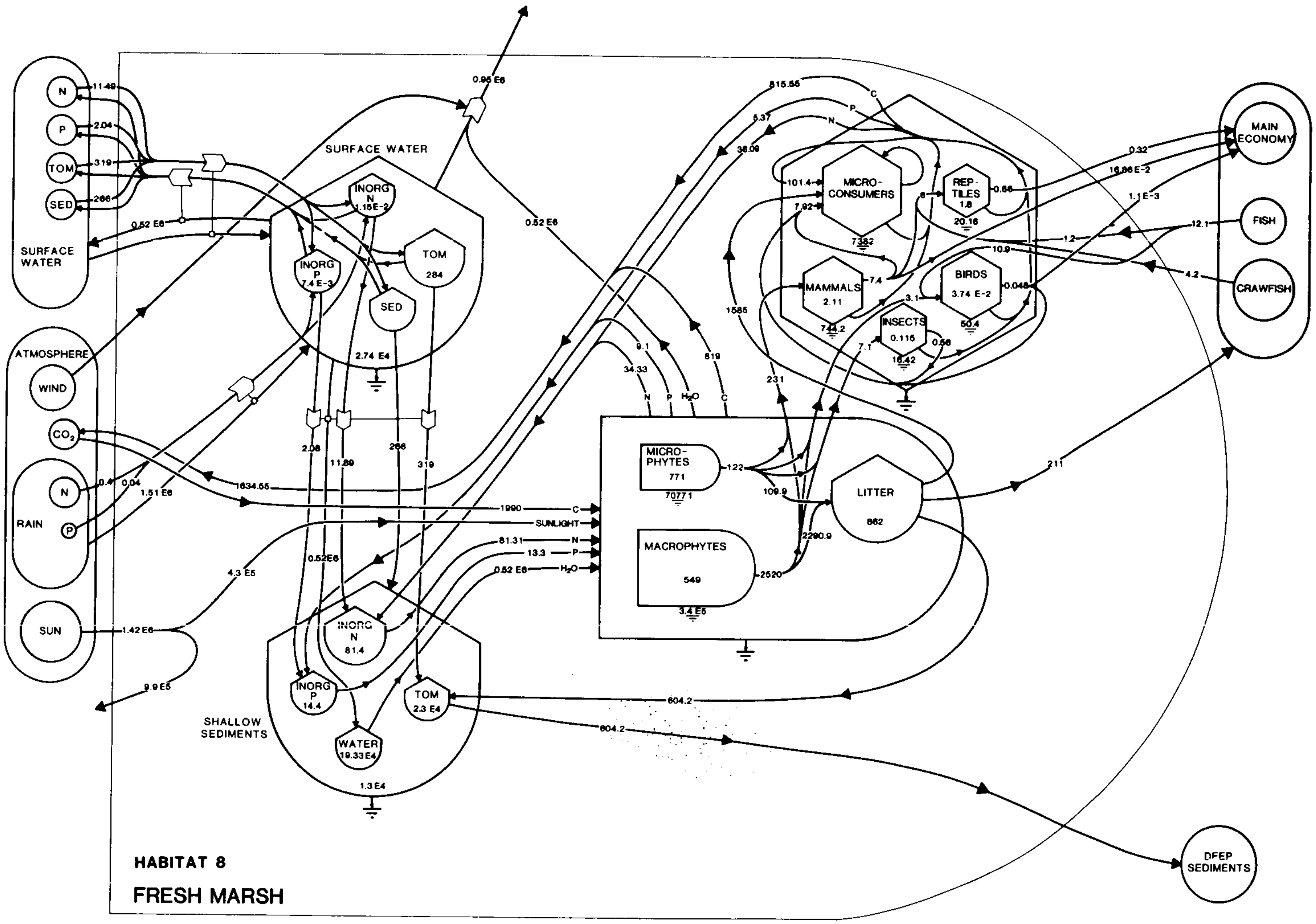


Figure 22. Fresh marsh habitat flow diagram.

Table 75. Input-output table for fresh marsh habitat.

HABITAT 8
FRESH MARSH

COMMODITIES		1 SURFACE WATER	2 SHALLOW SOIL/SEDIMENT	3 MICROPHYTES	4 MACROPHYTES	5 LITTER	6 DECOMPOSERS	7 INSECTS	8 MAMMALS	9 BIRDS	10 REPTILES	11 IMPORTS & EXPORTS	TOTAL	UNITS
		PROCESSES												
WATER	1	1.51 1.51 2.74	0.52 0.52 19.33	0.09 0.09	0.43 0.43							1.51 1.51	4.06 4.06 2.74	10^6 g/m^2/yr 10^6 g/m^2/yr 10^4 g/m^2
INORGANIC NITROGEN	2	11.89 11.89 1.15 E-2	81.31 81.31 81.4	7.4 6.25	73.91 27.08		35.62	0.013	0.27	3.7 E-3	0.18	11.89	174.51 174.51 85.6	g N/m^2/yr g N/m^2/yr g N/m^2
INORGANIC PHOSPHORUS	3	2.06 2.06 7.4 E-3	13.3 13.3 14.4	2.16 1.83	11.14 4.02		5.31	1.7 E-3	3.6 E-2	4.9 E-4	0.02	2.06	26.66 26.66 17.1	g P/m^2/yr g P/m^2/yr g P/m^2
INORGANIC CARBON	4			168 142.6	1822 676.4		743.54	2.02	64.32	4.05	1.62	1634.55 1990	3624.55 3624.55	g C/m^2/yr g C/m^2/yr
TOTAL ORGANIC MATTER	5	319 319 284	319 604.2 2.3 E4				101.04	3.6	90.7	5.0	1.74	604.2 319	1343.24 1343.24 2.33 E4	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
SHALLOW SEDIMENTS	6	266 266	266 1.3 E4									266	532 532 1.3 E4	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
MICROPHYTIC BIOMASS	7			122 771		109.9		0.36	11.55	0.15			122 122 771	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
MACROPHYTIC BIOMASS	8				2520 549	2290.9		6.74	219.45	2.95			2520 2520 549	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
LITTER BIOMASS	9		604.2			2400.8 862	1565					211	2400.2 2400.8 862	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
INSECT BIOMASS	10						0.56	0.56 0.115					0.56 0.56 0.115	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
MAMMAL BIOMASS	11						6.97		7.4 2.11		0.6	0.17	7.4 7.4 2.11	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
BIRD BIOMASS	12						4.69 E-2			4.8E-2 3.74 E-2		1.1 E-3	4.8E-2 4.8E-2 3.74 E-2	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
REPTILE BIOMASS	13						0.34				0.66 1.8	0.32	0.66 0.66 1.8	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
FISH BIOMASS	14									10.9	1.2	12.1	12.1 12.1	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
CRAWFISH BIOMASS	15										4.2	4.2	4.2 4.2	g dry wt/m^2/yr g dry wt/m^2/yr g dry wt/m^2
HEAT	16			70771	3.4 E5		7362	16.42	744.2	50.4	20.16	4.19 E5	4.19 E5 4.19 E5	kcal/m^2/yr kcal/m^2/yr
SUNLIGHT	17			0.7	3.6							9.9 14.2	14.2 14.2	10^6 kcal/m^2/yr 10^6 kcal/m^2/yr

One of the most dramatic differences among the marsh types found in the deltaic plain is the number of plant species that make up the various marsh communities. The fresh marshes are the most diverse, containing up to 93 species of vascular plants (Chabreck 1972) in contrast to brackish marshes, which contain about 40 species, and salt marshes, which have up to 17 species.

Although the diversity of the fresh marsh as a whole is high, some fresh marsh areas are composed almost exclusively of a single species. These are generally confined to newly colonized areas at the mouths of the Mississippi and Atchafalaya rivers. The flotant marshes display a greater diversity of species than the emergent marshes. This may be due to the fact that the flotant marshes are not subject to flooding as are the emergent marshes. The most common species found in MDPR fresh marshes is Panicum, or maidencane, which covers about one-fourth of the total area of fresh marsh (Table 78). Other species characteristic of the fresh marsh habitat are Sagittaria falcata, Alternanthera philoxeroides, and Phragmites communis. Spartina patens is characteristic of areas that have some tidal influence.

The net primary productivity of MDPR fresh marsh macrophytes was estimated to be 2520 g dry wt/sq m/yr (Table 78). Although this estimate includes both above and belowground production, the belowground production must be taken as an extremely rough estimate since this value has not been measured in the MDPR fresh marshes. A complete understanding of primary production in fresh marshes will not be possible until belowground production has been measured.

One should note that fresh marshes in many areas of the MDPR are burned annually. This undoubtedly influences net production, nutrient regeneration, and the species composition. Experiments conducted in Mississippi marshes by Faulkner and de la Cruz (1982) show that vegetation growth may be stimulated by fire. Concentrations of sodium, phosphorus, potassium, calcium, magnesium, and manganese were higher in shoots growing in plots which had been burned. Evidence from other studies also indicates that primary production may be enhanced by periodic winter burning. Marsh burning also influences species composition by destroying shallow-rooted plants that compete with rhizomatous genera such as Juncus, Scirpus, Eleocharis, and Typha (Vogl 1974).

Microphytes or periphyton contribute 122 g/sq m/yr to the net production of the fresh marsh (see 7,3,0). There have been no studies of MDPR fresh marsh microphytes. This estimate is based on estimates from marshes with similar species found outside the deltaic plain.

Although there is more direct consumption of fresh marsh macrophytes than of brackish or salt marsh macrophytes, most net production is consumed by detritivores (Gosselink et al. 1979). Insects, mammals (nutria, muskrats, and raccoons), and waterfowl consume approximately 9% of annual net production in the fresh marsh. The remaining 91% is either exported from the marsh system during periods of flooding, incorporated into the sediment as TOM, or consumed by decomposers (Gosselink et al. 1979). The top carnivores in the fresh marsh are reptiles, of which the largest consumer is the alligator.

The detrital pathway is one of the most important in marsh systems, since it is the decomposers that ultimately break down the plant and animal biomass and recycle nutrients. There have been no detailed studies on the detrital pathways of the MDPR fresh marsh. Until this aspect of the fresh marsh is investigated, knowledge of nutrient cycling in these marshes will be incomplete.

The hydrology of the fresh marsh is a function of the direct input from rainfall and the rate of runoff from terrestrial sources. Terrestrial runoff is dependent upon the slope of the land, marsh friction, and sediment characteristics. The differences between emergent and flotant marsh hydrology are particularly important. Flotant marshes do not experience flooding since they float above the water. In an emergent marsh, nutrients in flood water enter the sediments and are subsequently taken up by plants. Plants in the flotant marshes obtain nutrients from the water under the root mat. Dredging canals and creating spoil banks in areas where flotant marshes predominate could interrupt the flow of water under the mat, limiting the nutrients available to plants in these marshes (Sasser et al. 1981).

Direct outputs from the fresh marsh to the economy are the harvests of furbearers, waterfowl, and alligators. Because fresh marshes also supply organic matter to adjacent streams and lakes, they help support fish populations in these areas. This is an important habitat not only in terms of the economic value of the harvest of these natural products, but also in terms of its relationship to the other habitats in the MDPR that depend on the export of materials from fresh marshes.

Notes to Fresh Marsh Habitat Model

Water.

1,1,I Input of water to surface water. 1.51 E6 g/sq m/yr. Rain was assumed to account for all incoming water (Table 97). Data needed to determine the input of water through runoff from adjacent habitats are unavailable at this time. The information in note (1,1,S) is not adequate to estimate any value other than water storage. The data provide information on the number of days that an average depth of 0.1 m of water is present on the marsh. However, there is not enough additional information to determine the amount of water that entered as runoff and that entering as precipitation.

1,1,O Output of water from surface water. 1.51 E6 g/sq m/yr. Assuming steady state conditions, the output of water from the marsh is equal to the input, 1.51 E6 g/sq m/yr (1,1,I). Included in this output is 0.52 E6 g/sq m/yr transported to the soils (1,2,I), 0.95 E6 g/sq m/yr lost to evapotranspiration (1,11,I), and 0.56 E6 g/sq m/yr lost to other habitats as runoff (1,11,I).

1,1,S Storage of surface water. 2.74 E4 g/sq m. According to Sasser (1977), the average volume of water on the marsh during periods of flooding is 0.1 cu m/sq m, and the flood duration is 100 days. Therefore the fresh marsh is flooded 24.7% of the year. The average annual volume of water is equal to the product of these two values, 0.0274 cu m/sq m. The density of water is 1.0 E6 g/cu m. The storage of water is 2.74 E4 g/ sq m.

1,2,I Input of water to soil/sediment. 0.52 E6 g/sq m/yr. Assuming steady state conditions, the amount of water entering the soil is equal to the output from the soil (1,2,O).

1,2,O Output of water from soil/sediment. 0.52 E6 g/sq m/yr. The output of water from the soil is equal to the uptake of water by producers. Uptake by microphytes and macrophytes is 0.09 E6 (1,3,I) and 0.43 E6 (1,4,I) g/sq m/yr, respectively. The total output is the sum of these values.

1,2,S Storage of water in soil/sediment. 19.33 E4 g/sq m. There are 3.6 E4 g dry wt of fresh marsh soil per sq m (6,2,S). The moisture content of the soil is 84.3% (Ho and Schneider 1976). The percent dry weight of soil is 15.7%. The ratio of soil moisture to dry weight is 84.3/15.7, or 5.37. The storage of water in fresh marsh soil is equal to the product of 5.37 and 3.6 E4.

1,3,I Water uptake by microphytes. 0.09 E6 g/sq m/yr. Assuming steady state conditions, the input of water to microphytes is equal to the output (1,3,O).

1,3,O Transpiration by microphytes. 0.09 E6 g/sq m/yr. Total transpiration of marsh producers is equal to 0.52 E6 g/sq m/yr (1,11,I). Gross primary production (GPP) of microphytes and macrophytes is 801 (4,3,I) and 4008 (Table 80) g dry wt/sq m/yr, respectively. Microphytes and macrophytes account for 16.7 and 83.3% of GPP, respectively. Assuming that transpiration by marsh producers is proportional to GPP, the amount of water transpired by microphytes is equal to the product of 0.167 and 0.52 E6.

1,4,I Water uptake by macrophytes. 0.43 E6 g/sq m/yr. Assuming steady state conditions, the input of water to macrophytes is equal to the output (1,4,0).

1,4,0 Transpiration by macrophytes. 0.43 E6 g/sq m/yr. Total transpiration of producers is equal to 0.52 E6 g/sq m/yr (1,11,I), 0.09 E6 of which is from microphytes (1,3,0). The remaining 0.43 E6 g/sq m/yr are transpired by macrophytes.

1,11,I Net output of water. 1.51 E6 g/sq m/yr. Assuming steady state conditions, output is equal to input, and export is therefore 1.51 E6 g/sq m/yr (1,1,I). This export occurs as evaporation, transpiration, and runoff. Evapotranspiration is equal to 37.3 in/yr (Gagliano et al. 1973), or 0.95 m/yr. The density of water is 1 E6 g/cu m. The total evapotranspiration is 0.95 E6 g/sq m/yr. The ratio of transpiration to evapotranspiration is estimated from data in Wetzel (1975) to be 0.55. The transpiration is equal to the product of 0.95 E6 and 0.55, or 0.52 E6 g/sq m/yr. Evaporation is equal to the difference, or 0.43 E6 g/sq m/yr. The input of rain is equal to 1.51 E6 g/sq m/yr (1,1,I). The difference between 1.51 E6 and 0.95 E6 is the amount of runoff, 0.56 E6 g/sq m/yr.

1,11,0 Net input of water. 1.51 E6 g/sq m/yr. The total amount of water entering the system is assumed to be through input of rain, 1.51 E6 g/sq m/yr (1,1,I).

Inorganic nitrogen.

2,1,I Input of inorganic nitrogen to surface water. 11.89 g N/sq m/yr. Assuming steady state conditions, the input of N to surface water must be equal to the output (2,1,0). The amount of nitrogen entering through rain water is 0.4 g N/sq m/yr (Kemp and Day, in press). The amount of nitrogen entering through surface water from outside the fresh marsh is 11.49 g N/sq m/ yr (calculated by difference).

2,1,0 Output of inorganic N from surface water. 11.89 g N/sq m/yr. Output of N from surface water is equal to the flow of N from surface waters to the sediments. The total input of N to the sediments is 81.31 g N/sq m/yr (2,2,0), 69.42 of which come from respiration and decomposition (2,3,0-2,10,0). Under steady state conditions, input must equal output, and therefore the remaining N comes from the surface water. Output of N from surface water is equal to the difference between 81.31 and 69.32.

2,1,S Storage of inorganic nitrogen in surface water. 1.15 E-2 g N/sq m. The concentration of nitrogen in surface water is 0.42 mg/l (Day et al. 1977), or 0.42 g/cu m. The average annual volume of water in the fresh marsh is 0.0274 cu m/sq m (1,1,S). The product of these two values yields the nitrogen storage in surface water.

2,2,I Input of inorganic nitrogen to soil/sediment. 81.31 g N/sq m/yr. Assuming steady state conditions, the input of N to the sediment is equal to the output (2,2,0).

2,2,0 Output of inorganic nitrogen from soil/sediment. 81.31 g N/sq m/yr. Uptake of N by microphytes and macrophytes is 7.4 (2,3,I) and 73.91 (2,4,I) g N/sq m/yr, respectively. Assuming the output of N from the sediment is equal to the uptake by primary producers, output is equal to the sum of these two values.

2,2,S Storage of nitrogen in soil/sediment. 81.4 g N/sq m. The concentration of inorganic nitrogen in the sediment is 0.226% (Table 76). The amount of soil per sq m is 3.6 E4 g dry wt (6,2,S). The storage of soil N is equal to the product of these values.

2,3,I Nitrogen uptake by microphytes. 7.4 g N/sq m/yr. The concentration of nitrogen in microphytes is 0.92% (Browder et al. 1981). The GPP of microphytes is 801 g dry wt/sq m/yr (4,3,I). The product of these values gives the uptake of nitrogen by microphytes.

2,3,O Nitrogen release from microphytes. 6.25 g N/sq m/yr. The respired biomass of microphytes is 679 g dry wt/sq m/yr, and their percent N is 0.92% (Browder et al. 1981). The output of N is the product of these two values.

2,4,I Nitrogen uptake by macrophytes. 73.91 g N/sq m/yr. Table 80.

2,4,O Nitrogen release from macrophytes. 27.08 g N/sq m/yr. The respired biomass of macrophytes is 1488 g dry wt/sq m/yr (Table 80). The weighted percent N of macrophytes is 1.82% (Table 79). The output of N is equal to the product of these two values.

2,6,O Nitrogen release by decomposers. 35.62 g N/sq m/yr. Table 81.

2,7,O Output of inorganic nitrogen from insects. 0.013 g N/sq m/yr. Loss of N in insects is equal to the product of the rate of N loss, 0.115 g dry N/g body wt/yr (Table 104), and the biomass of insects, 0.115 g dry wt/sq m (10,7,S).

2,8,O Output of inorganic nitrogen from mammals. 0.27 g N/sq m/yr. Loss of nitrogen in mammals is equal to the product of the biomass of mammals, 2.11 (11,8,S), and the N loss value of 0.128 g N/g body wt/yr (Table 105).

2,9,O Output of inorganic nitrogen from birds. 3.7 E-3 g N/sq m/yr. The loss of N in birds is equal to the product of N loss, 0.10 g N/g body wt/yr (Table 105), and the biomass of birds, 3.74 E-2 (Table 134).

2,10,O Output of inorganic nitrogen from reptiles. 0.18 g N/sq m/yr. Loss of N in reptiles is equal to the product of N loss, 0.10 g N/g body wt/yr (note b, Table 105), and the biomass of reptiles, 1.8 g dry wt/sq m (13,10,S).

2,11,O Total import of inorganic nitrogen. 11.89 g N/sq m/yr. Total import is equal to the sum of input through rain and from outside surface water (2,1,I and 2,1,O).

Inorganic phosphorus.

3,1,I Input of inorganic phosphorus to surface water. 2.08 g P/sq m/yr. Assuming steady state conditions, the input of P to surface water equals the output (3,1,O). Phosphorus entering the marsh in rain water is equal to 0.04 g P/sq m/yr (Kemp and Day, in press). Total input is equal to 2.08 g P/sq m/yr, therefore the inorganic phosphorus entering through surface water outside the fresh marsh is equal to 2.04 g P/sq m/yr (by difference).

3,1,O Output of inorganic phosphorus from the surface water. 2.08 g P/sq m/yr. The total output of P from the sediment is 13.3 g P/sq m/yr (3,2,O). Respiration and decomposition return 11.22 g P/sq m/yr to the sediments (3,3,O-3,10,O). The remaining P comes from the surface water. Output of P from the surface water to the sediments is the difference between 13.3 and 11.22, or 2.08 g P/sq m/yr.

3,1,S Storage of inorganic phosphorus in the surface water. 7.4 E-3 g P/sq m. The concentration of phosphorus in the surface water is 0.27 mg/l (Day et al. 1977), or 0.27 g/cu m. The average annual volume of water in the fresh marsh is 0.0274 cu m/sq m (2,1,S). The product of these two values yields the storage of phosphorus.

3,2,I Input of inorganic phosphorus to soil/sediment. 13.3 g P/sq m/yr. Assuming steady state conditions, the total input of P to the sediment is equal to the output (3,2,O).

3,2,O Output of inorganic phosphorus from the soil/sediment. 13.3 g P/sq m/yr. Uptake of P by microphytes and macrophytes is 2.16 (3,3,I) and 11.14 (3,4,I) g P/sq m/yr, respectively. Therefore, the output of phosphorus is equal to the sum of these two values, 13.3 g P/sq m/yr.

3,2,S Storage of inorganic phosphorus in soil/sediment. 14.4 g P/sq m. The concentration of inorganic phosphorus in fresh marsh sediment is equal to 0.4 ppt (Chabreck 1972). There are 3.6 E4 g dry wt of soil per sq m in the fresh marsh (6,2,S). The storage is equal to the product of these values.

3,3,I Phosphorus uptake by microphytes. 2.16 g P/sq m/yr. The concentration of phosphorus in microphytes is assumed to be equal to the weighted average of P in macrophytes, 0.27% (Table 79). The GPP of microphytes is 801 g dry wt/sq m/yr (4,3,I). The product of these two values yields the uptake of phosphorus.

3,3,0 Phosphorus release by microphytes. 1.83 g P/sq m/yr. The respired biomass of microphytes is 679 g dry wt/sq m/yr (4,3,0). The weighted average percent P for macrophytes is 0.27% (Table 79). Assuming the percent P for microphytes is equal to that for macrophytes, the loss of P in respiration is equal to the product of these two values.

3,4,I Phosphorus uptake by macrophytes. 11.14 g P/sq m/yr. Table 80.

3,4,0 Phosphorus release by macrophytes. 4.02 g P/sq m/yr. The respired biomass of macrophytes is 1488 g dry wt/sq m/yr (4,4,0). The weighted average percent P for macrophytes is 0.27% (Table 79). The product of the two yields a loss of phosphorus from macrophytes of 4.02 g P/sq m/yr.

3,6,0 Phosphorus release by decomposers. 5.31 g P/sq m/yr. Table 81.

3,7,0 Phosphorus release by insects. 1.7 E-3 g P/sq m/yr. Loss of P in insects is equal to the product of the rate of P loss, 0.015 g P/g body wt/yr (Table 104), and the biomass of insects, 0.115 g dry wt/sq m (10,7,S).

3,8,0 Phosphorus release by mammals. 3.6 E-2 g P/sq m/yr. Loss of P in mammals is equal to the product of the rate of P loss, 0.017 g P/g body wt/yr (Table 105), and the biomass of mammals, 2.11 (11,8,S).

3,9,0 Phosphorus release by birds. 4.9 E-4 g P/sq m/yr. Loss of P in birds is equal to the product of the rate of P loss, 0.013 g P/g body wt/yr (Table 105), and the biomass of birds, 3.74 E-2 (Table 134). 3,10,0 Phosphorus release by reptiles. 0.02 g P/sq m/yr. Loss of P in reptiles is equal to the product of the rate of P loss, 0.013 g P/g body wt/yr (note b, Table 105), and the biomass of reptiles, 1.8 g dry wt/sq m/yr (13,10,S). 3,11,0 Total import of phosphorus. 2.08 g P/sq m/yr. Assuming a steady state, the output from import/export is equal to the input of P from outside waters and from rain (3,1,I).

Inorganic carbon.

4,3,I Carbon uptake by microphytes. 168 g C/sq m/yr. Based on data in Browder et al. (1981), gross primary production is equal to 801 g dry wt/sq m/yr. C content of periphyton is 21% (Browder et al. 1981). The product of these two values is the uptake of C by microphytes.

4,3,0 Carbon release by microphytes. 142.6 g C/sq m/yr. Respiration by microphytes was estimated from production to respiration ratios in Browder et al. (1981), and is 679 g dry wt/sq m/yr. Since microphyte biomass is 21% carbon (Browder et al. 1981), the C loss due to respiration is 142.6 g C/sq m/yr.

4,4,I Carbon uptake by macrophytes. 1822 g C/sq m/yr (Table 80).

4,4,0 Carbon release by macrophytes. 676.4 g C/sq m/yr. Respiration by macrophytes is equal to 1488 g dry wt/sq m/yr (Table 80). Using a conversion of 1 g C/ 2.2 g dry wt (Whittaker 1975), C output is equal to 676.4 g C/sq m/yr.

4,6,0 Carbon release by decomposers. 743.54 g C/sq m/yr. Table 81.

4,7,0 Carbon release by insects. 2.02 g C/sq m/yr. The ratio of insect respiration to biomass is 26.4 (Table 104). The biomass of insects in the fresh marsh is 0.115 g dry wt/sq m/yr (10,7,S). The product of these two values yields a respired biomass for insects of 3.04 g dry wt/sq m/yr. Using a ratio of 0.663 g C/g dry wt (Table 104), C loss is 2.02 g C/sq m/yr.

4,8,0 Carbon release by mammals. 64.32 g C/sq m/yr. The respiration biomass of mammals is equal to 132.9 g dry wt/sq m/yr (Table 137). The mean % C in mammal biomass is 48.4 (Table 105). C loss is equal to the product of these values.

4,9,0 Carbon release by birds. 4.05 g C/sq m/yr. The respiration biomass for birds is equal to 9.0 g dry wt/sq m/yr (Table 133). The mean %C for animals is 45% (Table 105). C loss is equal to the product of these values.

4,10,0 Carbon release by reptiles. 1.62 g C/sq m/yr. The average oxygen consumption of alligators is 1.84 ml oxygen/g body wt/day (Coulson and Hernandez 1964). The average wet weight of an alligator is 23 kg (13,10,S). The product of these two values yields the amount of oxygen respired, 42320 ml oxygen/individual/day, or 1.5 E7 ml oxygen/individual/yr. The product of this value and the alligator density, 2.47 E-4 individuals/sq m (13,10,S) is the total oxygen consumption. This is equal to 3705 ml oxygen/sq m/yr. Using the conversion factors 4.86 kcal/1000 ml oxygen and 0.2 g dry wt/kcal (Whittaker 1975), the respiration biomass is 3.6 g dry wt/sq m/yr. Using a conversion of 45% C per g dry wt (Table 105), C loss is equal to 1.62 g C/sq m/yr.

4,11,I Total export of carbon. 1634.55 g C/sq m/yr. The input of carbon to import/export is equal to the sum of all respired carbon (4,3,0-4,10,0).

4,11,0 Total import of carbon. 1990 g C/sq m/yr. The output of carbon to import/export is equal to the sum of all C uptake by producers (4,3,I and 4,4,I).

Total organic matter (TOM).

5,1,I Input of TOM to surface water. 319 g dry wt/sq m/yr. Assuming a steady state, the input of TOM to the surface water is equal to the output (5,1,0).

5,1,0 Output of TOM from surface water. 319 g dry wt/sq m/yr. The output of TOM from surface water is equal to the amount of TOM entering the sediments from the surface water (5,2,I). This was calculated as organic matter deposited during sedimentation (6,2,I).

5,1,S Storage of TOM in surface water. 0.77 g dry wt/sq m. The concentration of total organic carbon (TOC) in fresh marsh surface water is 12.9 mg/l (Day et al. 1977), or 12.9 g/cu m. The average annual volume of water is .0274 cu m/sq m (1,1,S). of water. The product of these two values gives the storage of TOC in the fresh marsh surface water, 0.35 g C/sq m. Using a conversion of 2.2 g dry wt/g C (Whittaker 1975), the storage of TOM in the surface water is 0.77 g dry wt/sq m.

5,2,I Input of TOM to soil/sediment. 319 g dry wt/sq m/yr. The input is equal to the amount of organic matter deposited from surface water (6,2,I).

5,2,0 Output of TOM from soil/sediment. 604.2 g dry wt/sq m/yr. The output of TOM from the shallow sediments is equal to the input of litter to the sediments (9,2,I).

5,2,S Storage of TOM in soil/sediment. 2.3 E4 g dry wt/sq m. There are 3.6 E4 g of soil per sq m in the fresh marsh (6,2,S). The percent organic matter is 63.6% (Hatton 1981). The storage of organic matter in the sediment is equal to the product of these values.

5,6,I Input of TOM to decomposers. 101.04 g dry wt/sq m/yr. Assuming that all of the organic matter deposited by the organisms in the fresh marsh is completely broken down, the organic matter resulting from fecal deposition must be further processed by the decomposers in the marsh. The input of organic matter to decomposers is the sum of all organic matter deposited as feces (5,7,0 - 5,10,0).

5,7,0 Output of TOM from insects. 3.6 g dry wt/sq m/yr. The output of TOM is equal to the rate of fecal deposition. Fecal deposition is equal to consumption minus respiration and secondary production. These three values are equal to 7.1 (8,7,I), 3.0 (4,7,0), and 0.52 (10,6,I) g dry wt/sq m/yr, respectively.

5,8,0 Output of TOM from mammals. 90.7 g dry wt/sq m/yr. The output of TOM from mammals is equal to the rate of fecal deposition by mammals. Fecal deposition is equal to 90.7 g dry wt/sq m/yr (Table 137).

5,9,0 Output of TOM from birds. 5.0 g dry wt/sq m/yr. The output of TOM is equal to the rate of fecal deposition. Fecal deposition is 5.0 g dry wt/sq m/yr (Table 133).

5,10,0 Output of TOM from reptiles. 1.74 g dry wt/sq m/yr. Fecal deposition is equal to 29% of the total ingestion rate (13,10,0).

5,11,I Net output of TOM. 604.2 g dry wt/sq m/yr. The input of TOM into import/export is equal to the amount of TOM incorporated into the deep sediments, which is equal to the output of TOM from shallow sediments (5,2,0).

5,11,0 Net import of TOM. 319 g dry wt/sq m/yr. The output of TOM from import/export is equal to the input to the surface water (5,1,I) and (6,2,I).

Inorganic sediments.

6,1,I Input of inorganic sediment to surface water. 266 g dry wt/sq m/ yr. Assuming a steady state, the input of inorganic sediment to the surface water is equal to the output (6,1,0).

6,1,0 Output of inorganic sediment from surface water. 266 g dry wt/ sq m/yr. The output of inorganic sediment from surface water is equal to the amount of sediment entering shallow soil/sediment from the surface water (6,2,I).

6,2,I Input of inorganic sediment to soil/sediment. 266 g dry wt/ sq m/yr. The vertical accretion rate of sediment in the fresh marsh is equal to 6.5 mm/yr, or 0.65 cm/yr (Hatton 1981). The bulk density of fresh marsh soils is 0.09 g/cu cm (Hatton 1981). The product of these two values yields the input of sediment from surface water, 0.0585 g/sq cm/yr, or 585 g/sq m/yr. Of this total, 145 g C/sq m/yr are deposited (Hatton 1981). Using a conversion of 2.2 g dry wt/g C (Whittaker 1975), the input of organic matter is 319 g dry wt/sq m/yr. The difference between the total input, 585, and the organic matter input, 319, is the input of inorganic sediment.

6,2,S Storage of inorganic sediment in soil/sediment. 1.3 E4 g dry wt/sq m. The bulk density of fresh marsh soils is 0.09 g dry wt/cu cm (Hatton 1981). Since there was no available estimate of the ratio of inland to streamside area for a fresh marsh, all area was assumed to have the value of inland sites. Rooting depth in the fresh marsh is 40 cm (Sasser et al. 1981). There are therefore 3.6 g drywt of soil per sq cm, or 3.6 E4 g dry soil wt/sq m. Percent organic matter is 63.6% (Hatton 1981). Percent inorganic matter is 36.4%. The storage of inorganic sediments is equal to the product of 0.364 and the density, 3.6 E4.

6,11,0 Net import of inorganic sediment. 266 g dry wt/sq m/yr. Assuming a steady state, the import of inorganic sediment to the marsh is equal to the input from surface water (6,1,I).

Microphytes.

7,3,0 Net production of microphytes. 122 g dry wt/sq m/yr. Net production was estimated from data in Browder et al. (1981).

7,3,S Standing crop of microphytes. 771 g dry wt/sq m. The standing stock of live microphytes was estimated from data in Browder et al. (1981).

7,5,I Input of microphytes to litter. 109.93 g dry wt/sq m/yr. The input of microphytes to litter is equal to the net primary production (NPP) of microphytes, 122 g dry wt/sq m/yr (Browder et al. 1981), minus the amount of microphytes consumed by insects, 0.36 g dry wt/sq m/yr (7,7,I), by mammals, 11.55 g dry wt/sq m/yr (7,8,I), and by birds, 0.15 g dry wt/sq m/yr (7,9,I).

7,7,I Insect consumption of microphytes. 0.36 g dry wt/sq m/yr. NPP of macrophytes and microphytes is 2520 (Table 80) and 122 (7,3,0) g dry wt/sq m/yr. Microphytes account for 5% of total NPP. Assuming all insect consumption is from producers and that the consumption of microphytes is proportional to the percent of net primary production, consumption of microphytes by insects is equal to the product of 0.05 and the total insect consumption, 7.1 g dry wt/sq m/yr (8,7,I).

7,8,I Mammal consumption of microphytes. 11.55 g dry wt/sq m/yr. Consumption of vegetation by mammals is equal to 231 g dry wt/sq m/yr (Table 137). Assuming microphytes are consumed in proportion to their NPP (ratio of microphyte NPP to total NPP is 0.05; see 7,7,I), the consumption of microphytes is equal to the product of these two values.

7,9,I Waterfowl consumption of microphytes. 0.15 g dry wt/sq m/yr. Microphytes account for 5% of NPP (7,7,I). The consumption of microphytes by waterfowl is equal to the product of 0.05 and 3.1 g dry wt/sq m/yr, the total consumption by waterfowl (Table 134).

Macrophytes.

8,4,O Net production of macrophytes. 2520 g dry wt/sq m/yr. Table 80.

8,4,S Standing crop of macrophytes. 549 g dry wt/sq m. Table 77.

8,5,I Input of macrophytes to litter. 2290.9 g dry wt/sq m/yr. The input of macrophytes to litter is equal to the difference of NPP, 2520 g dry wt/sq m/yr (8,4,0), and the amount of biomass consumed by insects, 6.74 (8,7,I), mammals, 219.45 (8,8,I), and birds, 2.95 (8,9,I).

8,7,I Insect consumption of macrophytes. 6.74 g dry wt/sq m/yr. The consumption to biomass ratio for insects in MDPR marshes is 62.1 (Table 130). Insect biomass in the fresh marsh is 0.115 g dry wt/sq m (10,7,S). The consumption of macrophytes is 7.1 g dry wt/sq m/yr, minus the amount of microphytes consumed, 0.36 g dry wt/sq m/yr (7,7,I).

8,8,I Mammal consumption of macrophytes. 219.45 g dry wt/sq m/yr. Input of macrophytes to mammals is equal to the ingestion rate of mammals, 231 g dry wt/sq m/yr (Table 137), minus the 11.55 g dry wt/sq m/yr that mammals consume from microphytes (7,8,I).

8,9,I Waterfowl consumption of macrophytes. 2.95 g dry wt/sq m/yr. The input of macrophyte biomass to birds is equal to the ingestion by waterfowl, 3.1 g dry wt/sq m/yr (Table 133), minus consumption of microphytes, 0.15 g dry wt/sq m/yr (7,9,I).

Litter.

9,2,I Input of litter to soil/sediment. 604.2 g dry wt/sq m/yr. Of the total annual primary production of a Chenier Plain fresh marsh, 11% is grazed and 21% is deposited in the sediments (Gosselink et al. 1979). Since total NPP is equal to 2642 g dry wt/sq m/yr (9,5,0), these are equal to 290.6 and 554.8 g dry wt/sq m/yr, respectively. Grazing by insects, mammals, and birds is calculated here as actually being equal to 241.2 g dry wt/sq m/yr (9,5,0). It is assumed that the difference between the two different grazing values is also deposited to the sediments. Total input of litter to sediments is therefore equal to the sum of 554.8 and 49.4, or 604.2 g dry wt/sq m/yr.

9,5,0 Output of litter. 2400.8 g dry wt/sq m/yr. The total amount of NPP is equal to 122 g dry wt/sq m/yr (7,3,0) and 2520 (8,4,0), or 2642 g dry wt/sq m/yr. NPP consumed by insects, mammals, and birds is equal to the sum of 7.10 (8,7,I), 231 (Table 137), and 3.1 (Table 133) g dry wt/sq m/yr, respectively, or 241.2 g dry wt/sq m/yr. The difference between these two values yields the total output of litter.

9,5,S Storage of litter. 862 g dry wt/sq m. The storage of litter is equal to the average yearly standing stock of dead plant biomass (Table 77).

9,6,I Input of litter to decomposers. 1585 g dry wt/sq m/yr. The input of litter to decomposers is equal to 60% of total NPP (Gosselink et al. 1979).

9,11,I Total export of litter. 211 g dry wt/sq m/yr. The export of litter from the fresh marsh is equal to 8% of total NPP (Gosselink et al. 1979).

Insects.

10,6,I Input of insects to decomposers. 0.56 g dry wt/sq m/yr. The input of insect biomass to decomposers is equal to the rate of mortality. Secondary production is equal to 0.56 g dry wt/sq m/yr (10,7,0). Assuming consumption of insects by other consumers is negligible, all production is deposited to decomposers as mortality. The input to decomposers is equal to 0.56.

10,7,0 Output of insect biomass. 0.56 g dry wt/sq m/yr. The output of insect biomass is equal to the amount of secondary production, 0.56 g dry wt/sq m/yr (10,6,I). Fecal deposition is equal to consumption minus respiration and secondary production. These three values are equal to 7.1 (8,7,I), 3.0 (4,7,0), and 0.56 (see below) g dry wt/sq m/yr, respectively. The rate of fecal deposition is 3.6 g dry wt/sq m/yr. Production was estimated using a production to biomass ratio of 4.9 (Table 130). The biomass of insects in the fresh marsh is equal to 0.115 g dry wt/sq m (10,7,S). Secondary production is equal to 0.56 g dry wt/sq m/yr.

10,7,S Insect standing crop. 0.115 g dry wt/sq m. Biomass of insects in the fresh marsh is estimated from two studies, one of the secondary production of grasshoppers in a Mississippi salt marsh (Parsons and de la Cruz 1980), and one of the insect community (excluding grasshoppers) in a Louisiana intermediate marsh (Farlow et al. 1978). The biomass of grasshoppers at the salt marsh site is 0.087 g dry wt/sq m (Table 130). The aboveground biomass of macrophytes at this site is 863 g dry wt/sq m (Parsons and de la Cruz 1980), compared to 549 for the fresh marsh (Table 77.). Adjusting for macrophyte biomass differences between the sites by multiplying by 0.64 yields a grasshopper biomass of 0.056 g dry wt/sq m. Non-grasshopper biomass in the intermediate marsh is equal to 0.097 g dry wt/sq m (Table 130). Aboveground live biomass in the brackish marsh is equal to 898 g dry wt/sq m (Table 28). Adjusting for biomass by multiplying by 0.61 yields a biomass of 0.059 g dry wt/sq m.

Mammals.

11,6,I Input of mammals to decomposers. 6.97 g dry wt/sq m/yr. The input of mammal biomass to decomposers is equal to mortality. Mortality is equal to secondary production minus consumption by reptiles and harvest by man. The secondary production of mammals is equal to 7.4 g dry wt/sq m/yr (Table 137). The consumption of mammals by reptiles is equal to 0.6 g dry wt/sq m/yr (11,10,I), and the harvest of mammals by man is equal to 16.86 E-2 g dry wt/sq m/yr (11,11,I). Mortality is therefore equal to 6.97 g dry wt/sq m/yr.

11,8,0 Output of mammal biomass. 7.4 g dry wt/sq m/yr. The output of mammal biomass is equal to the amount of secondary production. (Table 137).

11,8,S Mammal standing crop. 21.117 E-1 g dry wt/sq m. The biomass of furbearers in the MDPR fresh marsh is equal to the sum of biomass estimates for raccoon, nutria, and muskrat. These are equal to 3.04 E-1, 18.03 E-1, and 0.047 E-1 g dry wt/sq m/yr, respectively (Table 137).

11,10,I Input of mammal biomass to reptiles. 0.6 g dry wt/sq m/yr. The input of mammal biomass to reptiles is equal to 10% of the ingestion of alligators (13,10,0).

11,11,I Export of mammals. 16.86 E-2 g dry wt/sq m/yr. The harvest of furbearers from the fresh marsh is equal to the sum of harvests for muskrat, nutria, and raccoon. These are equal to 0.40 E-2, 16.31 E-2, and 0.15 E-2 g dry wt/sq m/yr, respectively (Table 141).

Birds.

12,6,I Input of bird biomass to decomposers. 4.69 E-2 g dry wt/sq m/yr. The input of bird biomass to decomposers is equal to the rate of mortality. The mortality of birds is equal to the secondary production minus the harvest of waterfowl. This is equal to 4.8 E-2 (Table 133) minus 1.1 E-3 (12,11,I), or 4.69 E-2 g dry wt/sq m/yr.

12,9,O Output of bird biomass. 4.8 E-2 g dry wt/sq m/yr. The output of bird biomass is equal to the amount of secondary production for both wading birds and waterfowl. Secondary production is equal to 4.8 E-2 g dry wt/sq m/yr (Table 133).

12,9,S Bird standing crop. 3.74 E-2 g dry wt/sq m. The biomass of birds in the fresh marsh is equal to the sum of the biomass of wading birds and the biomass of waterfowl, 2.91 E-2 and 0.83 E-2 g dry wt/sq m, respectively (Table 134).

12,11,I Harvest of birds. 1.1 E-3 g dry wt/sq m/yr. The export of bird biomass from the fresh marsh is equal to the harvest of waterfowl (Table 137).

Reptiles.

13,6,I Input of reptile biomass to decomposers. 0.34 g dry wt/sq m/yr. The input of reptile biomass to decomposers is equal to the rate of mortality. Mortality is equal to secondary production minus the amount harvested by man. These two values are equal to 0.66 (13,10,O) and 0.32 (13,11,I) g dry wt/sq m/yr. Mortality is equal to 0.34 g dry wt/sq m/yr.

13,10,O Output of reptile biomass. 0.66 g dry wt/sq m/yr. The output of reptile biomass is equal to the amount of secondary production. Kitchell and Windell (1972) report a gross assimilation efficiency of 71% for reptiles. Thus fecal deposition is equal to 29% of total ingestion. The amount of food consumed by an alligator in a fresh marsh is assumed to be approximately 200 g wet wt/day/alligator. This estimate is based on data in Chabreck (1971). The ratio of wet wt/dry wt is approximately 3:1 (Kitchell and Windell 1972). Therefore, consumption is equal to 67 g dry wt/individual/day, or 24,455 g dry wt/individual/yr. The density of alligators in the fresh marsh is 2.47 E-4 individuals/sq m (McNease and Joanen 1978). The consumption by alligators is 6 g dry wt/sq m/yr. Fecal deposition is therefore equal to 1.74 g dry wt/sq m/yr (excretion is considered negligible). Secondary production is equal to ingestion minus the sum of losses due to respiration and fecal deposition. These latter two values are equal to 3.6 (4,10,O) and 1.74 g dry wt/sq m/yr. Thus secondary production is equal to 0.66 g dry wt/sq m/yr.

13,10,S Reptile standing crop. 1.8 g dry wt/sq m. Based on data in Chabreck (1971) and Kellog (1929), the average wet weight of an alligator in the MDPR is assumed to be 23 kg. This weight corresponds to an alligator 5 to 6 feet in length. The ratio of wet wt/dry wt is 3.10 (Kitchell and Windell 1972). The average dry weight is thus 7.4 kg dry wt/alligator. The alligator biomass in the fresh marsh is equal to the product of alligator weight and density, which is 2.47 E-4 individuals/sq m (McNease and Joanen 1978). Biomass is equal to 1.8 g dry wt/sq m.

13,11,I Harvest of alligators. 0.32 g dry wt/sq m/yr. Since the density of alligators in the brackish and saline marshes is extremely low, it is assumed that alligators were harvested only from the fresh marsh. The 1980 alligator harvest in the deltaic plain was 7174 individuals (Joanen, unpublished data). Assuming that the average weight of an alligator is 7.4 kg dry wt (13,10,S), the total harvest of alligators is equal to 5.3 E4 kg dry wt/yr. The total area of fresh marsh is 165,265 ha (Table 3). The harvest is then equal to the the total weight of harvested alligators divided by the area of fresh marsh in the deltaic plain.

Fish.

14,9,I Input of fish biomass to birds. 10.9 g dry wt/sq m/yr. The input of fish biomass to birds is equal to the consumption rate of wading birds in the fresh marsh (Table 133).

14,10,I Input of fish biomass to reptiles. 1.2 g dry wt/sq m/yr. According to information in Kellog (1929) and Chabreck (1971), alligator diet is composed of several items (mammals, fish, insects, crustaceans, crawfish, and birds). Assuming the diet is composed of crawfish, fish, and mammals, the diet can be broken down in the following way: 70% crawfish, 20% fish, and 10% mammals. This is based information in Chabreck (1971) obtained from gut content analysis of alligators in freshwater areas. The input of fish to alligators is 20% of the ingestion by alligators, 6 g dry wt/sq m/yr (13,10,0), or 1.2 g dry wt/sq m/yr.

14,11,0 Import of fish biomass. 12.1 g dry wt/sq m/yr. There is an import of fish biomass from fresh open water to the wading birds and the alligators. Assuming these birds are eating only fish, the import is equal to the consumption by wading birds, 10.9 g dry wt/sq m/yr (Table 133), plus the consumption of fish by alligators, 1.2 g dry wt/sq m/yr (14,10,I).

Crawfish.

15,10,I The input of crawfish to reptiles. 4.2 g dry wt/sq m/yr. The input of crawfish to alligators is equal to 70% of the total ingestion of alligators, 6 g dry wt/sq m/yr (13,10,0).

15,11,0 Import of crawfish. 4.2 g dry wt/sq m/yr. The input of crawfish from other habitats is equal to the consumption by alligators (15,10,I).

Heat.

16,3,0 Total heat output from microphytes. 70,771 kcal/sq m/yr. Heat output of microphytes is equal to the sum of heat lost during photosynthesis and heat lost through respiration. The ratio of waste heat to biomass production is 84.2 kcal/g dry wt (Table 143, note b). Heat lost due to photosynthesis is thus the product of 84.2 and the GPP of microphytes, 801 g dry wt/sq m/yr (4,3,I), or 67,444 kcal/sq m/yr. Heat loss through respiration is equal to the product of respiration biomass and the heat content of the plant. Respiration of microphytes is 679 g dry wt/sq m/yr (Browder et al. 1981). Algae have a heat content of 4.9 kcal/g dry wt (E. P. Odum 1971). Assuming the heat content of microphytes is equal to that of algae, the heat lost through respiration is equal to the product of 679 and 4.9, or 3327 kcal/sq m/yr. Total heat loss is thus equal to the sum of 67,444 and 3327, or 70,771 kcal/sq m/yr.

16,4,0 Total heat output from macrophytes. 3.4 E5 kcal/sq m/yr. Heat loss by macrophytes is equal to the sum of heat lost during photosynthesis plus loss from respiration. Gross production of macrophytes is equal to 4008 g dry wt/sq m/yr (Table 80). The ratio of heat loss to biomass production is 84.2 kcal/g dry wt (Table 143, note b). The product of these two values yields the heat loss due to photosynthesis, 3.4 E5 kcal/sq m/yr. The heat lost through respiration is equal to the product of respiration biomass, 1488 g dry wt/sq m/yr (Table 80), and the heat content of the plant. Whittaker (1975) gives a heat content of 4.25 kcal/g dry wt for land plants. Assuming macrophytes have a similar heat value, the heat lost through respiration is then equal to 6324. Total heat loss is the sum of 3.4 E5 and 6324, or 3.4 E5 kcal/sq m/yr.

16,6,0 Heat output from decomposers. 7382 kcal/sq m/yr. Heat loss by decomposers is assumed to be equal to the heat content of the biomass they consume. The heat content of vertebrate and invertebrate animals is 5.6 and 5.4 kcal/g dry wt, respectively (E. P. Odum 1971). The total input of vertebrate animal biomass to decomposers is equal to the sum of inputs from mammals, reptiles, and birds. These values are equal to 94.7 (11,6,I), 2.7 (13,6,I), and 5.0 (12,6,I) g dry wt/sq m/yr, respectively, or 102.4 g dry wt/sq m/yr. The heat content is thus the product of 5.6 and 102.4, or 573.4 kcal/sq m/yr. The input of insects is 4.2 g dry wt/sq m/yr (10,6,I). The product of the input of insects and the invertebrate heat content is thus 22.7 kcal/sq m/yr. The input of microphyte biomass to decomposers is 79.2 g dry wt/sq m/yr (Table 81), and the heat content is 4.9 kcal/g dry wt (16,3,0). The product is therefore the heat content of the microphyte litter, 388.1 kcal/sq m/yr. The input of macrophyte biomass to litter is 1505.4 g dry wt/sq m/yr (Table 81). The heat content of macrophytes is 4.25 kcal/g dry wt (16,4,0). The total heat content of macrophyte litter is 6398 kcal/sq m/yr. Assuming all material is completely decomposed, the output of heat from decomposers is equal to the sum of the heat contents of the inputs, 573.4, 22.7, 388.1, and 6398.

16,7,0 Metabolic heat output from insects. 16.42 kcal/sq m/yr. Heat loss by insects through respiration is equal to the product of the respired biomass, 3.04 g dry wt/sq m/yr (4,7,0) and its heat content, 5.4 kcal/g dry wt (E. P. Odum 1971).

16,8,0 Metabolic heat output from mammals. 744.2 kcal/sq m/yr. Respired biomass of mammals is 132.9 g dry wt/sq m/yr (Table 137) Heat output is equal to the product of the respired biomass and the heat content, 5.6 kcal/g dry wt (E. P. Odum 1971).

16,9,0 Metabolic heat output from birds. 50.4 kcal/sq m/yr. Respired biomass of birds is 9.0 g dry wt/sq m/yr (Table 133). Heat output is equal to the product of the respired biomass and the heat content, 5.6 kcal/g dry wt (E. P. Odum 1971).

16,10,0 Metabolic heat output from reptiles. 20.16 kcal/sq m/yr. Heat loss by reptiles through respiration is equal to the product of the respired biomass, 3.6 g dry wt/sq m/yr (4,10,0), and the heat content, 5.6 kcal/g dry wt (E. P. Odum 1971).

16,11,I Net output of heat. 4.19 E5 kcal/sq m/yr. Input of heat to import/export is equal to the total heat lost by the system (15,3,0-15,10,0).

Sunlight.

17,3,I Sunlight absorbed by microphytes. 0.7 E5 kcal/sq m/yr. The ratio of sunlight to biomass production is 88.7 kcal/g dry wt (Table 144). Gross production of microphytes is 801 g dry wt/sq m/yr (4,3,I). The input of sunlight to microphytes is equal to the product of 801 and 88.7.

17,4,I Sunlight absorbed by macrophytes. 3.6 E5 kcal/sq m/yr. The sunlight to biomass production ratio is 88.7 kcal/g dry wt (Table 144). The GPP of macrophytes is 4008 g dry wt/sq m/yr (Table 80). The input of sunlight to macrophytes is the product of these two values.

17,11,I Net output of sunlight. 9.9 E5 kcal/sq m/yr. Export of sunlight is equal to the amount of sunlight lost to the system as albedo. Total sunlight used by microphytes and macrophytes is 0.7 E5 (16,3,I) and 3.6 E5 (16,4,I) kcal/sq m/yr, respectively, or 4.3 E5 kcal/sq m/yr. The total input of sunlight to the marsh is 1.42 E6 kcal/sq m/yr (16,11,0). The difference between the input of sunlight and the amount absorbed by plants is albedo.

17,11,0 Net input of sunlight. 1.42 E6 kcal/sq m/yr. Average solar insolation from 1952-1975 at New Orleans, La., was 386.8 cal/sq m/day, (Knapp et al. 1980). The product of the average solar insolation and 365 days/yr is the net input of sunlight.

Table 76. Determination of nitrogen concentrations in fresh marsh sediments.[a]

Date of sample	Inorganic N NH_4	Inorganic N NO_3-NO_2	Organic N	Ratio[b]	Percent total N	Percent inorg. N[c]
6-73	3.37	0.96	4.52	0.489	0.614	0.300
8-73	1.02	0.85	12.34	0.132	1.030	0.136
10-73	2.14	3.40	20.11	0.216	1.456	0.314
12-73	-	-	-	-	0.471	-
2-74	0.82	0.75	10.11	0.134	0.573	0.077
4-74	1.96	1.05	12.78	0.191	1.579	0.302
Avg.	1.86	1.40	11.97		0.954	0.226

[a] All data are from station 8, on Bayou Blue, of the Louisiana Offshore Oil Port sampling study (Ho and Schneider 1976). Units for inorganic and organic N are mg N/l.

[b] Ratio of inorganic nitrogen (NH4 plus NO3-NO2) to total nitrogen (inorganic plus organic).

[c] Percent inorganic N is found by multiplying percent total N by the ratio of inorganic to total N (see Note b).

Table 77. Biomass of fresh marsh macrophytes.

Plant	Percent cover[a]	Standing crop[b] Live	Standing crop[b] Dead	Weighted standing crop[b] Live	Weighted standing crop[b] Dead
Panicum spp.[c]	26.43	642	388	170	103
A. philoxeroides	5.34	674	1361[d]	36	73
Sagittaria spp.	15.15	199	228	30	34
S. patens	3.74	900	1530	34	57
Phragmites	2.54	478	2222	12	56
Other macrophytes[e]	46.80	570	1151	267	539
Total	100.00			549	862

[a]The percent coverage is an average based on the coverage for each hydrologic unit, taken from Chabreck (1972).

[b]As g dry wt/sq m/yr. Aboveground biomass only. Weighted standing crop is calculated by multiplying standing crop by the percent cover. References are Sasser et al. 1981 (*Panicum*), Boyd 1969 (*Alternanthera philoxeroides*), and Hopkinson et al. 1978b (*Sagittaria*, *Spartina patens*, and *Phragmites*).

[c]The values for *Panicum* are based on data from a fresh marsh *Panicum* community.

[d]Dead biomass of *Alternanthera philoxeroides* is found by multiplying its live biomass by 2.02, the average dead/live biomass ratio for *Panicum*, *Sagittaria*, *Spartina*, and *Phragmites*.

[e]The average ratio of live biomass to aboveground net primary production for *Panicum*, *Alternanthera*, *Sagittaria*, *Spartina*, and *Phragmites* is 0.26 (see Table 78 for NPP data). Therefore, live biomass of other macrophytes is equal to the aboveground NPP of other macrophytes, 2192 (Table 78) multiplied by 0.26, or 570 g dry wt/sq m/yr. The dead standing crop is equal to 570 multiplied by 2.02 (see Note d).

Table 78. Net primary production of fresh marsh macrophytes.

Plant	Percent plant cover	NPP[a]		Weighted NPP[a]	
		Above-ground	Below-ground[b]	Above-ground	Below-ground
Panicum spp.	26.43	1700	425	449	112
A. philoxeroides	5.34	3140	785	168	42
Sagittaria spp.	15.15	1501	375	227	57
S. patens	3.74	2300	575	86	22
Phragmites spp.	2.54	2318	580	59	15
Other[c]	46.80	2192	548	1026	256
Total	100.00			2015	504

[a] Net primary production, as g dry wt/sq m/yr. Weighted values are found by multiplying NPP by the percent cover. References are Sasser et al. 1981 (_Panicum_), Boyd 1969 (_Alternanthera_), and Hopkinson et al. 1978b (_Sagittaria_, _Spartina_, and _Phragmites_).

[b] The belowground production is assumed to be 25% of the aboveground production (Klopatek and Stearns 1978).

[c] The aboveground NPP for other macrophytes is assumed to be equal to the average NPP of the known fresh water marsh macrophytes.

Table 79. Percent nitrogen and phosphorus in fresh marsh plants.

Plant	N[a]	P[a]	Reference[b]
Panicum spp.[c]	1.76	0.14	3
Alternanthera philoxeroides	2.88	0.36	1
Sagittaria spp.	1.84	0.32	2
Spartina patens	0.78	0.86	2
Phragmites spp.	1.53	0.22	2
Weighted Avg.[d]	1.82	0.27	

[a] Percent of total dry weight.
[b] 1. Boyd and Scarsbrook 1975, 2. Boyd 1969, 3. Gosselink et al. 1977.
[c] The percent N and P values for *Panicum* are based on averages of the known percentages for *Alternanthera*, *Sagittaria*, *Spartina*, and *Phragmites*.
[d] The weighted average is found by multiplying the percent N or P for each plant by its percent cover (Table 78). Since these plants only account for 53.2% of all cover, this weighted value is divided by 0.532 to estimate 100% cover.

Table 80. Gross primary production, respiration, and nutrient uptake of fresh marsh macrophytes.[a]

Plant	NPP	Resp.[b]	GPP[c]	N[d]	P[d]	C[e]
Panicum spp.	562	332	894	15.73	1.25	406.4
A. philoxeroides	210	124	334	9.62	1.20	151.8
Sagittaria spp.	284	168	452	8.32	1.45	205.5
Spartina patens	108	64	172	1.34	1.48	78.2
Phragmites spp.	74	44	118	1.81	0.26	53.6
Other	1282	756	2038	37.09	5.50	926.4
Total	2520	1488	4008	73.91	11.14	1821.9

[a]All units are g/sq m/yr. Net primary production from Table 78. Values may not add exactly due to rounding.

[b]The respiration to production ratio for fresh marsh macrophytes is assumed to be the same as that for salt marsh macrophytes, 0.59 (Table 113). Respiration values were obtained by multiplying the R/P ratio and the NPP values.

[c]Gross primary production is the sum of NPP and respiration.

[d]Nitrogen and phosphorus uptake are the product of percent N and P (Table 79) and the GPP. N and P uptake for other macrophytes is found by multiplying GPP by the weighted average percent N and P (Table 79).

[e]The carbon uptake is equal to GPP multiplied by 1 g C/2.2 g dry wt (Whittaker 1975).

Table 81. Output of nitrogen, phosphorus, and carbon from fresh marsh decomposers.[a]

Biomass Type	Biomass Input[b]	%N[c]	N Output	%P[d]	P Output	%C[e]	C Output
Micro-litter	79.2	0.92	0.73	0.27	0.21	21	16.6
Macro-litter	1505.4	1.82	27.40	0.27	4.06	f	684.3
Insects	0.56	6.88	0.04	0.95	0.005	39	0.22
Mammals	6.97	6.88	0.48	0.95	0.066	39	2.72
Birds	0.05	6.88	3 E-3	0.95	4.4 E-4	39	0.02
Reptiles	0.34	6.88	0.02	0.95	0.003	39	0.13
TOM[g]	101.04	6.88	6.95	0.95	0.96	39	39.55
Total			35.62		5.31		743.54

[a]The output of N, P, and C to decomposers is assumed to be equal to their inputs. This is found by multiplying biomass input into litter by the percent of N, P, or C.

[b]In g dry wt/sq m/yr. Input values were calculated in the following ways: Microphytes. Total input of litter to decomposers is equal to 1584.6 g dry wt/sq m/yr (see 9,6,I). Litter is composed of dead microphyte and macrophyte biomass. Since microphytes account for 5% of NPP (7,7,I), it is assumed that 5% of the litter entering decomposers is from microphytes. This is equal to 79.2 g dry wt/sq m/yr; Macrophytes. Total contribution of litter to decomposers is 1584.6 g dry wt/sq m/yr, 79.2 of which is from microphytes (see above). Contribution of macrophytes is 1505.4 g dry wt/sq m/yr; Animals. See Notes 10,6,I-13,6,I.

[c]Nitrogen content of microphyte and macrophyte litter is assumed to be the same as the concentration in the living plants. These values were taken from Browder et al. 1981 and Table 79, respectively. For animals, percent N was found in the following way: according to E. P. Odum (1971), 16 moles N are required to produce 3258 g of protoplasm. The molecular weight of N is 14, therefore 224 g N are required. The percent N in protoplasm is 6.88%. It is assumed that this is the concentration in animal biomass.

[d]Phosphorus content of microphyte and macrophyte litter is assumed to be the same as the concentration in the living plants. These values were taken from Note 3,3,I and Table 79, respectively. For animals, percent P was found in the following way: According to E. P. Odum

(continued)

Table 81. Concluded.

(1971), 1 mole P is required to produce 3258 g of protoplasm. The molecular weight of P is 31, therefore 31 g P are required. The percent P in protoplasm is thus 0.95%. It is assumed that this is the concentration in animal biomass.

[e]Carbon content of microphyte litter is assumed to be the same as the concentration in living plants. This value was taken from Note 4,3,I. For animals, percent C was found in the following way: According to E. P. Odum (1971), 106 moles C are required to produce 3258 g of protoplasm; the molecular weight of C is 12, and thus 1272 g C are required. The percent C in protoplasm is thus 39%. It is assumed that this is the concentration in animal biomass.

[f]Carbon output of macrophytes found by multiplying biomass input by 1 g C/2.2 g dry wt (Whittaker 1975).

[g]TOM input is equal to the sum of all fecal material produced by insects, birds, mammals, and reptiles (5,7,0-5,10,0). This organic matter is assumed to have the same nitrogen and phosphorus content as animal biomass.

9. FRESH OPEN WATER

Inland freshwater bodies include lakes, ponds, and impounded freshwater areas. These lakes are typically shallow (depths less than 2 m) and bordered by cypress-tupelo swamps and freshwater Sagittaria falcata, Phragmites communis, and Typha marshes. In 1978, the habitat covered 35,824 ha in the MDPR (Wicker et al. 1980a). A map of the distribution of fresh open water habitat is shown in Figure 23.

Lac des Allemands was selected to be specifically modeled as a typical MDPR fresh aquatic system. The lake is typical of MDPR freshwater lakes. It is large (62 sq km), slightly alkaline, shallow (average depth 2.1 m), turbid (average Secchi depth 0.41 m), and eutrophic (Butler 1975). It is also hydrologically connected to downstream estuarine water bodies. Most importantly, Lac des Allemands and adjacent swamps and bayous have been the subject of ecosystem-level investigations (Butler 1975; Conner and Day 1976; Day et al. 1977; Kemp 1978; Hopkinson and Day 1979; Hopkinson and Day 1980a, 1980b).

Two swamp streams, Bayou Chevreuil and Bayou Boeuf, and overland flow through adjacent marshes contribute water to the lake (Day et al. 1977). The inflow of water to the lake is shown in the upper left of the flow diagram (Figure 24). Flows of water carry nitrogen, phosphorus, and organic matter to the lake, and fluxes of these nutrients are shown coupled with water flow in the model. Precipitation also carries nutrients, but nutrient input via rainfall is small compared with inputs from runoff.

Freshwater lakes in the MDPR are typically heavily affected by human development. Eutrophication caused by agricultural runoff is accelerating, most dramatically in the upper freshwater regions of MDPR hydrologic basins (Craig and Day 1977, Day et al. 1977; Kemp 1978). Frequent algal blooms, populations of catfish, gar, and shad, and periodic fish kills characterize such eutrophic waterbodies (Hopkinson and Day 1979).

Water flows from Lac des Allemands through Bayou des Allemands were measured by Butler (1975). Nitrogen, phosphorus, and organic matter are carried out of the lake by runoff as shown in the upper left portion of the model (Day et al. 1977). Nitrogen and phosphorus inflows to the lake exceed outflows by 1.9 and 1.8 times, respectively, indicating that the lake is acting as a nutrient sink. Such a property limits nutrient input to and eutrophication of downstream waterbodies. This is shown in the model as a change in lake storage of nitrogen and phosphorus.

The dominant primary producers in the lake are blue-green algae (Cyanophyta) and green algae (Chlorophyta) (Butler 1975), with blue-green algae being the most abundant (Lantz 1970). Day et al. (1982) reported that practically no light reaches the bottom of Lake Salvador in the Barataria Basin. Since Lac des Allemands is deeper and more turbid than Lake Salvador, benthic algal production was assumed to be zero. Phytoplankton is the only primary producer included in the model.

The lake ecosystem is heterotrophic; annual community respiration exceeds community primary production. Carbon import exceeds carbon export, as shown by exchange of total organic matter (TOM) in the upper left of the model. Lac des Allemands is very productive throughout the year. Gross production as measured by Butler (1975) is 3286 g oxygen/sq m/yr, or 2191 g dry wt/sq m/yr (0.3 g carbon fixed per g oxygen released, Cole 1975; and 0.45 g carbon/g dry wt, Whittaker 1975). Bayous and rivers in the MDPR typically have lower primary production and respiration than freshwater lakes because overhanging trees reduce the sunlight reaching the water. (For a more complete description of these systems see Habitat 14, River, stream, and bayou.) Seasonally, Lac des Allemands is most productive between April and September, a period of extensive blue-green algal blooms (Day et al. 1977).

Fresh aquatic habitat consumers are aggregated in the model into the three groups that were judged to be the major components of the lake food chain: (1) zooplankton, (2) benthos, and (3) fish.

Of the zooplankton, Cladocera and Rotifera are the most abundant in Lac des Allemands (Lantz 1970). The zooplankton feed on organic matter and phytoplankton, as shown in the model. Chironomidae and Tubificidae are the most abundant lake benthos (Lantz 1970). The lake's fish population is composed of many species, of which gizzard shad and channel catfish make up most of the biomass. (Other fish species and their standing crops are shown in Table 84).

Reptiles, including alligators (Alligator mississippiensis) and many species of snakes, occur in fresh aquatic habitats. Amphibians, wading birds, waterfowl, and mammals are common consumers. All are responsible for an unknown amount of predation in these habitats and are not included in the model.

As shown in the model, Lac des Allemands supports a commercial catfish industry that harvests 1.12 million kg of fish annually (Lantz 1970). It was assumed that waterfowl hunting takes place in the fresh marsh, not in fresh open water, so the harvest of birds is included only in the fresh marsh model.

The I-O table for fresh open water habitat is shown in Table 8.

Notes to Fresh Open Water Habitat Model

Water.

1,1,I Inflow of water to surface water. 18.4 E6 g/sq m/yr. Equal to the sum of inputs from direct precipitation (1.6 E6 g/sq m/yr) (Table 64) and runoff from surrounding swamp and upland habitats (16.8 E6 g/sq m/yr). Precipitation was measured for nearby Donaldsonville, Louisiana and Thibodaux, Louisiana (Sklar 1980). The amount of incoming runoff was derived by dividing total flows of carbon, nitrogen, and phosphorus into Lac des Allemands as reported by Day et al. (1977) by the concentration of those nutrients in inflowing water (Butler 1975). Volume per sq m of lake was obtained by dividing water volume by lake area of 62 E6 sq m (Butler 1975).

1,1,O Output of water from surface water. 18.4 E6 g/sq m/yr. Sum of evaporation (8.1 E6 g/sq m/yr) and runoff to downstream estuaries (10.3 E6 g/sq m/yr). Volume of water runoff was derived by dividing total flows of carbon, nitrogen, and phosphorus out of Lac des Allemands (Day et al. 1977) by the concentration of those nutrients in outflowing water (Butler 1975). Evaporation was calculated as the difference between total inflow (1,1,I) and outflowing runoff. Volumes per square meter of lake were obtained by dividing water volumes by lake area of 62 E6 sq m (Butler 1975).

1,1,S Water storage 2.1 E6 g/sq m. The average depth of Lac des Allemands is 2.1 m (Butler 1975), which represents 2.1 E6 g/sq m of water storage.

1,7,I Net export of water 18.4 E6 g/sq m/yr. Equal to the sum of runoff and evaporation (1,1,O).

1,7,O Net import of water 18.4 E6 g/sq m/yr. Equal to the sum of runoff and precipitation (1,1,I).

Inorganic nitrogen.

2,1,I Input of inorganic nitrogen to surface water. 138.7 g/sq m/yr. Sum of inputs in runoff, precipitation, phytoplankton regeneration, and animal regeneration. Nitrogen input in runoff (31.7 g/sq m/yr) was

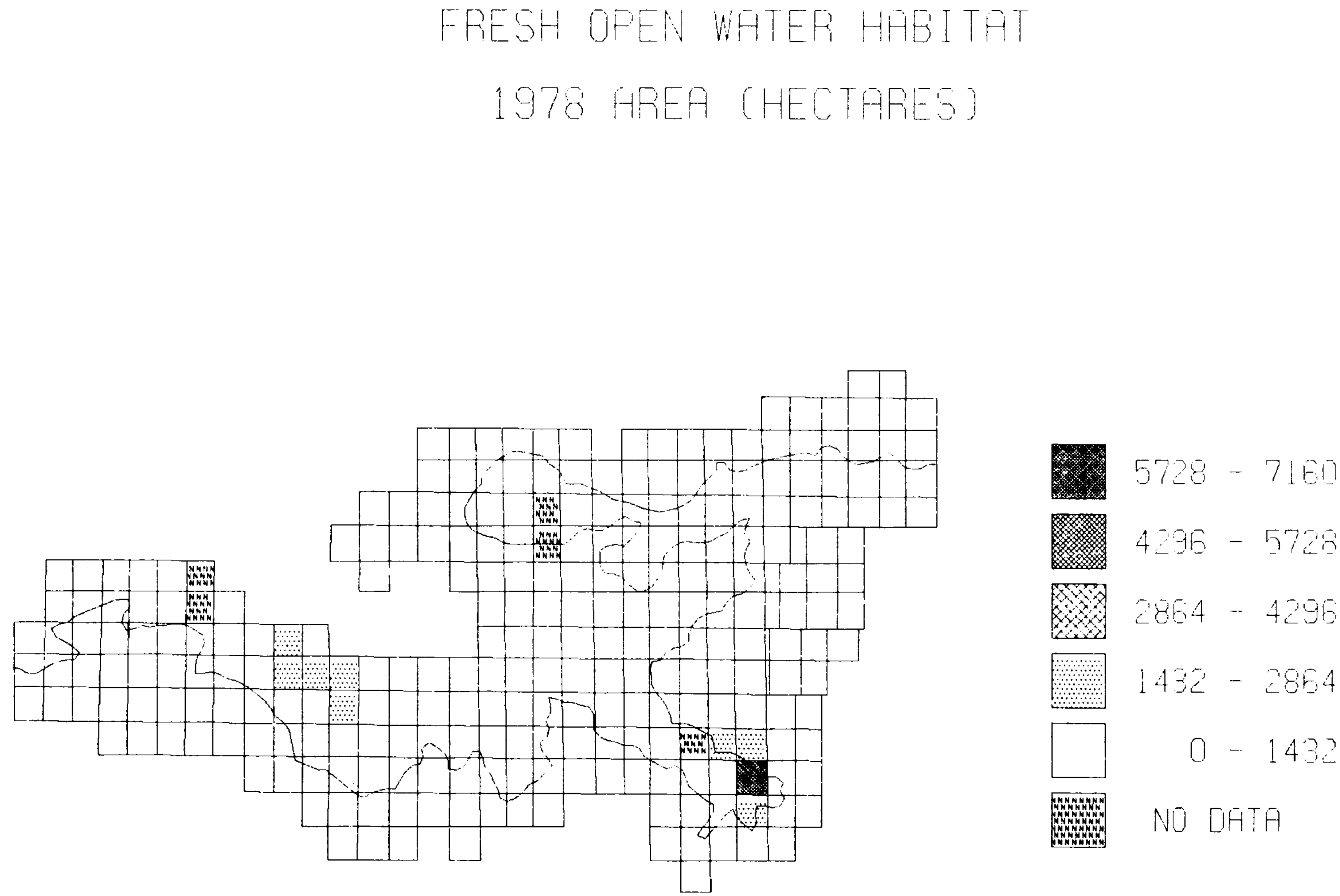


Figure 23. The distribution of MDPR fresh open water habitat.

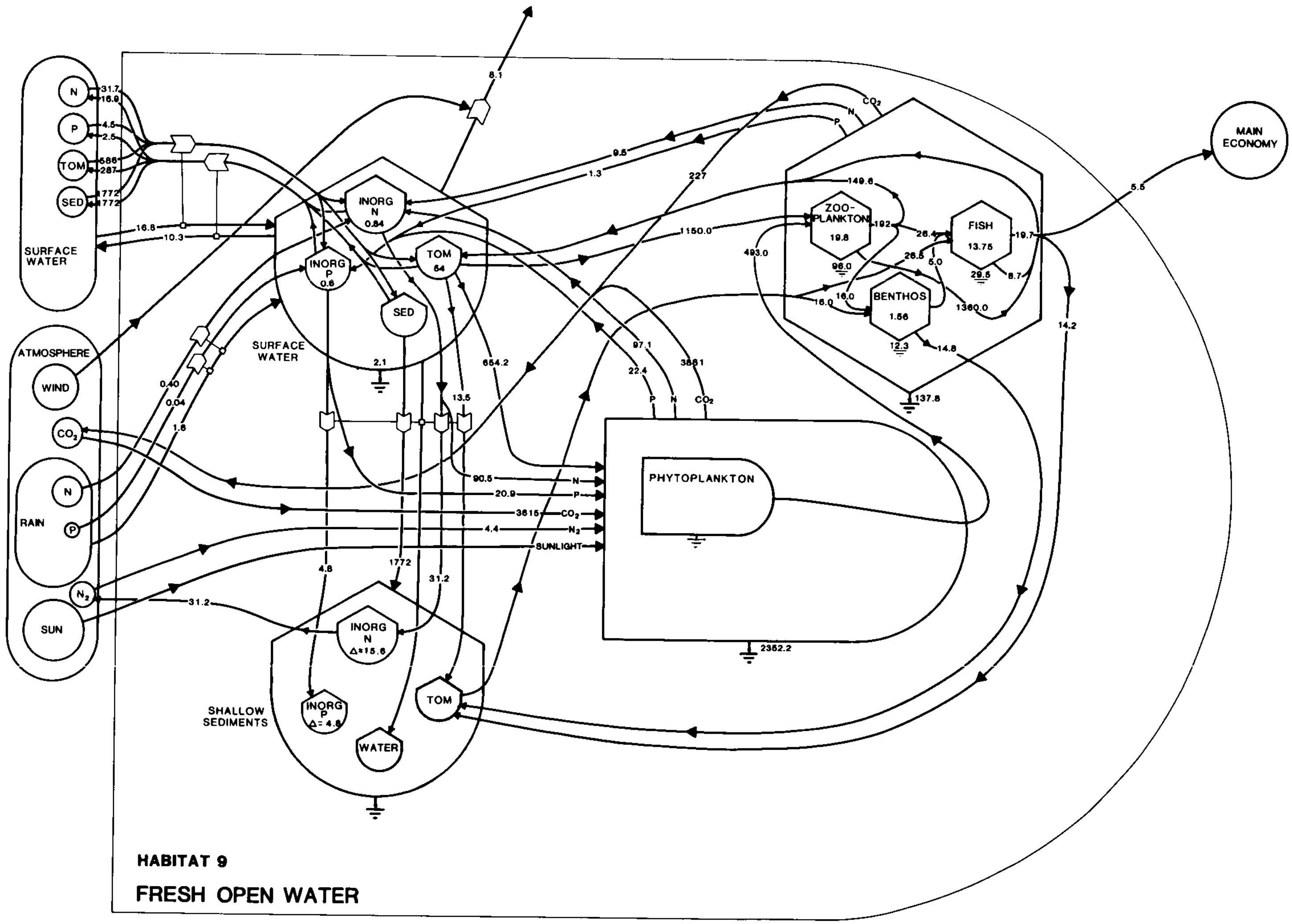


Figure 24. Fresh open water habitat flow diagram.

Table 82. Input-output table for fresh open water habitat.

HABITAT 9 FRESH OPEN WATER COMMODITIES		PROCESSES SURFACE WATER 1	SHALLOW SEDIMENTS 2	PHYTOPLANKTON 3	ZOOPLANKTON 4	BENTHOS 5	FISH 6	IMPORTS & EXPORTS 7	CHANGE IN STORAGE 8	TOTAL	UNITS
WATER	1	18.4 18.4 2.1						18.4 18.4		36.8 36.8 2.1	10^6 g $H_2O/m^2/yr$ 10^6 g $H_2O/m^2/yr$ 10^6 g H_2O/m^2
INORGANIC NITROGEN	2	138.7 138.7 0.84	31.2 31.2	94.9 97.1	6.6	0.8	2.0	48.1 36.5	15.6	297.3 297.3 0.84	g $N/m^2/yr$ g $N/m^2/yr$ g N/m^2
INORGANIC PHOSPHORUS	3	28.2 28.2 0.6	4.8 4.8	20.9 22.4	0.9	0.1	0.3	2.5 4.5	4.8	61.2 61.2	g $P/m^2/yr$ g $P/m^2/yr$ g P/m^2
CARBON DIOXIDE	4			3615 3861	168	20	49	4108 3615		7723 7723	g $CO_2/m^2/yr$ g $CO_2/m^2/yr$ g CO_2/m^2
TOTAL ORGANIC MATTER	5	2104.7 2104.7 54	42.5 42.5	654.2	1150 1509.6	16 14.8	26.5 22.9	267 566.4		4260.9 4260.9 54	g dry $wt/m^2/yr$ g dry $wt/m^2/yr$ g dry wt/m^2
INORGANIC SEDIMENTS	6	1772 1772						1772 1772		3544 3544	g dry $wt/m^2/yr$ g dry $wt/m^2/yr$
PHYTOPLANKTON BIOMASS	7			493	493					493 493	g dry $wt/m^2/yr$ g dry $wt/m^2/yr$ g dry wt/m^2
ZOOPLANKTON BIOMASS	8	149.6			192 19.8	16.0	26.4			192 192 19.8	g dry $wt/m^2/yr$ g dry $wt/m^2/yr$ g dry wt/m^2
BENTHOS BIOMASS	9					5.0 1.56	5.0			5.0 5.0 1.56	g dry $wt/m^2/yr$ g dry $wt/m^2/yr$ g dry wt/m^2
FISH BIOMASS	10	14.2					19.7 13.75	5.5		19.7 19.7 13.75	g dry $wt/m^2/yr$ g dry $wt/m^2/yr$ g dry wt/m^2
HEAT	11			194 980	422	55	133	195 590		195 590 195 590	$kcal/m^2/yr$ $kcal/m^2/yr$
SUNLIGHT	12			194 254				1 228 746 1 423 000		1 423 000 1 423 000	$kcal/m^2/yr$ $kcal/m^2/yr$

calculated by dividing the total nitrogen import into Lac des Allemands of 1966 metric tons/yr (Day et al. 1977) by the lake area of 62 sq m (Butler 1975). Nitrogen input in rainfall was measured at 0.4 g/sq m/yr for a nearby swamp (Kemp and Day, in press). Nitrogen regeneration by phytoplankton (97.1 g/sq m/yr) was calcultated by multiplying phytoplankton respiration (2352.2 g dry wt/sq m/yr) (11,3,0) by the nitrogen content of phytoplankton (in this case blue-green algae) (0.0413 g N/g dry wt) (Williams and Burris 1952). Animal nitrogen regeneration (9.5 g/sq m/yr) was calculated by multiplying animal respiration (137.8 g dry wt /sq m/yr) (Sum of, in g dry wt, 11,4,0; 11,5,0; 11,6,0) by nitrogen content of biomass (0.069 g N/g dry wt respired) (E. P. Odum 1971).

2,1,0 Output of inorganic nitrogen from surface water. 138.7 g/sq m/yr. Nitrogen concentration in surface water was assumed to be in steady state, so total nitrogen output equals total input. Equal to the sum of outputs in runoff, phytoplankton uptake, denitrification, and sedimentation. Nitrogen output in runoff (16.9 g/sq m/yr) was calculated by dividing total nitrogen export from Lac des Allemands of 1047 metric tons/yr (Day et al. 1977) by lake area of 62 E6 sq m (Butler 1975). Phytoplankton uptake (90.5 g/sq m/yr) was calculated by multiplying phytoplankton gross primary production (2191 g/sq m/yr) (Table 83) by the nitrogen content of blue-green algae (0.0413 g N/g dry wt) (Williams and Burris 1952). Sedimentation was assumed to account for the remainder (31.2 g/sq m/yr) of the nitrogen output from surface water.

2,1,S Storage of inorganic nitrogen in surface water. 0.84 g/sq m. Taken to be the concentration of inorganic nitrogen in water flowing out of Lac des Allemands (0.04 mg/l, or 0.04 g/cu m) (Day et al. 1977) times the average lake depth of 2.1 m (Butler 1975).

2,2,I Input of inorganic nitrogen to sediment. 31.2 g/sq m/yr. Equal to nitrogen deposited in sediment. (2,1,0).

2,2,0 Output of inorganic nitrogen from sediment. 31.2 g/sq m/yr. Equal to denitrification. Since nitrogen in sediment was assumed to be in steady state, denitrification equals the input of nitrogen to sediment (2,1,0).

2,3,I Input of inorganic nitrogen to phytoplankton. 94.9 g/sq m/yr. Equal to the sum of phytoplankton uptake from surface water (90.5 g/sq m/yr) (2,1,0) and fixation (4.4 g/sq m/yr). Fixation was measured for Lake George, Uganda (Mague 1977), a similar shallow, eutrophic lake dominated by blue-green algae (Burgis and Dunn 1978).

2,3,0 Nitrogen output from phytoplankton. 97.1 g/sq m/yr. Equal to regeneration by phytoplankton (2,1,I).

2,4,0 Nitrogen output from zooplankton. 6.6 g/sq m/yr. Equal to zooplankton respiration (96 g dry wt /sq m/yr) (Figure 25) multiplied by nitrogen content of biomass (0.069 g N/g dry wt respired) (E. P. Odum 1971).

2,5,0 Nitrogen output from benthos. 0.8 g/sq m/yr. Equal to benthos respiration (12.3 g dry wt/sq m/yr) (Figure 26) multiplied by nitrogen content of biomass (0.069 g N/g dry wt respired) (E. P. Odum 1971).

2,6,0 Nitrogen output from fish. 2.0 g/sq m/yr. Equal to fish respiration (29.5 g dry wt /sq m/yr) (Figure 27) multiplied by nitrogen content of biomass (0.069 g N/g dry wt respired) (E. P. Odum 1971).

2,7,I Net export of inorganic nitrogen. 48.1 g/sq m/yr. Equal to output in runoff (16.9 g/sq m/yr) (2,1,0) plus denitrification (31.2 g/sq m/yr) (2,1,0).

2,7,0 Net import of inorganic nitrogen. 36.5 g/sq m/yr. Equal to inputs in runoff (31.7 g/sq m/yr) (2,1,I), plus fixation (4.4 g/sq m/yr) (2,1,I), plus precipitation (0.4 g/sq m/yr) (2,1,I).

2,8,I Change in inorganic nitrogen storage in sediment. Δ15.6 g/sq m/yr. Equals input to sediment (2,2,I) since this flow represents net transfer.

Inorganic phosphorus.

3,1,I Input of inorganic phosphorus to surface water. 28.2 g/sq m/yr. Equal to inputs in runoff, phosphorus regeneration by phytoplankton, and phosphorus regeneration by animals. Phosphorus input in rainfall was measured at 0.04 g/sq m/yr (Kemp and Day, in press) and was considered insignificant. Phosphorus input in runoff (4.5 g/sq m/yr) was calculated by dividing total phosphorus input to Lac des Allemands of 281 metric tons/yr (Day et al. 1977) by lake area of 62 E6 sq m (Butler 1975). Phosphorus regeneration by phytoplankton (22.4 g/sq m/yr) was calculated by multiplying phytoplankton respiration (2352.2 g dry wt/sq m/yr) (11,3,0) by phosphorus content of biomass (0.00952 g P/g dry wt) (E. P. Odum 1971). Phosphorus regeneration by animals (1.3 g/sq m/yr) was calculated by multiplying animal respiration (137.8 g dry wt /sq m/yr) (11,4,0; 11,5,0; 11,6,0) by phosphorus content of biomass (0.00952 g P/g dry wt) (E. P. Odum 1971).

3,1,0 Output of inorganic phosphorus from surface water. 28.2 g/sq m/yr. Phosphorus concentration in surface water was assumed to be in steady state, so total phosphorus inputs equal total outputs. Equal to sum of outputs in runoff, phytoplankton uptake, and sedimentation. Phosphorus output in runoff (2.5 g/sq m/yr) was calculated by dividing the total phosphorus export from Lac des Allemands of 154 metric tons/yr (Day et al. 1977) by lake area of 62 E6 sq m (Butler 1975). Phosphorus uptake by phytoplankton (20.9 g/sq m/yr) was calculated by multiplying gross production (2191 g/sq m/yr) (Table 83) by phosphorus content of biomass (0.00952 g P/g dry wt) (E. P. Odum 1971). Phosphorus sedimented (4.8 g/sq m/ yr) was calculated by difference to balance surface water compartment (28.2 g/sq m/yr - 2.5 g/sq m/yr - 20.9 g/sq m/yr = 4.8 g/sq m/yr).

3,1,S Storage of inorganic phosphorus in surface water. 0.6 g/sq m. Equal to total phosphorus stored in Lac des Allemands of 36 mt (Day et al. 1977) divided by lake area of 62 E6 sq m (Butler 1975).

3,2,I Input of inorganic phosphorus to sediment. 4.8 g/sq m/yr. Equal to phosphorus deposited in sediment (3,1,0).

3,2,0 Output of inorganic phosphorus from sediment. 4.8 g/sq m/yr. Positive changes in storage are recorded as outputs from that sector. It was assumed that this is the net flux of phosphorus to the sediment (sediment phosphorus deposition exceeds regeneration by 4.8 g/sq m/yr).

3,3,I Input of inorganic phosphorus to phytoplankton. 20.9 g/sq m/yr. Phosphorus uptake by phytoplankton (3,1,0).

3,3,0 Output of inorganic phosphorus from phytoplankton. 22.4 g/sq m/yr. Equal to phosphorus regeneration by phytoplankton (3,1,I).

3,4,0 Phosphorus regeneration by zooplankton. 0.9 g/sq m/yr. Equal to zooplankton respiration (96 g dry wt/sq m/yr) (Figure 25) multiplied by phosphorus content of biomass (0.00952 g P/g dry wt) (E. P. Odum 1971).

3,5,0 Phosphorus regeneration by benthos. 0.1 g/sq m/yr. Equal to benthos respiration (12.3 g dry wt/sq m/yr) (Fiqure 26) multiplied by phosphorus content of biomass (0.00952 g P/g dry wt) (E. P. Odum 1971).

3,6,0 Phosphorus regeneration by fish. 0.3 g/sq m/yr. Equal to fish respiration (29.5 g dry wt/sq m/yr) (Figure 27) multiplied by phosphorus content of biomass (0.00952 g P/g dry wt) (E. P. Odum 1971).

3,7,I Net export of inorganic phosphorus. 2.5 g/sq m/yr. Equal to export in runoff (3,1,0).

3,7,0 Net import of inorganic phosphorus. 4.5 g/sq m/yr. Equal to import in runoff (3,1,I).

3,8,I Change in phosphorus storage in sediment. 4.8 g/sq m/yr. (3,1,0).

Carbon dioxide.

4,3,I Input of carbon dioxide to phytoplankton. 3615 g/sq m/yr. Equal to gross production (2191 g/sq m/yr) (Table 83) multiplied 0.45 g C/g dry wt (Whittaker 1975) and 3.667 (44 g CO_2/12 g C).

4,3,0 Output of carbon dioxide from phytoplankton. 3881 g/sq m/yr. Equal to phytoplankton respiration (2352.2 g dry wt /sq m/yr) (11,3,0) multiplied by 0.45 g C/g dry wt (Whittaker 1975) and 3.667 (44 g CO_2/12 g C).

4,4,0 Output of carbon dioxide from zooplankton. 158 g/sq m/yr. Equal to zooplankton respiration (96 g dry wt /sq m/yr) (Figure 25) multiplied by 0.45 g C/g dry wt (Whittaker 1975) and 3.667 (44 g CO_2/12 g C).

4,5,0 Output of carbon dioxide from benthos. 20 g/sq m/yr. Equal to benthos respiration (12.3 g dry wt /sq m/yr) (Figure 26) multiplied by 0.45 g C/g dry wt (Whittaker 1975) and 3.667 (44 g CO_2/12 g C).

4,6,0 Output of carbon dioxide from fish. 49 g/sq m/yr. Equal to fish respiration (29.5 g dry wt /sq m/yr) (Figure 27) multiplied by 0.45 g C/g dry wt (Whittaker 1975) and 3.667 (44 g CO_2/12 g C).

4,7,I Net export of carbon dioxide. 4108 g/sq m/yr. Equal to outputs from phytoplankton (3881 g/sq m/yr) (4,3,0), zooplankton (158 g/sq m/yr) (4,4,0), benthos (20 g/sq m/yr) (4,5,0), and fish (49 g/sq m/yr) (4,6,0).

4,7,0 Net import of carbon dioxide. 3615 g/sq m/yr. Equal to uptake by phytoplankton (4,3,I).

Total organic matter (TOM).

5,1,I Input of TOM to surface water. 2104.7 g/sq m/yr. TOM in surface water was assumed to be in steady state, so total input equals total output. Output equals flow from surface water to phytoplankton (654.2 g/sq m/yr; 5,3,I), zooplankton (1150 g/sq m/yr; 5,4,I), sediments (13.5 g/sq m/yr; 5,2,I), and export 287 g/sq m/yr. Export in runoff from Lac des Allemands was calculated by dividing total TOM export from the lake of 8016 metric tons (Day et al. 1977) by lake area of 62 E6 sq m (Butler 1975). Inputs of TOM to surface water are from zooplankton egestion (1360 g/sq m/yr; 5,4,0), zooplankton mortality (149.6 g/sq m/yr; 8,1,0), fish egestion (8.7 g/sq m/yr; 5,6,0), and import in runoff (586.4 g/sq m/yr). Import was calculated by difference.

5,1,0 Output of TOM from surface water. 2104.7 g/sq m/yr. See 5,1,I.

5,1,S Storage of TOM in surface water. 54 g/sq m. Equal to total organic carbon storage in Lac des Allemands of 1531 metric tons (Day et al. 1977), divided by lake area of 62 E6 sq m (Butler 1975) multiplied by 2.2 g dry organic matter/g carbon (Whittaker 1975).

5,2,I Input of TOM to sediment. 42.5 g/sq m/yr. TOM in the sediment was assumed to be in steady state, so inputs equal outputs. Equal to the sum of benthos egestion (14.8 g/sq m/yr; 5,5,0), fish mortality (14.2 g/sq m/yr; 10,5,0), and settling of TOM from the water column (13.5 g/sq m/yr). Settling was calculated by difference.

5,2,0 Output of TOM from sediment. 42.5 g/sq m/yr. Equal to benthos ingestion (16 g/sq m/yr; 5,5,I) and fish ingestion (26.5 g/sq m/yr). Fish are primarily catfish and were assumed to feed off the bottom.

5,3,I Input of TOM to phytoplankton. 654.2 g/sq m/yr. Input of TOM to phytoplankton was calculated to balance the phytoplankton compartment. Since the phytoplankton community is heterotrophic inputs to phytoplankton are GPP (2191 g/sq m/yr) (Table 83) and consumption of TOM. Outputs from phytoplankton are the flow of phytoplankton biomass to zooplankton (493 g/sq m/yr; 7,4,I) and respiration (2352.2 g dry wt/sq m/yr; 11,3,0). (2191 g/sq m/yr + x = 493 g/sq m/yr + 2352.2 g/sq m/yr, x = 654.2 g/sq m/yr).

5,4,I Input of TOM to zooplankton. 1150 g/sq m/yr. Zooplankton diet was assumed to be 70% organic matter (7,4,I). Total zooplankton ingestion equals 1643 g/sq m/yr (Figure 25) (1643 g/sq m/yr x 0.7 = 1150 g/sq m/yr).

5,4,0 Output of TOM from zooplankton. 1509.6 g/sq m/yr. Equal to zooplankton egestion plus mortality (Figure 25).

5,5,I Input of TOM to benthos. 16 g/sq m/yr. Half of benthos diet assumed to be organic matter (8,5,I). Total benthos ingestion equals 32 g/sq m/yr (Figure 26).

5,5,0 Output of TOM from benthos. 14.8 g/sq m/yr. Equal to benthos egestion (Figure 26).

5,6,I Input of TOM to fish. 26.5 g/sq m/yr. Fish were assumed to consume benthos, zooplankton, and organic matter (8,6,I).

5,6,0 Output of TOM from fish. 22.9 g/sq m/yr. Equal to fish egestion plus mortality (Figure 27).

5,7,I Net export of TOM. 287 g/sq m/yr. Equal to export in runoff (5,1,0).

5,7,0 Net import of TOM. 586.4 g/sq m/yr. Equal to inflow in runoff (5,1,I).

Sediment.

6,1,I Input of sediment to surface water. 1772 g/sq m/yr. Sediment in surface water assumed to be in steady state, so inputs to surface water equal outputs (6,1,0).

6,1,0 Output of sediment from surface water. 1772 g/sq m /yr. It was assumed that all the inorganic sediment that is deposited on fresh marshes surrounding Lac des Allemands (266 g/sq m marsh/yr) (see fresh marsh model) is carried there by Lac des Allemands surface water. The fresh marshes surrounding Lac des Allemands were equal to about 25% of the area of fresh marsh in the coastal zone in Barataria Basin in 1978 (0.25 x 165,267 ha = 41,317 ha = 4.13 E8 sq m). Sediment output from surface water per sq m of lake was derived by calculating the total sediment deposition on fresh marshes (266 g/sq m/yr x 4.13 E8 sq m = 1.1 E11 g/yr) and dividing by the lake area of 62 E6 sq m. This yields a sediment output from surface water of 1772 g/sq m lake/yr. Deposition of sediments on the lake bottom undoubtedly represents another sink for surface water-carried sediment, but since nothing is known about deposition in the lake, it was omitted.

6,7,I Net export of sediment. 1772 g/sq m/yr. Equal to export to fresh marshes (6,1,0).

6,7,0 Net import of sediment. 1772 g/sq m/yr. See (6,1,I).

Phytoplankton biomass.

7,3,0 Output of phytoplankton. 493 g/sq m/yr. Net production of phytoplankton was assumed to be just enough to supply 30% of zooplankton diet (7,4,I).

7,4,I Input of phytoplankton to zooplankton. 493 g/sq m/yr. Zooplankton were assumed to consume all net phytoplankton production. Zooplankton diet assumed to be 70% organic matter, 30% phytoplankton. Gillespie (1971) and Darnell (1958) reported that detritus was the predominant component of zooplankton diet in slightly brackish estuarine waters in Louisiana. Zooplankton ingestion in Lac des Allemands was calculated to be 1643 g/sq m/yr (Figure 25). (1643 g/sq m/yr x 0.3 = 493 g/sq m/yr).

Zooplankton biomass.

8,1,I Input of zooplankton to surface water 149.6 g/sq m/yr. Zooplankton mortality was assumed to contribute to water column TOM. It was calculated as the difference between production (192 g/sq m/yr; 8,4,0) and the sum of outputs to benthos (16 g/sq m/yr; 8,5,I) and fish (26.4 g/sq m/yr; 8,6,I).

8,4,0 Output of zooplankton. 192 g/sq m/yr. Production of zooplankton was calculated from a ratio of zooplankton production (P) to annual average standing crop (SC). A zooplankton energy budget was constructed from Richman (1958)

(Figure 25). The P/SC ratio equals 9.7/yr. Zooplankton standing crop equals 19.8 g/sq m (Figure 25), so production equals 192 g/sq m/yr.

8,4,S Zooplankton standing crop. 19.8 g/sq m. Zooplankton standing crop was calculated for Lac des Allemands from data from Lantz (1970). Average numbers of macro- and microzooplankton per liter of lake water were calculated. Two years of data were averaged to obtain 381 macrozooplankton/liter and 793 microzooplankton/liter. Average numbers of plankton per liter were multiplied by the average dry weight of micro- and macrozooplankton. (0.52 ug/ind and 24.8 ug/ind respectively). Weights of macro- and micro zooplankton were obtained by averaging the weights of 15 species of copepods and 25 species of rotifers respectively, as reported in Dumont et al. (1975). Product of 381 ind/l and 24.8 ug/ind = 9449 ug/l for macrozooplankton. Product of 793 ind/l and 0.52 ug/l = 412 ug/l for microzooplankton. Conversion to grams and multiplication by 1000 l/cu m yields 9.5 g/cu m for macrozooplankton and 0.4 g/cu m for microzooplankton. Since Lac des Allemands has an average depth of 2.1 m (Butler 1975), the total macrozooplankton standing crop equals 19.0 g/sq m. Total microzooplankton standing crop equals 0.8 g/m2. Total zooplankton standing crop equals the sum of micro- and macrozooplankton, or 19.8 g/m2.

8,5,I Input of zooplankton to benthos. 16 g/sq m/yr. Benthos assumed to feed 50% on zooplankton and 50% detritus. Total benthos ingestion equals 32 g/sq m/yr (Figure 26), of which 16 g/sq m/yr is zooplankton.

8,6,I Input of zooplankton to fish. 26.4 g/sq m/yr. Fish ingestion equals 57.9 g/sq m/yr (Figure 27), of which 5 g/sq m/yr is benthos consumption (9,6,I). The remainder of fish consumption (52.9 g/sq m/yr) was assumed to be 50% TOM and 50% zooplankton.

Benthos biomass.

9,5,O Output of benthos. 5.0 g/sq m/yr. Equal to production of benthos. Production (P) was estimated by multiplying benthos standing crop (SC) of 1.56 g/sq m (9,5,S) by P/SC ratio of 3.2/yr for an estuarine benthic community (Figure 26).

9,5,S Benthos standing crop. 1.56 g/sq m. Benthic standing crop in Lac des Allemands was calculated for 1965 and 1966, the years Lantz (1970) lists complete yearly data. The standing crops 0.214 g/sq ft (1965) and 0.076 g/sq ft (1966) were averaged to yield 0.145 g/sq ft, or 1.56 g/sq m.

9,6,I Input of benthos to fish. 5.0 g/sq m/yr. It was assumed that all benthos produced are eaten by fish. Lantz (1970) reports that channel catfish, the principal fish species in Lac des Allemands, feed heavily on benthos.

Fish biomass.

10,2,I Input of fish to sediments. 14.2 g/sq m/yr. Total fish production equals 19.7 g/sq m/yr (10,6,0). Harvest by man equals 5.5 g/sq m/yr (10,7,I). Fish mortality was assumed to contribute to sediment TOM and equals total fish production minus harvest by man. Fish move between the fresh aquatic system and nearby marshes and downstream estuaries. Fish migration to estuaries probably transports biomass in and out of the lake in a manner similar to other Barataria Basin waterbodies (Chambers 1980) but the magnitude or the transfer is unknown and it was assumed to be zero. Exchange of fish with marshes is also unknown and assumed to be zero.

10,6,O Output of fish biomass. 19.7 g/sq m/yr. Fish production was calculated as a ratio of fish annual production (P) to fish mean standing crop (SC). A P/SC ratio of 1.43/yr was calculated with data from Lake George, a shallow freshwater African lake (Figure 27) (1.43/yr x 13.75 g/sq m standing crop, 10,6,S = 19.7 g/sq m/yr).

10,6,S Fish standing crop. 13.75 g/sq m Lantz (1970) studied Lac des Allemands fish populations for two years. An estimate of total average fish standing crop was calculated from Table 84 .

10,7,I Export of fish biomass. 5.5 g/sq m/yr. Equals harvest by man. Harvest equals total tonnage of fish (in g Carbon) taken from Lac des Allemands (156 metric tons reported by Day et al. 1977) divided by lake area of 62 E6 sq m (Butler 1975). That yields 2.52 gC/sq m/yr, or 5.5 g dry wt /sq m/yr (2.2 g dry wt/g C, Whittaker 1975).

Heat.

11,3,O Output of heat from phytoplankton. 194,980 kcal/sq m/yr. Equal to the sum of the outputs of respiratory heat and heat loss due to the inefficiency of photosynthesis. Output of respiratory heat from phytoplankton equals 10,585 kcal/sq m/yr. Respiration of phytoplankton in g dry wt/sq m/yr equals total community respiration 2491 g dry wt/sq m/yr (Table 83) minus respiration by zooplankton (96 g dry wt/sq m/yr; 11,4,O), benthos (12.3 g dry wt/sq m/yr; 11,5,O) and fish (29.5 g dry wt/sq m/yr; 11,6,O). (2491 g/sq m/yr - 96 g/sq m/yr - 12.3 g/sq m/yr - 29.5 g/sq m/yr = 2352.2 g/sq m/yr). Conversion of g dry wt/sq m/yr to kcal by multiplication by 4.5 kcal/g dry wt (E. P. Odum 1971) yields 10,585 kcal/sq m/yr. Output of heat due to the inefficiency of photosynthesis equals 184,395 kcal/sq m/yr. Odum (1957) reports 84,16 kcal are dissipated for every g dry wt fixed in GPP. (2191 g dry wt/sq m/yr x 84.16 kcal/g dry wt = 184,395 kcal/sq m/yr.)

11,4,O Output of respiratory heat from zooplankton. 422 kcal/sq m/yr. Equal to respired biomass (96 g dry wt /sq m/yr; Figure 25) multiplied by 4.5 kcal/g dry wt (E. P. Odum 1971).

11,5,O Output of respiratory heat from benthos. 55 kcal/sq m/yr. Equal to respired biomass (12.3 g dry wt/sq m/yr; Figure 26) multiplied by 4.5 kcal/g dry wt (E. P. Odum 1971).

11,6,O Output of respiratory heat from fish. 133 kcal/sq m/yr. Equal to respired biomass (29.5 g dry wt/sq m/yr; Figure 27) multiplied by 4.5 kcal/g dry wt (E. P. Odum 1971).

11,7,I Net export of heat. 195,590 kcal/sq m/yr. Sum of outputs of heat from phytoplankton, zooplankton, benthos, and fish.

Sunlight.

12,3,I Input of sunlight to phytoplankton. 194,254 kcal/sq m/yr. According to Odum (1957), 410,000 kcal are required for every 20,810 kcal fixed in GPP, or converting kcal to dry wt (4.5 kcal = 1g dry wt; E. P. Odum 1971), 88.66 kcal are required per gram dry wt of GPP. Phytoplankton GPP = 2191 g dry wt/sq m/yr (Table 83) (2191 g dry wt/sq m/yr x 88.66 kcal/g dry wt = 194,254 kcal/sq m/yr.)

12,7,I Net output of sunlight. 1,228,746 kcal/sq m/yr. Net output of sunlight, or albedo, equals total input of sunlight (1,423,000 kcal/sq m/yr) (see 12,7,O) minus uptake by phytoplankton (194,254 kcal/sq m/yr) (see 12,3,I).

12,7,O Net input of sunlight. 1,423,000 kcal/sq m/yr. Total insolation equals 389.8 cal/sq cm/day at New Orleans, averaged from 1952 to 1975 (Knapp et al. 1980).

Table 83. Primary productivity and respiration in Lac des Allemands.

Production or respiration measurement	g Oxygen/ sq m/yr[a]	g Carbon/ sq m/yr[b]	g dry wt/ sq m/yr[c]
Net daytime photosynthesis	1418	425	944
Nighttime respiration	1868	560	1244
Gross primary productivity	3286	986	2191
Total respiration	3736	1121	2491
Net community productivity	-450	-135	-300

[a]Hopkinson and Day (1979).
[b]1 g oxygen = 0.3 g carbon (Cole 1975).
[c]0.45 g carbon/g dry wt (Whittaker 1975).

Table 84. Fish standing crop in Lac des Allemands for years 1965-1967. From Lantz (1970).

Fish Species	1965		1966		1967	
	lb/ac	g/sq m	lb/ac	g/sq m	lb/ac	g/sq m
Yellow bass	2.1	0.24	1.2	0.13	0.5	0.06
White crappie	0.8	0.09	0	0	0	0
Black crappie	3.4	0.38	1.3	0.15	1.8	0.20
Bluegill	1.3	0.15	0.4	0.04	0.1	0.01
Redear sunfish	0.3	0.03	0.3	0.03	0.1	0.01
Carp	4.8	0.54	1.8	0.20	1.5	0.17
American eel	13.1	1.47	0.2	0.02	0	0
Striped mullet	0.7	0.08	1.6	0.18	10.5	1.18
Channel catfish	37.3	4.18	70.3	7.88	154.8	17.35
Blue catfish	0.9	0.10	0.5	0.06	2.5	0.28
Flathead catfish	1.2	0.13	0	0	1.9	0.21
Bowfin	0	0	0.1	0.01	0	0
Spotted gar	0.4	0.04	0.3	0.03	0.2	0.02
Gizzard shad	11.2	1.26	0	0	37.7	4.23
Threadfin shad	0.2	0.02	0	0	0	0
Bay anchovy	0.3	0.03	0.3	0.03	0.1	0.01
TOTAL[a]	78.0	8.7	78.3	8.8	211.7	23.7

[a]Three year average equals 13.75 g/sq m.

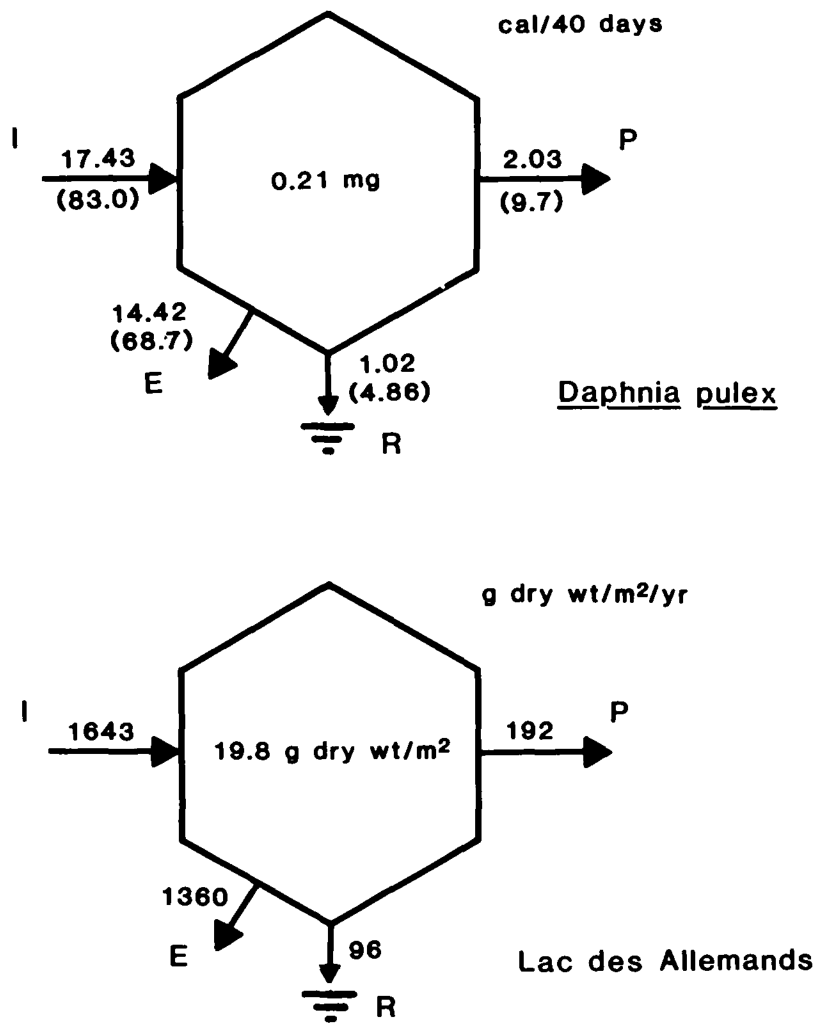


Figure 25. Fresh open water habitat zooplankton energy budget. An energy budget for MDPR fresh open water zooplankton was approximated from a study of *Daphnia pulex* by Richman (1958). Ingestion (I), egestion plus excretion (E), respiration (R), production (P), and standing crop (SC) were calculated for *Daphnia* (top), and ratios of I, E, R, and P to standing crop were derived (top, shown in parenthesis). These ratios were then multiplied by the zooplankton standing crop in Lac des Allemands (Lantz 1970; see also 7,5,S), to obtain I, E, R, and P of Lac des Allemands zooplankton (bottom). The energy budget for zooplankton does not balance exactly due to roundoff error.

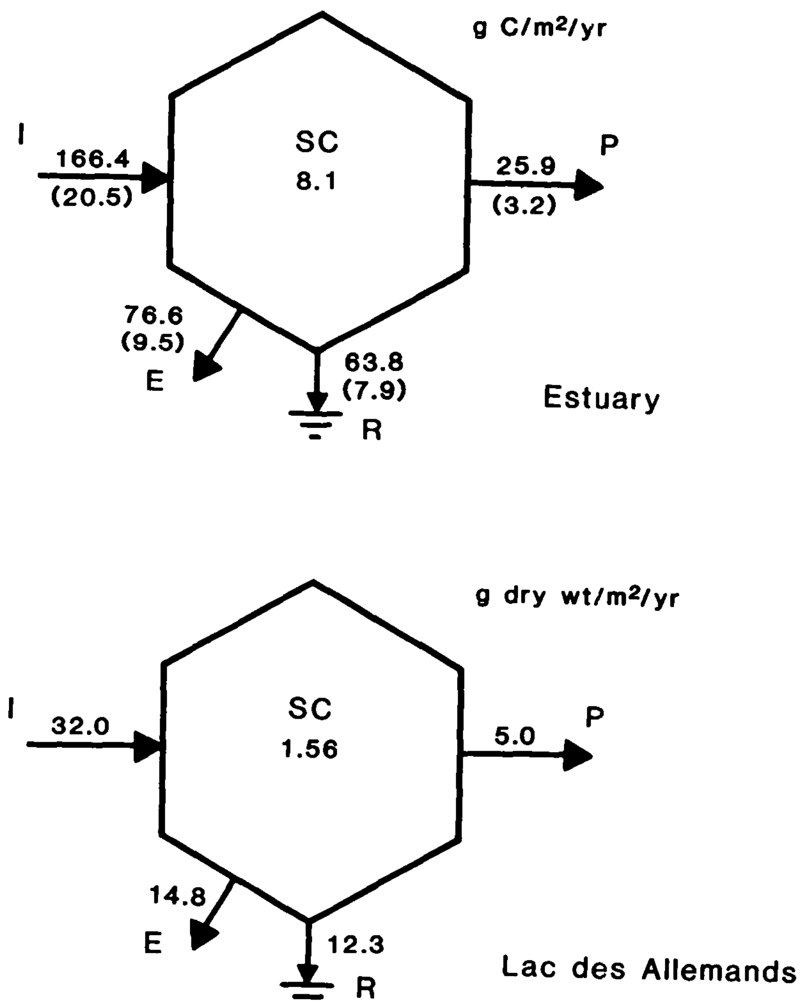


Figure 26. Fresh open water habitat benthos energy budget. Values for the benthic community in Lynher Estuary, Cornwall, U. K. were obtained from Warwick et al. (1979). Ratios of ingestion (I), egestion (E), respiration (R), and production (P) to standing crop (SC) are shown in parentheses. I, E, R, and P for Lac des Allemands benthos were calculated by multiplying the ratios obtained above by standing crop. Lac des Allemands benthos standing crop was obtained from Lantz (1970) (8,6,S).

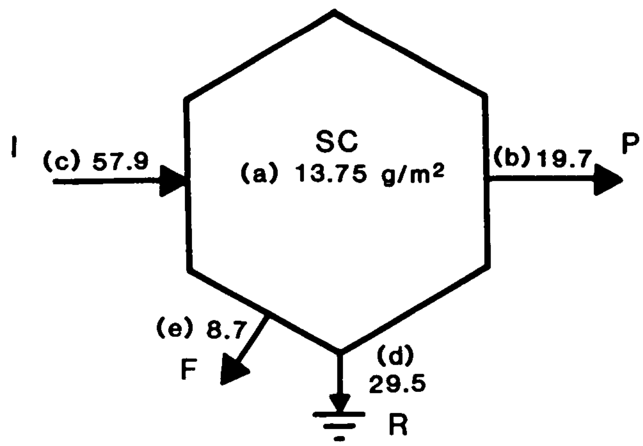


Figure 27. Fresh open water habitat fish energy budget.
(a) Standing crop: Average annual standing crop for Lac des Allemands equals 13.75 g/sq m (Lantz 1970) (Table 84).
(b) Production: The production/standing crop ratio for Lake George, Uganda, a similar shallow, eutrophic lake, is 1.43/yr (Burgis and Dunn 1978). (13.75 g/sq m x 1.43/yr = 19.7 g/sq m/yr.)
(c) Ingestion: 34% of ingestion in Lake George goes toward growth (production) (Burgis and Dunn 1978). (0.34 x I = 19.7 g/sq m/yr, I = 57.9 g/sq m/yr.)
(d) Respiration: Production plus respiration account for on the average 85% of ingestion in fish (Winberg 1956). (19.7 g/sq m/yr + R = 0.85 x 57.9 g/sq m/yr, R = 29.5 g/sq m/yr.)
(e) Fecal production: Fecal production accounts for on the average 15% of ingestion in fish (Winberg 1956). (0.15 x 57.9 g/sq m/yr = F, F = 8.7 g/sq m/yr.)

10. FRESH SCRUB/SHRUB

The scrub/shrub habitat is found in freshwater areas that are too dry or not flooded frequently enough to support marsh. Broad-leaved deciduous and evergreen shrubs are found in the habitat, including willow, cottonwood, and wax myrtle (Wicker 1980). Marshes invaded by baccharis, hackberry, button bush, and palmetto are also included as scrub/shrub habitat. The habitat contains both natural scrub/shrub communities as well as reclaimed wetlands with pioneer shrubs.

The scrub/shrub habitat is small in area, ranking 15th overall. It covered 13,187 ha in 1978 (0.4% of the total MDPR), an increase of more than 6000 hectares since 1955 (Wicker et al. 1980a). A map of the distribution of scrub/shrub habitat is shown in Figure 28.

Although scrub/shrub is found in all seven MDPR hydrologic units, more than 70% of this habitat exists within hydrologic units IV (Barataria), V (Terrebonne), and VII (Vermilion). All of the 4,000 ha of scrub/shrub in hydrologic units IV and V have been colonized by scrub/shrub vegetation since the 1950s.

Little ecological information on scrub/shrub habitat exists, and it was not selected for detailed modeling. The unquantified energy and material flow diagram for scrub/shrub is shown in Figure 29. It closely resembles the bottomland hardwood model, the most similar habitat for which more information is available.

11. MANGROVE

The black mangrove (*Avicennia germinans*) occupies a very small area in the MDPR (2955 ha in 1978; Wicker et al. 1980a), consisting of a fringe at the southernmost end of the region just inside the barrier islands. A map showing the distribution of mangrove habitat is shown in Figure 30.

Functionally, the black mangrove is an ecological analog of salt marsh grass (*Spartina alterniflora*) that grows in similar highly saline intertidal areas, produces organic matter (most of which decomposes to detritus), and has been linked to the support of fishery species. In addition, mangrove roots and stalks stabilize sediments and absorb storm wave energy, as do the stalks of *Spartina*.

This mangrove species is more abundant in coastal zones at lower latitudes (e.g., southern Florida) but its range is limited to about 29 N latitude because it cannot tolerate hard freezes. In the MDPR, freezes every 7 to 10 years result in dieback of the mangrove fringe. In the MDPR this plant is at the northern edge of its range and particularly vulnerable to additional cultural stress. The black mangrove's only occurrence in the northern gulf coast is in the MDPR. One has to travel east to near Cedar Key on the Florida gulf coast, or to the south Texas coast near Corpus Christi before encountering mangroves again. On the Atlantic coast of Florida, black mangroves occur as far north as Daytona Beach.

The distribution of mangroves within the MDPR reflects the salinity regime as well as climate. Mangroves are scarce in the Mississippi Delta and the Atchafalaya hydrologic units because of high freshwater input to these areas. They are absent from the Mississippi Sound unit, presumably because of low temperature, since other conditions are suitable for mangroves. Most of the mangrove area occurs in the Pontchartrain, Barataria, and Terrebonne hydrologic units.

Other than mapping, there have been essentially no biological studies of mangroves in the MDPR, so this habitat was not selected for detailed modeling. There is much information, however, on mangroves in the tropics that lends insight into the mangroves

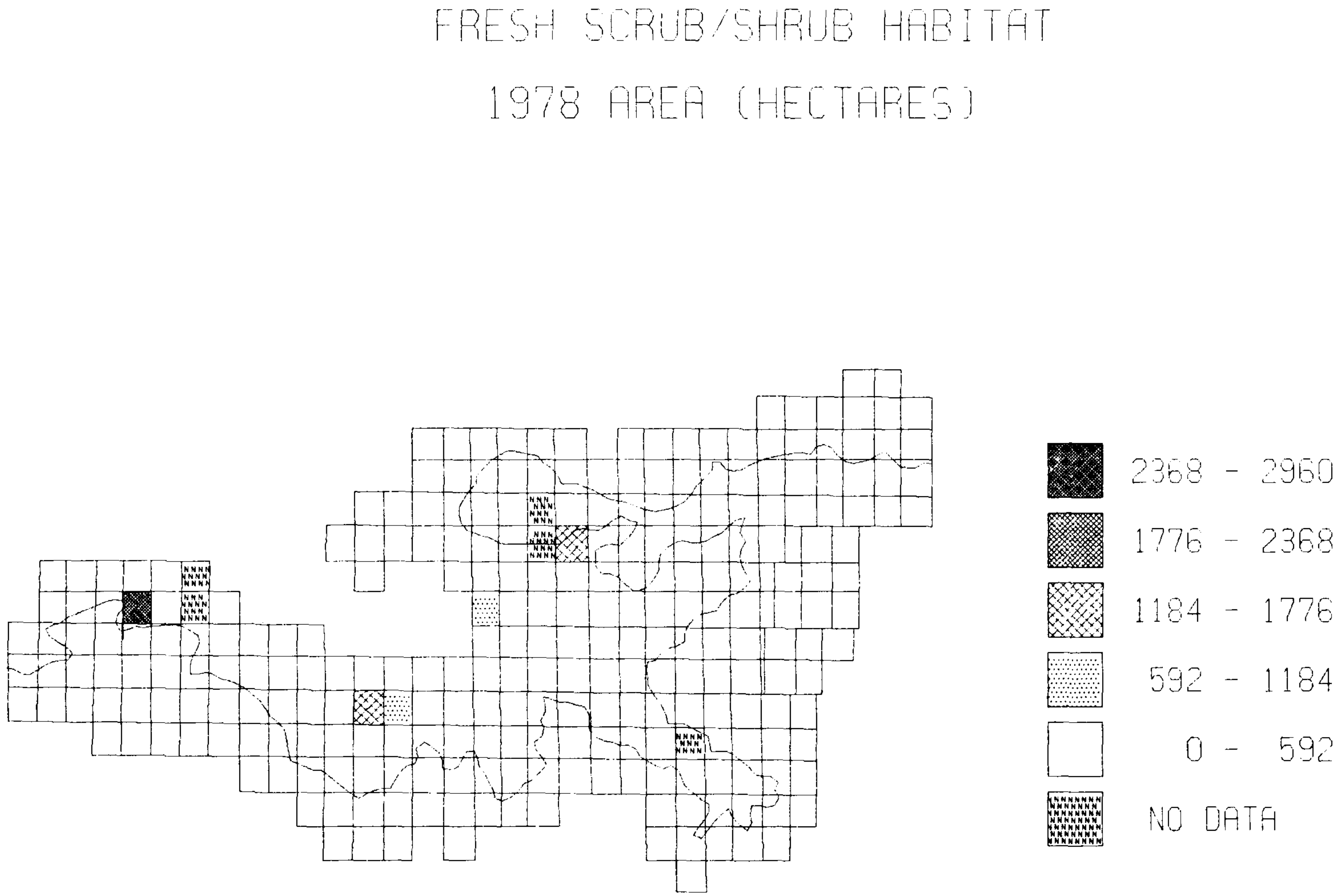


Figure 28. The distribution of MDPR fresh scrub/shrub habitat.

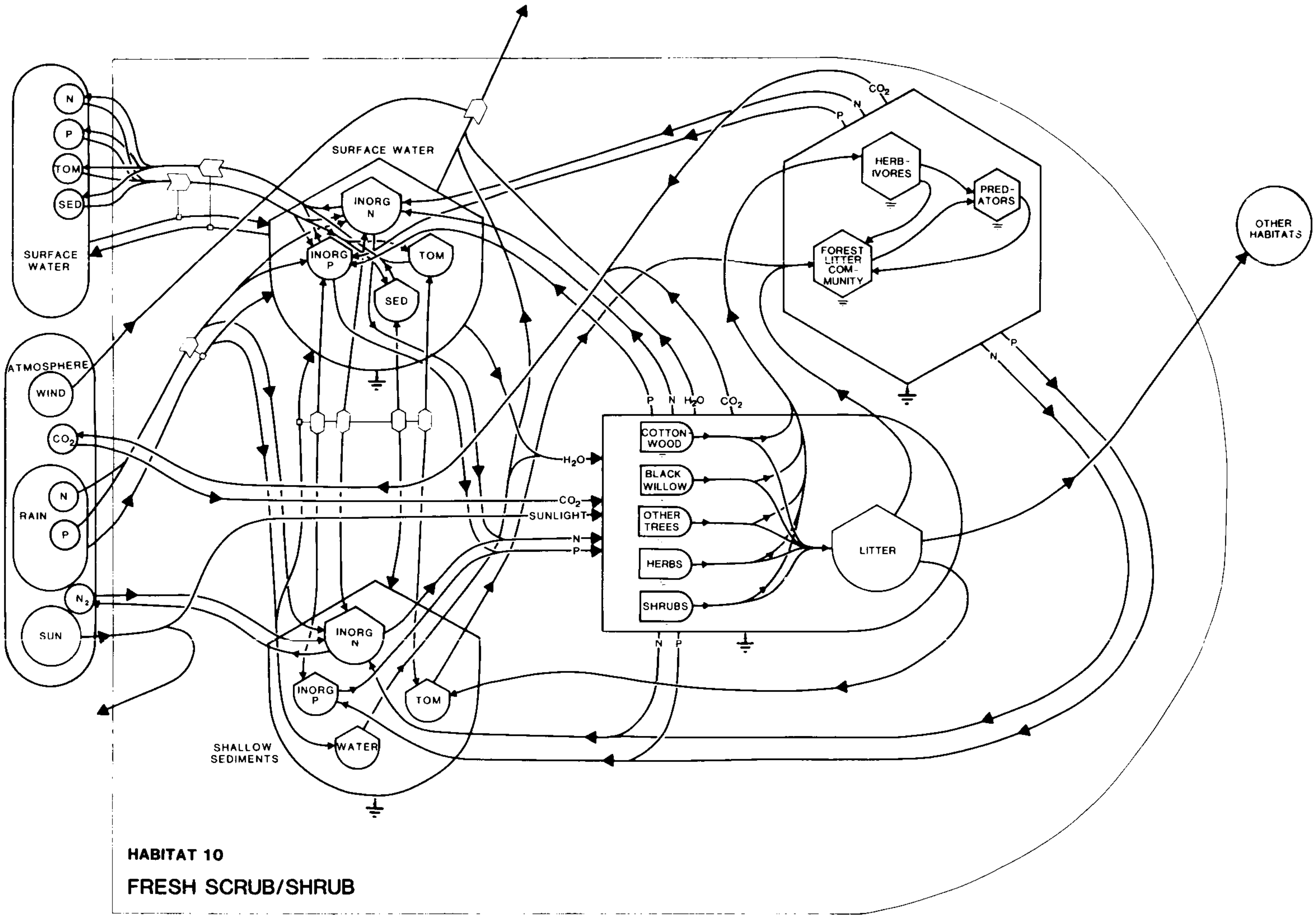


Figure 29. Fresh scrub/shrub habitat flow diagram.

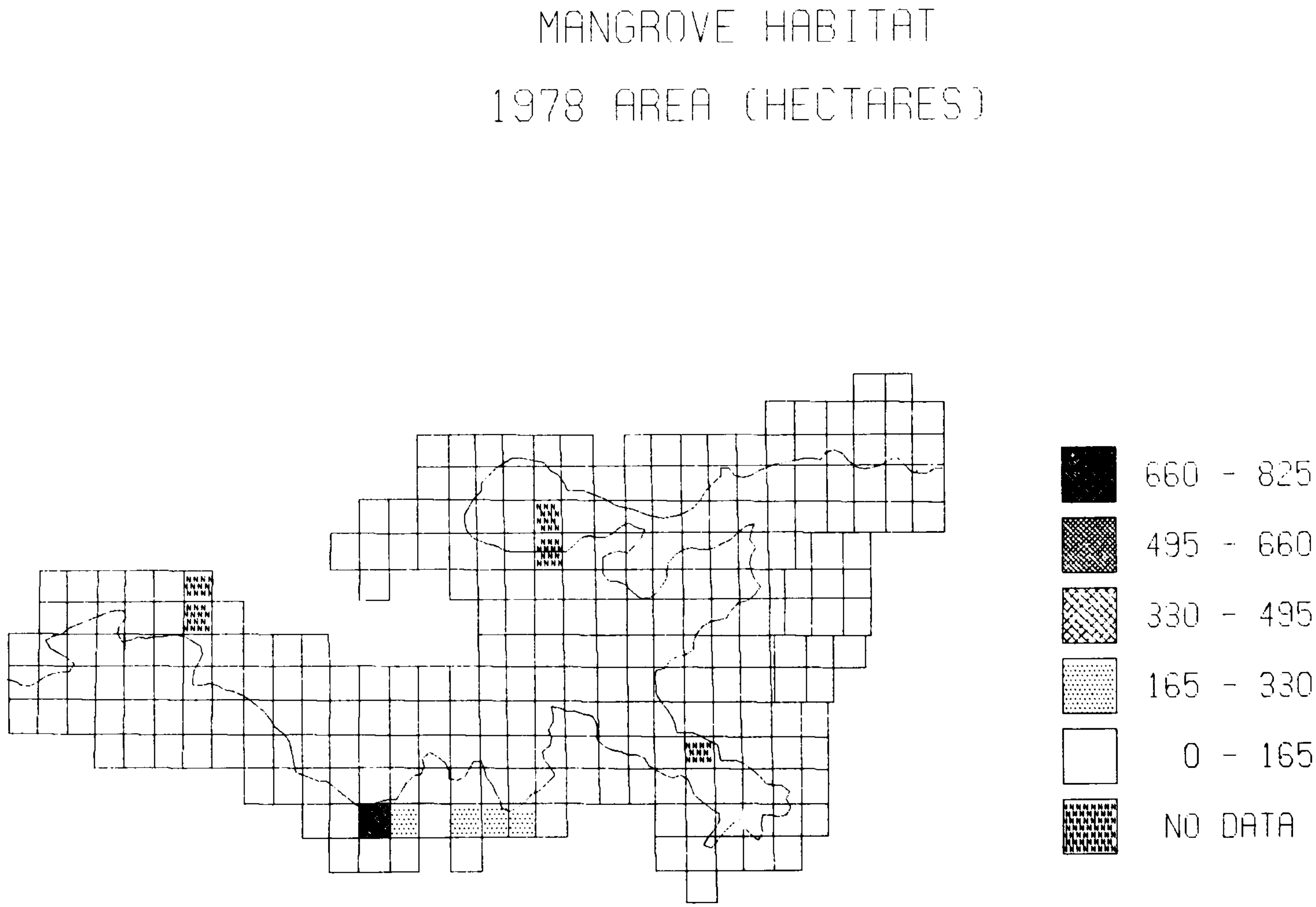


Figure 30. The distribution of MDPR mangrove habitat.

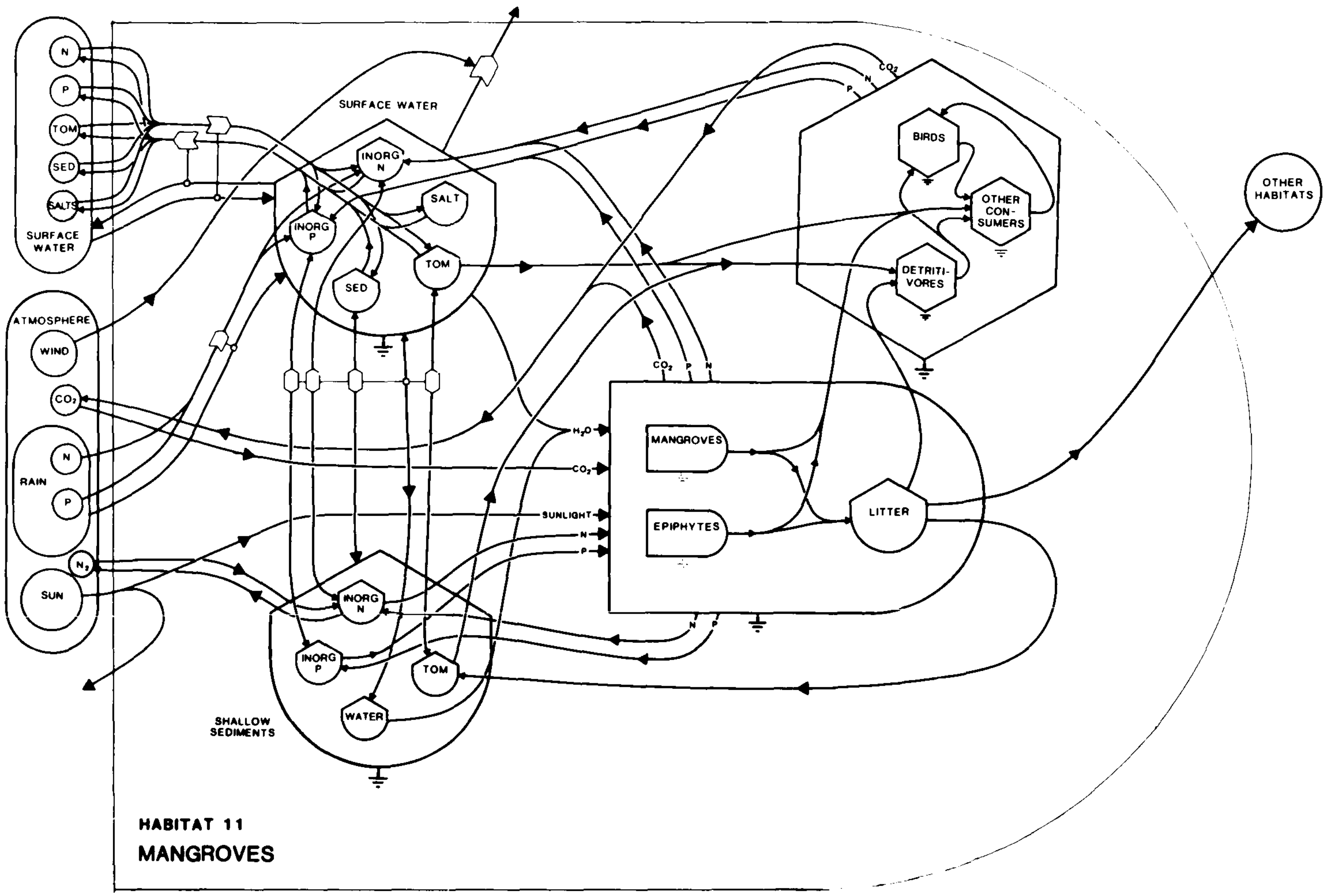


Figure 31. Mangrove habitat flow diagram.

of this region. The species that grows in Louisiana, Avicennia germinans, is one of three major species that are found in the New World tropics. The other two species are red mangroves (Rhizophora mangle) and white mangroves (Laguncularia racemosa). In tropical areas that have geomorphology and salinity similar to the MDPR, red mangroves usually occupy the wetland fringe. The red mangrove, however, is less tolerant to cold than is Avicennia, and does not occur in the MDPR.

Mangrove production rates as high as 3000 to 4000 g dry wt/sq m/yr have been reported. Review papers on mangrove swamps have been prepared by Walsh (1974), Lugo and Snedaker (1974), and Kuenzler (1974). As with salt marshes, the main factors that limit productivity are nutrients, salinity, and soil drainage characteristics. Most of the fauna in mangrove swamps are detritivores, and much of the production is exported.

The mangrove zone serves an additional vital role in the MDPR that salt marshes do not fill. The mangrove is a woody shrub that grows to a height of about 3 m, and provides extremely valuable elevated nesting sites over water for a number of species of wading birds, including egrets, herons, and ibises. Queen Bess Island behind Grand Terre Island is a small mangrove cay that is densely populated by pairs of nesting wading birds each spring. Unfortunately this island and many of its neighbors are diminishing in size each year because of erosion, making remaining mangrove area increasingly vital to the welfare of these birds.

The unquantified energy and material flow diagram for the mangrove habitat is shown in Figure 31.

12. MUD FLAT

Habitats classified as flats include several types of environments in the MDPR. However, 85% of the flats can be identified as one of three types: (1) unvegetated mud flats in estuarine areas, (2) unvegetated organic matter/mud deposits in estuarine and brackish areas, and (3) unvegetated mud flats in freshwater areas.

Flats in the MDPR covered 5160 ha in 1978 (Wicker et al. 1980a). A map of the distribution of the mud flat habitat is shown in Figure 32. Although this habitat is small in area, it is important in several respects. Mud flat soils contain organisms that are involved in nutrient recycling and the community found in this habitat supports higher level consumers. There have been only limited studies of mud flats in the MDPR; therefore most of what is known about the role of this habitat in estuarine systems is based on work done in other areas. This habitat was not selected for detailed modeling.

The most conspicuous characteristic of mud flats is the lack of vegetation, which gives the impression that this habitat is relatively unproductive. Although there are no large vascular plants found in this habitat, there are numerous forms of microalgae that grow on and in the sediments. Most of the algae are concentrated in the top 1 cm of sediment, although living algae are found as deep as 10 cm (Peterson and Peterson 1979). Blue-green algae (Oscillatoria sp., Microcoleus sp., and Spirulina sp.) and diatoms are the two most common groups found on and in mud flat sediments. While production in other habitats may be higher, much of the primary production on mud flats is consumed by benthic invertebrates in the sediments and directly converted into secondary production (Peterson and Peterson 1979).

Blue-green algae are nitrogen fixers. Casselman (1979) measured nitrogen-fixation rates in Louisiana mud flat soils in Barataria Bay and found rates of 1.56 gN/sq m/yr. During March, the mud flat was the site of more intense nitrogenase activity than that

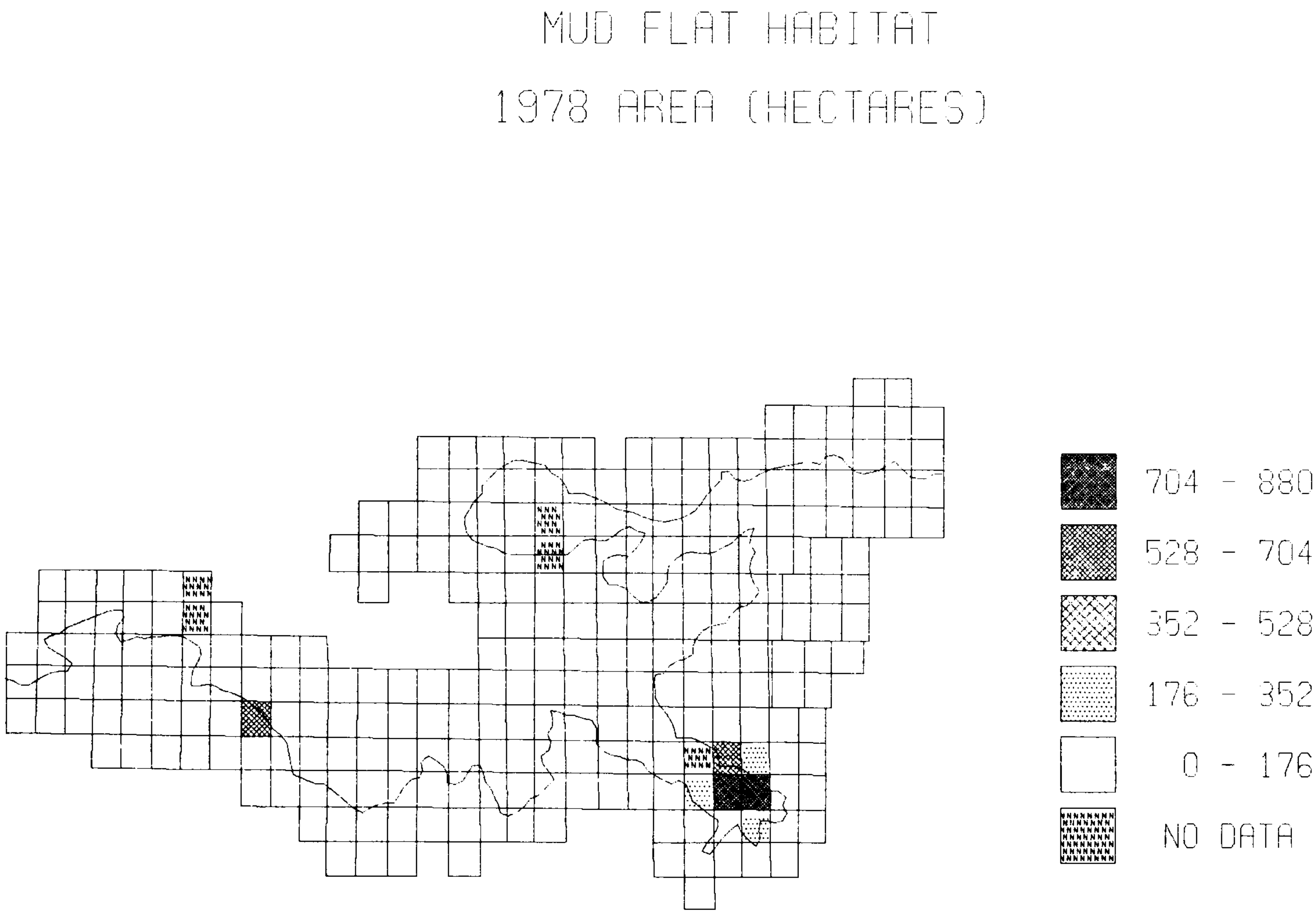


Figure 32. The distribution of MDPR mud flat habitat.

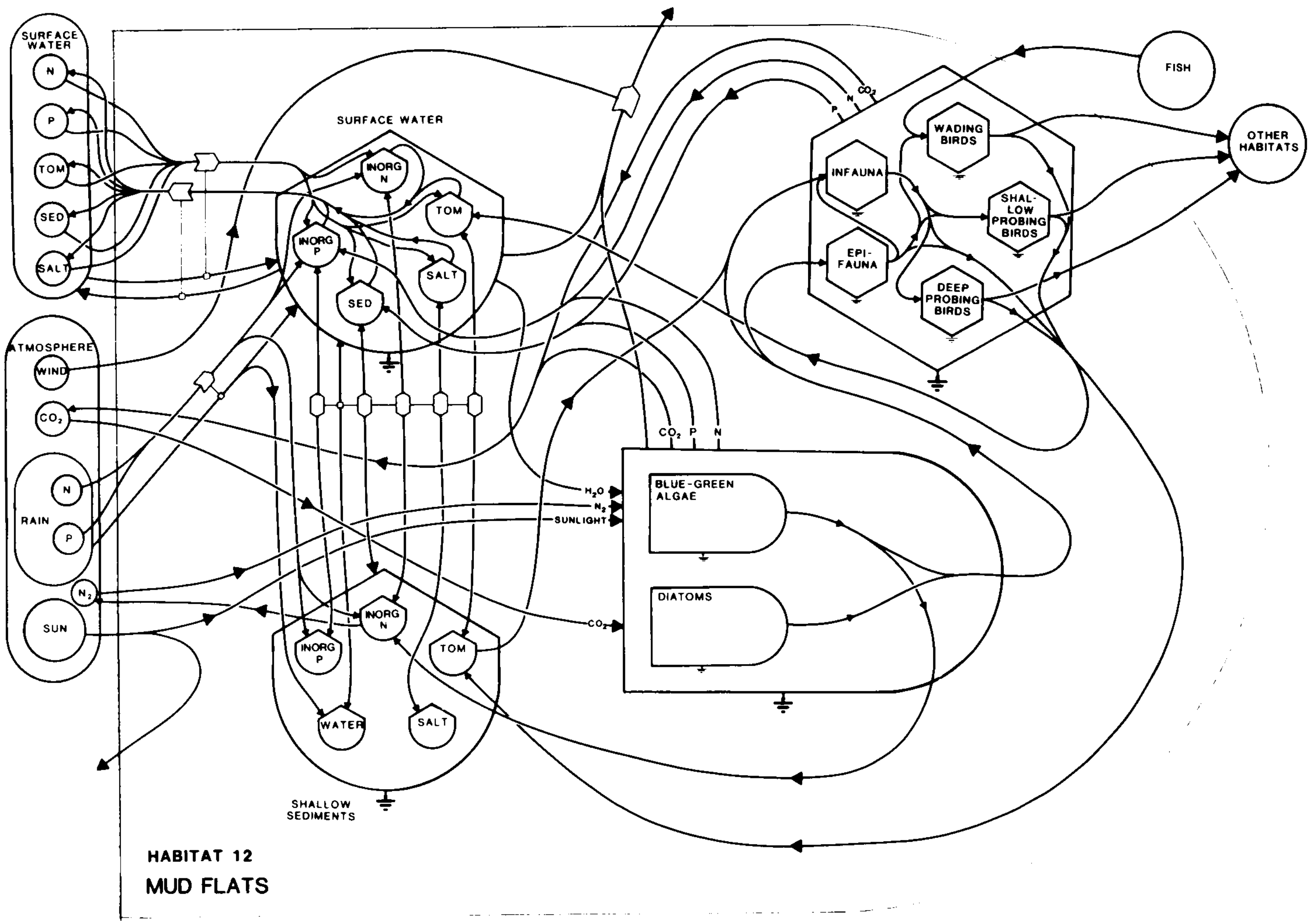


Figure 33. Mud flat habitat flow diagram.

in salt marsh soils in the same area. Bacteria and fungi are also numerous on mud flats. These two types of decomposers are also important in the process of converting detritus to inorganic nutrients. Wolaver et al. (1980) found that mud flats play an important role in the nutrient exchange between habitats in estuarine systems. As water flows over the mud flat during periods of tidal flooding, nutrients are released from the sediments to the overlying water to be carried to the adjacent marshes and utilized by organisms in the water column.

Microalgae associated with mud flat sediments are consumed by many species of benthic invertebrates. Both suspension feeders and deposit feeders are found in intertidal flats. Oysters are the most common suspension feeders found in this habitat (oyster reefs account for approximately 6% of the total area of this habitat). Benthic organisms found in the mud flat can be divided into two groups--the infauna, burrowing organisms that live in the sediment, and the epifauna, organisms that live on the surface of the mud flat. These organisms represent an important food source for other higher level consumers, particularly birds.

There are several groups of shorebirds that feed primarily on mud flats. The three most important groups are wading birds, shallow-probing birds, and deep-probing birds (Peterson and Peterson 1979). Most wading birds are fish eaters, although some species also consume shellfish, fiddler crabs, and other small crustaceans that are found on mud flats. Most of these birds fish in the shallow water adjacent to the mud flat or in tidal pools on the surface of the flat. Shallow-probing birds include several species of sandpipers, plovers, oystercatchers, rails and dowitchers. Many of these species depend on mud flats for most of their food. These birds are opportunistic feeders and consume those species of infauna that are most abundant. Some birds feed on the insects and crustaceans found on the surface of the mud flat. Deep probing birds are able to feed on larger invertebrates and include willets, long-billed curlews, godwits, and whimbrels.

Areas where the tide level fluctuates enough to regularly cover the mud flat serve as nursery grounds for fish. But since mud flats in the MDPR are of low tidal range, it is unlikely that they are critical areas for fish.

Until this habitat has been investigated further, it will be difficult to assess the role it plays in nutrient regeneration and food supply to higher trophic organisms. The evidence suggests that mud flats may be a critical habitat for certain species of birds and may play an important role in nutrient processing in estuarine and freshwater areas. Despite the small area encompassed by mud flats, they represent productive areas where primary production is consumed and transformed into various forms of animal biomass.

The unquantified energy and material flow diagram for mud flats is shown in Figure 33.

13. NEARSHORE GULF

The nearshore gulf habitat is found in highly saline open water bodies having high wave energy (Wicker 1980). The nearshore gulf is found exclusively to the east of the Chandeleurs and to the south of the Mississippi Gulf Islands. This habitat is not found west of the Mississippi River, because of the freshwater inputs from the Mississippi and Atchafalaya Rivers.

Nearshore gulf is the sixth largest habitat in the MDPR, containing 116,569 ha in 1978, or 3.4% of the total land and water area (Wicker et al. 1980a). Of this, 65% is found in the Pontchartrain hydrologic unit. A map of the distribution of the nearshore gulf habitat is shown in Figure 34.

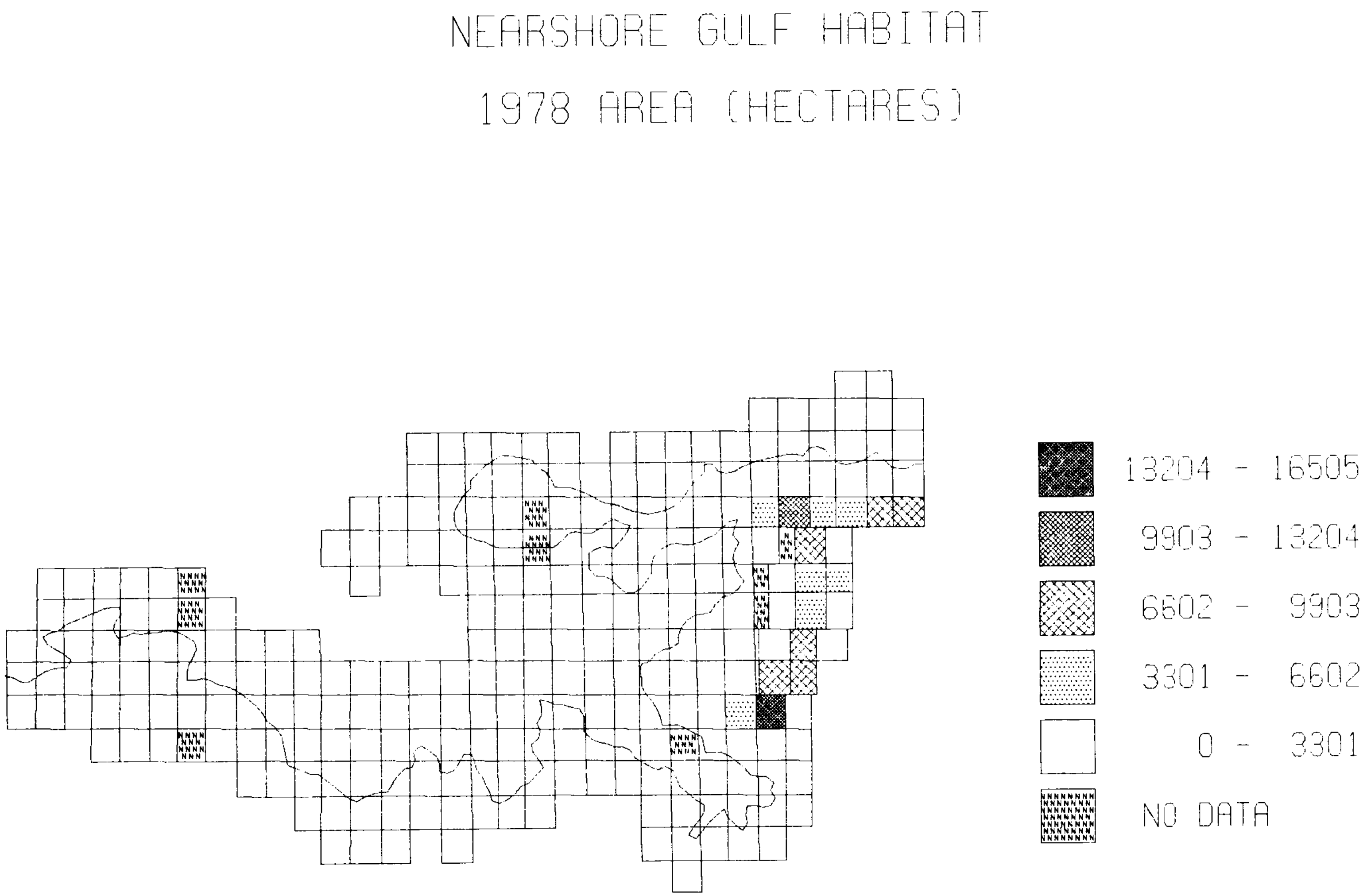


Figure 34. The distribution of MDPR nearshore gulf habitat.

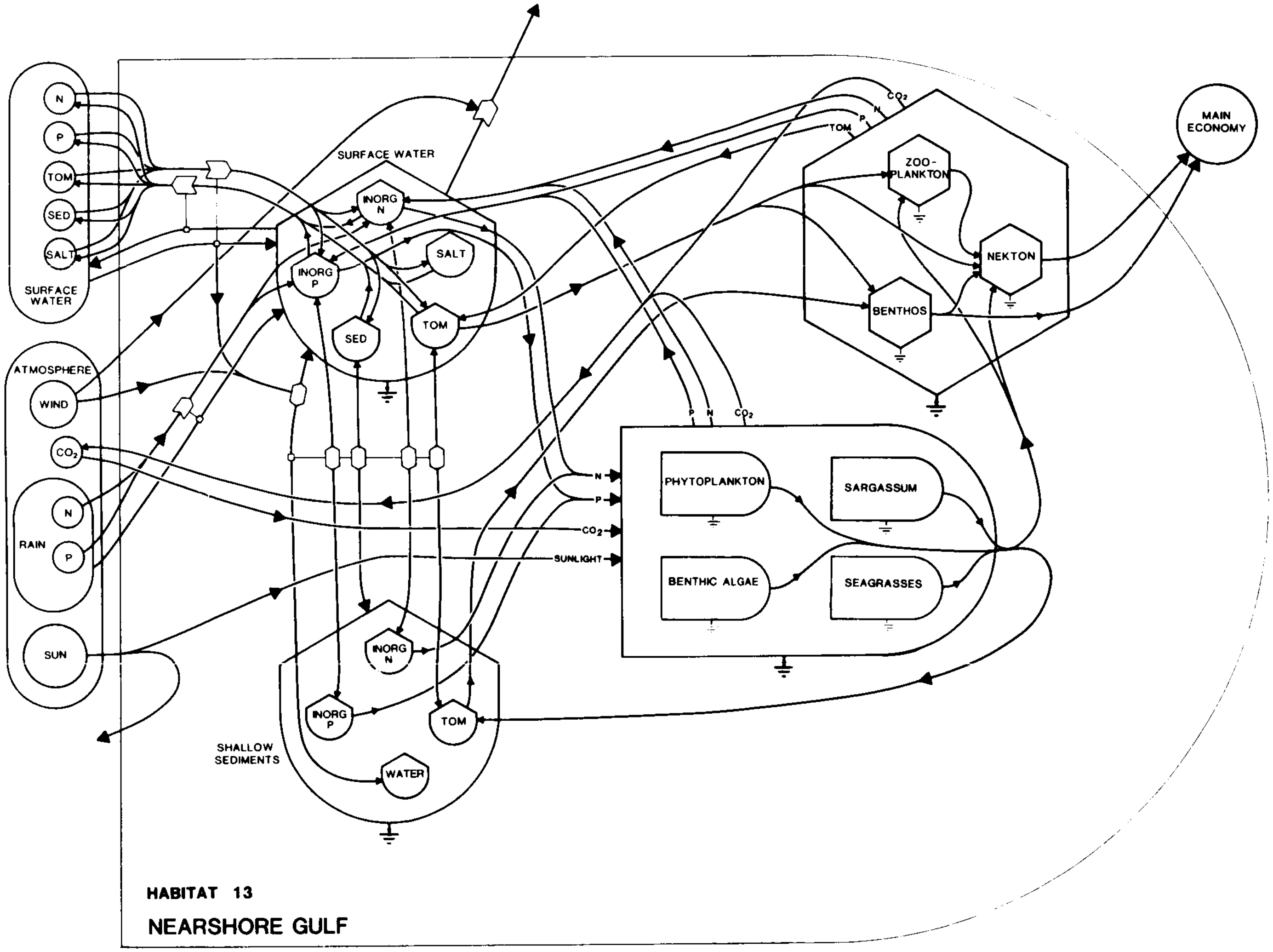


Figure 35. Nearshore gulf habitat flow diagram.

Ecological studies of this habitat are few and it was not selected for detailed modeling. One of the main sources of data is a study by Franks et al. (1972), who investigated nutrient chemistry, benthic fauna, and nekton. Two of their six sampling stations were located in the nearshore gulf.

Surface concentrations of nitrate in the nearshore gulf averaged 0.68 ug-at/l, with bottom concentrations of 0.38 ug-at/l. Nitrite was not detected in these waters. Total phosphate concentrations in surface and bottom waters averaged 1.75 and 1.78 ug-at/l, respectively. Bottom sediments at these sites were silty, containing much organic matter.

Oxygen concentrations of nearshore gulf bottom waters are often below saturation, particularly during the summer months (Fotheringham and Weissberg 1979; Hann and Randall 1980, Turner and Allen, unpublished). Stratification caused by freshwater discharge from the Mississippi and Atchafalaya rivers, respiration by benthos or sinking phytoplankton, and respiration of organic matter in river discharge have been proposed as causes for low oxygen levels (Fotheringham and Weissberg 1979; Turner and Allen, unpublished). Respiration values of 1 mg oxygen/cu m/hr coupled with observed stratification could cause low oxygen values, assuming no water exchange, reaeration, or photosynthesis in this zone (Turner and Allen, unpublished).

The major primary producers in the nearshore gulf are benthic algae, seagrasses, and sargassum (Earle 1972). The majority of the phytoplankton found are diatoms (Franks et al. 1972). Common marine invertebrates found in this area are the sea pansy (*Renilla mulleri*), brown shrimp (*Penaeus aztecus*), squid (*Lolliguncula brevis*), and mantis shrimp (*Squilla empusa*) (Franks et al. 1972). Copepods make up the majority of zooplankters found in this habitat. Other invertebrates studied in this area are amphipods (Stuck et al. 1980) and cnidarians (Burke 1975, 1976). The most abundant benthic fish in this habitat are croaker (*Micropogonias undulatus*), longspined porgy (*Stenotomus caprinus*), spot (*Leiostomus xanthurus*), and white trout (*Cynoscion arenarius*) (Franks et al. 1972). The nearshore gulf is also used by menhaden for spawning (Christmas and Waller 1975).

The unquantified energy and material flow diagram for nearshore gulf habitat is shown in Figure 35.

14. RIVER, STREAM, AND BAYOU

Historically, the Mississippi River and its distributaries have dominated the geology and ecology of MDPR wetland habitats. Currently, levees prevent annual overbank flooding in all but a few areas and limit the direct contact of river water with the wetlands. Today, the Mississippi River and its major distributary, the Atchafalaya River, act primarily as conduits, moving water, sediment, organic matter, and nutrients from the continent to Louisiana's estuarine open water areas.

Waters classified as rivers, streams, and bayous in the MDPR include swamp bayous, streams in freshwater marshes, and upland streams north of Lake Pontchartrain and in Mississippi. These habitats covered 37,504 ha in 1978 (Wicker et al. 1980a). A map of the distribution of river, stream, and bayou is shown in Figure 36. Because of lack of data and the great variation among riverine habitats, a detailed I-O model of this habitat was not constructed.

The combined Mississippi and Atchafalaya Rivers discharge is about 2.2 E13 cubic meters of water annually. The region's next largest river, the Pearl, carries about two orders of magnitude less water. The three rivers carry 2.7 E8 tons of sediment, 2.6 E7 tons of nitrogen, 4.9 E6 tons of phosphorus, and 1.7 E8 tons of organic carbon (Table 86).

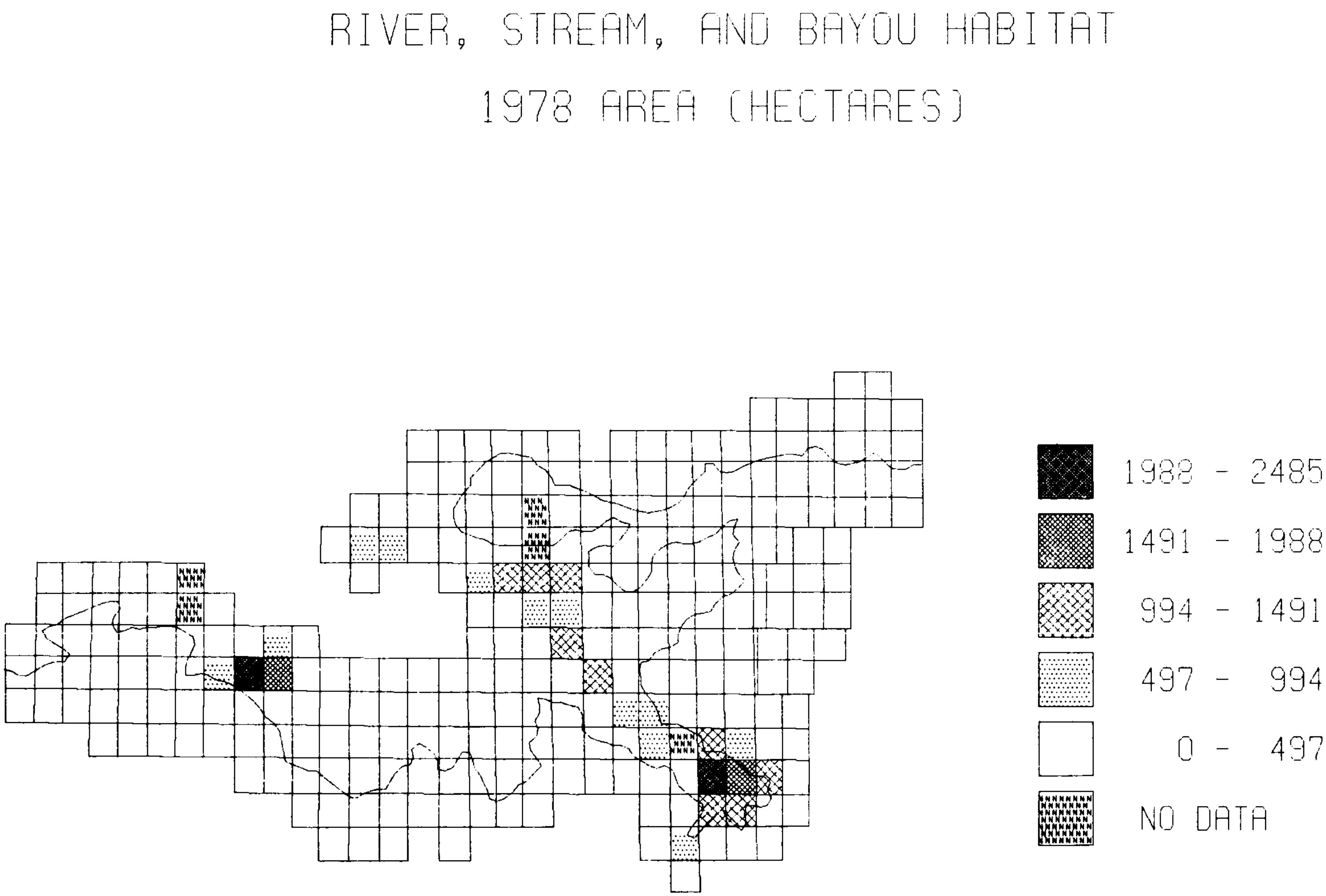


Figure 36. The distribution of MDPR river, stream, and bayou habitat.

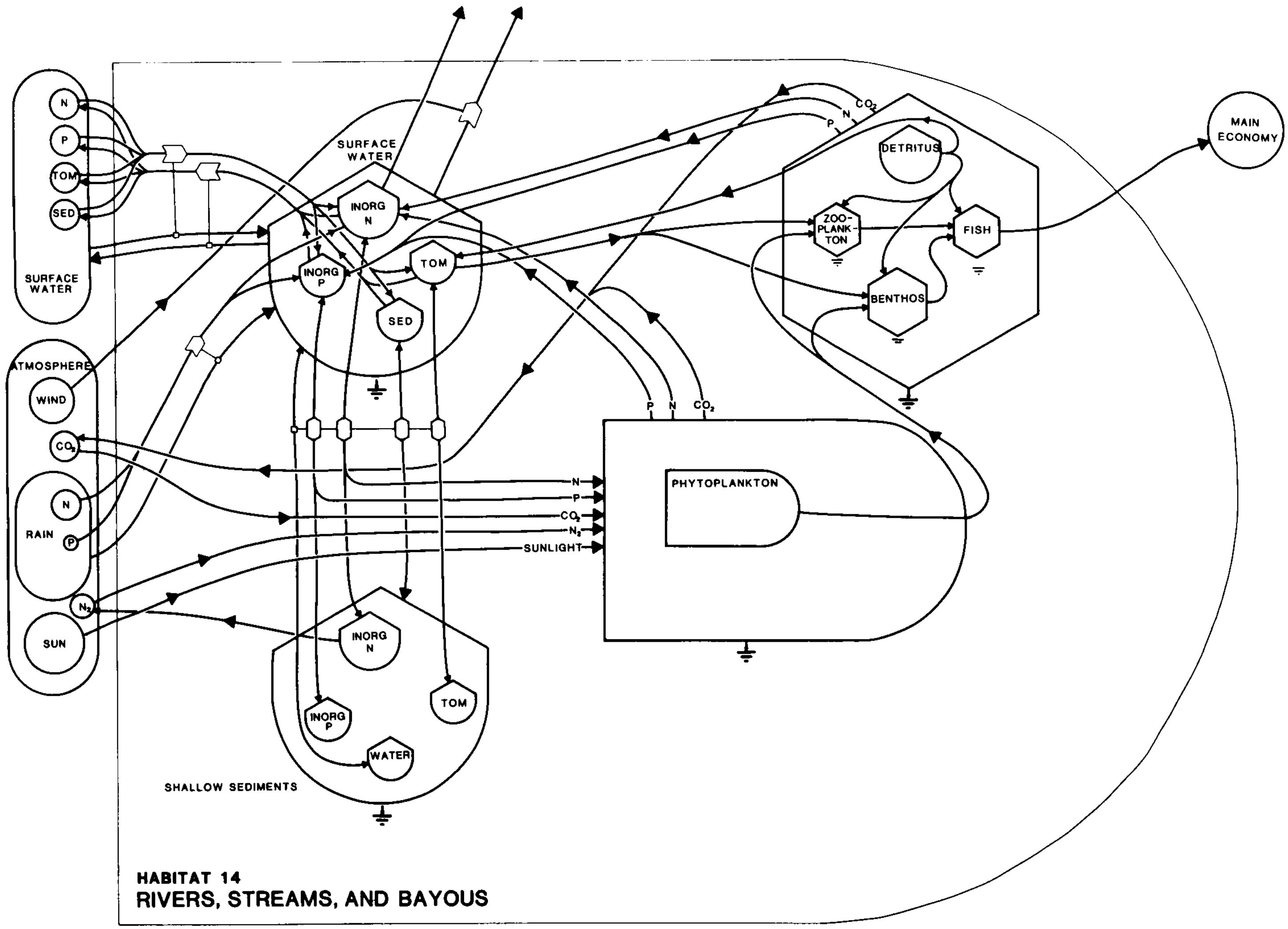


Figure 37. River, stream, and bayou habitat flow diagram.

Smaller streams and bayous are also important transporters of water and nutrients. Most of the water flow to Lake des Allemands in the swamp forest region of the upper Barataria Basin is carried through swamp bayous (Day et al. 1977). The trend toward greater channelization in the upper basin probably reduces the flow through natural channels and results in more rapid water movement out of the basin (Hopkinson and Day 1979). A Mississippi coastal plain stream studied by de la Cruz and Post (1977) carried between 36,000 and 538,000 kg of carbon per year.

Input from terrestrial habitats is the major source of organic matter for river and stream habitats (Hynes 1970). De la Cruz and Post (1977) calculated an input of particulate organic matter of about 400 g/sq m/yr for a Mississippi stream. Day et al. (1982) estimated annual organic matter loading into swamp bayous in the des Allemands region of Barataria Basin at 2.5% of net primary production.

Respiration exceeds production in rivers, streams, and bayous. Day et al. (1977) estimated bayou gross primary production at 229 g dry wt/ sq m/yr and community respiration at 298 g dry wt/sq m/yr. Bayou production is generally less than lake production because of shading by bordering trees.

The unquantified energy and material flow diagram for the river, stream, and bayou habitat is shown in Figure 37. Major rivers and bayous differ from non-flowing fresh open water areas in their community composition. Primary production, although still dominated by phytoplankton, is low. Except in a few shallow areas, benthic algal production is limited in MDPR rivers because of high turbidity. Zooplankton population levels are low. High concentration of organic matter in rivers and bayous supports a large benthic population, adapted to life in the current.

Small streams are insignificant in area and are a minor component of the river, stream, and bayou habitat.

15. ESTUARINE AQUATIC BED

Estuarine aquatic beds, also called seagrasses or submerged aquatic vegetation, are subtidal beds of generally rooted aquatic vegetation. This habitat occupied 14,319 ha in the MDPR in 1978 (Wicker et al. 1980a). A map of the distribution of estuarine aquatic bed habitat is shown in Figure 38. Although this area is relatively small, these beds have value as a habitat for many commercially important nekton species.

Studies of estuarine aquatic beds in the MDPR have mostly been descriptive, i.e., mapping and identification (Eleuterius 1973; Montz 1978; Turner et al. 1980). A detailed I-O model of the habitat was not constructed. The principal submergent macrophytes encountered in Louisiana are *Ruppia maritima*, *Vallisneria americana*, *Najas guadalupensis*, and *Potamogeton perfoliatus*. *Thalassia testudinum* has also been reported from the Chandeleur Islands in the Pontchartrain hydrologic unit. *Thalassia testudinum* and *Halodule wrightii* are the dominant seagrasses in Mississippi Sound.

The main factors that limit the distribution and production of submerged grassbeds are salinity, nutrient concentrations, and light. The two species of submergent macrophytes most commonly reported in estuarine waters are eelgrass (*Zostera marina*), from temperate latitudes, and turtle grass, (*Thalassia testudinum*), from the tropics. The salinity optimum for these species is in the range of 15 to 35 ppt. Within the MDPR, characteristically low salinities can prohibit colonization by these species.

The limited areal distribution of estuarine aquatic beds in the MDPR is presumably a result of low light rather than nutrient limitation. Most U. S. coastal areas where submerged grass beds occur are less turbid than in the MDPR, and submergent macrophytes

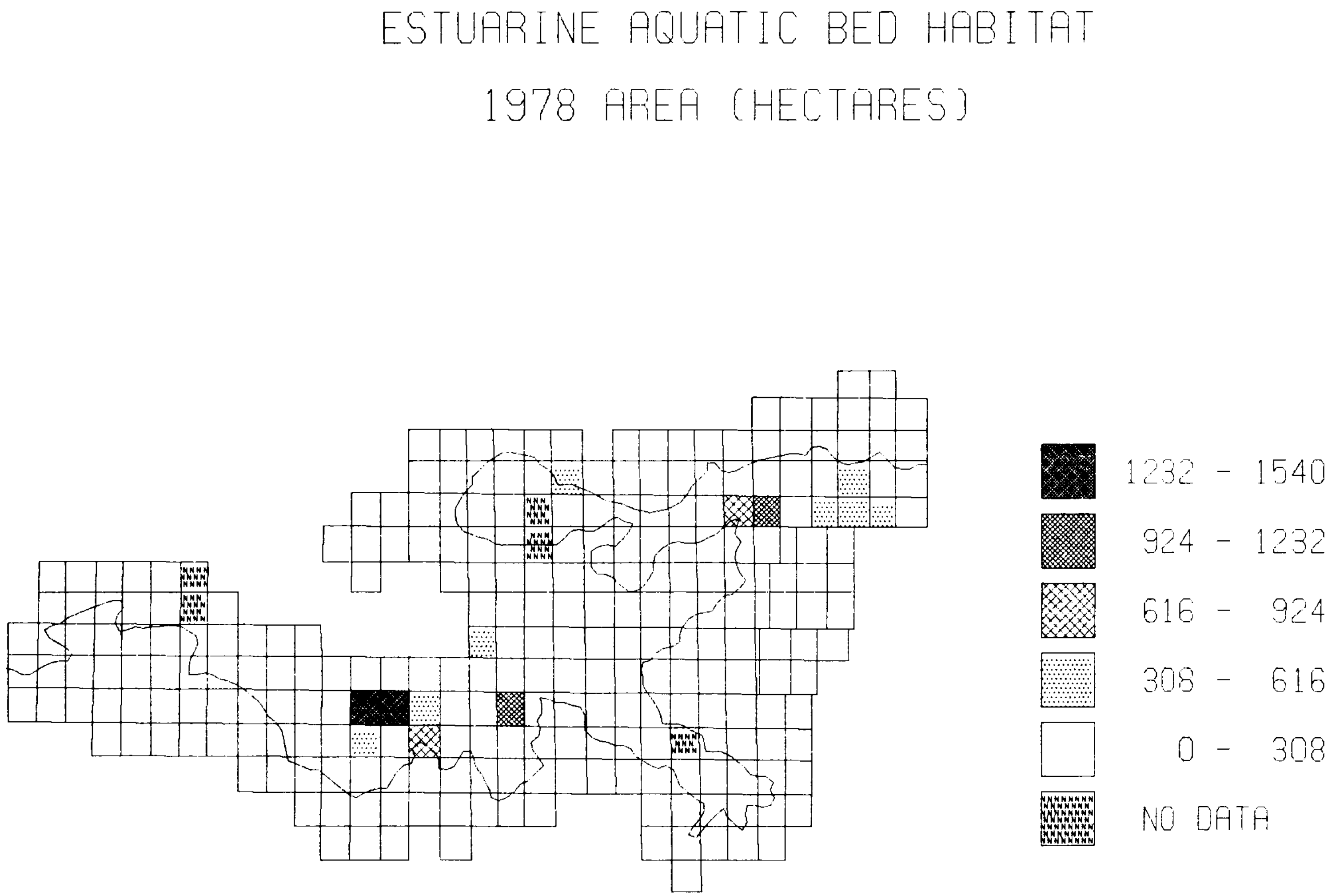


Figure 38. The distribution of MDPR estuarine aquatic bed habitat.

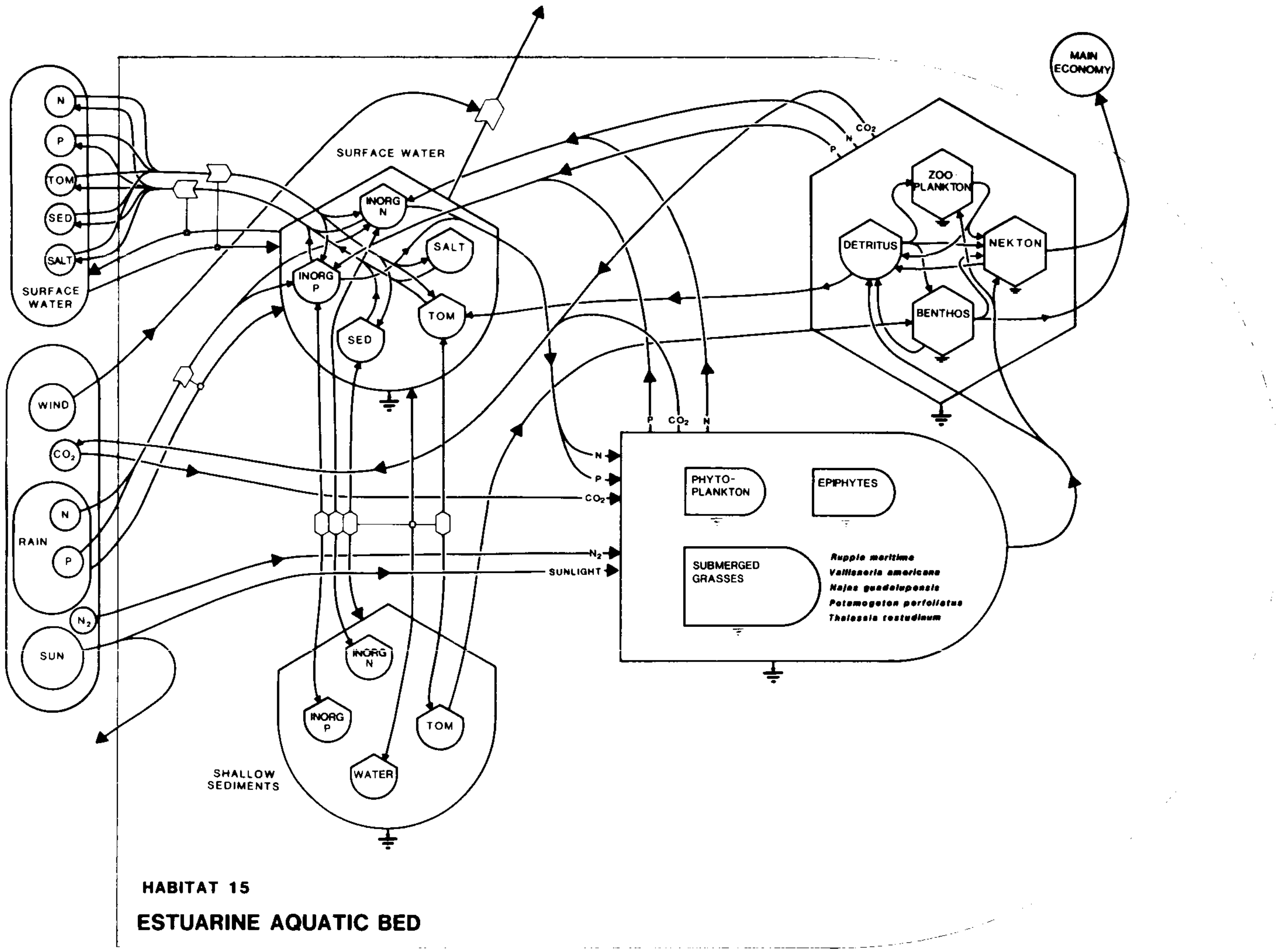


Figure 39. Estuarine aquatic bed habitat flow diagram.

are reported in water as deep as 10 m. Nutrient levels in very clear waters are typically very low, however, and in many areas submergent macrophytes may be limited by low levels of nutrients. Open water areas in the MDPR are, by contrast, nutrient rich and turbid, and submergent macrophytes are therefore rarely found in waters more than 1 m deep, except in Mississippi Sound. This suggests that turbidity is the major limiting factor.

The distribution of estuarine aquatic beds within individual hydrologic units supports this hypothesis. The Mississippi Delta, Atchafalaya, and Vermilion units have small areas of estuarine aquatic beds. These units are riverine-influenced and have high turbidity. The Terrebonne and Mississippi Sound units have greater areas of submerged aquatic vegetation. The Mississippi Sound hydrologic unit contains the greatest density of seagrasses, which is to be expected, since the clearer waters there favor the growth of submerged aquatic vegetation.

Although there are few studies on estuarine aquatic beds in the MDPR, extensive literature on seagrasses in other areas gives insight into the role of this habitat. Seagrasses in coastal marine and estuarine ecosystems constitute a unique shallow-water community. They are widespread throughout the world and make a substantial contribution to overall coastal productivity (McRoy and McMillan 1977). Most work has focused on the two commonest species, eelgrass and turtlegrass. Annual production is extremely high and ranges from about 500 gC/sq m/yr in the temperate zones to 1000 gC/sq m/yr in the tropics. Primary production in seagrass communities is divided among several components: sea grass, benthic macro- and microalgae, epiphytic algae, and phytoplankton. Jones (1968) and Penhale (1977) determined that 18 to 20% of total productivity of the habitat was contributed by epiphytes attached to sea grass.

In spite of the high rate of production in grass beds, only a few heterotrophs are known to utilize macrophyte tissue directly (Fenchel 1977; Zieman et al. 1979). A grazing trophic web is supported predominantly by phytoplankton, epiphytes, and benthic microalgae. The largest percentage of fixed carbon flows through a detritus-based food web dominated by vascular plant input (Thayer et al. 1975). Utilization of dead particulate matter from seagrass involves a diversity of organisms with complicated food interrelationships.

Although studies of fauna abound, there are few studies that have dealt quantitatively with the trophic network and dynamics beyond the detritus stage (Kikuchi and Pérès 1977). Seagrass habitats characteristically contain a high density of animals and a concomitantly high rate of secondary production. Such high rates of secondary production are attributed to detritus production and to the seagrass substrate that acts as a refugium for stabilizing sediments and for creating micro-habitats (Thayer et al. 1975; Kikuchi and Pérès 1977). The beds serve as important nursery and feeding areas for many marine nekton species (Yanez-Arancibia et al. 1980). Recent indications show a considerable transport of seagrass offshore, where it may serve as food for both surface and benthic feeding organisms.

The unquantified energy and material flow diagram for the estuarine aquatic bed habitat is shown in Figure 39.

16. ESTUARINE OPEN WATER

Estuarine open water habitat covered 56% of the MDPR, or 1,922,122 ha in 1978 (Wicker et al. 1980a), more than four times the area of any other habitat in the region. A map of the distribution of estuarine open water habitat is shown in Figure 40.

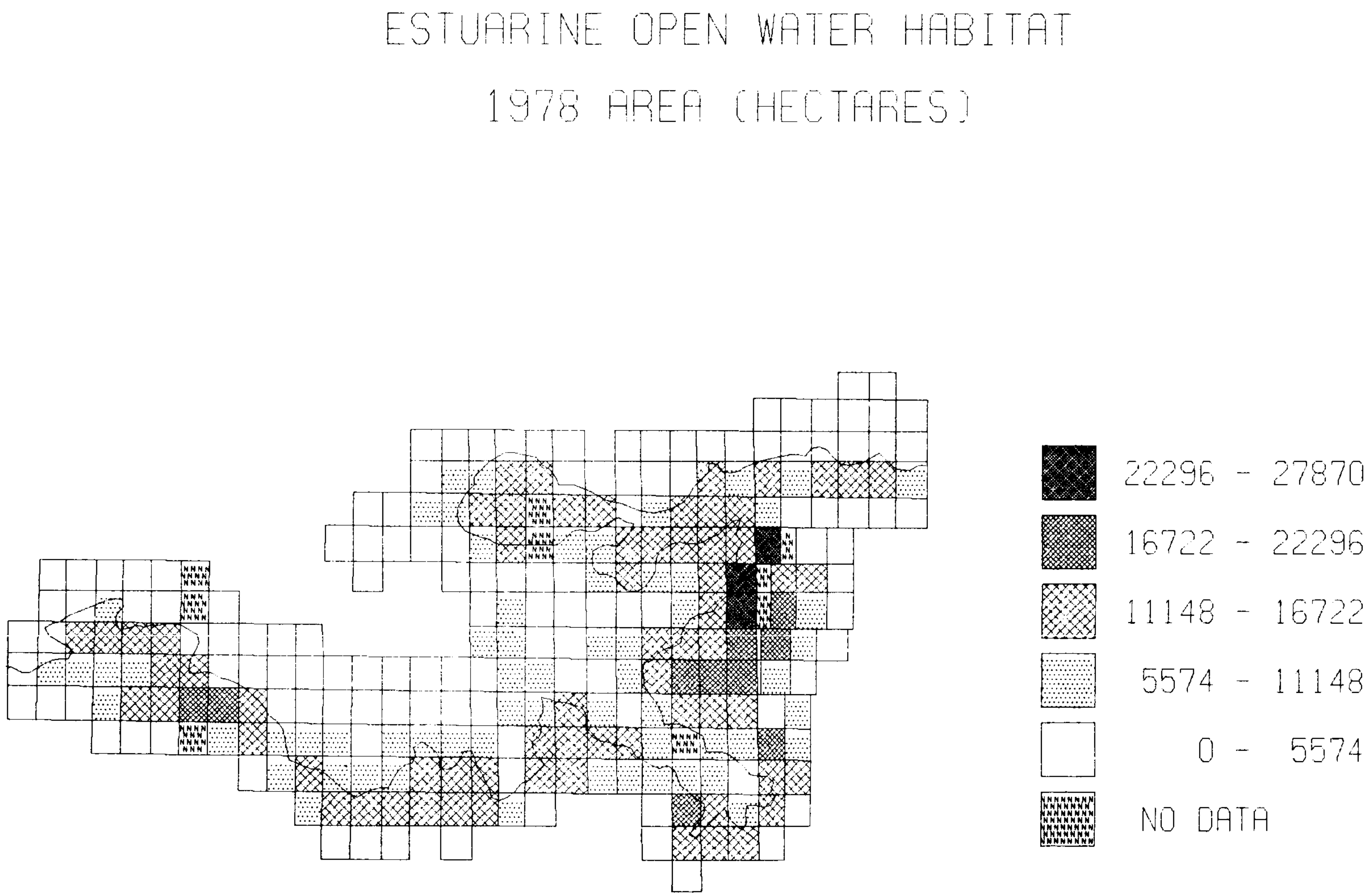


Figure 40. The distribution of MDPR estuarine open water habitat.

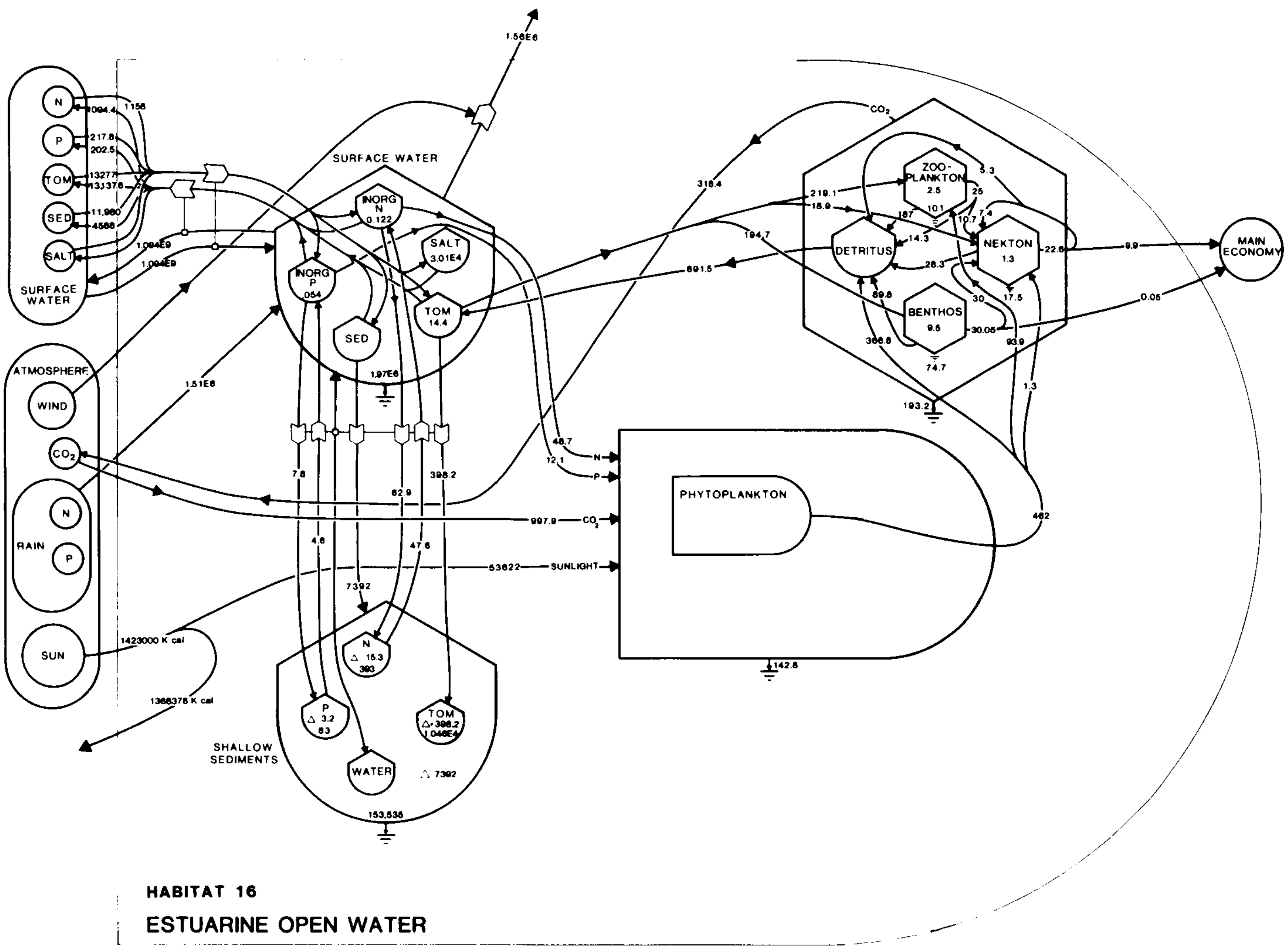


Figure 41. Estuarine open water habitat flow diagram.

Table 85. Input-output table for estuarine open water habitat.

HABITAT 16 ESTUARINE OPEN WATER

COMMODITIES		PROCESSES: SURFACE WATER 1	SEDIMENT 2	PHYTOPLANKTON 3	ZOOPLANKTON 4	BENTHOS 5	NEKTON 6	DETRITUS 7	IMPORTS & EXPORTS 8	CHANGE IN STORAGE 9	TOTAL	UNITS
WATER	1	1.096 1.096 1.97							1.096 1.096		2.192 2.192 1.97	10^6 g $H_2O/m^2/yr$ 10^6 g $H_2O/m^2/yr$ 10^6 g H_2O/m^2
INORGANIC NITROGEN	2	1206.0 1206.0 0.122	62.9 62.9 393	48.7					1094.4 1158.4	15.3	2427.3 2427.3 393.122	g $N/m^2/yr$ g $N/m^2/yr$ g N/m^2
INORGANIC PHOSPHORUS	3	222.4 222.4 0.054	7.8 7.8 83	12.1					202.5 217.8	3.2	448.0 448.0 83.054	g $P/m^2/yr$ g $P/m^2/yr$ g P/m^2
CARBON DIOXIDE	4			997.9	166.7	122.8	28.9		318.4 997.9		1316.6 1316.6	g $CO_2/m^2/yr$ g $CO_2/m^2/yr$
TOTAL ORGANIC MATTER	5	13,968.5 13,968.5 14.4	398.2 398.2 10,456		219.1 187.0	194.7 89.8	18.9 28.3	305.1 691.5	13,137.6 13,277	398.2	28,640.3 28,640.3 10,470.4	g $TOM/m^2/yr$ g $TOM/m^2/yr$ g TOM/m^2
INORGANIC SEDIMENTS	6	11,980 11,980	7392 7392 153,535						4588 11,980	7392	33,362 33,362 153,535	g $sediment/m^2/yr$ g $sediment/m^2/yr$ g $sediment/m^2$
SALT	7	30,060									30,060	g $salt/m^2$
PHYTOPLANKTON BIOMASS	8			462.0	93.9		1.3	366.8			462.0 462.0	g dry $wt/m^2/yr$ g dry $wt/m^2/yr$
ZOOPLANKTON BIOMASS	9				25 2.5		10.7	14.3			25.0 25.0 2.5	g dry $wt/m^2/yr$ g dry $wt/m^2/yr$ g dry wt/m^2
BENTHOS BIOMASS	10					30.05 9.5	30.0		0.05		30.05 30.05 9.5	g dry $wt/m^2/yr$ g dry $wt/m^2/yr$ g dry wt/m^2
NEKTON BIOMASS	11						7.4 22.6 1.3	5.3	9.9		22.6 22.6 1.3	g dry $wt/m^2/yr$ g dry $wt/m^2/yr$ g dry wt/m^2
HEAT	12			642.6	454.4	336.2	78.8		1512.0		1512.0 1512.0	k $cal/m^2/yr$ k $cal/m^2/yr$
SUNLIGHT	13			53,622					1,369,378 1,423,000		1,423,000 1,423,000	k $cal/m^2/yr$ k $cal/m^2/yr$

Estuarine open water in the MDPR varies in type from small ponds in saline or brackish marshes to vast offshore areas on the gulfward side of barrier islands. The salinity of this habitat ranges from near zero in inland lakes that are only occasionally influenced by coastal waters to about 30 ppt offshore. Some areas of estuarine open water are dominated by the freshwater discharges of the Mississippi or Atchafalaya Rivers.

The task of this project has been to construct a model for a generalized, or "average," MDPR estuarine open water habitat. Whenever possible, a number of measurements from various areas of the region were averaged to obtain a general value for a given flow or storage. Productivity and nutrient concentration estimates were obtained in this way. Often, accurate data on particular flows were not available from several different coastal estuarine locations, and measurements of only one area were used as model input data. Nutrient and sediment accumulation in the sediments of Airplane Lake, Louisiana, are examples of the use of data from only one MDPR location. This necessarily makes the model more representative of this location.

In the model, the discharge of the Mississippi, Atchafalaya, and Pearl Rivers contributes water, nitrogen, phosphorus, total organic matter (TOM), and sediment to the estuarine open water habitat. These flows are shown in the upper left of Figure 41. The contributions of nitrogen and phosphorus from precipitation are insignificant compared to riverine inputs.

Water is lost from the estuarine open water habitat through evaporation and movement offshore (shown as an outflow of water in the upper left of the model). Nutrients, TOM, and sediment were assumed to be either deposited in the sediments or to flow offshore in surface water. Flows of materials to the sediments were calculated from measurements of accumulation in the sediments of Airplane Lake, Louisiana (DeLaune et al. 1981). Accumulations of materials in the sediment storage compartment are noted as a positive change (Δ) in storage. The remainder was assumed to be transported offshore.

Regeneration of nitrogen and phosphorus from the sediments to the water column was calculated from studies of Southeast Atlantic coast estuaries (Nixon 1981). No quantitative information was available on the resuspension of TOM or sediment. In the model, the flow of TOM and sediment from the water column to the sediment represents the net accumulation of these materials in the sediment. The annual average concentrations of nitrogen, phosphorus, TOM, sediment, or salt used in the model are shown in the storage tanks within the sediment or surface water.

Phytoplankton are the most important estuarine open water primary producers in the MDPR (Day et al. 1973). It was assumed that turbid waters limit benthic algal production to near zero in most regions of the coastal zone (Taylor 1960). Phytoplankton are composed primarily of green algae (*Chlorophyta*), blue-green algae (*Cyanophyta*), and diatoms. In Lake Pontchartrain, for example, green algae was 59% and blue-green algae 20% of the taxa sampled (Stone et al. 1980). The most abundant phytoplankters were *Lyngbya*, *Cryptomonas*, *Phacotus*, *Ankistrodesmus*, *Anabaena*, *Oscillatoria*, *Microcystis*, and *Chlamydomonas* (Stone et al. 1980). In more saline conditions in Barataria Bay, diatoms were most abundant, followed by green algae, and blue-green algae (Day et al. 1973). All were grouped as "phytoplankton" in the model.

Zooplankton make up a consumer group in the estuarine open water habitat. The copepod *Acartia tonsa* is the most abundant single zooplankton species in a variety of MDPR estuaries (Cuzon du Rest 1963; Gillespie 1971; Stone et al. 1980). A zooplankton energy budget based primarily on *Acartia* (Day et al. 1973) was used in the model.

Benthos were included as another consumer group in the model. Benthos include both meiobenthos (including amphipods, polychaetes, oligochaetes, harpacticoid copepods, and nematodes) and macrobenthos (including fiddler crabs, snails, mussels, oysters, and larger polychaetes). The commercial and recreational harvest of oysters was included as a flow of benthos to the main economy.

Nekton make up the third consumer group. Nekton include all fish, shrimp, and blue crabs. Lists of the most common MDPR nekton species are given by Day et al. (1973) and Thompson and Verret (1980). Commercial and recreational harvest of nekton make up an important component of the economy of the MDPR, and are shown as a flow to the main economy in the right side of Figure 41.

Food chain relationships among consumer groups were derived primarily from Darnell's (1961) study of Lake Pontchartrain.

Organic matter egested by consumers and production of plants and animals not consumed in the food chain accumulate as detritus. Detritus then contributes organic matter to surface water.

The estuarine open water habitat I-O table is shown in Table 85.

<u>Notes to Estuarine Open Water Habitat Model</u>

<u>Water</u>.

1,1,I Input of water to surface water. 1.096 E9 g/sq m/yr. Equal to the sum of inputs in runoff from the major rivers in the MDPR (1.094 E9 g/sq m/yr) (Table 86) and inputs in precipitation (1.51 E6 g/sq m/yr) (NOAA 1980). Average precipitation in New Orleans since 1940 equals 59.6 in/yr. (59.6 in/yr x 0.0254 m/in = 1.51 m/yr. One meter of rainfall equals E6 g/sq m).

1,1,O Output of water from surface water. 1.096 E9 g/sq m/yr. The total amount of surface water in the estuarine open water habitat was assumed to be in steady state, so total water inputs equal outputs. Output by evaporation was calculated to be 1.56 E6 g/sq m/yr. Total evaporation for Houma, Louisiana was reported by NOAA for the years 1977-1979 to be 63.1, 62.8, and 58.6 inches, respectively, yielding an average of 61.5 in/yr. (65 in/yr x 0.0254 m/in = 1.56 m/yr. One meter of rainfall equals E6 g/sq m). The outflow of surface water to offshore was calculated as the difference between total inflow (precipitation and runoff; 1,1,I) and evaporation, or 1.094 E9 g/sq m/yr.

1,1,S Storage of water in surface water. 1.97 E6 g/sq m. The average depths of the Louisiana Wildlife and Fisheries Commission sample stations in five estuarine zones in coastal Louisiana were 3.94, 2.17, 1.19, 1.52, and 1.04 meters (Table 87), an average depth of 1.97 m. A water depth of one meter equals E6 g water storage/sq m.

1,8,I Net export of water. 1.096 E9 g/sq m/yr. Equal to the sum of evaporation (1.56 E6 g/sq m/yr; 1,1,O) and export to offshore (1.094 E9 g/sq m/yr; 1,1,O).

1,8,O Net import of water. 1.096 E9 g/sq m/yr. Equal to the sum of precipitation (1.51 E6 g/sq m/yr; 1,1,I) and inputs in river runoff (1.094 E9 g/sq m/yr; 1,1,I).

<u>Inorganic nitrogen</u>.

2,1,I Input of inorganic nitrogen to surface water. 1206.0 g/sq m/yr. Equal to inputs from river runoff (1158 g/sq m/yr) (Table 86), sediment nitrogen regeneration, and input in precipitation. Nitrogen regenerated from the sediment equals 47.6 g/sq m/yr. Nixon (1981) examined the net flux of NH_4 from the sediment to the surface water for different coastal marine systems.

Two values are reported for Southeast Atlantic coast estuaries, Patuxent River, Maryland (525 umol NH4/sq m/hr) and South River, North Carolina (250 umol NH4/sq m/yr). The two values were converted into g N/sq m/yr. For Patuxent River, N regenerated equals 14 g N/mol x 525 umol/sq m/hr x mol/E6 umol x 24 hr/day x 365 day/yr = 64.4 g N/sq m/yr. For South River, regeneration = 30.7 g N/sq m/yr. The two values were averaged to obtain 47.6 g N/sq m/yr. Nitrogen input in precipitation is approximately 0.4 g/sq m/yr (Kemp and Day, in press). Nitrogen fixation in the water column of Louisiana estuaries is negligible (Casselman 1979).

2,1,O Output of inorganic nitrogen from surface water. 1206.0 g/sq m/yr. The nitrogen content of the surface water was assumed to be in steady state, so total nitrogen inputs equal outputs. Output of nitrogen is equal to deposition in sediment (62.9 g/sq m/yr; 2,2,I), phytoplankton uptake (48.7 g/sq m/yr; 2,3,I), and export to offshore waters. Export was calculated by difference, to yield 1094.4 g/sq m/yr. (1206.0 g/sq m/yr - 62.9 g/sq m/yr - 48.7 g/sq m/yr = 1094.4 g/sq m/yr).

2,1,S Storage of inorganic nitrogen in surface water. 0.122 g/sq m. Nitrate and nitrite were sampled in the surface water of estuarine areas across Louisiana coast in 1968 by the the Louisiana Wildlife and Fisheries Commission (LWFC 1970). Average annual concentrations and a Louisiana average concentration were calculated from samples in MDPR coastal regions (Table 87). The year 1968 represents an "average" discharge year for the Mississippi River, so nutrient concentrations should be representative of "average" MDPR conditions. Nitrogen concentrations in Barataria and Caminada Bays in a high discharge year (1973) were measured by Ho and Barrett (1975) (Table 88), and proved to be higher than the nitrogen concentrations recorded by LWFC in 1968 (Table 87).

2,2,I Input of inorganic nitrogen to sediment. 62.9 g/sq m/yr. Nitrogen contributed to the sediment was assumed to equal sediment nitrogen accumulation plus regeneration to the water column. Regeneration equals 47.6 g/sq m/yr (2,1,I). Net nitrogen accumulation in the sediment of Airplane Lake, a shallow salt marsh pond in Barataria Basin, is 15.3 g/sq m/yr (DeLaune et al. 1981). Assuming the Airplane Lake values are an average for the MDPR, then 15.3 g/sq m/yr plus 47.6 g/sq m/yr = 62.9 g/sq m/yr.

2,2,O Ouput of inorganic nitrogen from sediment. 62.9 g/sq m/yr. Equal to sediment regeneration (47.6 g/sq m/yr) (2,1,I), plus input to sediment nitrogen storage (15.3 g/sq m/yr) (2,2,I).

2,2,S Storage of nitrogen in sediment. 393 g/sq m. Nitrogen concentration in the sediment of Airplane Lake, a shallow salt marsh pond in Barataria Basin, is 2.46 mg/g (DeLaune et al. 1981). The bulk density of the sediment is 0.57 g/cu cm (DeLaune et al. 1981). Sediment depth was assumed to be 28 cm, the same as sediment depth in the salt marsh (see notes to salt marsh model, note 6,2,S). Storage is the product of 2.46 mg N/g, 0.57 g/cu cm, 28 cm, g/1000 mg, and 10,000 sq cm/sq m, and equals 393 g N/sq m.

2,3,I Input of inorganic nitrogen to phytoplankton. 48.7 g/sq m/yr. Nitrogen uptake by phytoplankton was assumed be gross primary production (GPP) multiplied by the nitrogen content of phytoplankton. Phytoplankton GPP equals 604.8 g dry wt/sq m/yr. This was obtained by adding net primary production (462 g dry wt/ sq m/yr) (Table 89) and phytoplankton respiration (142.8 g dry wt/sq m/yr; 12,3,O). The nitrogen content of phytoplankton was estimated at 8.05 percent (Parsons and Takahashi 1977).

2,8,I Net export of inorganic nitrogen. 1094.4 g/sq m/yr. Equal to nitrogen exported to offshore (2,1,O).

2,8,O Net import of inorganic nitrogen. 1158.4 g/sq m/yr. Equal to the sum of nitrogen input in river runoff (1158 g/sq m/yr; 2,1,I) and precipitation (0.4 g/sq m/yr; 2,1,I).

2,9,I Change in inorganic nitrogen storage. 15.3 g/sq m/yr. Equal to nitrogen accumulation in sediment (2,2,I).

Phosphorus.

3,1,I Input of phosphorus to surface water. 222.4 g/sq m/yr. Equal to input in runoff (217.8 g/sq m/yr) (Table 86) plus sediment regeneration. Phosphorus regenerated from the sediment equals 4.6 g/sq m/yr. Nixon (1981) calculated the net flux of PO4 from the sediment to the surface water for different coastal marine systems. Two values are reported for Southeast Atlantic coast estuaries, Patuxent River, Maryland (17 umol PO4/sq m/hr), and South River, North Carolina (17 umol PO4/sq m/hr). The two values were converted to g P/sq m/yr. Phosphorus regenerated equals 31 g P/mol x 17 umol/sq m/hr x mol/E6 umol x 24 hr/day x 365 day/yr = 4.6 g P/sq m/yr. The phosphorus regeneration reported was the same for both systems, so the model estimate was taken to be that value, 4.6 g P/sq m/yr. Phosphorus input in rainfall (0.04 g/sq m/yr), measured for MDPR swamp (Kemp and Day, in press), was considered negligible.

3,1,O Output of phosphorus from surface water. 222.4 g/sq m/yr. The phosphorus content of surface water was assumed to be in steady state, so total phosphorus inputs equal outputs. Output equals deposition in sediments (7.8 g/sq m/yr; 3,2,I), phytoplankton uptake (12.1 g/sq m/yr; 3,3,I) and export to offshore waters. Export was calculated by difference, and is equal to 202.5 g/sq m/yr. (222.4 g/sq m/yr - 7.8 g/sq m/yr - 12.1 g/sq m/yr = 202.5 g/sq m/yr).

3,1,S Storage of phosphorus in surface water. 0.054 g/sq m. PO4 concentrations were sampled in the surface water of estuarine areas across the Louisiana coast in 1968 by the Louisiana Wildlife and Fisheries Commission (LWFC 1970). Samples in coastal regions in the MDPR were recorded, average annual concentrations were calculated (Table 87), and a Louisiana average concentration was calculated (Table 87). The year 1968 represents an about average discharge year for the Mississippi River, so nutrient concentrations should be representative of "average" MDPR conditions. Phosphorus concentrations in Barataria and Caminada Bays in a high discharge year (1973) were measured by Ho and Barrett (1975) (Table 88) and proved to be slightly lower than the phosphorus concentrations recorded in 1968 (LWFC 1970).

3,2,I Input of phosphorus to sediment. 7.8 g/sq m/yr. Phosphorus contributed to the sediment was assumed to equal sediment phosphorus accumulation plus regeneration to the water column. Regeneration equals 4.6 g/sq m/yr (3,1,I). Net phosphorus accumulation in the sediment of Airplane Lake, a shallow salt marsh pond in Barataria Basin, is 3.2 g/sq m/yr (DeLaune et al. 1981).

3,2,O Output of phosphorus from sediment. 7.8 g/sq m/yr. Equal to phosphorus regenerated from sediment (4.6 g/sq m/yr; 3,1,I) plus phosphorus input to change in storage (3.2 g/sq m/yr; 3,2,I and 3,9,I).

3,2,S Storage of phosphorus in sediment. 83 g/sq m. The phosphorus concentration in the sediment of Airplane Lake, a shallow salt marsh pond in Barataria Basin, is 0.52 mg P/g (DeLaune et al. 1981). The bulk density of the sediment is 0.57 g/cu cm (DeLaune et al. 1981). Sediment depth was assumed to be 28 cm, the same as sediment depth in the salt marsh (see notes to salt marsh model, note 6,2,S). The product of 0.52 mg P/g, 0.57 g/cu cm, 28 cm, g/1000 mg and 10,000 sq cm/sq m, equals 83 g/sq m.

3,3,I Input of phosphorus to phytoplankton. 12.1 g/sq m/yr. Phosphorus uptake was assumed to be the product of GPP and the phosphorus content of phytoplankton. Phytoplankton GPP equals 604.8 g dry wt/sq m/yr (2,3,I). Parsons and Takahashi (1977) state that the phosphorus concentration of phytoplankton may range from 0.5% to 3% of dry weight. Assuming a value of 2% for MDPR phytoplankton, the phosphorus uptake equals 0.02 x 604.8 g/sq m/ yr, or 12.1 g/sq m/yr.

3,8,I Net export of phosphorus. 202.5 g/sq m/yr. Equal to phosphorus exported to offshore waters (3,1,0).

3,8,0 Net import of phosphorus. 217.8 g/sq m/yr. Equal to phosphorus input in river runoff (3,1,I).

3,9,I Change in phosphorus storage. 3.2 g/sq m/yr. Equal to phosphorus accumulation in sediment (3,2,I).

Carbon dioxide.

4,3,I Input of carbon dioxide to phytoplankton. 997.9 g/sq m/yr. Carbon dioxide absorbed by phytoplankton equals the product of GPP (604.8 g/sq m/yr; 2,3,I), 0.45 g C/g dry wt (Whittaker 1975), and 44 g CO2/12 g C.

4,4,0 Output of carbon dioxide from zooplankton. 166.7 g/sq m/yr. Carbon dioxide released in zooplankton respiration equals the product of zooplankton respiration (101 g dry wt/sq m/yr) (Figure 42), 0.45 g C/g dry wt (Whittaker 1975), and 44 g CO2/12 g C.

4,5,0 Output of carbon dioxide from benthos. 122.8 g/sq m/yr. Carbon dioxide released in benthic respiration equals the product of benthic respiration (74.4 g dry wt/sq m/yr) (Figure 43), 0.45 g C/g dry wt (Whittaker 1975), and 44 g CO2/12 g C.

4,6,0 Output of carbon dioxide from nekton. 28.9 g/sq m/yr. Carbon dioxide released in nekton respiration equals the product of nekton respiration (17.5 g dry wt/sq m/yr) (Figure 44), 0.45 g C/g dry wt (Whittaker 1975), and 44 g CO2/12 g C.

4,8,I Net export of carbon dioxide. 318.4 g/sq m/yr. Equal to the sum of carbon dioxide output from zooplankton (166.7 g/sq m/yr; 4,4,0), output from benthos (122.8 g/sq m/yr; 4,5,0), and output from nekton (28.9 g/sq m/yr; 4,6,0).

4,8,0 Net import of carbon dioxide. 997.9 g/sq m/yr. Equal to carbon dioxide uptake by phytoplankton (4,3,I).

Total organic matter (TOM).

5,1,I Input of TOM to surface water. 13,968.5 g/sq m/yr. Equal to the inputs of TOM in runoff (13,277 g/sq m/yr) (Table 86) plus outputs from detritus (691.5 g/sq m/yr; 5,7,0).

5,1,0 Output of TOM from surface water. 13,968.5 g/sq m/yr. TOM in surface water was assumed to be in steady state, so TOM inputs equal outputs. Outputs are equal to the sum of sedimentation (398.2 g/sq m/yr; 5,2,I), zooplankton ingestion (219.1 g/sq m/yr; 5,4,I), benthos ingestion (194.7 g/sq m/yr; 5,5,I), nekton ingestion (18.9 g/sq m/yr; 5,6,I), and export to offshore waters. Export was calculated by difference (13,968.5 g/sq m/yr - 398.2 g/sq m/yr - 219.1 g/sq m/yr - 194.7 g/sq m/yr - 18.9 g/sq m/yr = 13,137.6 g/sq m/yr). No attempt was made to separate consumer ingestion of TOM from the water column from that ingested from the sediments. It was all assumed to be ingested from the water.

5,1,S Storage of TOM in surface water. 14.4 g/sq m. The average annual concentration of total organic carbon (TOC) in the water column averaged over six stations in upper Barataria Bay reported by Happ et al. (1977) was 7.1 mg TOC/l or 7.1 g TOC/cu m. Converting grams carbon to grams organic matter by multiplying by 1.724 g dry wt organic matter/g C (Wilson and Staker 1932) yields 12.2 g dry wt organic matter/cu m. Multiplication by water depth of 1.19 m yields a TOM concentration of 14.4 g dry wt/sq m (Louisiana Wildlife and Fisheries Commission 1970 sampled 10 stations in and near Barataria Bay, with an average depth of 1.19 m; see also Table 87-III).

5,2,I Input of TOM to sediment. 398.2 g/sq m/yr. The net flux of carbon to the sediment of Airplane Lake, a shallow salt marsh pond in Barataria Basin, is 231 g C/sq m/yr. Converting carbon to organic matter by multiplication by

1.724 (Wilson and Staker 1932), yields 398.2 g TOM/sq m/yr. Since no information on resuspension of TOM is available it was assumed to be zero.

5,2,0 Output of TOM from sediment. 398.2 g/sq m/yr. Equal to input to change in sediment storage of TOM (5,2,I).

5,2,S Storage of TOM in sediment. 10,456 g/sq m. Organic carbon makes up 3.8% of the sediment by weight in Airplane Lake, a shallow salt marsh pond in Barataria Basin (DeLaune et al. 1981). The bulk density of the sediment is 0.57 g/cu cm. (DeLaune et al. 1981). The sediment depth in Airplane Lake was assumed to be 28 cm, the same as sediment depth in the salt marsh (see notes to salt marsh model, note 6,2,S). The product of 0.038, 0.57 g/cu cm, 28 cm, and 10,000 sq cm/sq m equals 6065 g C/sq m. Conversion of carbon to organic matter by multiplication of 1.724 (Wilson and Staker 1932) yields 10,456 g TOM/sq m.

5,4,I Input of TOM to zooplankton. 219.1 g/sq m/yr. Zooplankton eat primarily organic matter and phytoplankton (Darnell 1961; Gillepsie 1971). A diet breakdown of 70% TOM, 30% phytoplankton was assumed. Total zooplankton ingestion equals 313 g/sq m/yr (Figure 42). (313 g/sq m/yr x 0.7 = 219.1 g/sq m/yr.)

5,4,0 Output of TOM from zooplankton. 187 g/sq m/yr. Equal to zooplankton egestion (Figure 42).

5,5,I Input of TOM to benthos. 194.7 g/sq m/yr. Benthos were assumed to eat only organic matter. Darnell (1961) stated benthos rely heavily on organic detritus and associated bacteria. This neglects phytoplankton consumption particularly by oysters, but this was assumed to be unimportant based on the very small relative area of oyster reefs in estuarine open water habitat. Benthos ingestion equals 194.7 g/sq m/yr (Figure 43).

5,5,0 Output of TOM from benthos. 89.8 g/sq m/yr. Equal to benthos egestion (Figure 43).

5,6,I Input of TOM to nekton. 18.9 g/sq m/yr. Nekton were calculated to ingest 27.7% TOM (Table 90). Total nekton ingestion equals 68.3 g/sq m/yr (Figure 44), so ingestion of TOM equals 68.3 g/sq m/yr x 0.277, or 18.9 g/sq m/yr.

5,6,0 Output of TOM from nekton. 28.3 g/sq m/yr. Equal to nekton egestion (Figure 44).

5,7,I Input of TOM to detritus. 305.1 g/sq m/yr. Equal to egestion by zooplankton (187 g/sq m/yr) (Figure 42), plus egestion by benthos (89.8 g/sq m/yr) (Figure 43), plus egestion by nekton (28.3 g/sq m/yr) (Figure 44).

5,7,0 Output of TOM from detritus. 691.5 g/sq m/yr. Detritus storage was assumed to be in steady state, so TOM inputs to detritus equal outputs. Inputs to detritus equal inputs of TOM (305.1 g/sq m/yr; 5,7,I), input of phytoplankton (366.8 g/sq m/yr; 8,7,I), input of zooplankton (14.3 g/sq m/yr; 9,7,I), and input of nekton (5.3 g/sq m/yr; 11,7,I).

5,8,I Net export of TOM. 13,137.6 g/sq m/yr. Equal to TOM exported to offshore (5,1,0).

5,8,0 Net import of TOM. 13,277 g/sq m/yr. Equal to TOM input in river runoff (5,1,I).

5,9,I Change in TOM storage. 398.2 g/sq m/yr. Equal to TOM accumulation in the sediment (5,2,I).

Sediment.

6,1,I Input of sediment to surface water. 11,980 g/sq m/yr. Sediment input to surface water consists of sediment contributed by the three major MDPR rivers and equals 1.198 E4 g/sq m/yr (Table 86). Resuspension of sediment occurs, but its magnitude is unknown and it was not included in the model.

6,1,0 Output of sediment from surface water. 11,980 g/sq m/yr. Sediment input to surface water was assumed to be either deposited in the sediment or exported to offshore waters. Export to offshore waters was calculated by difference

(11,980 g/sq m/yr (input) - 7392 g/sq m/yr (flow to sediment; 6,2,I) = 4588 g/sq m/yr (export)).

6,2,I Input of sediment to sediment. 7392 g/sq m/yr. Sediment was assumed to include mineral matter, potassium, iron, manganese, cadmium, lead, copper, and zinc. The total deposition of these elements was reported by DeLaune et al. (1981) to be 7392 g/sq m/yr for Airplane Lake, a shallow salt marsh pond in Barataria Basin.

6,2,0 Output of sediment from sediment. 7392 g/sq m/yr. Equal to input to change in sediment storage (6,2,I and 6,9,I).

6,2,S Storage of sediment in sediment. 153,535 g/sq m. Mineral matter (including potassium, iron, manganese, cadmium, lead, copper, and zinc) makes up 96.2% of the sediment by weight of Airplane Lake, a shallow salt marsh pond in Barataria Basin (DeLaune et al. 1981). Bulk density of the sediment equals 0.57 g/cu cm (DeLaune et al. 1981). Sediment depth was assumed to be 28 cm, the same as sediment depth in the salt marsh (see notes to salt marsh model, note 6,2,S). The product of 0.962, 0.57 g/cu cm, 28 cm and 10,000 sq cm/sq m, equals 153,535 g/sq m.

6,8,I Net export of sediment. 4588 g/sq m/yr. Equal to sediment exported to offshore waters (6,1,0).

6,8,0 Net import of sediment. 11,980 g/sq m/yr. Equal to sediment imported in river runoff (6,1,I).

6,9,I Change in sediment storage 7392 g/sq m/yr. Equal to sediment accumulation (6,2,I).

Salt.

7,1,S Storage of salt in surface water. 30,060 g/sq m/yr. Salinity was sampled in estuarine areas across the Louisiana coast in 1968 by the Louisiana Wildlife and Fisheries Commission (1970). Samples in coastal regions in the MDPR were recorded, average salinities were calculated, (Table 87), and a Louisiana average salinity was calculated (Table 87). The year 1968 represents an about average discharge year for the Mississippi River, so salinity should be representative of "average" MDPR conditions. Salinity in Barataria and Caminada Bays in a high discharge year (1973) was measured by Ho and Barrett (1975) (Table 88) and proved to be lower than salinity recorded by LWFC in 1968.

Phytoplankton biomass.

8,3,0 Output of phytoplankton biomass. 462 g/sq m/yr. Net phytoplankton production. An average of 462 g/sq m/yr was obtained from four productivity studies of MDPR estuarine areas (Table 89).

8,4,I Input of phytoplankton to zooplankton. 93.9 g/sq m/yr. Zooplankton eat primarily organic matter and phytoplankton (Darnell 1961; Gillespie 1971). A diet breakdown of 30% phytoplankton, 70% organic matter was assumed. Total zooplankton ingestion equals 313 g/sq m/yr (Figure 42), so ingestion of phytoplankton equals 313 g/sq m/yr x 0.3, or 93.9 g/sq m/yr.

8,6,I Input of phytoplankton to nekton. 1.3 g/sq m/yr. Nekton were calculated to feed on 1.9% phytoplankton (Table 90). Total nekton ingestion equals 68.3 g/sq m/yr (Figure 43), so ingestion of phytoplankton equals 68.3 g/sq m/yr x 0.019, or 1.3 g/sq m/yr.

8,7,I Input of phytoplankton to detritus. 366.8 g/sq m/yr. Phytoplankton net production not consumed was assumed to contribute to detritus. (462 g/sq m/yr -93.9 g/sq m/yr - 1.3 g/sq m/yr = 366.8 g/sq m/yr).

Zooplankton biomass.

9,4,0 Output of zooplankton biomass. 25 g/sq m/yr. Equal to zooplankton production (Figure 42).

9,4,S Storage of zooplankton biomass. 2.5 g/sq m. Equal to average zooplankton standing crop (Figure 42).

9,6,I Input of zooplankton to nekton. 10.7 g/sq m/yr. Nekton diet was calculated to consist of 15.6% zooplankton (Table 90). Product of total nekton ingestion (68.3 g/sq m/yr) (Figure 44) and 0.156 equals 10.7 g/sq m/yr.

9,7,I Input of zooplankton to detritus. 14.3 g/sq m/yr. Flow to detritus was assumed to equal zooplankton production (25 g/sq m/yr; 9,4,0) minus consumption by nekton (10.7 g/sq m/yr; 9,6,I).

Benthos biomass.

10,5,0 Output of benthos biomass. 30.05 g/sq m/yr. Equal to production of benthos. Benthos include amphipods, polychaetes, oligochaetes, harpacticoid copepods, nematodes, fiddler crabs, snails, mussels, and oysters. Production was calculated to be exactly enough to satisfy 43.9% of nekton diet (10,6,I and Table 91) plus 0.05 g/sq m/yr harvest by man (10,8,I). This is an admittedly crude way of estimating production, but insufficient data exist to estimate it directly. See Figure 43 for benthos energy budget.

10,5,S Storage of benthos biomass. 9.5 g/sq m/yr. Equal to benthos standing crop. From an energy budget of a population of estuarine benthos (Warwick et al. 1979) (Figure 26) it was calculated that benthic production equals 3.2 times standing crop. Production of 30.05 g/sq m/yr (10,5,0) yields a standing crop of 9.5 g/sq m/yr (see also Figure 43).

10,6,I Input of benthos to nekton. 30.0 g/sq m/yr. Benthos make up 43.9% of nekton diet (Table 90). Total nekton ingestion equals 68.3 g/sq m/yr (Figure 43), so 0.439 x 68.3 g/sq m/yr = 30.0 g/sq m/yr.

10,8,I Net export of benthos. 0.05 g/sq m/yr. Equal to the sum of commercial and recreational harvest of oysters. Recreational oyster harvest of 0.01 g/sq m/yr is shown in Table 93. Commercial harvest was calculated by dividing the average 1970-78 oyster harvest (meat only) of 11,237,000 lb wet wt (Table 92) by the total area of estuarine open water and nearshore Gulf habitat (2,136,755 ha) (Table 94). (11,237,000 lb x 454 g/lb x 1/2,136,755 ha x ha/10,000 sq m = 0.24 g wet wt/sq m/yr). (0.24 g wet wt/sq m/yr x 0.15 g dry wt/g wet wt (Bahr and Lanier 1981) = 0.04 g/sq m/yr).

Nekton biomass.

11,6,I Input of nekton to nekton. 7.4 g/sq m/yr. Nekton were estimated to comprise 10.9% of nekton diet (Table 90). Total nekton ingestion equals 68.3 g/sq m/yr (Figure 44). (68.3 g/sq m/yr x 0.109 = 7.4 g/sq m/yr).

11,6,0 Output of nekton biomass. Equal to nekton production of 22.6 g/sq m/yr (Figure 44).

11,6,S Storage of nekton biomass. 1.3 g/sq m. Equal to nekton standing crop (Figure 44).

11,7,I Input of nekton to detritus. 5.3 g/sq m/yr. Nekton production (22.6 g/sq m/yr; 11,6,0) not consumed by nekton (7.4 g/sq m/yr; 11,6,I) or caught by sport and recreational fisheries (9.9 g/sq m/yr; 11,8,I) was assumed to contribute to detritus.

11,8,I Net export of nekton. 9.9 g/sq m/yr. Equal to the sum of commercial and recreational harvest of fish, shrimp, and blue crabs. Commercial catch for 1970 to 1978 for Mississippi and Louisiana waters is shown in Table 93. Average annual nekton harvest was 1,483,538,000 pounds wet wt. This was harvested from estuarine and nearshore gulf habitat covering 2,136,755 ha in

1978 (Table 94). (1,483,538,000 lb wet wt x 454 g/lb x 1/2,136,755 ha x ha/10,000 sq m = 31.5 g wet wt/sq m/yr). Dry wt of fish equals 0.3 x wet wt (Day et al. 1973) and was used as an estimate for nekton, yielding a commercial nekton harvest of 9.45 g dry wt/sq m/yr. Recreational nekton harvest equals 0.46 g/sq m/yr (Table 93).

Heat.

12,3,0 Output of heat from phytoplankton. 642.6 kcal/sq m/yr. Respiration of phytoplankton equals 142.8 g dry wt/sq m/yr. Total community respiration equals 336 g dry w/sq m/yr (Table 89). Consumer respiration equals 193.2 g dry wt/sq m/yr (sum of 12,4,0; 12,5,0; 12,6,0), leaving 142.8 g dry wt/sq m/yr to be accounted for by phytoplankton respiration. 4.5 kcals are released for every gram of dry wt respired (E.P. Odum 1971). (4.5 kcal/g x 142.8 g/sq m/yr = 642 kcal/sq m/yr).

12,4,0 Output of heat from zooplankton. 454.4 kcal/sq m/yr. Zooplankton respiration equals 101 g dry wt/sq m/yr (Figure 42). 4.5 kcals are released for every gram of dry wt respired (E.P. Odum 1971). (4.5 kcal/g x 101 g/sq m/yr = 454.4 kcal/sq m/yr).

12,5,0 Output of heat from benthos. 336.2 kcal/sq m/yr. Benthos respiration equals 74.7 g/sq m/yr (Figure 43). 4.5 kcals are released for every gram of dry wt respired (E. P. Odum 1971). (4.5 kcal/g x 74.7 = 336.6 kcal/sq m/yr).

12,6,0 Output of heat from nekton. 78.8 kcal/sq m/yr. Nekton respiration equals 17.5 g dry wt/sq m/yr (Figure 44). 4.5 kcals are released for every gram of dry wt respired (E.P. Odum 1971). (4.5 kcal/g x 17.5 g/sq m/yr = 78.8 kcal/sq m/yr).

12,8,I Net export of heat. 1512.0 kcal/sq m/yr. Equal to the sum of heat outputs from phytoplankton (642.6 kcal/sq m/yr; 12,3,0), zooplankton (454.4 kcal/sq m/yr; 12,4,0), benthos (336.2 kcal/sq m/yr; 12 5,0), and nekton (78.8 kcal/sq m/yr; 12,6,0).

Sunlight.

13,3,I Input of sunlight to phytoplankton. 53,622 kcal/sq m/yr. According to Odum (1957), 410,000 kcals are required for every 20,810 kcals fixed in GPP, or converting kcals to dry wt (4.5 kcal = 1 g dry wt) (E.P. Odum 1971), 88.66 kcal/gram dry wt GPP. GPP = 604.8 g/sq m/yr (2,3,I). (604.8 g/sq m/yr 88.66 kcal/g = 53,622 kcal/sq m/yr).

13,8,I Net output of sunlight. 1,369,378 kcal/sq m/yr. Net output of sunlight, or albedo, equals total input of sunlight (1,423,000 kcal/sq m/yr; 13,8,0) minus uptake by phytoplankton (53,622 kcal/sq m/yr; 13,3,I).

13,8,0 Net input of sunlight. 1,423,000 kcal/sq m/yr. Total insolation = 389.8 cal/sq m/day at New Orleans, averaged from 1952-1975 (Knapp et al. 1980).

Table 86. Contribution of water, sediment, nitrogen, phosphorus, and organic carbon to MDPR estuarine open water habitat from the discharge of the three largest MDPR rivers.[a]

	Mississippi River (Tarbert Landing)	Atchafalaya River (Simmesport)	Pearl River (Near Bogalusa)	Total	Annual Contribution per sq m[b]
Discharge (g water/yr)	1.48 E19	7.15 E18	3.51 E17	2.23 E19	1.094 E9 g
Sediment Load (g sed/yr)	1.50 E14	9.34 E13	1.07 E12	2.44 E14	1.198 E4 g
Model No.	1	1	1		
Obs.[c]	84	84	128		
Inorganic Nitrogen (g N/yr)	1.75 E13	6.01 E12	9.83 E10	2.36 E13	1.158 E3 gN
Model No.[d]	1/3	3/-	2/3		
Obs.[d]	84/84	84/11	132/117		
Total Phosphorus (g P/yr)	3.11 E12	1.29 E12	3.51 E10	4.44 E12	2.178 E2 gP
Model No.	3	3	-		
Obs.	83	84	85		
Total Org Carbon (g C/yr)[e]	1.04 E14	5.08 E13	2.32 E12	1.57 E14	7.701 E3 gC
Model No.	3	-	3		
Obs.	84	13	102		

[a]Data are from U.S.G.S. (1970-1980). Values for Mississippi and Atchafalaya Rivers are seven year averages (1973-1979), and value for Pearl River is an eleven year average (1970-1980). Data for values other than discharge were incomplete and, when possible, a general linear model was used to predict missing values. Models are: (1) Nutrient = k1*Flow + k2*Month + k3*Flow*Month, (2) Nutrient = k4*Flow, (3) Nutrient = k5*Flow + k6*Sediment (models were run separately for each river). Reliability of these predictions ranged from an R-squared value of 0.894 for using model 3 to predict TOC at the Pearl River, to 0.058 for using model 2 to predict nitrate-nitrite at the Pearl River. Criteria for using a predicted value were (a) model had to be significant at the 0.1 level (lack of a model fulfilling this criterion is indicated by a dash), (b) if more than one model was significant, then the model chosen for a particular nutrient at a particular river was the one with the highest R-square value, and (c) predicted values were used only if they were greater than zero.

[b]The total area of estuarine open water and nearshore Gulf habitat in the MDPR is 2,038,691 ha (2.0387 E10 sq m) (Table 94).

[c]Number of observations (actual data plus predicted value) from which average was calculated.

[d]Nitrogen value is the sum of nitrate-nitrite plus ammonium. First value refers to nitrate-nitrite and second to ammonium.

[e]TOM = grams carbon x 1.724 (Wilson and Staker 1932).

Table 87. Average nitrate, nitrite, phosphate, and salinity for MDPR estuarine waterbodies for 1968--a year of average river discharge (Louisiana Wildlife and Fisheries Commission 1970). Numbers in parentheses are g/sq m.[a]

Region	Depth (m)	Nitrate (ug at/l)	Nitrite (ug at/l)	Phosphate (ug at/l)	Salinity (ppt)
Lake Borgne and vicinity	3.94	2.64(0.146)	0.28(0.015)	0.82(0.100)	13.2(52,008)
Miss. R. Delta	2.17	4.84(0.147)	0.55(0.017)	1.22(0.082)	16.9(36,673)
Barataria Bay and vicinity	1.19	4.92(0.082)	0.72(0.012)	0.69(0.025)	16.6(19,754)
Terrebonne-Timbalier Bay and vicinity	1.52	2.40(0.051)	0.44(0.009)	0.83(0.039)	19.4(29,488)
Fourleague-Caillou Bay and vicinity	1.04	8.38(0.122)	0.60(0.009)	0.81(0.026)	11.9(12,376)
LOUISIANA AVG		(0.110)	(0.012)	(0.054)	(30,060)

[a]The following conversion was used to obtain g N/sq m:

$$\frac{\text{ug-at}}{1} \times \frac{\text{g-at}}{\text{E6 ug-at}} \times \frac{\text{14 g N}}{\text{g-at}} \times \frac{\text{1000 l}}{\text{cu m}} \times \text{m} = \frac{\text{g N}}{\text{sq m}}$$

The following conversion was used to obtain g P/sq m:

$$\frac{\text{ug-at}}{1} \times \frac{\text{g-at}}{\text{E6 ug-at}} \times \frac{\text{31 g P}}{\text{g-at}} \times \frac{\text{1000 l}}{\text{cu m}} \times \text{m} = \frac{\text{g P}}{\text{sq m}}$$

The following conversion was used to obtain g salt/sq m:

$$\frac{\text{g salt}}{\text{1000 g water}} \times \frac{\text{1000 g water}}{1} \times \frac{\text{1000 l}}{\text{cu m}} \times \underset{\text{(m)}}{\text{water depth}} = \frac{\text{g salt}}{\text{sq m}}$$

Table 88. Nutrient distribution in Barataria Bay, Caminada Bay, and nearshore zone in 1973--a high water year.[a]

	Barataria Bay				Caminada Bay				Nearshore zone[b]			
	mg/ℓ (g/cu m)			ppt	mg/ℓ (g/cu m)			ppt	mg/ℓ (g/cu m)			ppt
Date	NH_4-N	NO_x-N	PO_4-P	Salinity	NH_4-N	NO_x-N	PO_4-P	Salinity	NH_4-N	NO_x-N	PO_4-P	Salinity
January	NA[c]	NA	NA	NA	0.018	0.025	0.014	16.8	0.022	0.491	0.027	13.1
March	0.065	0.259	0.025	13.4	0.098	0.113	0.013	16.7	0.047	0.354	0.033	20.9
May	0.032	0.027	0.015	10.9	0.022	0.053	0.011	18.5	0.031	0.052	0.007	17.9
September	0.071	0.022	0.022	16.1	0.076	0.006	0.023	18.0	0.034	0.055	0.015	25.6
Annual average	0.056	0.103	0.021	13.5	0.054	0.049	0.015	17.5	0.034	0.238	0.021	19.4

[a]Ho and Barrett (1975).

[b]Surface water sample. Average of nutrient concentrations for all Barataria, Caminada, and Quatre Bayou nearshore stations.

[c]Data not available.

Table 89. Net primary production and community respiration for MDPR estuarine open water areas.

Location	Description	NPP gC/sq m/yr	NPP gdw/sq m/yr[a]	Community Respiration gC/sq m/yr	Community Respiration gdw/sq m/yr[a]	Source
Barataria Bay, LA	Coastal estuarine bay	210	467	90	200	Day et al. 1973
Off Grand Isle, LA	Offshore, affected by Miss. R.	266	591			Sklar 1976
Lake Pontchartrain, LA[b]	Very large brackish water lake	158	351			Dow and Turner 1980
Airplane Lake, LA	Salt marsh pond	198	440			Stowe 1972
Airplane Lake, LA				126	280	Hopkinson et al. 1978a
Little Lake, LA	Shallow brackish water lake			236	524	Hopkinson and Day 1979
AVERAGE		208	462	151	336	

[a]Grams dry wt = 2.22 x grams carbon (Whittaker 1975).
[b]Average of four Lake Pontchartrain stations.

Table 90. Ingestion of multiple food types by MDPR nekton.

Species[a]	Percent of total biomass[b]	Percent Nekton c	Percent Nekton d	Percent Phyto c	Percent Phyto d	Percent Benthos c	Percent Benthos d	Percent T.O.M. c	Percent T.O.M. d	Percent Zoo c	Percent Zoo d
Anchoa mitchilli - Bay anchovy	23.90	---	0	5	.01195	10	.0239	35	.0837	50	.1195
Ictalurus punctatus - Channel catfish	31.73	10	.03173	--	0	65	.2062	25	.0793	--	0
Lepisosteus spatual - Alligator gar	17.72	35	.06202	--	0	65	.1152	--	0	--	0
Ictalurus furcatus - Blue catfish	6.34	10	.00634	--	0	50	.0317	25	.0159	15	.0095
Callinectes sapidus - Blue crab	5.14	--	0	--	0	70	.0360	30	.0154	--	0
Micropogon undulatus - Atlantic croaker	5.03	10	.00503	--	0	30	.0151	30	.0151	30	.0151
Penaeus aztecus - Brown shrimp	3.94	--	0	5	.00197	--	0	95	.0374	--	0
Brevoortia patronus - Menhaden	3.20	--	0	10	.0032	--	0	80	.0256	10	.0032
Dorosoma petenense - Thread fin shad	1.50	--	0	15	.00225	--	0	30	.0045	55	.0083
Lepisosteus oculatus - Spotted gar	1.50	30	.0045	--	0	70	.0105	--	0	--	0
TOTAL	100.00		.1096		.0194		.4386		.2769		.1556
Weighted average percent ingestion of each food type[e]			10.9		1.9		43.9		27.7		15.6

[a]The species listed are the ten most abundant species in the Barataria basin (Chambers 1980).

[b]The percent of total nekton biomass sampled for the ten species listed (Chambers 1980) indicate these ten species comprise 91.4% of the nekton sampled. These numbers have been corrected based on the assumption that these ten species comprise 100% of the total nekton biomass.

[c]The percent composition of food for each species is based on data from Darnell (1961).

[d]To obtain the weighted average of food intake from each group, the percent total biomass was multiplied by the percent of each group consumed.

[e]The sum of the weighted average times 100 yields the weighted average percent of each food group ingested by the total nekton population.

Table 91. Landings of fish, shrimp, crabs, and oysters in Louisiana and Mississippi, 1970-1978 (NOAA 1970-1978).

	Mississippi								Louisiana							
	Total fish		Total crabs		Total shrimp		Total oysters		Total fish		Total crabs		Total shrimp		Total oysters	
	1,000 lbs	$1,000	1,000 lbs	$1,000	1,000 lbs	$1,000	1,000 lbs	$1,000	1,000 lbs	$1,000	1,000 lbs	$1,000	1,000 lbs	$1,000	1,000 lbs	$1,000
1970	285,376	6,741	2,027	193	9,604	3,810	548	238	995,945	21,408	10,344	1,007	90,939	34,612	8,639	3,631
1971	384,462	7,404	1,259	126	9,589	4,362	1,215	473	1,273,943	22,304	12,313	1,382	92,476	43,284	10,528	4,638
1972	245,948	5,523	1,362	169	7,951	4,966	1,220	581	962,719	17,710	15,185	1,886	83,032	47,064	8,805	4,457
1973	261,455	12,283	1,815	231	3,681	3,698	612	366	933,205	40,763	23,199	2,943	58,646	44,511	9,953	5,544
1974	293,618	12,124	1,667	227	5,416	3,225	276	158	1,129,583	43,284	20,736	2,828	59,591	32,202	9,927	6,384
1975	299,496	9,810	1,137	177	4,045	3,825	1,080	535	1,026,181	33,673	17,254	2,665	53,134	40,968	13,687	7,174
1976	277,757	11,307	1,335	268	7,551	8,418	1,516	1,015	1,106,723	42,535	15,299	3,206	82,355	79,688	12,334	9,092
1977	299,107	13,774	1,919	473	10,539	10,079	1,386	1,156	787,035	35,521	16,379	4,335	104,018	87,213	10,065	10,363
1978	303,650	15,007	1,942	422	8,286	9,207	682	735	1,532,024	71,001	15,207	3,465	104,385	100,848	9,662	12,164

Table 92. Commercial harvest of nekton and benthos from Louisiana and Mississippi estuarine open water habitat (NOAA 1970-1978).

Year	Total harvest: Nekton[a] (1000 lb)	Total harvest: Benthos[b] (1000 lb)
1970	1,394,335	9187
1971	1,774,047	11,743
1972	1,316,197	10,025
1973	1,280,001	9565
1974	1,510,601	10,203
1975	1,401,247	14,767
1976	1,491,020	3850
1977	1,218,997	11,451
1978	1,965,497	10,344
AVERAGE	1,483,549	10,126

[a]Includes fish, shrimp, and crabs from Table 91.
[b]Includes oysters from Table 91.

Table 93. Recreational harvest of fish, shrimp, crabs, and oysters from Louisiana and Mississippi waters for 1975.

Category	Harvest: 1000 lb wet wt/yr[a]	Harvest: g wet wt/sq m/yr[b]	Harvest: g dry wt/sq m/yr[c]
Fish	61,541	1.301	0.3924
Shrimp	3386	0.072	0.0144
Crabs	11,390	0.242	0.0484
Oysters	3581	0.076	0.0114

[a]From Larson et al. (1980).
[b]Area of estuarine open water and nearshore gulf habitats in Louisiana and Mississippi from which harvest was taken is 2,136,755 ha (Table 94), or 2,136,755 E4 sq m.
[c]1 g wet wt = 0.2 g dry wt for shrimp and crabs (Day et al. 1973). 1 g wet wt = 0.15 g dry wt for oysters (Bahr and Lanier 1981). 1 g wet wt = 0.3 g dry wt for fish (Day et al. 1973).

Table 94. Areas of estuarine and marine habitat in Louisiana and Mississippi in 1978.

Region	Area (ha)[a]		Total
	Estuarine	Marine	
Mississippi Sound	146,402	41,849	188,251
MDPR--Hydrologic Unit II	797,036	74,721	871,757
MDPR--Hydrologic Units III-VII	978,684	-	978,684
Louisiana--Hydrologic Units VIII-IX[b].	98,064		98,064
MDPR--Total	1,922,122	116,569	2,038,691
Total Louisiana[c]	1,873,784	74,721	1,948,505
Total Louisiana and Mississippi[c]	2,020,186	116,569	2,136,755

[a]All area measurements from Wicker et al. (1980a) unless otherwise noted.
[b]From Chabreck (1972). Includes area of saline, brackish, and intermediate ponds and lakes, bays, and sounds. 1 acre = 0.4047 ha. 1 ha = 10,000 sq m.
[c]Differences due to roundoff error.

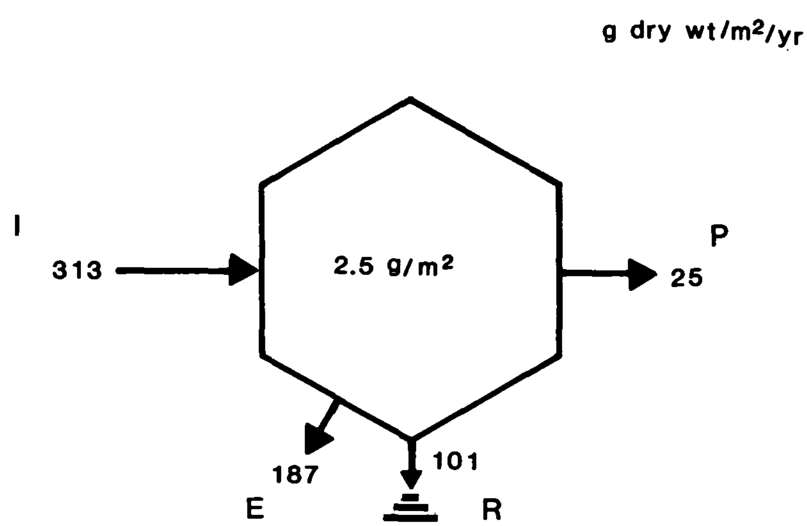


Figure 42. Estuarine open water habitat zooplankton energy budget. I = ingestion, E = egestion, R = respiration, and P = production. From Day et al. (1973).

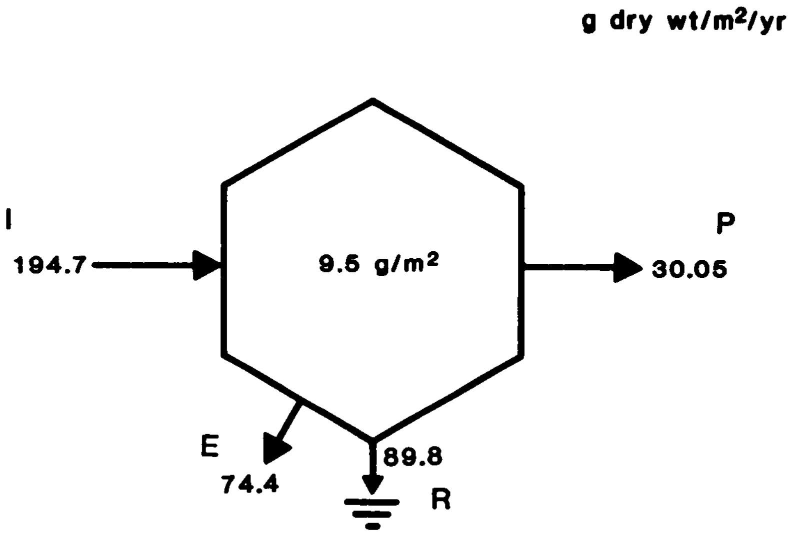


Figure 43. Estuarine open water habitat benthos energy budget. Benthos ingestion was estimated at 30.05 g/sq m/yr (10,5,0). Standing crop was calculated from a production: (P) to standing crop ratio of 3.2 measured for an estuarine benthic population by Warwick et al. (1979). Ingestion (I), egestion (E), and respiration (R) were calculated from standing crop using ratios from Warwick et al. (1979) (see also Figure 26). Budget does not balance exactly due to roundoff error.

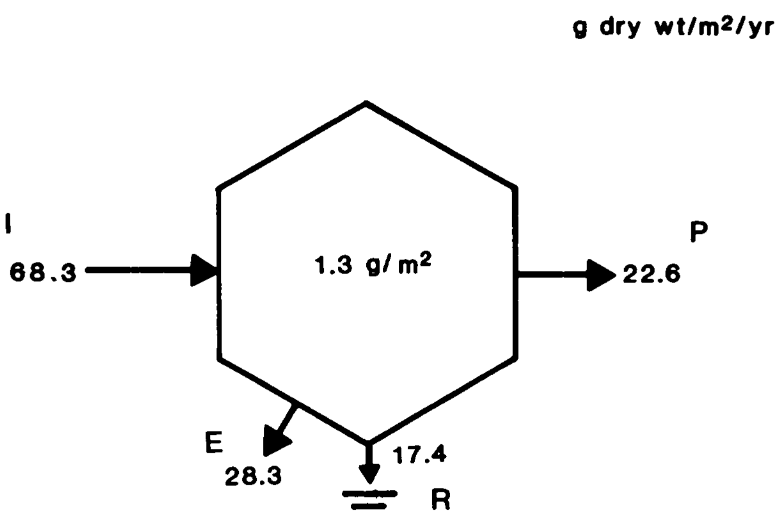


Figure 44. Estuarine open water habitat nekton energy budget. Nekton budget equals the sum of budgets for fish, shrimp, and blue crabs for a shallow bay estuarine system in Louisiana (Day et al. 1973). I = ingestion, E = egestion, R = respiration, and P = production.

17. SALT MARSH

The salt marsh is the third largest habitat in the MDPR, consisting of more than 182,000 ha in 1978 (Table 3). It is found in all but two (Mississippi Delta and Atchafalaya) of the seven MDPR hydrologic units. The areal distribution of the salt marsh habitat in the MDPR is shown in Figure 45.

Salt marshes are among the most intensively studied, well-understood ecological habitats. There have been a number of studies of plant production in the MDPR (e.g., de la Cruz 1974; Kirby and Gosselink 1976; Hopkinson et al. 1978b; White et al. 1978). Other research has been concerned with consumers (Alexander 1976, Rodriguez-Ortega and Day 1978) and sediment chemistry (DeLaune et al. 1976, DeLaune and Patrick 1980). Most of this work examines only one aspect of the ecology of the salt marsh at a time. A study by Day et al. (1973) attempted to describe and quantify the dynamics and interrelationships of the entire salt marsh habitat. In this report, the basic salt marsh model presented by Day et al. (1973) was updated to include the most current information available. Even with these new data, however, there are still large uncertainties and gaps in our understanding of the MDPR salt marsh habitat. An energy circuit diagram of the salt marsh model is shown in Figure 46 with the corresponding input-output table shown in Table 95.

As defined here, the salt marsh includes only those portions of the marsh that support macrophytes; mudflats, streams, and ponds are considered separate habitats. Further, the bottom-most boundary is defined as the rooting depth, which averages 28 cm (Table 101, note f).

The most conspicuous feature of the salt marsh is the macrophyte _Spartina alterniflora_. Of the 182,000 ha of MDPR salt marsh, 111,000 are covered by _S. alterniflora_ (Table 112). Other important marsh macrophytes are _Juncus roemerianus_, _Distichlis spicata_, and _Spartina patens_.

Various authors have studied net primary production of marsh macrophytes (Table 110). Aboveground net primary production of an average MDPR salt marsh is estimated as 2459 g dry wt/sq m/yr (Table 114). Studies have pointed out the possible significance of belowground macrophyte production (Gallagher and Plumley 1979, Stout 1978, Valiela et al. 1976). Using the assumption that belowground net production is equal to belowground decomposition plus loss of organic matter through subsidence, it is estimated that belowground production contributes an additional 2310 g dry wt/sq m/yr (Table 109), a value slightly greater than aboveground production. This is only a rough estimate, however, since this value has not been measured adequately in the MDPR. Our understanding of MDPR salt marshes is will be limited until this important value is better measured.

Marsh microflora, such as epiphytic algae, phytoplankton, and benthic algae, also contribute to the productivity of the habitat. It is estimated that these plants contribute 406 g dry wt/sq m/yr (Table 107), giving a total net community production of 4769 g dry wt/sq m/yr.

The food chain of the salt marsh is primarily detritus-based, as shown in Figure 46. Most marsh animals do not consume living flora directly, but feed on soil detritus or organic matter in the water column. For example, consumption of living producers by the snail _Littorina irrorata_ accounts for only 4% of its total dietary intake (Alexander 1976). Grazing of _S. alterniflora_ is minimal. Of the 2459 g dry wt/sq m/yr of aboveground net production (Table 114), only 104 g dry wt/sq m/yr, less than 5%, are consumed directly as living materials (Table 121). The major macroconsumers in the salt marsh are crabs, mussels, _Littorina_, insects, birds, and furbearers such as muskrats, nutria, and raccoons. Since the marsh as defined here excludes tidal

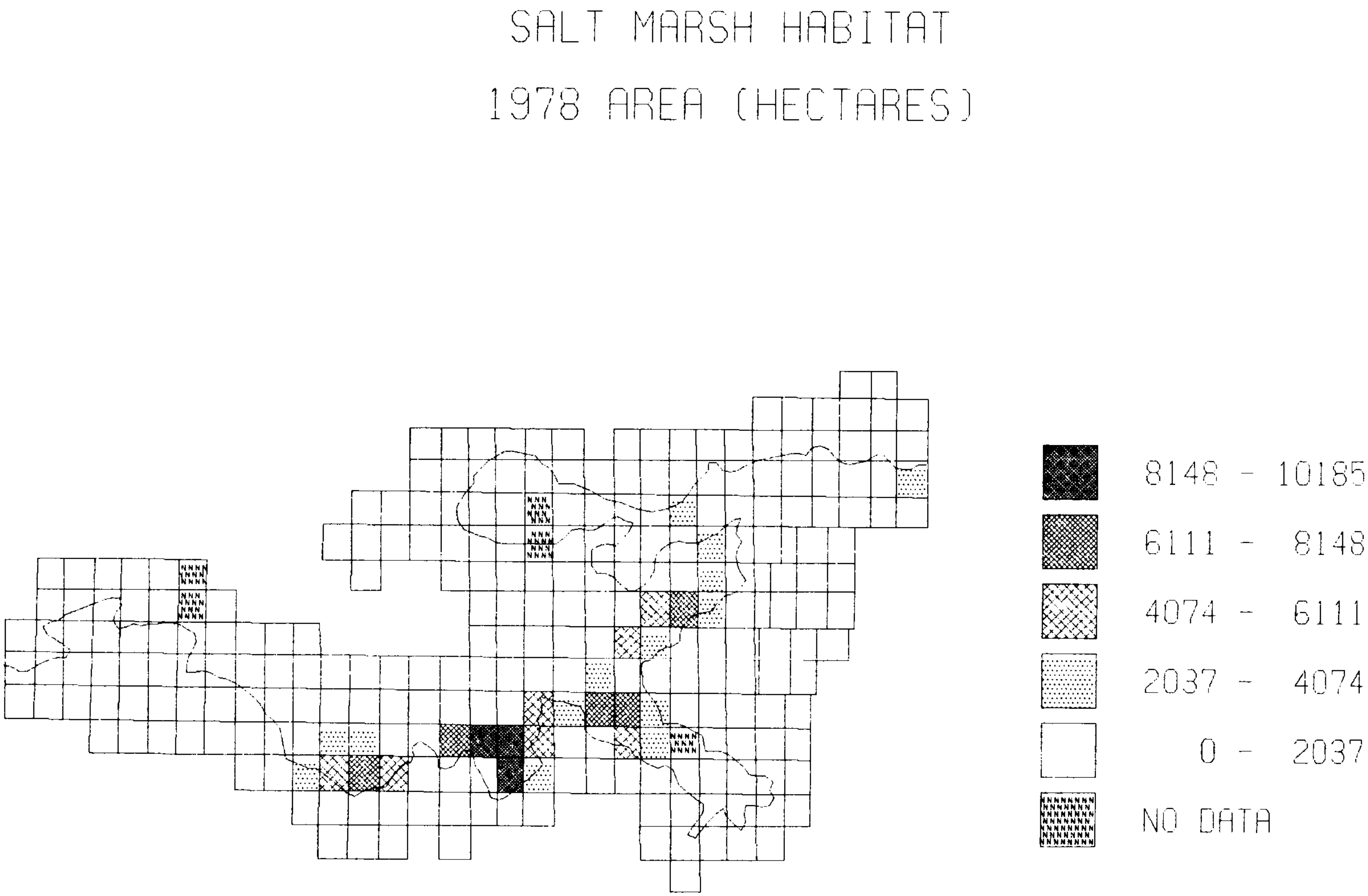


Figure 45. The distribution of MDPR salt marsh habitat.

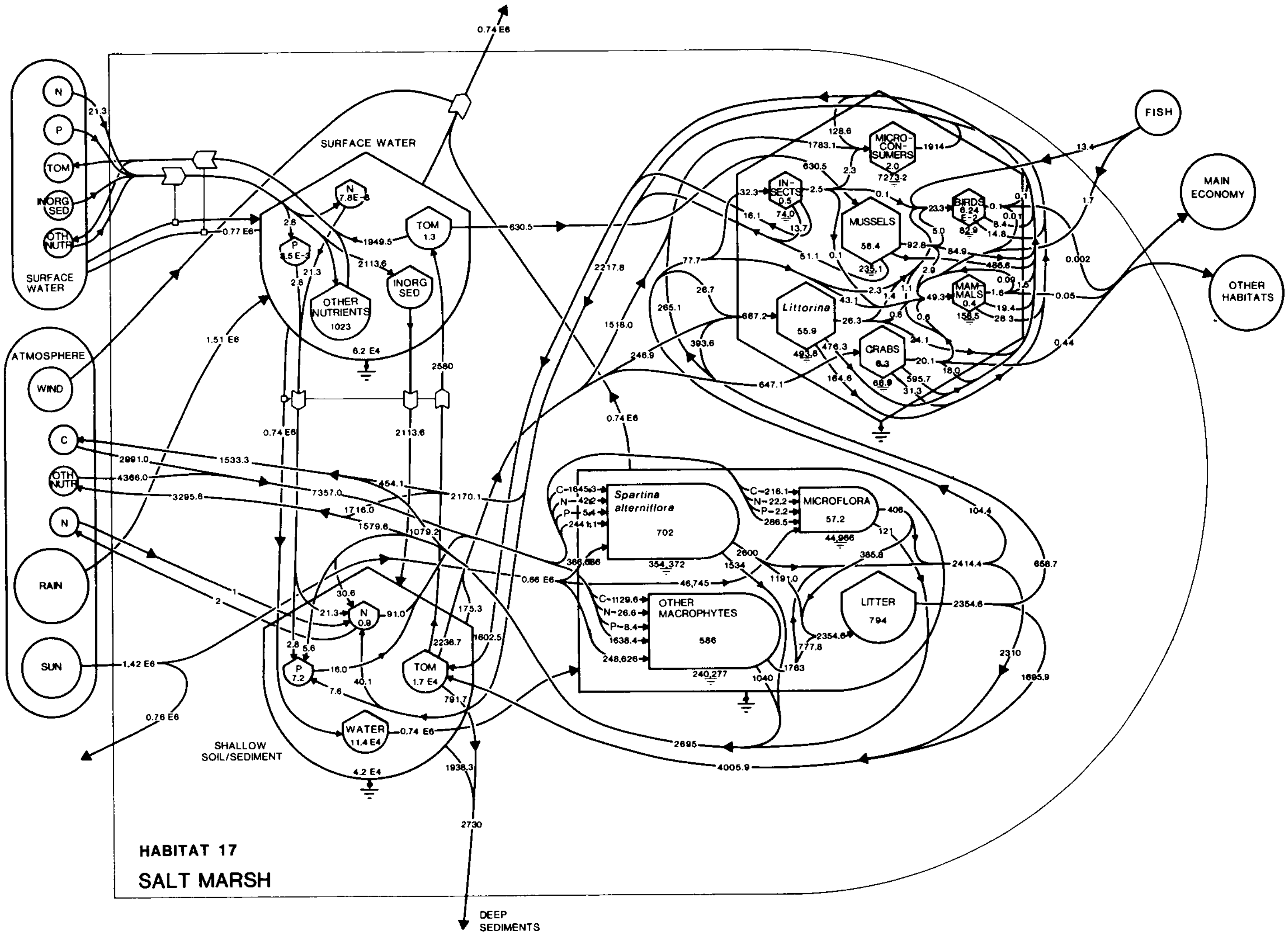


Figure 46. Salt marsh habitat flow diagram.

Table 95. Input-output table for salt marsh habitat.

HABITAT 17
SALT MARSH

COMMODITIES		PROCESSES: SURFACE WATER 1	SHALLOW SOIL/SEDIMENT 2	MICROFLORA 3	*S. alterniflora* 4	OTHER MACROPHYTES 5	LITTER 6	MICROCONSUMERS 7	CRABS 8	MUSSELS 9	*Littorina* 10	INSECTS 11	BIRDS 12	MAMMALS 13	IMPORTS & EXPORTS 14	TOTAL	UNITS
INORGANIC NITROGEN	1	21.3 21.3 7.8 E-3	93.0 93.0 0.9	22.2 5.1	42.2 15.6	26.6 9.9		11.5	3.6	4.3	14.0	1.6	1.5	3.6	2.0 22.3	207.3 207.3 0.9	g N/m²/yr g N/m²/yr g N/m²
INORGANIC PHOSPHORUS	2	2.8 2.8 3.5 E-3	16.0 16.0 7.2	2.2 0.5	5.4 2.0	8.4 3.1		3.8	0.5	0.6	1.8	0.2	0.2	0.5	2.8	34.8 34.8	g P/m²/yr g P/m²/yr g P/m²
INORGANIC CARBON	3			216.1 49.6	1645.3 610.5	1129.6 419.1		317.7	20.8	20.4	65.7	9.1	6.7	13.7	1533.3 2991.0		g C/m²/yr g C/m²/yr
OTHER NUTRIENTS	4	1023		286.5 65.8	2441.1 905.9	1638.4 607.9		1581.0	6.4	25.8	83.1	2.8	6.4	10.6	3295.6 4366.0	7661.6 7661.6 1023	g/m²/yr g/m²/yr g/m²
TOTAL ORGANIC MATTER	5	2580 2580 1.3	1602.5 5608.4 1.7 E4					1518.0	647.1 595.7	630.5 486.6	71.6 476.3	16.1	8.4	19.4	2741.2	9790.9 9790.9 1.7 E4	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
INORGANIC SEDIMENTS	6	2113.6 2113.6	2113.6 2113.6 4.2 E4								175.3				1938.3 2113.6	6340.8 6340.8 4.2 E4	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
WATER	7	1.51 E6 1.51 E6 6.2 E4	740794 740794 11.4 E4	63892 63892	368610 368610	308292 308292									1.51 E6 1.51 E6	4.5 E6 4.5 E6 17.6 E4	g/m²/yr g/m²/yr g/m²
MICROFLORA BIOMASS	8			406 57.2			385.8					5.3	0.8	14.1		406.0 406.0	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
S. alterniflora BIOMASS	9		1377		2600 702		1191.0				15.9	16.1				2600 2600 702	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
OTHER MACROPHYTIC BIOMASS	10		933			1763 586	777.8				10.8	10.9	1.5	29.0		1763 1763 586	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
LITTER BIOMASS	11		1695.9				2354.6 794	265.1			393.6					2354.6 2354.6 1686	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
MICROCONSUMER BIOMASS	12							2.0								2.0	g dry wt/m²
CRAB BIOMASS	13							18.0	20.1 6.3				1.1	0.6	0.4	20.1 20.1 6.3	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
MUSSEL BIOMASS	14							64.9		92.8 56.4			5.0	2.9		92.8 92.8 56.4	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
Littorina BIOMASS	15							24.1			26.3 55.9		1.4	0.8		26.3 26.3 55.9	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
INSECT BIOMASS	16							2.3				2.5 0.5	0.1	0.1		2.5 2.5 0.5	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
BIRD BIOMASS	17							0.1					8.0 E-2 6.24 E-2	0.01	2.1 E-3	0.1 0.1 6.24 E-2	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
MAMMAL BIOMASS	18							1.5						0.09 1.6 0.4	4.7 E-2	1.6 1.6 0.4	g dry wt/m²/yr g dry wt/m²/yr g dry wt/m²
FISH BIOMASS	19												13.4	1.7	15.1	15.1 15.1	g dry wt/m²/yr g dry wt/m²/yr
HEAT	20			44966	354372	240277		7273.2	66.9	235.1	493.8	74.0	82.9	158.5	648001	648001 648001	kcal/m²/yr kcal/m²/yr
SUNLIGHT	21			46745	366686	248626									0.76 E6 1.42 E6	1.42 E6 1.42 E6	kcal/m²/yr kcal/m²/yr

Table 96. Monthly tide levels in cm for 1958-1959 along the central Louisiana coast (adapted from Chabreck 1972).

Month	Mean high tide	Mean low tide	Mean water level	Mean tidal range
Jan.	11.9	-10.7	0.6	22.6
Feb.	17.1	- 7.9	4.6	25.0
Mar.	18.3	- 5.5	6.4	23.8
Apr.	23.8	2.7	13.1	21.1
May	34.4	12.2	23.2	22.2
June	36.3	5.5	21.0	30.8
July	25.3	- 1.8	11.9	27.1
Aug.	25.3	3.4	14.3	21.9
Sept.	38.4	21.0	29.6	17.4
Oct.	32.3	11.9	21.9	20.4
Nov.	25.9	2.1	14.0	23.8
Dec.	11.3	-18.9	- 3.7	30.2
Avg.	25.0	1.2	13.1	23.9

streams, fish are not considered part of the marsh system. Thus the 15.1 g dry wt/sq m/yr of fish consumed by birds and mammals (Tables 135 and 140) is considered an import to the system.

Of the remaining plant material, some is decomposed by microconsumers. Microconsumers as used here includes not only the decomposers but also other microfauna, such as protozoans and nematodes. Microconsumers play an important role in the salt marsh. They not only make food available to other consumers, but they also break down dead plant and animal material and return nitrogen, phosphorus, and other nutrients to the water column and sediments. Microconsumers consume 1914 g dry wt/sq m/yr (Table 122), or 40% of total community net production.

Organic matter is lost to the salt marsh system through sedimentation and by exports to streams, bayous, and/or the gulf. The loss of organic matter to deep sediments is small--about 790 g dry wt/sq m/yr (Table 97, note d). It is estimated that 1950 g dry wt/sq m/yr of organic matter (40% of total net production) is exported to nearby streams and estuaries (note 5,14,I). Export of organic matter has not been directly measured and there are uncertainties in the data for total net production and total decomposition; thus this is an imprecise estimate. Additional research is needed on belowground production, community respiration, and detrital export.

Tidal flushing is an important mechanism for export of dead plant material in the salt marsh. Mean tidal ranges vary from 17 to 31 cm (Table 11), although occasional hurricanes and storms cause much greater surges. Tidal inundation of the marsh occurs throughout the year, although water levels are lower during the winter months, because of northerly winds. Water movement also provides an exchange of nitrogen, phosphorus, carbon, organisms, and sediment between the estuary and the marsh. It is estimated that tidal waters deposit 2114 g/sq m/yr of inorganic sediments into the marsh (Table 97). Salinities of salt marsh waters range from 16 to 19 ppt (Rainey 1979). In addition to surface and subsurface flow, water leaves the marsh through evaporation and plant transpiration.

The salt marsh provides man with some economically valuable commodities. Mammals such as nutria, raccoon, and muskrat are trapped for fur; waterfowl are hunted for food and sport; and crabs are harvested. Output of organic matter from the marsh also provides a source of food for fish that are caught commercially and for sport.

Notes to Salt Marsh Habitat Model

Inorganic nitrogen.

1,1,I	Input of inorganic nitrogen to surface water. 21.3 g N/sq m/yr. Table 97.
1,1,O	Output of inorganic nitrogen from surface water. 21.3 g N/sq m/yr. Table 97.
1,1,S	Storage of inorganic nitrogen in surface water. 7.8 E-3 g N/sq m. Table 98.
1,2,I	Input of inorganic nitrogen to soil. 93.0 g N/sq m/yr. Table 100.
1,2,O	Output of inorganic nitrogen from soil. 93.0 g N/sq m/yr. Table 100.
1,2,S	Storage of inorganic nitrogen in soil. 0.9 g N/sq m. Table 101.
1,3,I	Uptake of inorganic nitrogen by microflora. 22.2 g N/sq m/yr. Table 102.
1,3,O	Release of inorganic nitrogen by microflora. 5.1 g N/sq m/yr. Table 102.
1,4,I	Uptake of inorganic nitrogen by *Spartina alterniflora*. 42.2 g N/sq m/yr. Table 102.
1,4,O	Release of inorganic nitrogen by *Spartina alterniflora*. 15.6 g N/sq m/yr. Table 102.
1,5,I	Uptake of inorganic nitrogen by other macrophytes. 26.6 g N/sq m/yr. Table 102.
1,5,O	Release of inorganic nitrogen by other macrophytes. 9.9 g N/sq m/yr. Table 102.

1,7,0 Release of inorganic nitrogen by microconsumers. 11.5 g N/sq m/yr. Table 103.

1,8,0 Release of inorganic nitrogen by crabs. 3.6 g N/sq m/yr. Table 104.

1,9,0 Release of inorganic nitrogen by mussels. 4.3 g N/sq m/yr. Table 104.

1,10,0 Release of inorganic nitrogen by _Littorina_ _irrorata_. 14.0 g N/sq m/yr. Table 104.

1,11,0 Release of inorganic nitrogen by insects. 1.6 g N/sq m/yr. Table 104.

1,12,0 Release of inorganic nitrogen by birds. 1.5 g N/sq m/yr. Table 105.

1,13,0 Release of inorganic nitrogen by mammals. 3.6 g N/sq m/yr. Table 105.

1,14,I Input of inorganic nitrogen to import/export. 2.0 g N/sq m/yr. Total export of inorganic nitrogen from the system, equal to the rate of denitrification (DeLaune et al. 1976).

1,14,0 Output of inorganic nitrogen from import/export. 22.3 g N/sq m/yr. Total import of inorganic nitrogen to the system, equal to input to surface water (Table 97) plus an atmospheric input of 1 g N/sq m/yr through nitrogen fixation (DeLaune et al. 1976).

Inorganic phosphorus.

2,1,I Input of inorganic phosphorus to surface water. 2.8 g P/sq m/yr. Table 97.

2,1,0 Output of inorganic phosphorus from surface water. 2.8 g P/sq m/yr. Table 97.

2,1,S Storage of inorganic phosphorus in surface water. 3.5 E-3 g P/sq m. Table 98.

2,2,I Input of inorganic phosphorus to soil. 16.0 g P/sq m/yr. Table 100.

2,2,0 Output of inorganic phosphorus from soil. 16.0 g P/sq m/yr. Table 100.

2,2,S Storage of inorganic phosphorus in soil. 7.2 g P/sq m. Table 101.

2,3,I Uptake of inorganic phosphorus by microflora. 2.2 g P/sq m/yr. Table 102.

2,3,0 Release of inorganic phosphorus by microflora. 0.5 g P/sq m/yr. Table 102.

2,4,I Uptake of inorganic phosphorus by _Spartina_ _alterniflora_. 5.4 g P/sq m/yr. Table 102.

2,4,0 Release of inorganic phosphorus by _Spartina_ _alterniflora_. 2.0 g P/sq m/yr. Table 102.

2,5,I Uptake of inorganic phosphorus by other macrophytes. 8.4 g P/sq m/yr. Table 102.

2,5,0 Release of inorganic phosphorus by other macrophytes. 3.1 g P/sq m/yr. Table 102.

2,7,0 Release of inorganic phosphorus by microconsumers. 3.8 g P/sq m/yr. Table 103.

2,8,0 Release of inorganic phosphorus by crabs. 0.5 g P/sq m/yr. Table 104.

2,9,0 Release of inorganic phosphorus by mussels. 0.6 g P/sq m/yr. Table 104.

2,10,0 Release of inorganic phosphorus by _Littorina_ _irrorata_. 1.8 g P/sq m/yr. Table 104.

2,11,0 Release of inorganic phosphorus by insects. 0.2 g P/sq m/yr. Table 104.

2,12,0 Release of inorganic phosphorus by birds. 0.2 g P/sq m/yr. Table 105.

2,13,0 Release of inorganic phosphorus by mammals. 0.5 g P/sq m/yr. Table 105.

2,14,0 Output of inorganic phosphorus from import/export. 2.8 g P/sq m/yr. Total import of inorganic phosphorus to the system, equal to input to surface water (Table 97).

Inorganic carbon.

3,3,I Uptake of inorganic carbon by microflora. 216.1 g C/sq m/yr. Table 102.

3,3,0 Release of inorganic carbon by microflora. 49.6 g C/sq m/yr. Table 102.

3,4,I Uptake of inorganic carbon by _Spartina_ _alterniflora_. 1645.3 g C/sq m/yr. Table 102.

3,4,0 Release of inorganic carbon by <u>Spartina alterniflora</u>. 610.5 g C/sq m/yr. Table 102.

3,5,I Uptake of inorganic carbon by other macrophytes. 1129.6 g C/sq m/yr. Table 102.

3,5,0 Release of inorganic carbon by other macrophytes. 419.1 g C/sq m/yr. Table 102.

3,7,0 Release of inorganic carbon by microconsumers. 317.7 g C/sq m/yr. Table 103.

3,8,0 Release of inorganic carbon by crabs. 20.8 g C/sq m/yr. Table 104.

3,9,0 Release of inorganic carbon by mussels. 20.4 g C/sq m/yr. Table 104.

3,10,0 Release of inorganic carbon by <u>Littorina irrorata</u>. 65.7 g C/sq m/yr. Table 104.

3,11,0 Release of inorganic carbon by insects. 9.1 g C/sq m/yr. Table 104.

3,12,0 Release of inorganic carbon by birds. 6.7 g C/sq m/yr. Table 105.

3,13,0 Release of inorganic carbon by mammals. 13.7 g C/sq m/yr. Table 105.

3,14,I Input of inorganic carbon to import/export. 1533.3 g C/sq m/yr. Total export of inorganic carbon from the system, equal to the sum of all respired carbon (Tables 102-105).

3,14,0 Output of inorganic carbon from import/export. 2991.0 g C/sq m/yr. Total import of inorganic carbon to the system, equal to the sum of carbon assimilation by producers (Table 102).

<u>Other nutrients</u>.

4,1,S Storage of other nutrients (salts) in surface water. 1023 g/sq m. Table 98.

4,3,I Uptake of other nutrients by microflora. 286.5 g/sq m/yr. Table 102.

4,3,0 Release of other nutrients by microflora. 65.8 g/sq m/yr. Table 102.

4,4,I Uptake of other nutrients by <u>Spartina alterniflora</u>. 2441.1 g/sq m/yr. Table 102.

4,4,0 Release of other nutrients by <u>Spartina alterniflora</u>. 905.9 g/sq m/yr. Table 102.

4,5,I Uptake of other nutrients by other macrophytes. 1638.4 g/sq m/yr. Table 102.

4,5,0 Release of other nutrients by other macrophytes. 607.9 g/sq m/yr. Table 102.

4,7,0 Release of other nutrients by microconsumers. 1581.0 g/sq m/yr. Table 103.

4,8,0 Release of other nutrients by crabs. 6.4 g/sq m/yr. Table 104.

4,9,0 Release of other nutrients by mussels. 25.8 g/sq m/yr. Table 104.

4,10,0 Release of other nutrients by <u>Littorina irrorata</u>. 83.1 g/sq m/yr. Table 104.

4,11,0 Release of other nutrients by insects. 2.8 g/sq m/yr. Table 104.

4,12,0 Release of other nutrients by birds. 6.4 g/sq m/yr. Table 105.

4,13,0 Release of other nutrients by mammals. 10.5 g/sq m/yr. Table 105.

4,14,I Input of other nutrients to import/export. 3295.6 g/sq m/yr. Total export of other nutrients from the system, equal to the release of all other nutrients (Tables 102-105). It is assumed that other nutrients are mostly hydrogen and oxygen and thus are lost through the atmosphere.

4,14,0 Output of other nutrients from import/export. 4366.0 g/sq m/yr. Total import of other nutrients to the system, equal to the sum of all other nutrients assimilated (Table 102). It is assumed that other nutrients are mostly hydrogen and oxygen and thus are assimilated through the atmosphere.

<u>Organic matter</u>.

5,1,I Input of organic matter to surface water. 2580 g dry wt/sq m/yr. Table 97.

5,1,0 Output of organic matter from surface water. 2580 g dry wt/sq m/yr. Table 97.

5,1,S Storage of organic matter in surface water. 1.3 g dry wt/sq m. Table 98.

5,2,I Input of organic matter (egested material) to soil. 1602.5 g dry wt/sq m/yr. Table 100, note d.

5,2,O Output of organic matter from soil. 5608.4 g dry wt/sq m/yr. Table 100.

5,2,S Storage of organic matter in soil. 1.7 E4 g dry wt/sq m. Table 101.

5,7,I Input of soil organic matter to microconsumers. 1518.0 g dry wt/sq m/yr. Table 122.

5,8,I Uptake of organic matter by crabs. 647.1 g dry wt/sq m/yr. Table 124. It is assumed that the only significant input to crabs is soil organic matter.

5,8,O Release of organic matter by crabs (egestion). 595.7 g dry wt/sq m/yr. Table 124.

5,9,I Uptake of organic matter by mussels. 630.5 g dry wt/sq m/yr. Table 127. It is assumed that the only significant input to mussels is surface water organic matter.

5,9,O Release of organic matter by mussels (egestion). 486.6 g dry wt/sq m/yr. Table 127.

5,10,I Uptake of organic matter by <u>Littorina irrorata</u>. 71.6 g dry wt/sq m/yr. Table 129.

5,10,O Release of organic matter by <u>Littorina irrorata</u> (egestion). 476.3 g dry wt/sq m/yr. Table 128.

5,11,O Release of organic matter by insects (egestion). 16.1 g dry wt/sq m/yr. Table 130.

5,12,O Release of organic matter by birds (egestion). 8.4 g dry wt/sq m/yr. Table 133.

5,13,O Release of organic matter by mammals (egestion). 19.4 g dry wt/sq m/yr. Table 137.

5,14,I Input of organic matter to import/export. 2741.2 g dry wt/sq m/yr. Total export of organic matter from the system, equal to losses of organic matter from the deep sediments due to subsidence (Table 97, note d) plus loss from surface water. Surface water losses are equal to input to surface water (Table 97) minus uptake by mussels (Table 127), or 1949.5 g dry wt/sq m/yr.

<u>Inorganic sediments</u>.

6,1,I Input of inorganic sediments to surface water. 2113.6 g/sq m/yr. Table 97.

6,1,O Output of inorganic sediments from surface water. 2113.6 g/sq m/yr. Table 97.

6,2,I Input of inorganic sediments to soil. 2113.6 g/sq m/yr. Table 100.

6,2,O Output of inorganic sediments from soil. 2113.6 g/sq m/yr. Table 100.

6,2,S Storage of inorganic sediments in soil. 4.2 E4 g/sq m. Table 101.

6,10,I Uptake of inorganic sediments by <u>Littorina irrorata</u>. 175.3 g dry wt/sq m/yr. Table 129.

6,14,I Input of inorganic sediments to import/export. 1938.3 g/sq m/yr. Total export of inorganic sediments from the system, equal to loss to the deep sediments due to subsidence (Table 100, note e).

6,14,O Output of inorganic sediments from import/export. 2113.6 g/sq m/yr. Total import of inorganic sediments to the system, equal to input to surface water (Table 97).

<u>Water</u>.

7,1,I Input of water to surface water. 1.51 E6 g water/sq m/yr. Table 97.

7,1,O Output of water from surface water. 1.51 E6 g water/sq m/yr. Table 97.

7,1,S Storage of water in surface water. 6.2 E4 g water/sq m. Table 98.

7,2,I Input of water to soil. 740,794 g water/sq m/yr. Table 100.

7,2,O Output of water from soil. 740,794 g water/sq m/yr. Table 100.

7,2,S Storage of water in soil. 11.4 E4 g water/sq m. Table 101.

7,3,I Uptake of water by microflora. 63,892 g water/sq m/yr. Assumed equal to release (transpiration). Table 106.

7,3,O Release of water by microflora (transpiration). 63,892 g water/sq m/yr. Table 106.

7,4,I Uptake of water by _Spartina alterniflora_. 368,610 g water/sq m/yr. Assumed equal to release (transpiration). Table 106.

7,4,O Release of water by _Spartina alterniflora_ (transpiration). 368,610 g water/sq m/yr. Table 106.

7,5,I Uptake of water by other macrophytes. 308,292 g water/sq m/yr. Assumed equal to release (transpiration). Table 106.

7,5,O Release of water by other macrophytes (transpiration). 308,292 g water/sq m/yr. Table 106.

7,14,I Input of water to import/export. 1.51 E6 g water/sq m/yr. Total export of water from the system, assumed equal to total import (Table 97).

7,14,O Output of water from import/export. 1.51 E6 g water/sq m/yr. Total import of water to the system, equal to annual rainfall (Table 97).

Microflora.

8,3,O Output of microflora biomass (net primary production). 406 g dry wt/sq m/yr. Table 107.

8,3,S Storage of microflora biomass. 57.2 g dry wt/sq m. Table 107.

8,6,I Input of microflora to litter. 385.8 g dry wt/sq m/yr. Table 121.

8,11,I Uptake of microflora by insects. 5.3 g dry wt/sq m/yr. Table 131.

8,12,I Uptake of microflora by birds. 0.8 g dry wt/sq m/yr. Table 135.

8,13,I Uptake of microflora by mammals. 14.1 g dry wt/sq m/yr. Table 140.

Spartina alterniflora.

9,2,I Input of _Spartina alterniflora_ to soil. 1377 g dry wt/sq m/yr. Equal to belowground NPP (Table 109).

9,4,O Output of _Spartina alterniflora_ biomass (net primary production). 2600 g dry wt/sq m/yr. Table 109.

9,4,S Storage of living _Spartina alterniflora_ biomass. 702 g dry wt/sq m. Table 116.

9,6,I Input of _Spartina alterniflora_ to litter. 1191.0 g dry wt/sq m/yr. Table 121.

9,10,I Uptake of _Spartina alterniflora_ by _Littorina irrorata_. 15.9 g dry wt/sq m/yr. Table 129.

9,11,I Uptake of _Spartina alterniflora_ by insects. 16.1 g dry wt/sq m/yr. Table 131.

Other macrophytes.

10,2,I Input of other macrophytes to soil. 933 g dry wt/sq m/yr. Equal to belowground NPP (Table 109).

10,5,O Output of other macrophytes biomass (net primary production). 1763 g dry wt/sq m/yr. Table 109.

10,5,S Storage of living other macrophytes biomass. 586 g dry wt/sq m. Table 116.

10,6,I Input of other macrophytes to litter. 777.8 g dry wt/sq m/yr. Table 121.

10,10,I Uptake of other macrophytes by _Littorina irrorata_. 10.8 g dry wt/sq m/yr. Table 129.

10,11,I Uptake of other macrophytes by insects. 10.9 g dry wt/sq m/yr. Table 131.

10,12,I Uptake of other macrophytes by birds. 1.5 g dry wt/sq m/yr. Table 135.

10,13,I Uptake of other macrophytes by mammals. 29.0 g dry wt/sq m/yr. Table 140.

Litter.

11,2,I Input of litter to soil. 1695.9 g dry wt/sq m/yr. Table 100, note d.

11,6,O Output of litter biomass. 2354.6 g dry wt/sq m/yr. Assumed equal to total input (Table 121).

11,6,S Storage of litter. 794 g dry wt/sq m. Equal to aboveground portions of dead Spartina alterniflora and other macrophytes (Table 116).

11,7,I Input of litter to microconsumers. 265.1 g dry wt/sq m/yr. Table 122.

11,10,I Uptake of litter by Littorina irrorata. 393.6 g dry wt/sq m/yr. Table 129.

Microconsumers.

12,7,S Storage of microconsumer biomass. 2.0 g dry wt/sq m. Based on the standing crop of meiobenthos (Day et al. 1973). It is assumed that these organisms make up the major bulk of microconsumer biomass.

Crabs.

13,7,I Input of crabs to microconsumers. 18.0 g dry wt/sq m/yr. Table 123.

13,8,O Output of crab biomass (production). 20.1 g dry wt/sq m/yr. Table 124.

13,8,S Storage of crab biomass. 6.3 g dry wt/sq m. Table 124.

13,12,I Uptake of crabs by birds. 1.1 g dry wt/sq m/yr. Table 135.

13,13,I Uptake of crabs by mammals. 0.6 g dry wt/sq m/yr. Table 140.

13,14,I Input of crabs to import/export. 0.4 g dry wt/sq m/yr. Total export of crabs from the system, equal to crab harvest (Table 126).

Mussels.

14,7,I Input of mussels to microconsumers. 84.9 g dry wt/sq m/yr. Table 123.

14,9,O Output of mussel biomass (production). 92.8 g dry wt/sq m/yr. Table 127.

14,9,S Storage of mussel biomass. 56.4 g dry wt/sq m. Table 127.

14,12,I Uptake of mussels by birds. 5.0 g dry wt/sq m/yr. Table 135.

14,13,I Uptake of mussels by mammals. 2.9 g dry wt/sq m/yr. Table 140.

Littorina.

15,7,I Input of Littorina irrorata to microconsumers. 24.1 g dry wt/sq m/yr. Table 123.

15,10,O Output of Littorina irrorata biomass (production). 26.3 g dry wt/sq m/yr. Table 128.

15,10,S Storage of Littorina irrorata biomass. 55.9 g dry wt/sq m. Table 128.

15,12,I Uptake of Littorina irrorata by birds. 1.4 g dry wt/sq m/yr. Table 135.

15,13,I Uptake of Littorina irrorata by mammals. 0.8 g dry wt/sq m/yr. Table 140.

Insects.

16,7,I Input of insects to microconsumers. 2.3 g dry wt/sq m/yr. Table 123.

16,11,O Output of insect biomass (production). 2.5 g dry wt/sq m/yr. Table 130.

16,11,S Storage of insect biomass. 0.5 g dry wt/sq m. Table 130.

16,12,I Uptake of insects by birds. 0.1 g dry wt/sq m/yr. Table 135.

16,13,I Uptake of insects by mammals. 0.1 g dry wt/sq m/yr. Table 140.

Birds.

17,7,I Input of birds to microconsumers. 0.1 g dry wt/sq m/yr. Table 123.

17,12,O Output of bird biomass (production). 8.0 E-2 g dry wt/sq m/yr. Table 133.

17,12,S Storage of bird biomass. 6.24 E-2 g dry wt/sq m. Table 134.

17,13,I Uptake of birds by mammals. 0.01 g dry wt/sq m/yr. Table 140.

17,14,I Input of birds to import/export. 2.1 E-3 g dry wt/sq m/yr. Total export of birds from the system, equal to harvest (Table 136).

Mammals.

18,7,I Input of mammals to microconsumers. 1.5 g dry wt/sq m/yr. Table 123.

18,13,1 Uptake of mammals by mammals. 0.09 g dry wt/sq m/yr. Table 140.

18,13,0 Output of mammal biomass (production). 1.6 g dry wt/sq m/yr. Table 137.

18,13,S Storage of mammal biomass. 0.4 g dry wt/sq m. Table 137.

18,14,I Input of mammals to import/export. 4.7 E-2 g dry wt/sq m/yr. Total export of mammals from the system, equal to harvest (Table 141).

Fish.

19,12,I Uptake of fish by birds. 13.4 g dry wt/sq m/yr. Table 135.

19,13,I Uptake of fish by mammals. 1.7 g dry wt/sq m/yr. Table 140.

19,14,0 Output of fish from import/export. 15.1 g dry wt/sq m/yr. Total import of fish into the system, equal to consumption by birds (Table 135) plus consumption by mammals (Table 140).

Heat.

20,3,0 Release of heat by microflora. 44,966 kcal/sq m/yr. Table 143.

20,4,0 Release of heat by Spartina alterniflora. 354,372 kcal/sq m/yr. Table 143.

20,5,0 Release of heat by other macrophytes. 240,277 kcal/sq m/yr. Table 143.

20,7,0 Release of heat by microconsumers. 7273.2 kcal/sq m/yr. Table 143.

20,8,0 Release of heat by crabs. 68.9 kcal/sq m/yr. Table 143.

20,9,0 Release of heat by mussels. 235.1 kcal/sq m/yr. Table 143.

20,10,0 Release of heat by Littorina irrorata. 493.8 kcal/sq m/yr. Table 143.

20,11,0 Release of heat by insects. 74.0 kcal/sq m/yr. Table 143.

20,12,0 Release of heat by birds. 82.9 kcal/sq m/yr. Table 143.

20,13,0 Release of heat by mammals. 158.5 kcal/sq m/yr. Table 143.

20,14,I Input of heat to import/export. 648,001 kcal/sq m/yr. Total export of heat from the system (Table 143).

Sunlight.

21,3,I Uptake of sunlight by microflora. 46,745 kcal/sq m/yr. Table 144.

21,4,I Uptake of sunlight by Spartina alterniflora. 366,686 kcal/sq m/yr. Table 144.

21,5,I Uptake of sunlight by other macrophytes. 248,626 kcal/sq m/yr. Table 144.

21,14,I Input of sunlight to import/export. 0.76 E6 kcal/sq m/yr. Total export of sunlight from the system, equal to albedo (Table 145).

21,14,0 Output of sunlight from import/export. 1.42 E6 kcal/sq m/yr. Total import of sunlight from the system, equal to insolation (Table 145).

Table 97. Nutrient movement in MDPR salt marsh surface waters.[a]

Nutrient	Value
N[b]	21.3
P[c]	2.8
Organic matter[d]	2580.0
Inorganic sediments[e]	2113.6
Water[f]	1.51 E6

[a]Values as g/sq m/yr. It is assumed that there is no net change in the storage of a nutrient and that flow in is equal to flow out.

[b]Uptake of inorganic nitrogen from soils is equal to 93.0 g N/sq m/yr (Table 100). Inputs to the soil by plants, microconsumers, invertebrates, and vertebrates are 30.6 (Table 102), 11.5 (Table 103), 23.5 (Table 104), and 5.1 (Table 105) g N/sq m/yr, respectively. In addition, nitrogen fixation returns an additional 1 g N/sq m/yr (DeLaune et al. 1976). This gives a total of 71.7 g N/sq m/yr. Assuming a steady state, input of the remaining 21.3 g N/sq m/yr are from the surface water.

[c]Uptake of inorganic phosphorus from soils is equal to 16.0 g P/sq m/yr (Table 100). Inputs to the soil by plants, microconsumers, invertebrates, and vertebrates are 5.6 (Table 102), 3.8 (Table 103), 3.1 (Table 104), and 0.7 (Table 105) g P/sq m/yr, respectively, giving a total of 13.2. Assuming a steady state, input of the remaining 2.8 g P/sq m/yr are from the surface water.

[d]The total input of organic matter to soils is equal to 5608.4 g dry wt/sq m/yr (Table 100). Microconsumers, crabs, and <u>Littorina irrorata</u> consume 1518.0 (Table 122), 647.1 (Table 124), and 71.6 (Table 129) g dry wt/sq m/yr, respectively, for a total of 2236.7. In addition, 791.7 g dry wt/sq m/yr of organic matter are lost to deep sediments (total soil loss to deep sediments is 2730 g soil/sq m/yr, 1938.3 of which are inorganic sediments; Table 100, note e). This gives a total of 3028.4 g dry wt/sq m/yr. Assuming a steady state, the remaining 2580.0 g dry wt/sq m/yr enter the surface water.

[e]Total output of inorganic sediments from the soil is 2113.6 g/sq m/yr (Table 100). Assuming a steady state, this same amount enters the soil from the surface water.

[f]Calculated as total input of rain. The 40 year average rate of precipitation for New Orleans, Louisiana was 59.64 in/yr (NOAA 1981), or 1.51 cu m/sq m/yr. This is equivalent to 1.51 E6 g/sq m/yr.

Table 98. Storage of nutrients and organic matter in MDPR surface water.[a]

Component	Storage
N[b]	7.8 E-3
P[c]	3.5 E-3
Other nutrients[d]	1023.0
Organic matter[e]	1.3
Total water[f]	6.2 E4

[a]Values as g/sq m. Storages of nutrients and organic matter calculated by multiplying the total amount of water by the concentration of that nutrient.

[b]The concentration of inorganic nitrogen in the surface water of the marsh is 1.25 E-4 g/l (Table 99).

[c]The concentration of inorganic phosphorus in the surface water of the marsh is 5.7 E-5 g/l (Table 99).

[d]The concentration of salts in the surface water of the marsh is 16.5 parts per thousand (16.5 g/1000 g).

[e]The concentration of total organic carbon in the surface water of the marsh is 5.2 E-3 g C/l (Cramer 1978). Based on four particle sizes of *Spartina alterniflora* and five periods of decomposition, the dry weight to carbon ratio for detritus is 4.1 g dry wt/g C (Kirby 1971). This gives a concentration of 2.1 E-2 g/l.

[f]Salt marshes are flooded 50.2% of the year, with a mean flooding depth of 12.3 cm (Baumann 1980). There is no surface water during the remaining portion of the year. The average depth of water over the entire year is therefore 6.2 cm, or 6.2 cu cm/sq cm. This is equivalent to 6.2 E4 g/sq m, and is also equivalent to 62 l/sq m.

Table 99. Nutrient chemistry of surface water in MDPR salt and brackish marshes.[a]

Date	Salt marsh	Nutrient	Brackish marsh
		Inorganic N	
June 1973	7.17 E-2		0.17
Aug. 1973	12.45 E-2		0.09
Oct. 1973	8.08 E-2		0.14
Dec. 1973	19.75 E-2		0.37
Feb. 1974	18.08 E-2		1.07
Apr. 1974	9.35 E-2		0.10
Avg.	12.48 E-2		0.32
		Inorganic P	
June 1973	5.28 E-2		1.6 E-2
Aug. 1973	3.35 E-2		5.2 E-2
Oct. 1973	4.25 E-2		4.0 E-2
Dec. 1973	10.35 E-2		1.7 E-2
Feb. 1974	5.40 E-2		5.5 E-2
Apr. 1974	5.75 E-2		14.2 E-2
Avg.	5.73 E-2		5.4 E-2
		Salinity	
June 1973	15.6		9.8
Aug. 1973	15.7		7.5
Oct. 1973	16.8		4.2
Dec. 1973	22.3		10.7
Feb. 1974	12.0		4.3
Apr. 1974	16.8		7.1
Avg.	16.5		7.3

[a]Nitrogen and phosphorus as mg/l, and salinity as parts per thousand. Salt marsh values are averages of four locations from the Louisiana Offshore Oil Port study (stations 3, 4, 5, and 6). Brackish marsh values are from station 7. Data from Ho and Schneider 1976.

Table 100. Nutrient movement in MDPR salt marsh soils.[a]

Nutrient	Value
N[b]	93.0
P[c]	16.0
Organic matter[d]	5608.4
Inorganic sediments[e]	2113.6
Water[f]	740,794

[a]Values as g/sq m/yr. It is assumed that there is no net change in the storage of a nutrient and that flow in is equal to flow out.

[b]Calculated as the sum of soil loss through plant uptake and denitrification. These are equal to 91.0 (Table 102) and 2.0 (DeLaune et al.1976) g N/sq m/yr, respectively.

[c]Calculated as soil loss through plant uptake (Table 102).

[d]Calculated as the sum of inputs from belowground NPP, litter, and egesta. Total belowground NPP is equal to 2310 g dry wt/sq m/yr (Table 109). The total amount of litter produced is 2354.6 g dry wt/sq m/yr (Table 121), with consumption of litter by Littorina irrorata and microconsumers equal to 393.6 (Table 129) and 265.1 (Table 122) g dry wt/sq m/yr. Thus input of litter to soil is equal to the remaining 1695.9 g dry wt/sq m/yr. Egestion rates for crabs, mussels, L. irrorata, insects, birds, and mammals are 595.7 (Table 124), 486.6 (Table 127), 476.3 (Table 128), 16.1 (Table 130), 8.4 (Table 133), and 19.4 (Table 137) g dry wt/sq m/yr, respectively, for a total of 1602.5.

[e]Calculated as soil loss through uptake by consumers and loss to the deep sediments. Uptake of sediments by L. irrorata is equal to 175.3 g dry wt/sq m/yr (Table 129). The subsidence rate of MDPR soils is 1.3 cm/yr (Baumann 1980), and the bulk density of salt marsh soils averages 0.21 g soil/cu cm (Table 101, note f). Loss of soil to deep sediments is therefore 0.273 g/sq cm, or 2730 g/sq m. The percent organic matter of salt marsh soils is 29% (Table 101, note d) with inorganic sediments making up the other 71%. Loss of inorganic sediments to the deep sediments is therefore equal to 1938.3 g/sq m/yr.

[f]Calculated as soil loss through plant uptake, which is assumed equal to transpiration (Table 106).

Table 101. Storage of nutrients, organic matter, and moisture in MDPR salt marsh soils.[a]

Component	Storage
Soil	
N[b]	0.9
P[c]	7.2
Organic matter[d]	1.7 E4
Inorganic sediments[e]	4.2 E4
TOTAL[f]	5.9 E4
Moisture[g]	11.4 E4

[a]Values as g/sq m.
[b]The concentration of inorganic nitrogen at a streamside and inland marsh site is 9.4 and 16.3 ug N/g soil, respectively (Brannon 1973). The relative proportions of streamside and inland marsh are 0.254 and 0.746, respectively (Table 110, note e), giving a weighted average of 14.5 ug N/g soil. Soil N is calculated by multiplying this by the total storage of soil.
[c]The concentration of inorganic phosphorus at a streamside and inland marsh site is 126.7 and 119.5 ug P/g soil, respectively (DeLaune et al. 1979), giving a weighted average of 121.3 ug P/g soil (note b above). Soil P is calculated by multiplying this by the total storage of soil.
[d]The percent organic matter at a streamside and inland marsh site is 19 and 33%, respectively (Brannon 1973), giving a weighted average of 29% (note b above). Soil organic matter is calculated by multiplying this by the total storage of soil.
[e]Calculated as total minus organic matter.
[f]The bulk densities of streamside and inland soils are 0.27 and 0.19 g dry soil/cu cm, respectively (DeLaune et al. 1979), giving a weighted average of 0.21 g soil/cu cm (note b above). The rooting depths of streamside and inland marsh sites are 50 and 20 cm, respectively (DeLaune et al. 1979), giving a weighted average of 28 cm. The density of soil is therefore 5.9 g dry soil/sq cm, or 5.9 E4 g dry soil/sq m.
[g]The moisture content of a marsh soil is 66% (Hood 1970), and thus the dry portion represents 34% of the total weight of a wet soil. The wet to dry ratio is therefore 66/34 = 1.94. Soil moisture is calculated by multiplying this by the total dry weight of the soil.

Table 102. Nutrient uptake and release by MDPR salt marsh flora.[a]

Nutrient	Microflora[b]	*Spartina alterniflora*[c]	Other macrophytes[d]
Uptake			
N	22.2	42.2	26.6
P	2.2	5.4	8.4
C	216.1	1645.3	1129.6
Other[e]	286.5	2441.1	1638.4
Release			
N	5.1	15.6	9.9
P	0.5	2.0	3.1
C	49.6	610.5	419.1
Other[f]	65.8	905.9	607.9

[a]Values are g/sq m/yr. Uptake is calculated as gross primary production multiplied by the percent composition of each nutrient, and release is calculated as respiration multiplied by the percent composition. GPP and respiration for microflora are from Table 107, and from Table 109 for *S. alterniflora* and other macrophytes.

[b]The average %N, %P, and %C of algae from ponds and lakes in the Southeastern U.S. was 4.22, 0.42, and 41.0%, respectively (Jorgensen 1979). This was based on analyses of 15, 15, and 14 species, respectively.

[c]The average %N and %P for *S. alterniflora* is 1.02 and 0.13%, respectively (Gosselink et al. 1977). The average %C is 39.8% (de la Cruz 1973).

[d]The %N for *Distichlis spicata*, *Juncus roemerianus*, and *Spartina patens* is 1.04, 0.98, and 0.78%, respectively (Gosselink et al. 1977). The relative proportions of net production by these producers is 0.263, 0.490, and 0.247, respectively (Table 115). The weighted %N for other macrophytes is therefore 0.95%. The %P of *D. spicata*, *J. roemerianus*, and *S. patens* is 0.12, 0.12, and 0.86, respectively (Gosselink et al. 1977), giving a weighted average of 0.30%. The %C for *D. spicata* and *J. roemerianus* is 36.6 and 42.6%, respectively (de la Cruz 1973). Assuming *S. patens* has a C content similar to *S. alterniflora*, it has a %C of 39.8% (note c above). This gives a weighted average of 40.3%.

[e]Uptake of other nutrients (primarily oxygen and hydrogen) is calculated as gross primary production minus uptake of N, P, and C.

[f]Release of other nutrients (primarily oxygen and hydrogen) is calculated as respiration minus release of N, P, and C.

Table 103. Release of nutrients by microconsumers in MDPR salt marshes.[a]

Nutrient	Value
N[b]	11.5
P[c]	3.8
C[d]	317.7
Other[e]	1581.0

[a]Values as g/sq m/yr. Calculated by multiplying the respiration rate of microconsumers by the nutrient concentrations of detritus. A respiration value of 870 g C/sq m/yr (1914 g dry wt/sq m/yr) is used based on a Georgia salt marsh (Howarth and Hobbie 1982). Nutrient concentrations are based on analyses of Juncus roemerianus which included partially decayed pieces, decomposed fragments, and particulate detritus (de la Cruz and Gabriel 1974).
[b]%N in detritus equal to 0.6%.
[c]%P in detritus equal to 0.2%.
[d]%C in detritus equal to 16.6%.
[e]Calculated as respiration minus release of N, P, and C.

Table 104. Nutrient release by MDPR salt marsh invertebrates.[a]

Nutrient	Crabs[b]	Mussels[c]	*Littorina irrorata*[c]	Insects[b]
Release				
N	3.6	4.3	14.0	1.6
P	0.5	0.6	1.8	0.2
C	20.8	20.4	65.7	9.1
Other[d]	6.4	25.8	83.1	2.8

[a]Values are g/sq m/yr. Release is calculated as respiration multiplied by the percent composition of each nutrient. Respiration for crabs, mussels, *L. irrorata*, and insects is taken from Tables 124, 127, 128, and 130, respectively.

[b]The N to biomass (ash free dry weight) ratio for invertebrates is 0.090, based on an analysis of 19 species (Jorgensen 1979). The ratio of dry weight to ash free dry weight is 1.28 for crabs (Table 124, note b), giving an N to biomass ratio of 0.115. There is one mole of P (30.1 g) incorporated with every 16 mole of N (224 g) in protoplasm (E. P. Odum 1971), giving a P to N ratio of 0.13. Using this to convert the N to biomass ratio gives a P to biomass ratio of 0.015. The C to biomass (ash free dry weight) ratio for invertebrates is 0.518, based on an analysis of 19 species (Jorgensen 1979). This gives a ratio of 0.663 on a dry weight basis.

[c]The %N of molluscs is 8.5% (Jorgensen 1979). Using a P to N ratio of 0.13 (note b above) gives a %P of 1.1%. The %C of molluscs is 39.9% (Jorgensen 1979).

[d]Release of other nutrients (primarily oxygen and hydrogen) is calculated as respiration minus uptake of N, P, and C.

Table 105. Nutrient release by MDPR salt marsh vertebrates.[a]

Nutrient	Birds[b]	Mammals[c]
Release		
N	1.5	3.6
P	0.2	0.5
C	6.7	13.7
Other[d]	6.4	10.5

[a]Values are g/sq m/yr. Release is calculated as respiration multiplied by the percent composition of each nutrient. Respiration for birds and furbearers are taken from Tables 133 and 137, respectively.
[b]The mean %N for animals is 10% (Jorgensen 1979). Using a P to N ratio of 0.13 (Table 104, note b), gives a %P of 1.3%. The mean %C for animals is 45% (Jorgensen 1979).
[c]The mean %N for mammals is 12.8% (Jorgensen 1979). Using a P to N ratio of 0.13 (Table 104, note b) gives a %P of 1.7%. The mean %C for mammals is 48.4% (Jorgensen 1979).
[d]Release of other nutrients (primarily oxygen and hydrogen) is calculated as respiration minus uptake of N, P, and C.

Table 106. Transpiration by producers in MDPR salt marshes.[a]

Process	Value
Microflora[b]	63,892
Spartina alterniflora[c]	368,610
Other macrophytes[d]	308,292
TOTAL	740,794

[a]Values as g water/sq m/yr. Calculated by multiplying aboveground biomass by a transpiration to biomass ratio. Transpiration ratios in Florida marshes range from 414-1820 g water/g dry wt (Lugo et al. 1979 as cited in Brown 1981). The middle value, 1117 g water/g dry wt, is used.
[b]Biomass equal to 57.2 g dry wt/sq m (Table 107).
[c]Biomass equal to 330 g dry wt/sq m (Table 116).
[d]Biomass equal to 276 g dry wt/sq m (Table 116).

Table 107. Gross primary production, net primary production, respiration, and biomass of microflora in MDPR salt marshes.[a]

Process	Value
Gross primary production[b]	527
Net primary production[c]	406
Respiration[d]	121
Biomass[e]	57.2

[a]Biomass as g dry wt/sq m. All other values as g dry wt/sq m/yr.
[b]Gross primary production of microflora is calculated by multiplying total gross primary production of macrophytes (6937 g dry wt/sq m/yr) (Table 109) by a microflora GPP to macrophyte GPP ratio of 0.076 (Table 108).
[c]Ricklefs (1979) cites net to gross production ratios of 0.79 and 0.75 for algae and phytoplankton, respectively. The average of these two, 0.77, is used to calculate net primary production from gross primary production.
[d]Gross primary production minus net primary production.
[e]The average NPP to biomass ratio of three algae (*Agarum cribrosum*, *Laminaria digitata*, and *L. longicruris*) is 7.1 (Jorgensen 1979). Biomass is calculated by dividing NPP by this value.

Table 108. Ratio of microflora gross primary production to macrophyte gross primary production in a Louisiana salt marsh.

Date	Microflora GPP[a]	Macrophyte GPP[b]	Ratio[c]
Dec. 1975	40	340	0.118
Mar. 1976	36	516	0.070
May 1976	27	662	0.041
Avg.			0.076

[a]Values are mg C/0.075 sq m/day. Data from Gosselink et al. 1977.
[b]Values are mg C/0.075 sq m/day. Data from Table 113.
[c]Ratio of microflora gross primary production to macrophyte gross primary production.

Table 109. Net primary production, respiration, and gross primary production of salt marsh macrophytes in the MDPR.[a]

	Spartina alterniflora	Other macrophytes[b]	Total
Aboveground NPP[c]	1223	830	2053
Belowground NPP[d]	1377	933	2310
TOTAL NPP	2600	1763	4363
Respiration[e]	1534	1040	2574
Gross primary production[f]	4134	2803	6937

[a]Values are g dry wt/sq m/yr.
[b]Distichlis spicata, Juncus roemerianus, Spartina patens.
[c]From Table 110.
[d]In Georgia salt marshes, anaerobic processes (denitrification, sulfate reduction, and methanogenesis) cause the decomposition of 690 g C sq m/yr, or 1518 g dry wt/sq m/yr (Howarth and Hobbie 1982). It is assumed that belowground production of MDPR macrophytes is equal to this loss plus the amount of organic matter lost by sedimentation (792 g dry wt/sq m/yr) (Table 97, note d). This gives a total belowground production of 2310 g dry wt/sq m/yr. This belowground production is distributed amongst the S. alterniflora and other macrophytes according to their proportion of aboveground net primary production (59.6 and 40.4%, respectively).
[e]Respiration is calculated by multiplying total NPP by a respiration to NPP ratio of 0.59 (Table 113).
[f]Gross primary production is equal to the sum of NPP and respiration.

Table 110. Aboveground net primary production of MDPR salt marsh macrophytes.[a]

Plant	Production	Method[b]	Reference[c]
Distichlis spicata			
	1484	MH	2
	3237	WE	3
	1162	WE	8
Average	1961		
Weighted avg.[d]	218		
Juncus roemerianus			
	1697	MW	2
	3416	WE	3
	3078	S	7
	1806	WE	8
Average	2499		
Weighted avg.	407		
Spartina alterniflora (streamside)[e]			
	2658	WE	3
	2645	WE	4
Subaverage[f]	2652		
	1964	MH	2
	2895	WE	8
Average	2504		
Weighted avg.	421		
Spartina alterniflora (inland)[e]			
	1323	WE	4
	2230	WE (g)	6
Subaverage[f]	1776		
	1089	MH	2
	2029	S	7
Average	1631		
Weighted avg.	802		
Spartina patens			
	3808	WE (h)	1
	1922	MH	2
	6043	WE	3
	2128	S	5
	1428	WE	8
Average	3066		
Weighted avg.	205		
Total, S. alterniflora	1223		
Total, Other macrophytes	830		
TOTAL	2053		

(continued)

Table 110. Concluded.

[a]Production reported as g dry wt/sq m/yr.
[b]MH - Milner and Hughes (1968); S - Smalley (1959b); WE - Wiegert and Evans (1964). For a discussion of these methods see Shew et al. (1981).
[c]1. Cramer et al. 1981; 2. de la Cruz 1974; 3. Hopkinson et al. 1978b; 4. Kirby and Gosselink 1976; 5. Payonk 1975; 6. Table 111; 7. Stout 1978; 8. White et al. 1978.
[d]The weighted average is the product of the average production and a weighting factor. Weighting factors are 0.111, 0.163, 0.168, 0.492, and 0.067 for *D. spicata*, *J. roemerianus*, streamside *S. alterniflora*, inland *S. alterniflora*, and *S. patens*, respectively (Table 112 except for S. alterniflora, which is from note e below).
[e]*Spartina alterniflora* is found in two height forms in the deltaic plain. The tall form is found alongside marsh streams and bayous, and is referred to as streamside marsh. The short form is found further from the streams, and therefore is referred to as inland marsh. The proportions of streamside vegetation, inland vegetation, and bare ground at Airplane Lake, La., were measured as 18, 53, and 29%, respectively (Kirby and Gosselink 1976). If bare ground is excluded, the proportions of streamside and inland marsh are 25.4 and 74.6%, respectively. Since *S. alterniflora* accounts for 66% of MDPR vegetation (Table 112), streamside and inland *S. alterniflora* represent 16.8 and 49.2% of MDPR vegetation, respectively.
[f]Hopkinson et al. (1978b), Kirby and Gosselink (1976), and Sasser et al. (1981; upon which Table 111 is based) all studied marshes that were relatively close together, near Airplane Lake by Caminada Bay. To average these sites with others would bias the values towards the Airplane Lake data. To avoid this, these data were subaveraged first.
[g]Average monthly production at the Louisiana Offshore Oil Port site is 185.8 g dry wt/sq m (Table 111). Annual production is thus 2230 g dry wt/sq m.
[h]Average of four Lake Pontchartrain marsh sites.

Table 111. Salt marsh productivity in the Louisiana Offshore Oil Port study area based on a modified Wiegert and Evans method.[a]

Date	Dead biomass[b]	Avg. dead biomass[c]	Dead loss[d]	Change in dead biomass[e]	Mortality[f]	Live biomass[b]	Change in live biomass[e]	Production[g]
2-80	1061.6					190.0		
		1079.2	159.7	35.3	195.0		84.6	279.6
3-80	1096.9					274.6		
		1114.6	165.0	35.3	200.3		84.6	284.9
4-80	1132.2					359.2		
		1135.6	168.1	6.7	174.8		102.2	277.0
5-80	1138.9					461.4		
		1067.8	158.0	-142.2	15.8		254.6	270.4
6-80	996.7					716.0		
		1046.4	154.9	99.3	254.2		49.4	303.6
7-80	1096.0					765.4		
		1011.5	149.7	-169.0	-19.3		32.8	13.5
8-80	927.0					798.2		
		800.6	118.5	-252.8	134.3		-162.6	0.0
9-80	674.2					635.6		
		737.6	109.2	126.7	235.9		-156.9	79.0
10-80	800.9					478.7		
		839.0	124.2	76.3	200.5		150.0	350.0
11-80	877.2					628.7		
		1000.0	148.0	245.6	393.6		-450.0	0.0
12-80	1122.8					178.7		

[a] Dead and live biomass are means of 10 replications, and were calculated from data in Sasser et al. (1981). Biomass is in g dry wt/sq m. For a discussion of the Wiegert and Evans method, see Wiegert and Evans (1964) and Shew et al. (1981).

[b] March data were not collected and so were calculated as the average of February and April data.

[c] The average dead biomass of an interval is equal to $(D(t) + D(t+1))/2$, where $D(t)$ and $D(t+1)$ are the values of dead biomass at months t and t+1.

[d] Loss, in g dry wt/sq m/mo, is equal to the product of the average dead biomass and the monthly instantaneous loss rate (r). An average loss rate of 0.148 for inland marsh is taken from Kirby and Gosselink (1976).

[e] The monthly change in dead or live biomass is equal to $B(t+1) - B(t)$, where $B(t+1)$ and $B(t)$ are biomass values at times t+1 and t.

[f] Mortality, in g/sq m/mo, is the sum of dead loss and change in dead biomass.

[g] Production, in g/sq m/mo, is equal to the sum of mortality and change in live biomass. A value of zero is assigned to negative productions.

Table 112. Vegetative composition of MDPR salt marshes.

Plant	Hydrologic unit[a] I	II	IV	V	VII	Total
Distichlis spicata						
Percent[b]	-	11.5	10.0	11.7	-	11.1
Area[c]	-	5266	6536	6770	-	18572
Juncus roemerianus						
Percent[d]	86.4	13.1	14.9	3.7	-	16.3
Area	9417	5999	9738	2141	-	27295
Spartina alterniflora						
Percent	3.2	64.2	62.8	67.7	27.3	66.0
Area	349	29399	41045	39175	694	110662
Spartina patens						
Percent	10.3	2.4	7.8	6.8	-	6.7
Area	1123	1099	5098	3935	-	11255
Total						
Percent[e]	99.9	91.2	95.5	89.9	27.3	100.1 (f)
Area[g]	10889	41763	62417	52021	694	167784 (h)

[a]Hydrologic units are: Mississippi Sound (I), Pontchartrain (II), Barataria (IV), Terrebone (V), and Vermilion (VII). Mississippi Delta (III) and Atchafalaya (VI) are not included since they do not contain salt marsh.

[b]The percent coverage of each of the four major salt marsh macrophytes is taken from Eleuterius (1972) for hydrologic unit I and from Chabreck (1972) for the remaining four units. Hydrologic unit II as used here is equivalent to Chabreck's units I and II. To calculate percent cover for this unit the percent cover of Chabreck's units I and II were weighted by the area of salt marsh in those units. The total percentage of the MDPR covered by each of the four major macrophytes was calculated by dividing the total area of each of (18572/167784)*100 = 11.1% for *D. spicata.*

[c]The area of each hydrologic unit covered by each of the four major macrophytes (in hectares) is calculated by multiplying percent coverage by the total amount of salt marsh in a particular hydrologic unit. The area of salt marsh in units I, II, IV, V, and VII is 10899, 45793, 65358, 57866, and 2541 ha, respectively (Tables 13, 15, 19, 21, and 25). Total area of each plant for the entire MDPR is the sum of the areas in the five hydrologic units.

(continued)

Table 112. Concluded.

[d]According to de la Cruz (1974), 10% of the cover in marshes dominated by *Juncus roemerianus* in Mississippi Sound is *Spartina patens*. Mississippi Sound data have been adjusted accordingly.

[e]The percent of a hydrologic unit's salt marsh covered by the four major macrophytes is calculated by dividing the total area of these four plants by the total amount of salt marsh in that hydrologic unit (see note c for salt marsh areas).

[f]Percentages do not add to 100% due to rounding errors.

[g]Total area covered by the four major macrophytes is the sum of the four areas for each hydrologic unit.

[h]Area inhabited by these four plants represents 92% of the total MDPR salt marsh area.

Table 113. Ratio of respiration to net primary production for *Spartina alterniflora* in coastal Louisiana.

Date	R[a]	GPP[b]	NPP[c]	R/NPP
Dec. 1975	192	340	148	1.30
Mar. 1976	120	516	396	0.30
May 1976	96	662	566	0.17
Avg.				0.59

[a]The daily respiration rate, R, is the product of hourly respiration and 24 hr/day. Units for R are mg C/0.075 sq m/day. Data are from Gosselink et al. 1977.

[b]Daily gross primary production is equal to the product of hourly gross primary production and the hours of daylight. Hours of light per day in December, March, and May are 10, 12, and 13.5, respectively (pers. comm., R. A. Muller, Dept. Geol. and Anthro., LSU). Units for GPP are mg C/0.075 sq m/day. Production data from Gosselink et al. 1977.

[c]Net primary production, in mg C/0.075 sq m/day, is equal to GPP - R.

Table 114. Aboveground net primary production in MDPR salt marshes by producer.

Producer	Aboveground NPP[a]	Percent of Total
Microflora[b]	406	16.5
Spartina alterniflora[c]	1223	49.7
Other macrophytes[d]	830	33.8
TOTAL	2459	100.0

[a]Net primary production as g dry wt/sq m/yr.
[b]From Table 107.
[c]From Table 109.
[d]*Distichlis spicata*, *Juncus roemerianus*, and *Spartina patens* From Table 109.

Table 115. Aboveground net primary production of other macrophytes in MDPR salt marshes.[a]

Producer	Aboveground NPP[b]	Percent of Total
Distichlis spicata	218	26.3
Juncus roemerianus	407	49.0
Spartina patens	205	24.7
TOTAL	830	100.0

[a]Data are from Table 110.
[b]Net primary production as g dry wt/sq m/yr.

Table 116. Total live and dead biomass of MDPR salt marsh macrophytes.[a]

	Spartina alterniflora	Other macrophytes[b]	Total
Live Biomass			
Aboveground[c]	330	276	606
Belowground[d]	372	310	682
TOTAL	702	586	1288
Dead Biomass			
Aboveground[c]	491	303	794
Belowground[d]	552	340	892
TOTAL	1043	643	1686

[a] Values are g dry wt/sq m.
[b] *Distichlis spicata*, *Juncus roemerianus*, and *Spartina patens*.
[c] From Table 117.
[d] From Table 118.

Table 117. Aboveground biomass of MDPR salt marsh macrophytes.

Plant	Biomass[a] Live	Biomass[a] Dead	Reference[b]
<u>Distichlis spicata</u>			
	560	1143	2
	443	235	8[c]
Average	502	689	
Weighted avg.[d]	56	76	
<u>Juncus roemerianus</u>			
	827	905	2
	700	750	7
	1297	957	8[c]
Average	941	871	
Weighted avg.	153	142	
<u>Spartina alterniflora</u> (streamside)[e]			
	469	958	2
	581	1185	3,4
Subaverage[f]	525	1072	
	631	532	8[c]
Average	578	802	
Weighted avg.	97	135	
<u>Spartina alterniflora</u> (inland)[e]			
	343	892	3,4
	499	993	6
Subaverage[f]	421	942	
	527	504	7
Average	474	723	
Weighted avg.	233	356	
<u>Spartina patens</u>			
	1287	1841	1[g]
	900	1530	2
	760	708	5
	1066	1011	8[c]
Average	1003	1272	
Weighted avg.	67	85	
Total, <u>Spartina alterniflora</u>	330	491	
Total, Other macrophytes	276	303	
Total, All	606	794	

(continued)

Table 117. Concluded.

[a] Biomass as g dry wt/sq m.

[b] 1. Cramer et al. (unpublished data); 2. Hopkinson et al. 1978b; 3. Kirby 1971; 4. Kirby and Gosselink 1976; 5. Payonk 1975; 6. Table 111; 7. Stout 1978; 8. White et al. 1978.

[c] White et al. (1978) list regression coefficients of fourth-order equations for daily live and dead biomass. To calculate biomass, these equations were integrated over 365 days and then divided by 365 to give the mean biomass.

[d] The weighted average is the product of the average biomass and a weighting factor. Weighting factors are 0.111, 0.163, 0.168, 0.492, and 0.067 for *D. spicata*, *J. roemerianus*, streamside *S. alterniflora*, inland *S. alterniflora*, and *S. patens*, respectively (Table 112 except for *S. alterniflora*, which is from Table 110, note e).

[e] *Spartina alterniflora* is found in two height forms in the deltaic plain. The tall form is found alongside marsh streams and bayous, and is referred to as streamside marsh. The short form is found further from the streams and therefore is referred to as inland marsh (Table 110, note e).

[f] Hopkinson et al. (1978b), Kirby (1971), Kirby and Gosselink (1976), and Sasser et al. (1981; upon which Table 111 is based) all studied marshes that were relatively close together, near Airplane Lake by Caminada Bay. To average these sites with other sites would bias the values towards the Airplane Lake data. To avoid this, these data were subaveraged first.

[g] Average of four Lake Pontchartrain marsh sites.

Table 118. Belowground biomass of salt marsh macrophytes in the MDPR.

	Spartina alterniflora	Other macrophytes[a]	Total
Belowground NPP[b]	1377	933	-
Ratio[c]			
Live	0.270	0.332	-
Dead	0.401	0.365	-
Belowground biomass (d)			
Live	372	310	682
Dead	552	340	892

[a] *Distichlis spicata*, *Juncus roemerianus*, and *Spartina patens*.
[b] Net primary production in g dry wt/sq m/yr. From Table 109.
[c] Ratio of aboveground live or dead biomass to aboveground net primary production from Table 119.
[d] Values are g dry wt/sq m. Calculated by multiplying belowground net primary production by the biomass to production ratio.

Table 119. Ratios of live and dead aboveground biomass to aboveground net primary production.

	Spartina alterniflora	Other macrophytes[a]
Aboveground biomass[b]		
Live	330	276
Dead	491	303
Aboveground NPP[c]	1223	830
Ratio[d]		
Live	0.270	0.332
Dead	0.401	0.365

[a] *Distichlis spicata*, *Juncus roemerianus*, and *Spartina patens*.
[b] Values are g dry wt/sq m. From Table 116.
[c] Values are g dry wt/sq m/yr. From Table 109.
[d] Ratio of aboveground live or dead biomass to aboveground net primary production.

Table 120. Comparison of aboveground macrophyte biomass at various marsh sites with average MDPR salt marsh biomass.

Site	Biomass[a]	Ratio[b]
MDPR[c]	606	-
Airplane Lake, La.		
Streamside[c]	525	1.15
Average[d]	447	1.36
Mississippi[e]	863	0.70
Brackish marsh[f]	898	0.67

[a] Values are g dry wt/sq m.
[b] Ratio of aboveground biomass at an average MDPR salt marsh to the biomass at each of the specific sites.
[c] From Table 116.
[d] From Table 117, the macrophyte biomass at streamside and inland sites at Airplane Lake is equal to 525 and 421 g dry wt/sq m, respectively. The proportion of Airplane Lake marsh that is streamside and inland is 25.4 and 74.6%, respectively (Table 110, note e). Thus the average biomass is calculated by weighting the two biomass values by the percent area.
[e] From Gabriel and de la Cruz 1974.
[f] Average aboveground biomass of macrophytes in MDPR brackish marshes. From Table 28.

Table 121. Input of plant matter into litter in MDPR salt marshes.[a]

Source	Value
Microflora[b]	385.8
Spartina alterniflora[c]	1191.0
Other macrophytes[d]	777.8
TOTAL	2354.6

[a]Values as g dry wt/sq m/yr. Calculated as aboveground net primary production minus consumption. NPP for each producer taken from Tables 107 and 109.
[b]NPP equal to 406 g dry wt/sq m/yr. Consumption by insects, birds, and mammals equal to 5.3, 0.8, and 14.1 g dry wt/sq m/yr, respectively (Tables 131, 135, and 140).
[c]NPP equal to 1223 g dry wt/sq m/yr. Consumption by *Littorina irrorata* and insects equal to 15.9 and 16.1 g dry wt/sq m/yr, respectively (Tables 129 and 131).
[d]NPP equal to 830 g dry wt/sq m/yr. Consumption by *Littorina irrorata*, insects, birds, and mammals equal to 10.8, 10.9, 1.5, and 29.0 g dry wt/sq m/yr, respectively (Tables 129, 131, 135, and 140).

Table 122. Total input of organic materials to microconsumers in MDPR salt marshes.[a]

Source	Value
Soil organic matter[b]	1518.0
Litter[c]	265.1
Animal remains[d]	130.9
TOTAL	1914.0

[a]Values as g dry wt/sq m/yr. It is assumed that total input to microconsumers is equal to respiration, or 1914 g dry wt/sq m/yr (Table 103). Decomposition of belowground materials is equal to 1518 g dry wt/sq m/yr (Table 109) and the remaining 396 are from aboveground sources.
[b]Rate of decomposition of soil organic matter is 1518 g dry wt/sq m/yr (Table 109).
[c]Total decomposition of aboveground materials is equal to 396 g dry wt/sq m/yr (note a above), 130.9 of which is from animal remains (note d below). The remaining 265.1 g dry wt/sq m/yr are from litter.
[d]From Table 123.

Table 123. Input of marsh animals to microconsumers by source.[a]

Source	Value
Crabs[b]	18.0
Mussels[c]	84.9
Littorina irrorata[d]	24.1
Insects[e]	2.3
Birds[f]	0.1
Mammals[g]	1.5
TOTAL	130.9

[a]Values as g dry wt/sq m/yr. Calculated as secondary production minus consumption and/or harvest.

[b]Production equal to 20.1 g dry wt/sq m/yr (Table 124). Consumption by birds and mammals equal to 1.1 and 0.6 g dry wt/sq m/yr, respectively (Tables 135 and 140). Harvest by man equal to 0.4 g dry wt/sq m/yr (Table 126).

[c]Production equal to 92.8 g dry wt/sq m/yr (Table 127). Consumption by birds and mammals equal to 5.0 and 2.9 g dry wt/sq m/yr, respectively (Tables 135 and 140).

[d]Production equal to 26.3 g dry wt/sq m/yr (Table 128). Consumption by birds and mammals equal to 1.4 and 0.8 g dry wt/sq m/yr, respectively (Tables 135 and 140).

[e]Production equal to 2.5 g dry wt/sq m/yr (Table 130). Consumption by birds and mammals equal to 0.1 and 0.1 g dry wt/sq m/yr, respectively (Tables 135 and 140).

[f]Production equal to 8.0 E-2 g dry wt/sq m/yr (Table 133). Consumption by mammals equal to 0.01 g dry wt/sq m/yr (Table 140). Harvest by man equal to 2.1 E-3 g dry wt/sq m/yr (Table 136).

[g]Production equal to 1.6 g dry wt/sq m/yr (Table 137). Consumption by mammals equal to 0.09 g dry wt/sq m/yr (Table 140). Harvest by man equal to 4.7 E-2 g dry wt/sq m/yr (Table 141).

Table 124. Biomass and energy budget for crabs at an Airplane Lake, La. salt marsh and for MDPR salt marshes.[a]

	Airplane Lake	MDPR
Biomass[b]	4.61	6.27
Consumption[c]	475.8	647.1
Egestion[d]	438.0	595.7
Respiration[e]	23.0	31.3
Production[f]	14.8	20.1

[a]Biomass in g dry wt/sq m. All other values as g dry wt/sq m/yr. MDPR data calculated by correcting Airplane Lake data for the difference in macrophyte biomass between the two areas. There is 1.36 times more macrophyte biomass in an average MDPR salt marsh than at Airplane Lake (Table 120).

[b]Biomass values of 2.54, 0.86, and 0.20 g ash free dry wt/sq m were measured for *Uca pugnax*, *Sesarma reticulatum*, and *Callinectes sapidus*, respectively, in an MDPR salt marsh (Day et al. 1973). This gives a total value of 3.60 g ash free dry wt/sq m. Ash makes up 21.7% of the dry weight of crustaceans (Jorgensen 1979), and thus the ash free portion is 78.3% of the total dry weight. This gives a dry weight to ash free dry weight ratio of 1.28. This value was used to convert the ash free biomass to a dry weight biomass.

[c]Consumption is equal to the sum of egestion, respiration, and production.

[d]Calculated by multiplying an egestion to biomass ratio of 95.0 (Table 125) by the biomass value.

[e]Calculated by multiplying a respiration to biomass ratio of 5.0 (Table 125) by the biomass value.

[f]Calculated by multiplying a production to biomass ratio of 3.2 (Table 125) by the biomass value.

Table 125. Biomass and energy budget for crabs in a North Carolina salt marsh.[a]

	Caloric value[b]	Caloric content[c]	Biomass value[d]	Biomass ratio[e]
Biomass	20.0	2.612	7.6	-
Egestion	1742.2	2.412	722.3	95.0
Respiration	99.8	2.612	38.2	5.0
Production	64.2	2.612	24.6	3.2

[a]Data from Cammen et al. 1980.
[b]Biomass in kcal/sq m. All other values as kcal/sq m/yr.
[c]Values are kcal/g dry wt.
[d]Biomass in g dry wt/sq m. All other values are g dry wt/sq m/yr. Calculated by dividing the caloric value by the caloric content.
[e]Ratio of egestion, respiration, or production (g dry wt/sq m/yr) to biomass (g dry wt/sq m).

Table 126. Harvest of crabs in MDPR marshes.

	Salt	Brackish	Fresh
Total catch[a]	7.52 E8	9.40 E8	1.88 E8
Catch per area[b]	0.44	0.24	0.11

[a]Values as g dry wt/yr. The 1978 crab harvest from the eastern and central districts of Louisiana was 12.74 E6 lb live wt (NOAA 1980). Using the conversions 453.6 g/lb and 0.326 g dry wt/g live wt (Thayer et al. 1973) gives a total catch of 1.88 E9 g dry wt/yr. Estimates of the proportions of crab caught in salt, brackish, and fresh marshes are 40, 50, and 10%, respectively (pers. comm., Mr. Gerald Adkins, La. Dept. of Wildlife and Fisheries).
[b]Values as g dry wt/sq m/yr. Calculated by dividing total catch for eastern and central Louisiana by the area of marsh in hydrologic units 2-7. Area of salt, brackish, and fresh marsh are 1.72 E9 (Table 112), 3.89 E9 (Table 27), and 1.64 E9 (Tables 15, 17, 19, 21, and 23) sq m, respectively. Catch per area in Mississippi Sound assumed equal to Louisiana averages.

Table 127. Biomass and energy budget for mussels at an Airplane Lake, La. salt marsh and for MDPR salt marshes.[a]

	Airplane Lake	MDPR
Biomass		
Shell[b]	39.2	-
Tissue[c]	2.3	-
TOTAL	41.5	56.4
Consumption[d]	463.6	630.5
Egestion[e]	357.8	486.6
Respiration[f]	37.6	51.1
Production[g]	68.2	92.8

[a]Biomass in g dry wt/sq m. All other values as g dry wt/sq m/yr. MDPR data calculated by correcting Airplane Lake data for the difference in macrophyte biomass between the two areas. There is 1.36 times more macrophyte biomass in an average MDPR salt marsh than at Airplane Lake (Table 120).

[b]Total mussel biomass was measured as 6.45 g ash free dry wt/sq m at Airplane Lake (Rodriguez-Ortega 1974). 64.3% of mussel ash free weight is shell, and the ratio of shell dry weight to shell ash free weight is 9.46 (Kuenzler 1961). Shell biomass (in g dry wt/sq m) is therefore equal to the product of these three values.

[c]35.7% of mussel ash free dry weight is tissue, and the ratio of tissue dry weight to ash free weight is 1.002 (Kuenzler 1961). These two values are used to convert the biomass value listed in note b above to tissue biomass.

[d]Consumption is equal to the sum of egestion, respiration, and production.

[e]The rate of fecal deposition by mussels is 23.5 mg dry wt/ind/day (Kraeuter 1976), and there is an average of 27.8 ind/sq m at Airplane Lake (Rodriguez-Ortega 1974). This is equivalent to a fecal deposition rate of 238.5 g dry wt/sq m/yr. It is estimated from data in Jordan and Valiela (1982) that other sources of excretion are approximately equal to one half of the fecal deposition rate, giving a total egestion rate of 357.8 g dry wt/sq m/yr.

[f]Respiration was measured as 50.9 g oxygen/sq m/yr at Airplane Lake (Rodriguez-Ortega 1974). Using a kcal to oxygen ratio of 4.86 kcal/l oxygen (Kuenzler 1961) and a caloric content of 4.6 kcal/g dry wt (Golley 1961) gives a respiration value of 37.6 g dry wt/sq m/yr (liters of oxygen are converted to g by multiplying by 1.428)

[g]The growth rate of mussels at Airplane Lake is 10.6 g ash free dry wt/sq m/yr (Rodriguez-Ortega 1974), and the ratio of total dry weight to total ash free dry weight is 41.5/6.45 = 6.43 (notes b and c above). This gives a growth rate of 68.2 g dry wt/sq m/yr.

Table 128. Biomass and energy budget for *Littorina irrorata* at an Airplane Lake, La. salt marsh and for MDPR salt marshes.[a]

	Airplane Lake	MDPR
Biomass[b]	48.6	55.9
Consumption[c]	580.2	667.2
Egestion[d]	414.2	476.3
Respiration[e]	143.1	164.6
Production[f]	22.9	26.3

[a]Biomass in g dry wt/sq m. All other values as g dry wt/sq m/yr. MDPR data calculated by correcting Airplane Lake data (collected at a streamside marsh) for the difference in macrophyte biomass between the two areas. There is 1.15 times more macrophyte biomass in an average MDPR salt marsh than at the streamside marsh (Table 120).

[b]From Alexander 1976.

[c]The total quantity of organic matter consumed by *Littorina irrorata* is 284.3. The percentage of this coming from live *Spartina alterniflora*, dead *S. alterniflora*, and sediments is 4, 59, and 37%, respectively (Alexander 1976). This gives the following:

$$L/T = 0.04 \quad (1)$$
$$D/T = 0.59 \quad (2)$$
$$S/T = 0.37 \quad (3)$$

where L, D, and S are the amounts of live *Spartina*, dead *Spartina*, and sediments consumed, respectively, and T is the total amount consumed. Manipulating these equations gives the following:

$$L = 0.04 * T \quad (4)$$
$$D = 0.59 * T \quad (5)$$
$$S = 0.37 * T \quad (6)$$

The organic content of live *S. alterniflora*, dead *S. alterniflora*, and sediments is 0.85 (Gosselink and Kirby 1974), 0.66, and 0.18 (Alexander 1976), respectively. Combining this information with the consumption rate of 284.3 mentioned above gives the following:

$$(L * 0.85) + (D * 0.66) + (S * 0.18) = 284.3 \quad (7)$$

(continued)

Table 128. Concluded.

Combining equation 7 with equations 4-6 gives:

$$((0.04 * 0.85) + (0.59 * 0.66) + (0.37 * 0.18)) * T = 284.3 \qquad (8)$$

Solving for T gives a total consumption value of 580.2 g dry wt/sq m/yr.

[d]The average egestion rate of Airplane Lake *Littorina* is 1.97 mg dry wt/ind/hr, and there are an average of 24 ind/sq m (Alexander 1976). This gives an egestion rate of 414.2 g dry wt/sq m/yr.

[e]The ratio of respiration to assimilation for *Littorina* is 0.862 (Smalley 1959a). Assimilation is equal to ingestion minus egestion and is equal to 166.0 g dry wt/sq m/yr at Airplane Lake. Thus respiration is equal to 143.1 g dry wt/sq m/yr.

[f]Production is equal to consumption minus egestion and respiration.

Table 129. Dietary breakdown for *Littorina irrorata*.[a]

Source	Value
Spartina alterniflora[b]	15.9
Other macrophytes[c]	10.8
Litter[d]	393.6
Soil organic matter[e]	71.6
Inorganic sediments[f]	175.3
TOTAL	667.2

[a]Values as g dry wt/sq m/yr. Total consumption taken from Table 128.

[b]Of the total amount of food consumed by *L. irrorata*, 4% comes from marsh macrophytes (Table 128, note c), or 26.7 g dry wt/sq m/yr. The amount of *S. alterniflora* consumed by *L. irrorata* is assumed proportional to its percent of aboveground net primary production. This is equal to 1223/2053 = 0.596 (Table 109). Consumption is therefore equal to 15.9 g dry wt/sq m/yr.

[c]Consumption of macrophytes by *L. irrorata* is equal to 26.7 g dry wt/sq m/yr, 15.9 of which is from *S. alterniflora* (note b above). The remaining 10.8 g dry wt/sq m/yr are from other macrophytes.

[d]Of the total amount of food consumed by *L. irrorata*, 59% comes from litter (Table 128, note c), or 393.6 g dry wt/sq m/yr.

[e]Of the total amount of food consumed by *L. irrorata*, 37% comes from sediments (Table 128, note c), or 246.9 g dry wt/sq m/yr. Since soil has an organic content of 0.29 (Table 101, note d), the consumption of soil organic matter is equal to 71.6 g dry wt/sq m/yr.

[f]Consumption of sediments by *L. irrorata* is equal to 246.9 g dry wt/sq m, 71.6 of which are organic matter (note e above). The remaining 175.3 g dry wt/sq m/yr are inorganic sediments.

Table 130. Biomass and energy budget for insects in MPDR salt marshes.[a]

Process	Value
Biomass[b]	0.52
Consumption[c]	32.3
Egestion[d]	16.1
Respiration[e]	13.7
Production[f]	2.5

[a]Biomass in g dry wt/sq m. All other values as g dry wt/sq m/yr.

[b]The production of grasshoppers in a Mississippi salt marsh on a per area basis is 10 kJ/sq m/yr, and 115.3 kJ/g dry wt/yr on a per weight basis (Parsons and de la Cruz 1980). Dividing these two gives a biomass value of 10/115.3 = 0.087 g dry wt/sq m. The biomass of macrophytes at an average MDPR salt marsh is only 70% the value at this Mississippi site (Table 120). Thus, correcting for biomass gives a grasshopper biomass of 0.061 g dry wt/sq m. The density of insects other than grasshoppers was measured at a brackish marsh as 404.7 ind/sq m (Farlow et al. 1978). The average weight of four emergent insects (Glyptotendipes, Diptera, Trichoptera, and Zygoptera) is equal to 1.67 mg dry wt/ind (Jorgensen 1979). This gives a biomass of 0.68 g dry wt/sq m. The biomass of macrophytes at an average MDPR salt marsh is only 67% the value at this brackish marsh (Table 120). Correcting for biomass gives a non-grasshopper biomass of 0.46 g dry wt/sq m. Total biomass is the sum of this value and the grasshopper number.

[c]The consumption to biomass ratio for grasshoppers in Mississippi salt marshes is 62.1 (Parsons and de la Cruz 1980). Consumption is found by multiplying this number by the biomass of MDPR insects.

[d]Egestion is calculated as consumption minus respiration and production.

[e]The respiration rate of grasshoppers in Mississippi is 51 kJ/sq m/yr (Parsons and de la Cruz 1980), or 12.2 kcal/sq m/yr. The caloric content of insects is 5.4 kcal/g dry wt (E. P. Odum 1971). This gives a respiration rate of 2.3 g dry wt/sq m/yr. The biomass at this site is 0.087 g dry wt/sq m (note b above), giving a respiration to biomass ratio of 26.4. This value is multiplied by the biomass of MDPR insects to give a respiration rate.

(continued)

Table 130. Concluded.

[f]The rate of production of grasshoppers in Mississippi is 9.7 kJ/sq m/yr (Parsons and de la Cruz 1980), or 2.3 kcal/sq m/yr. The caloric content of insects is 5.4 kcal/g dry wt (E. P. Odum 1971). This gives a at this site is 0.087 g dry wt/sq m (note b above), giving a production to biomass ratio of 4.9. This value is multiplied by the biomass of MDPR insects to give a production rate.

Table 131. Dietary breakdown for insects.[a]

Source	Value
Microflora	5.3
Spartina alterniflora	16.1
Other macrophytes	10.9
TOTAL	32.3

[a]Values as g dry wt/sq m/yr. Total consumption taken from Table 130. It is assumed that all consumption by marsh insects is from flora, and that the consumption of each plant is proportional to its percent of total aboveground net primary production. Percent of NPP by microflora, *S. alterniflora*, and other macrophytes is equal to 16.5, 49.7, and 33.8%, respectively (Table 114).

Table 132. Secondary production by MDPR salt marsh invertebrates.[a]

	Production	Percent of Total
Crabs	20.1	14.2
Mussels	92.8	65.5
Littorina irrorata	26.3	18.5
Insects	2.5	1.8
TOTAL	141.7	100.0

[a]Production reported as g dry wt/sq m/yr. Production values for crabs, mussels, *L. irrorata*, and insects are taken from Tables 124, 127, 128, and 130, respectively.

Table 133. Energy budget for birds in MDPR marshes.[a]

Process	Salt marsh	Brackish marsh	Fresh marsh
Consumption			
Wading birds	17.4	7.1	10.9
Waterfowl	5.9	7.3	3.1
Total	23.3	14.4	14.0
Egestion			
Wading birds	6.3	2.6	3.9
Waterfowl	2.1	2.6	1.1
Total	8.4	5.2	5.0
Respiration			
Wading birds	11.0	4.5	7.0
Waterfowl	3.8	4.7	2.0
Total	14.8	9.2	9.0
Production			
Wading birds	6.0 E-2	2.4 E-2	3.7 E-2
Waterfowl	2.0 E-2	2.5 E-2	1.1 E-2
Total	8.0 E-2	4.9 E-2	4.8 E-2

[a]All units in g dry wt/sq m/yr. Values found by multiplying biomass values in Table 134 by appropriate conversion factors calculated from data in Kale (1965). Conversions are: 373.9 (consumption), 135.3 (egestion), and 1.28 (production). Respiration is equal to consumption minus egestion and production.

Table 134. Bird biomass in MDPR marshes.[a]

	Salt marsh	Brackish marsh	Fresh marsh
Wading Birds[b]			
Density	6.22 E-5	2.52 E-5	3.88 E-5
Biomass	4.66 E-2	1.89 E-2	2.91 E-2
Percent[c]	74.7	49.3	77.8
Waterfowl[d]			
Density	7.43 E-5	9.14 E-5	3.93 E-5
Biomass	1.58 E-2	1.94 E-2	0.83 E-2
Percent[c]	25.3	50.7	22.2
Total Biomass	6.24 E-2	3.83 E-2	3.74 E-2

[a]Density as ind/sq m and biomass as g dry wt/sq m. Data from Mabie 1976.

[b]Herons, egrets, and ibises. The average wet weight of wading birds is assumed to be 2.5 kg, which is the weight of a woodstork (Kahl 1964). Using the conversion 100 g wet/30 g dry (Table 138, note d), this is equivalent to 750 g dry wt/ind.

[c]Percent of total biomass.

[d]Puddle ducks, diving ducks, and coots. The average wet weight of waterfowl is assumed to be 708 g, based on the weights of black ducks and coots (Penney and Bailey 1970). Using the conversion 100 g wet/30 g dry (Table 138, note d), this is equivalent to 212 g dry wt/ind.

Table 135. Dietary breakdown for birds.[a]

Source	Value
Microflora[b]	0.8
Other macrophytes[c]	1.5
Crabs[d]	1.1
Mussels[e]	5.0
Littorina irrorata[f]	1.4
Insects[g]	0.1
Fish[h]	13.4
TOTAL	23.3

[a]Values as g dry wt/sq m/yr. Total consumption taken from Table 133.

[b]Plant consumption by waterfowl is estimated as 32% of dietary intake, based on data for mottled ducks (Guidry 1977). For wading birds, a value of 2.1% is assumed, based on the average consumption of plants by the great white heron and the roseate spoonbill (Cottam and Knappen 1939). Waterfowl and wading birds account for 25.3 and 74.7% of total bird biomass, respectively (Table 134). The weighted average for percent plant intake is therefore 9.7%, giving an intake rate of 2.3 g dry wt/sq m/yr. It is assumed that *Spartina alterniflora* is not consumed by birds and that consumption of microflora and other macrophytes is proportional to their percent of NPP, which for microflora is equal to 406/(406 + 830) = 32.8% (Table 114). Thus, consumption of microflora is equal to the product of 0.328 and 2.3, or 0.8 g dry wt/sq m/yr.

[c]Total consumption of plants is equal to 2.3 g dry wt/sq m/yr, 0.8 of which is microflora (note b above). Assuming *Spartina alterniflora* is not consumed by birds, the remaining 1.5 g dry wt/sq m/yr comes from other macrophytes.

[d]Invertebrate consumption by waterfowl is estimated as 56% of dietary intake, based on data for mottled ducks (Guidry 1977). For wading birds, a value of 25% is assumed, based on the average consumption of invertebrates by the great white heron and the roseate spoonbill (Cottam and Knappen 1939). The weighted average (note b above) for percent intake of invertebrates is therefore 32.8%, giving an invertebrate uptake rate of 7.6 g dry wt/sq m/yr. Crabs account for 14.2% of invertebrate secondary production (Table 132). Multiplying this value by 7.6 gives a crab intake of 1.1 g dry wt/sq m/yr.

(continued)

Table 135. Concluded.

[e]Consumption of invertebrates by birds is equal to 7.6 g dry wt/sq m/yr (note d above). Mussels account for 65.5% of invertebrate secondary production (Table 132). Multiplying this value by 7.6 gives a mussel intake rate of 5.0 g dry wt/sq m/yr.

[f]Consumption of invertebrates by birds is equal to 7.6 g dry wt/sq m/yr (note d above). *Littorina* accounts for 18.5% of invertebrate secondary production (Table 132). Multiplying this value by 7.6 gives a *Littorina* intake rate of 1.4 g dry wt/sq m/yr.

[g]Consumption of invertebrates by birds is equal to 7.6 g dry wt/sq m/yr (note d above). Insects account for 1.8% of invertebrate secondary production (Table 132). Multiplying this value by 7.6 gives an insect intake rate of 0.1 g dry wt/sq m/yr.

[h]Fish consumption by waterfowl is estimated as 12% of dietary intake, based on data for mottled ducks (Guidry 1977). For wading birds, a value of 73% is assumed, based on the average consumption of invertebrates by the great white heron and the roseate spoonbill (Cottam and Knappen 1939). The weighted average (note b above) for percent fish uptake is therefore 57.6%, giving a fish intake rate of 13.4 g dry wt/sq m/yr.

Table 136. Waterfowl harvest in MDPR marshes.

Marsh type	Percent of total harvest[a]	Harvest[b]
Salt	36.2	2.1 E-3
Brackish	44.6	2.6 E-3
Fresh	19.2	1.1 E-3

[a]It is assumed that the percent of waterfowl harvested in these three habitats is proportional to the waterfowl density in these habitats. Densities are from Table 134.

[b]Chabreck (1978) reports that 13.2% of the waterfowl in the Chenier Plain were harvested. Assuming that the same ratio holds for the MDPR, the harvest in these three habitats is equal to the product of 0.132 and 4.35 E-2, the total waterfowl biomass in these marsh habitats (Table 134). Total harvest is thus equal to 5.74 E-3 g dry wt/sq m/yr. Harvest for each habitat is equal to the product of the total marsh harvest and the percent of total harvest.

Table 137. Biomass and energy budget for furbearers in MDPR marshes.[a]

Process	Salt marsh	Brackish marsh[b]	Fresh marsh
Biomass[c]	0.4	1.1	2.1
Consumption[d]	49.3	117.2	231.0
Egestion[e]	19.4	46.0	90.7
Respiration[f]	28.3	67.4	132.9
Production[g]	1.6	3.8	7.4

[a]Furbearers are muskrats, nutria, and raccoons. All values are g/sq m/yr.
[b]Intermediate marsh included with brackish marsh.
[c]From Tables 138 and 139.
[d]A consumption rate of 90 g/kg wet wt/day was estimated for muskrat from a graph in McEwan et al. (1974). Using a conversion of 1 kg wet/300 g dry (Table 138, note d) and converting to years, this is equivalent to 109.5 g/g dry wt/yr. Assuming similar values for nutria and raccoon, consumption is found by multiplying this number by total biomass.
[e]Whitney and Underwood (1952) report fecal deposition rates ranging from 16-305 g/day for raccoons with an average wet weight of 10 lb (4536 g). Assuming similar deposition rates for muskrat and nutria and using an average rate of 160.5 g/day, this is equivalent to 12.9 g/g wet wt/yr. Using a conversion of 100 g wet/30 g dry (Table 138, note d) gives a value of 43.0 g/g dry wt/yr. Multiplying this value by biomass gives fecal deposition. It is assumed that this is the only significant source of egestion.
[f]Respiration is equal to consumption minus egestion and production.
[g]A table in Ricklefs (1979) lists the production efficiencies (production divided by consumption) of several small terrestrial homeotherms. Efficiencies of least weasel, grasshopper mouse, kangaroo rat, vole, jackrabbit, and cottontail rabbit are 2.2, 4.4, 4.2, 2.1, 2.9, and 3.1, respectively, for an average of 3.2%. Furbearer production in the different marshes is calculated by multiplying consumption rates by 0.032.

Table 138. Muskrat biomass in southeastern Louisiana marshes.[a]

	Salt marsh	Brackish marsh[b]	Fresh marsh
Avg. number of houses in area inventoried	268	1076	63
Area inventoried (sq m)	7.24 E 6	14.08 E 6	11.23 E 6
House density (houses/sq m)	3.70 E-5	7.64 E-5	0.56 E-5
Muskrat density[c] (ind/sq m)	1.18 E-4	2.44 E-4	0.18 E-4
Biomass[d] (g dry wt/sq m)	3.05 E-2	6.31 E-2	0.47 E-2

[a]Data from Palmisano (1972) except where noted.
[b]Intermediate marsh included with brackish marsh.
[c]A conversion of 3.19 muskrats per house is used (Palmisano 1972). It should be noted, however, that this value is extremely variable over area and time, and can range from 0.5-20 muskrats per house (pers. comm., Mr. Greg Linscombe, La. Wildlife and Fisheries).
[d]O'Neil (1949) reports an average wet weight of 1.9 lb (861.8 g) for LaFourche and Vermilion Parish muskrats. Based on measurements of mice, Day et al. (1973) estimated that the dry weight of marsh mammals was 30% of their wet weight. Thus a conversion of 258.5 g dry wt/ind is used.

Table 139. Nutria and raccoon biomass in MDPR marshes.

	Salt marsh	Brackish marsh[a]	Fresh marsh
Nutria			
Fur harvest[b]	269.40	646.68	1355.69
Density[c]	2.98 E-4	7.15 E-4	14.99 E-4
Biomass[d]	3.58 E-1	8.60 E-1	18.03 E-1
Raccoon			
Fur harvest[b]	19.81	25.35	13.87
Density[e]	0.58 E-4	1.39 E-4	2.92 E-4
Biomass[f]	0.60 E-1	1.45 E-1	3.04 E-1

[a] Intermediate marsh included with brackish marsh.

[b] Harvest, in pelts per 1000 ha, are 7 yr averages and are from Linscombe as reported in Sasser et al. (1981).

[c] From conversations with La. Wildlife and Fisheries personnel (pers. comm., Mr. Greg Linscombe) and data in Robicheaux (1978), nutria populations were estimated as 2.98 nutria/ha for the salt marsh. The nutria density to nutria harvest ratio is therefore 1.106 E-2 in the salt marsh. This ratio is used with brackish and fresh marsh harvests to calculate densities for these two habitats. Density figures are converted to sq m.

[d] The average weight of nutria is 8.84 lb (4010 g) wet wt (Kays 1956). Dry weight is 30% of this (Table 138, note d), or 1203 g dry wt/ind.

[e] In a study in Southwest Louisiana, initial captures of raccoon were only 19.5% the initial captures of nutria (Robicheaux 1978). Assuming that these animals are both captured as readily, the raccoon population densities would be 19.5% the nutria densities. Thus raccoon density is obtained by multiplying nutria density for each habitat by 0.195.

[f] Fleming (1975) lists an average weight of 7.66 lb (3474.6 g) for 46 raccoons in Louisiana. This includes adults and immatures. Dry weight is 30% of this (Table 138, note d), or 1042.4 g dry wt/ind.

Table 140. Dietary breakdown for mammals.[a]

Source	Value
Microflora[b]	14.1
Other macrophytes[c]	29.0
Crabs[d]	0.6
Mussels[e]	2.9
Littorina irrorata[f]	0.8
Insects[g]	0.1
Birds[h]	0.01
Mammals[i]	0.09
Fish[j]	1.7
TOTAL	49.3

[a]Values as g dry wt/sq m/yr. Total consumption taken from Table 137.

[b]Plant consumption by raccoons is equal to 6% of dietary intake (Fleming 1975). Nutria and muskrats are herbivores and therefore 100% of the food they consume is plant matter (O'Neil 1949; Shirley 1979; Love 1981). Based on Tables 138 and 139, raccoons, nutria, and muskrats make up 13.4, 79.8, and 6.8% of total mammal biomass, respectively. The weighted average for percent plant consumption is therefore 87.4%, giving an intake rate of 43.1 g dry wt/sq m/yr. It is assumed that *Spartina alterniflora* is not consumed by mammals and that intake of microflora and other macrophytes is proportional to their percent of NPP, which for microflora is equal to 406/(406 + 830) = 32.8% (Table 114). Thus consumption of microflora is equal to the product of 0.328 and 43.1, or 14.1 g dry wt/sq m/yr.

[c]Total consumption of plants is equal to 43.1 g dry wt/sq m/yr, 14.1 of which is microflora (note b above). Assuming *Spartina alterniflora* is not consumed by mammals, the remaining 29.0 g dry wt/sq m/yr comes from other macrophytes.

[d]Approximately 67% of consumption by raccoons is invertebrates (Fleming 1975). Nutria and muskrats are herbivorous. The weighted average (note b above) for percent invertebrate intake is therefore 9.0%, giving an invertebrate intake rate of 4.4 g dry wt/sq m/yr. Crabs account for 14.2% of invertebrate secondary production (Table 132). Multiplying this value by 4.4 gives a crab intake rate of 0.6 g dry wt/sq m/yr.

[e]Uptake of invertebrates by mammals is equal to 4.4 g dry wt/sq m/yr (note d above). Mussels account for 65.5% of invertebrate secondary production (Table 132). Multiplying this value by 4.4 gives a mussel intake rate of 2.9 g dry wt/sq m/yr.

(continued)

Table 140. Concluded.

[f]Consumption of invertebrates by mammals is equal to 4.4 g dry wt/sq m/yr (note d above). Littorina accounts for 18.5% of invertebrate secondary production (Table 132). Multiplying this value by 4.4 gives a Littorina intake rate of 0.8 g dry wt/sq m/yr.

[g]Consumption of invertebrates by mammals is equal to 4.4 g dry wt/sq m/yr (note d above). Insects account for 1.8% of invertebrate secondary production (Table 132). Multiplying this value by 4.4 gives an insect intake rate of 0.1 g dry wt/sq m/yr.

[h]Approximately 2% of consumption by raccoons is vertebrates (Fleming 1975). Nutria and muskrats are herbivorous. The weighted average (note b above) for percent vertebrate consumption is therefore 0.3%, giving a vertebrate intake rate of 0.1 g dry wt/sq m/yr. Birds account for 5.9% of vertebrate secondary production (Table 142). Multiplying this value by 0.1 gives a bird intake rate of 0.01 g dry wt/sq m/yr.

[i]Consumption of vertebrates by mammals is equal to 0.1 g dry wt/sq m/yr, 0.01 of which is birds (note h above). The remaining 0.09 g dry wt/sq m/yr comes from mammals.

[j]Approximately 25% of consumption by raccoons is fish (Fleming 1975). Nutria and muskrats are herbivorous and do not consume fish. The weighted average (note b above) for percent fish intake is therefore 3.4%, giving a fish intake rate of 1.7 g dry wt/sq m/yr.

Table 141. Annual harvest of furbearers in MDPR marshes.[a]

Furbearers	Salt marsh	Brackish marsh[b]	Fresh marsh
Muskrat			
ind/sq m	4.80 E-5	4.34 E-5	1.54 E-5
g dry wt/sq m	1.24 E-2	1.12 E-2	0.40 E-2
Nutria			
ind/sq m	2.69 E-5	6.47 E-5	13.56 E-5
g dry wt/sq m	3.24 E-2	7.78 E-2	16.31 E-2
Raccoon			
ind/sq m	0.20 E-5	0.25 E-5	0.14 E-5
g dry wt/sq m	0.21 E-2	0.26 E-2	0.15 E-2
TOTAL[c]	4.7 E-2	9.2 E-2	16.9 E-2

[a]Catch data are 7 year averages and are from Linscombe as reported in Sasser et al. (1981). Harvest by number converted to harvest by weight by using the following conversions for muskrat, nutria, and raccoon: 258.5, 1203, and 1042.4 g dry wt/ind, respectively (Table 138, note d and Table 139, notes d and f).
[b]Intermediate marsh included with brackish marsh.
[c]Total harvest in g dry wt/sq m/yr.

Table 142. Secondary production by MDPR salt marsh vertebrates.[a]

Vertebrates	Production	Percent of Total
Birds	0.1	5.9
Mammals	1.6	94.1
TOTAL	1.7	100.0

[a]Production values for birds and mammals are taken from Tables 133 and 137, respectively.

Table 143. Release of heat by MDPR salt marsh organisms.[a]

Source	Value
Producers[b]	
Microflora[c]	44,966
Spartina alterniflora[d]	354,372
Other macrophytes[e]	240,277
Consumers[f]	
Microconsumers[g]	7273.2
Crabs[h]	68.9
Mussels[i]	235.1
Littorina irrorata[j]	493.8
Insects[k]	74.0
Birds[l]	82.9
Mammals[m]	158.5
TOTAL	648,001

[a]Values as kcal/sq m/yr.

[b]Producers release heat in the process of photosynthesis, since the reaction is not 100% efficient, and also in the process of catabolism when biomass is broken down for energy requirements. Heat loss by catabolism is calculated by multiplying the respired biomass by the heat content of that material. Losses due to photosynthesis were calculated by multiplying GPP by a heat to GPP ratio that was derived from H. T. Odum (1957), who reports that a heat loss of 389,190 kcal/sq m/yr was associated with a GPP rate of 20,810 kcal/sq m/yr (4624 g dry wt/sq m/yr). This gives a heat to GPP ratio of 84.2 kca;/g dry wt.

[c]GPP and respiration of microflora are equal to 527 and 121 g dry wt/sq m/yr, respectively (Table 107). The heat content of microflora is 4.9 kcal/g dry wt, based on the heat content of algae (E. P. Odum 1971).

[d]GPP and respiration of _S. alterniflora_ are equal to 4134 and 1534 g dry wt/sq m/yr, respectively (Table 109). The heat content of _S. alterniflora_ is 4.1 kcal/g dry wt (Golley 1961).

[e]GPP and respiration of other macrophytes are equal to 2803 and 1040 g dry wt/sq m/yr, respectively (Table 109). The heat content of _S. alterniflora_ is used for other macrophytes (note d above).

[f]Consumers release heat only through catabolic processes. Heat loss is calculated by mutiplying respired biomass by the heat content.

[g]Respiration of microconsumers is equal to 1914 g dry wt/sq m/yr (Table 122). The heat content of detritus is 3.8 kcal/g dry wt, based on four detritus size fractions of _Spartina alterniflora_ (Gosselink and Kirby 1974).

(continued)

Table 143. Concluded.

[h]Respiration of crabs is equal to 31.3 g dry wt/sq m/yr (Table 124). The heat content of crabs is 2.2 kcal/g dry wt (Golley 1961).

[i]Respiration of mussels is equal to 51.1 g dry wt/sq m/yr (Table 127). The heat content of mussels is 4.6 kcal/g dry wt (Golley 1961).

[j]Respiration of *Littorina* is equal to 164.6 g dry wt/sq m/yr (Table 128). A heat content of 3.0 kcal/g dry wt is used, based on the average heat content of invertebrates (E. P. Odum 1971).

[k]Respiration of insects is equal to 13.7 g dry wt/sq m/yr (Table 130). The heat content of insects is 5.4 kcal/g dry wt (E. P. Odum 1971).

[l]Respiration of birds is equal to 14.8 g dry wt/sq m/yr (Table 133). The heat content of birds is equal to 5.6 kcal/g dry wt, based on an average for the blue jay, thrush, house sparrow, partridge, and common cardinal (Jorgensen 1979).

[m]Respiration of mammals is equal to 28.3 g dry wt/sq m/yr (Table 137). A heat content of 5.6 kcal/g dry wt is used, based on the average heat content of vertebrates (E. P. Odum 1971).

Table 144. Assimilation of sunlight by MDPR salt marsh producers.[a]

Producer	Value
Microflora	46,745
Spartina alterniflora	366,686
Other macrophytes	248,626
TOTAL	662,057

[a]Values as kcal/sq m/yr. Studies by H. T. Odum (1957) found that a gross primary production rate of 20,810 kcal/sq m/yr (4624 g dry wt/sq m/yr) required 410,000 kcal/sq m/yr of sunlight, giving a sunlight/GPP ratio of 88.7 kcal/g dry wt. Assimilation is calculated by multiplying this ratio by GPP. GPP taken from Tables 107 and 109.

Table 145. Solar insolation and albedo in MDPR salt marshes.[a]

Process	Value
Insolation[b]	1.42 E6
Assimilation[c]	0.66 E6
Albedo[d]	0.76 E6

[a]Values as kcal/sq m/yr.
[b]The average solar insolation at New Orleans, Louisiana, for 1952-1975 was 389.8 cal/sq cm/day (Knapp et al. 1980). This is equivalent to 1.42 E6 kcal/sq m/yr.
[c]Total assimilation of sunlight by marsh producers, from Table 144.
[d]Calculated as insolation minus assimilation.

18. SPOIL

Spoil is the term used to describe the mixture of water and sediment that results from dredging in aquatic and wetland habitats. Piles of spoil material are commonly placed adjacent to the dredged site, where they rise above the surrounding natural landscape forming spoil banks.

Spoil banks are highly variable, depending on such factors as age, sediment type, dredging method, elevation, and location. For example, hydraulically dredged sediment which is high in clay may remain soupy for a long time, while bucket-dredged sediment from a high intertidal area may be relatively consolidated. In the former case, the sediment slurry will spread out unless constrained by a dike, while in the latter case the sediment may initially remain in place without being confined. All unconstrained spoil will inevitably slump and spread out to some extent, blanketing a surface area of wetland much larger than the area dredged. Thus, the dredging of canals in wetlands creates spoil banks that are three or more times greater in area than the canal from which the spoil is removed.

A typical spoil bank in the MDPR is a linear structure resulting from the construction of an oil well access canal, a pipeline canal, or a navigation canal. A spoil bank may initially rise as much as 3 m above the surrounding wetland elevation, and equal about 30 m in width (Monte 1978). Most older spoil banks from oil access canals are considerably lower, perhaps 1 m in elevation.

Monte (1978) estimated that more than 200,000 ha of spoil bank habitat exist in the wetland regions of Louisiana. Estimates from the MDPR habitat mapping study (Wicker et al. 1980a) indicate about 36,000 hectares of spoil in the MDPR in 1978. A map of the distribution of spoil in the MDPR is shown in Figure 47.

The area of spoil in Louisiana is increasing. The state receives about 2,200 permit applications yearly for various wetland dredging projects. The majority of the requests come from parishes in the MDPR, especially Terrebonne, Plaquemines, Lafourche, Jefferson, and St. Bernard. During 1981, 70% of all petroleum-related dredging permit requests involved saline and brackish marsh and estuarine open water habitats (Louisiana Department of Natural Resources 1982). Most of these projects involve the production of spoil banks.

The vegetation on wetland spoil banks typically follows a pattern of succession to more upland habitat, most frequently regional climax bottomland forest (Monte 1978). In salt marshes, the high soil salt content of newly created spoil banks prevents colonization by plants other than salt marsh grass (*Spartina alterniflora*). After several years, as leaching decreases the spoil salt content, the banks become dominated by salt meadow grass (*Spartina patens*). A 10-year-old spoil bank contains little salt and is covered with shrubs (mostly silverling, *Baccharis halimifolia*, and marsh elder, *Iva frutescens*). After 30 years, salt marsh spoil banks contain trees, (primarily toothache trees, *Zanthoxylen clava-herrulis*, and hackberry, *Celtis laevigata*) up to 25 cm in diameter. Sixty-four percent of the plant species found on 30-year-old salt marsh spoil banks is typical of upland rather than marsh habitats.

Succession on brackish marsh spoil banks follows a similar pattern, but lower initial soil salt content allows more rapid colonization by upland species. Thirty-year-old brackish spoil banks are typically dominated by hackberry, toothache tree, chinaberry (*Melia azedarach*) and black willow (*Salix nigra*) , up to 10 m in height. Seventy-one percent of the plant species found are typical of upland rather than wetland habitats (Monte 1978).

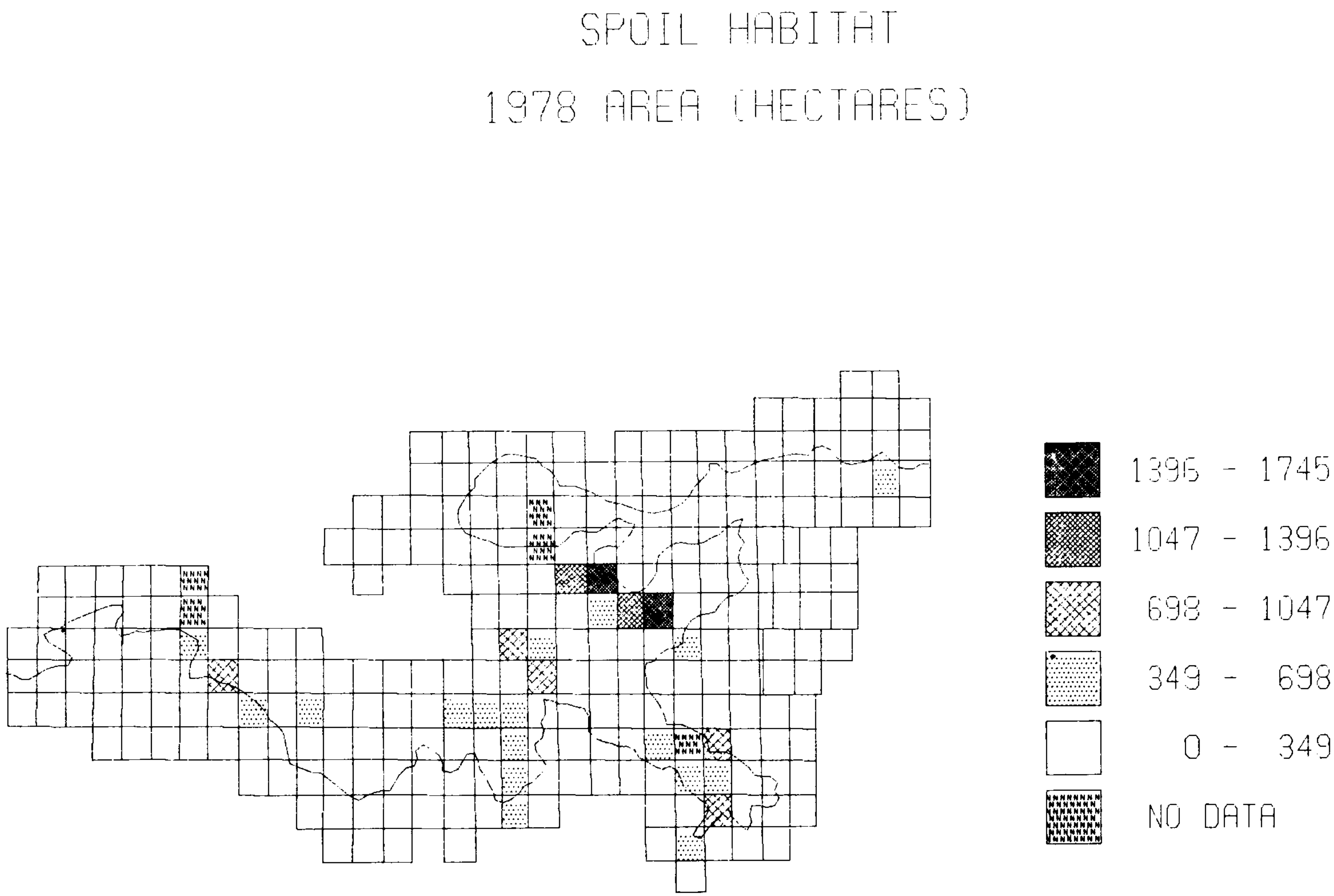


Figure 47. The distribution of MDPR spoil habitat.

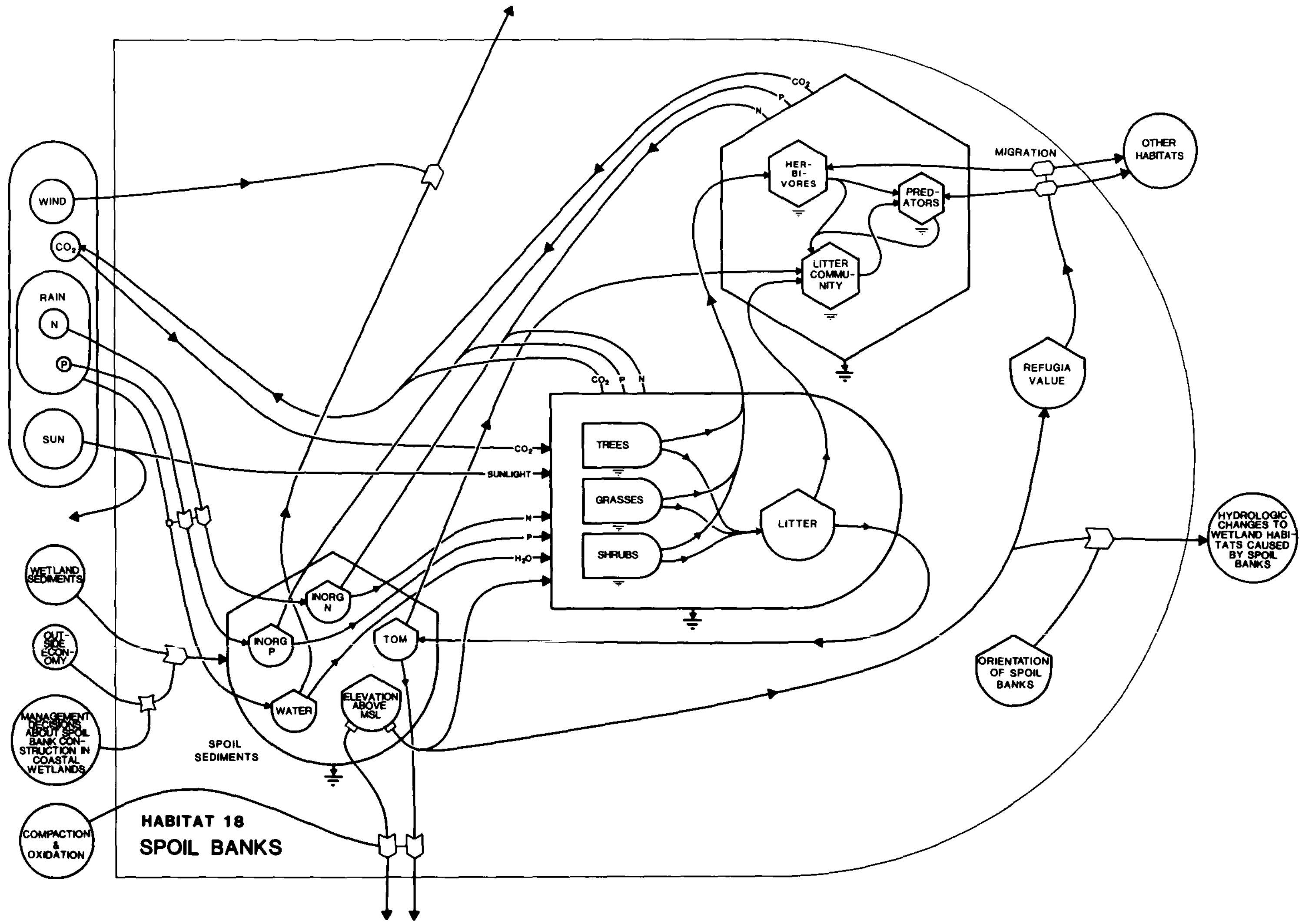


Figure 48. Spoil habitat flow diagram.

Fresh marsh and swamp spoil bank succession proceeds even faster because of the absence of soil salts. Ten-year-old spoil is often vegetated by such bottomland hardwood species as cottonwood (Populus deltoides), red maple (Acer rubrum), black willow, and green ash (Fraxinus pennsylvanica). Monte (1978) found fresh marsh and swamp spoil banks to be dominated by 47% and 69% upland vegetation, respectively, after 30 years. One benefit of spoil banks in all marsh types may be an increase in habitat diversity (Monte 1978), but this local effect must be weighed in most cases against disruption of natural hydrology.

During its ecological succession, a spoil bank consolidates and slumps and some of its organic sediments oxidize and go off as carbon dioxide. Its elevation gradually diminishes, which in turn increases its flooding frequency, ultimately controlling the makeup of its climax community. The specific makeup of the climax community is extremely sensitive to elevation. The highest and oldest spoil banks resemble the natural levee ridge (upland forest) habitat, in terms of species composition; however, they would have to survive for hundreds of years to reach maturity. With a subsidence rate of about 1 m per century, this is unlikely to occur.

The ecological impacts of spoil banks on the habitat on which they are superimposed are as variable as the vegetation. These impacts can be divided into two classes: local (direct) impacts and general (cumulative) impacts. Local impacts include the direct loss of wetlands because of their blanketing by sediment, and the imposition of a barrier to hydrologic flow between marsh and open water. This interruption of flow can seriously reduce the viability of wetland vegetation by reducing its irrigation and nutrient acquisition and changing its salinity regime. These changes are sublethal stresses that reduce primary productivity, as demonstrated by Mendelssohn et al. (in prep.). Even a few centimeters of artificial increase in elevation may interrupt normal hydrology. Spoil banks also prevent the local export of plant-derived carbon into natural water bodies or canals.

Spoil banks in local wetland areas may also be highly significant in increasing local species diversity by allowing the colonization of upland vegetation and the migration of large animals (including cattle) into marsh areas. Spoil banks also function as refugia during periods of high water. Mammals that often inhabit spoil banks include raccoons, deer, rabbits, and armadillos. Wading birds, such as herons and egrets, may use spoil banks as nesting areas, and migratory birds, such as warblers and swallows, use them as resting areas. Increased area for forestry, agriculture, and habitat for terrestrial fauna resulting from spoil banks must be weighed against losses in wetland productivity caused by hydrological modifications.

The unquantified energy and material flow diagram for spoil habitat is shown in Figure 48.

19. UPLAND FOREST

Upland forests in the MDPR occur on the Pleistocene Terrace north of Lake Pontchartrain, in Mississippi, and on a series of narrow natural levee ridges that extend as peninsulas into wetland areas. This habitat occupied about 71,000 ha of the MDPR in 1978 (Wicker et al. 1980a). A map of the distribution of MDPR upland forest habitat is shown in Figure 49.

The prehistoric area of the upland forest habitat was much greater, having occupied most of the natural levee ridge area within the MDPR. Thus the upland forest habitat has probably been more drastically reduced in the MDPR than any other natural habitat. Most of this formerly forested area has been developed for agriculture and urban-industrial use because it is the most elevated land in a region where development has often been limited to high land.

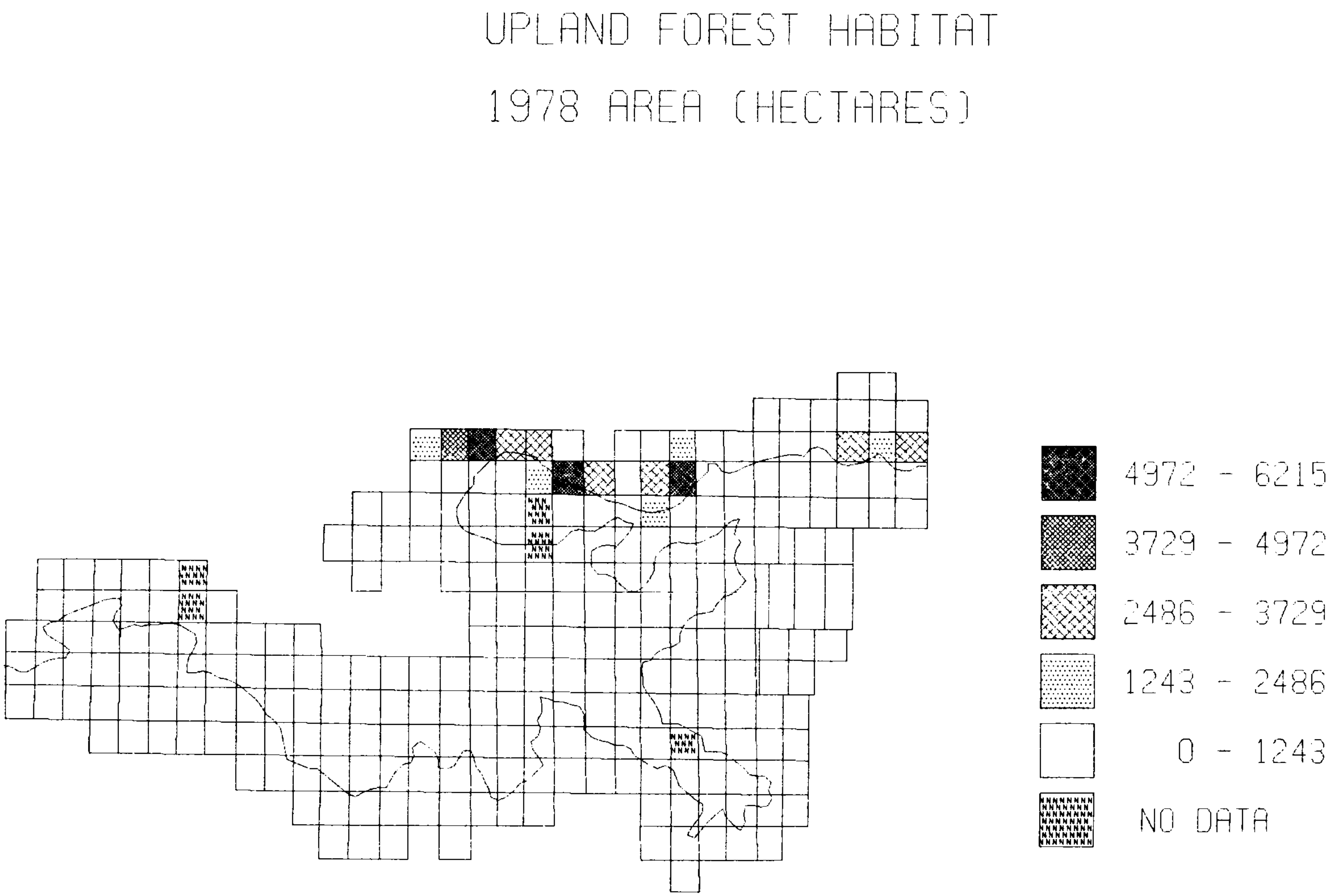


Figure 49. The distribution of MDPR upland forest habitat.

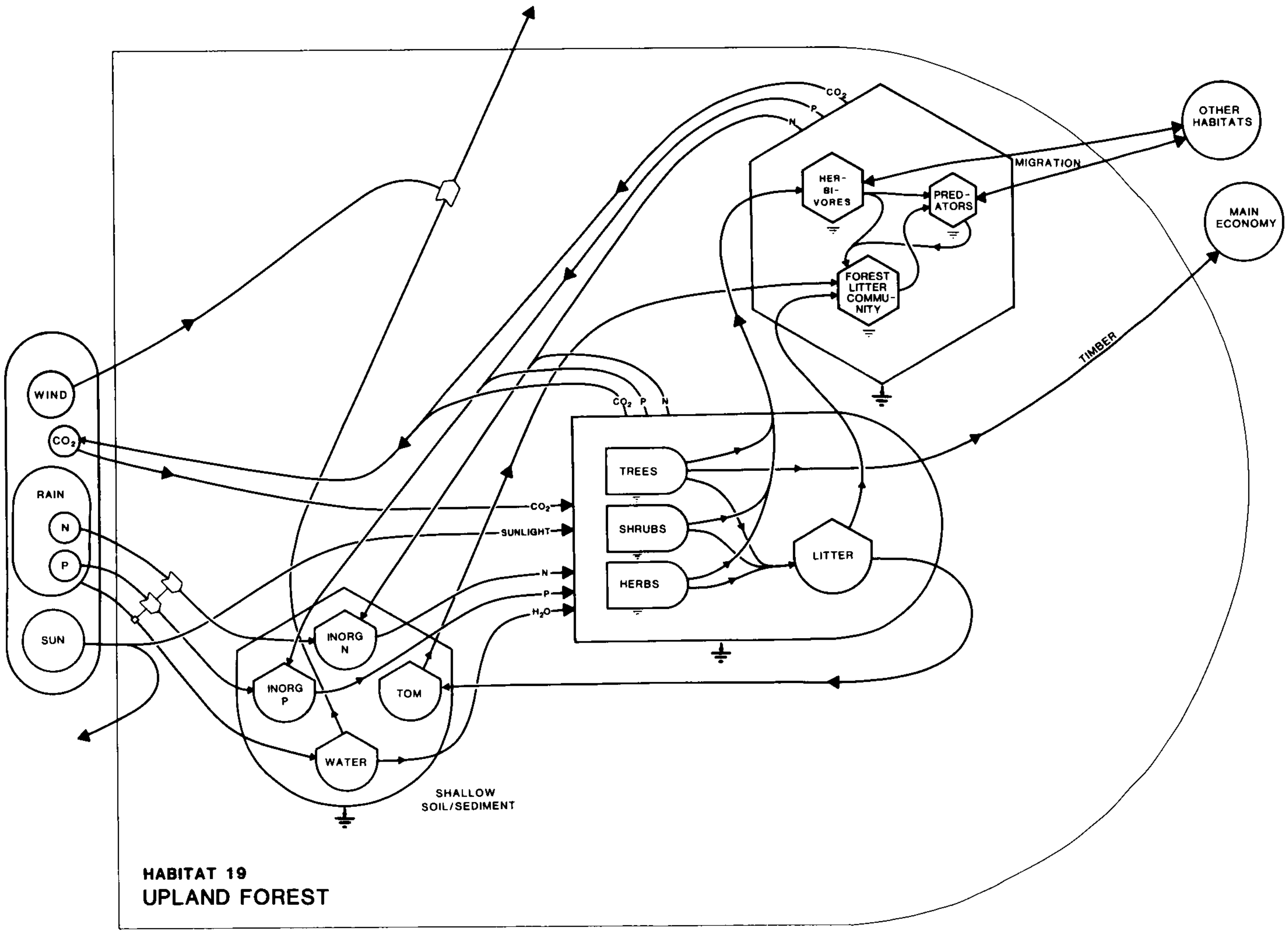


Figure 50. Upland forest habitat flow diagram.

Upland forest habitat grades imperceptibly into bottomland hardwood habitat as elevation declines and flooding frequency increases. This occurs on the lateral slopes of the natural levee ridges. Bottomland hardwood habitat in turn grades into swamp forest habitat with further decline in elevation toward the low-lying portions of each hydrologic basin.

The natural levee ridges on which the remaining upland forest habitat is found are characterized by Mississippi River alluvial soils. On the tops of the levee ridges these soils are characteristically silty loams, which are well oxygenated. On the slopes at lower elevation the soils are more clayey and firm when moist (Monte 1978). The maximum elevation of the natural levee ridges in the MDPR is less than 6 m, and most levee areas are less than 3 m above sea level (Monte 1978).

Natural climax vegetation on well-drained and undeveloped Pleistocene Terrace sites is dominated by mixed deciduous and evergreen trees that are less tolerant to flooding than are many bottomland hardwood species. These include, for example, oaks (*Quercus virginiana*, *Q. alba*, *Q. nigra*), shagbark hickory (*Carya ovata*), hackberry (*Celtis laevigata*), sweetgum (*Liquidambar styraciflua*), pecan (*Carya illinoensis*), magnolia (*Magnolia* sp.), and various pines. Some of the pine woodlands are now artificially cultivated.

Ridges supporting upland vegatation are prominent in marsh zones because they support woody vegetation and they are often visibly dominated by mature (sometimes stunted and dying) live oak trees. Natural levee ridges serve as avenues or migration routes for some terrestrial animals and they are also havens for many animals that venture into the marsh for food during low water. During very high tides and storm surges, the levee ridges may provide the only visible sign of emergent vegetation for miles, and they can become very densely populated with a variety of animals.

From prehistoric times until the present, natural levees in the MDPR have also provided human beings with the only naturally occurring firm living and transportation space available in the central region. The cultural pressure on natural levee ridges is intense, and undisturbed natural levee habitat is scarce. Natural levee ridge habitats in the MDPR include the Bayou Lafourche ridge, the Metairie-New Orleans ridge and the old Bayou Teche ridge, upon which Morgan City is located.

The Caminada Ridges, which are not natural levees but stranded beach ridges parallel to the coast line, are the only structures of that sort in the MDPR, and are the best examples of chenier ridges east of the Chenier Plain. Prehistoric people who used the ridges in the Barataria Basin often left shell middens and burial mounds that provide the highest relief in the surrounding area.

Upland forest was not selected for detailed modeling. The unquantified energy and material flow diagram for upland forest habitat is shown in Figure 50.

20. URBAN/INDUSTRIAL

The urban/industrial system is not often thought of as a "habitat" since human settlements have acquired the connotations of artifical and even un-natural environments. Humans and their artifacts are, however, affected by many of the same constraints and limitations as other forms of life and it is the intention of this study to treat them in the same manner. The urban/industrial habitat is considered to be a system that can be studied using methods that are equally applicable to any system. This approach allows the interdependence between the human and non-human habitats to be more easily quantified and understood.

Urban/industrial habitat covered 102,103 ha in the MDPR in 1978 (Wicker et al. 1980). The region's major metropolitan center is the city of New Orleans. A map of the distribution of urban/industrial habitat is shown in Figure 51.

The details of the urban/industrial habitat are much better known than are those for any of the non-human habitats. The input-output format, applied in this study to non-human as well as human habitats, was originally developed to keep track of the interconnections between components in urban/industrial systems (Leontief 1941). The main data sources for this habitat are published input-output studies (Hargrave and Burford 1973; Nissan et al. 1980) adjusted and expanded to reflect the MDPR economy and the special features of the format used in this study. Notes detailing this procedure follow the narrative. The energy and material flow diagram and input-output table for the urban/industrial habitat are shown in Figure 52 and Table 146. The urban/industrial system is different from the other habitats in the MDPR because it does not contain significant photosynthetic (primary producer) components. This is evident in Figure 52, which is made up entirely of "consumer" modules. Table 146 is unique compared to most economic input-output tables because it is scaled to reflect the average annual transactions on a unit area of urban/industrial land in the MDPR. It includes households and government as internal sectors, and it explicitly indicates the resource consumption and waste production of the economic sectors in the commodity-by-process format. Agriculture was not included as a sector in the urban/industrial model since a separate habitat model was prepared for it, but inputs of agricultural products to the other sectors are included.

The urban/industrial habitat shown in Figure 52 and Table 146 contains 13 internal processes or "sectors," which are aggregations of the much larger number for which national statistics are maintained. They represent the major urban/industrial activities that occur in the MDPR. On the left of Figure 52 are the three major "raw materials processing" sectors; forestry and fisheries, oil and gas extraction, and other mining (which includes mainly sulphur and salt mining in the MDPR). These three sectors process inputs received directly from the local environment and produce products for use by other local sectors and for export. Inspection of the "Total" column of Table 146 shows that oil and gas extraction is by far the dominant raw material activity in terms of dollar value, accounting for more than $1/year for every square meter of urban/industrial land. Of this, more than 70% is exported from the region. Oil and gas extraction activities will eventually diminish, however. The more modest $.015/sq m/yr of forestry and fisheries production represents a sustainable value derived from the annual production of the local ecological systems.

Moving to the right on Figure 52, the next column of sectors represents the major goods producing components of the economy at an average intensity of $.26/sq m/yr. The construction sector produces most of the capital goods and structures used in the region and exports about 18% of its total output. The petroleum refining, chemicals, and allied products sector is economically important in the MDPR, producing at an intensity of $.69/sq m/yr. Most of its production (80%) is exported to the national market. Other manufacturing occurs in the region, but a net import of about 10% of the total requirements is necessary to satisfy all local users.

The next group of five sectors represent the services component of the economy, divided into transportation and communication services: utilities, wholesale and retail trade, finance, insurance, real estate services, and other services. The services sectors represent an essential component in the MDPR economy, managing the flow of goods and information through the economy. Together they contribute $1.67/sq m/yr to the MDPR economy.

Finally, the households and local government sectors complete the picture of the MDPR urban/industrial habitat. Households represent a major component in the economy, consuming much of the local production of the other sectors and providing labor services that are a major input to all the other sectors at an average intensity of \$2.14/sq m/yr. Table 146 indicates that about 10% of the required labor services must be imported from outside the MDPR. In contrast, about 90% of government services are imported from outside the MDPR (from state and federal governments).

Figure 52 and Table 146 also indicate resource use and waste production by the sectors in the MDPR urban/industrial habitat. The use of agricultural products, natural products (fish, wildlife, and forest products), water, fossil fuel, wind, and solar energy by the sectors are estimated and listed in Table 146, as are the production of waste water, elemental wastes, heavy metals, organic carbon, hydrocarbons, air pollutants, and solid wastes. Figure 52 indicates only the total undistributed quantities for most of these commodities.

Notes to Urban/Industrial Habitat Model

Unlike the other habitat models, it was generally not necessary to estimate each entry in Table 23 independently from primary sources, because the major data sources were already in input-output format. The estimation procedure consisted mainly of "scaling" an existing I-O model of the Louisiana economy to the conditions and special format requirements of the MDPR, and then adding information about resource use and waste product production. Thus the notes which follow refer to blocks of estimates rather than individual entries.

Forestry and fisheries products through other commercial services.

1,1,I through 11,15,O This section of the urban/industrial habitat model was estimated from data in Hargrave and Burford (1973) adjusted to reflect the MDPR economy using location quotients based on employment. Table 147 is an input-output total transactions table for Louisiana with 11 commercial and industrial sectors, plus exports and imports, other final demand, value added, and other transactions categories. These 11 sectors represent aggregations of the 25 sectors used in the Hargrave and Burford study, which in turn were aggregations of the more than 300 sectors used in the national I-O statistics. Table 147 lists the direct sales of products and services from the sector on the left of the table to the sector listed along the top. For example, forestry and fisheries sold \$21.2 E6 worth of products in 1967 (the base year for this study) to the "other manufacturing" sector. At the far right of the table are purchases by households (personal consumption expenditures), local government, and "other final demand and net exports," which includes gross investment, net inventory change, and net exports. At the bottom of the table are inputs from industries not located in Louisiana, from agriculture (which was excluded from this model since a separate model was prepared for it) and value added (which includes wages, taxes, and property type income). The next step involved scaling the aggregated Louisiana table (Table 147) to reflect the economy of the MDPR using the method known as "location quotients." A location quotient is a measure of the relative importance of a sector in the region of interest compared with its relative importance in some other system for which more detailed data are available. In this study, location quotients were calculated based on taxable payroll data for Louisiana as a whole and the 14 parishes in the MDPR (U.S. Dept. of Commerce 1972) using the following formula:

$$LQ_i = \frac{TP_{MDPR,i} \;/\; TP_{MDPR,total}}{TP_{LA,i} \;/\; TP_{LA,total}}$$

275

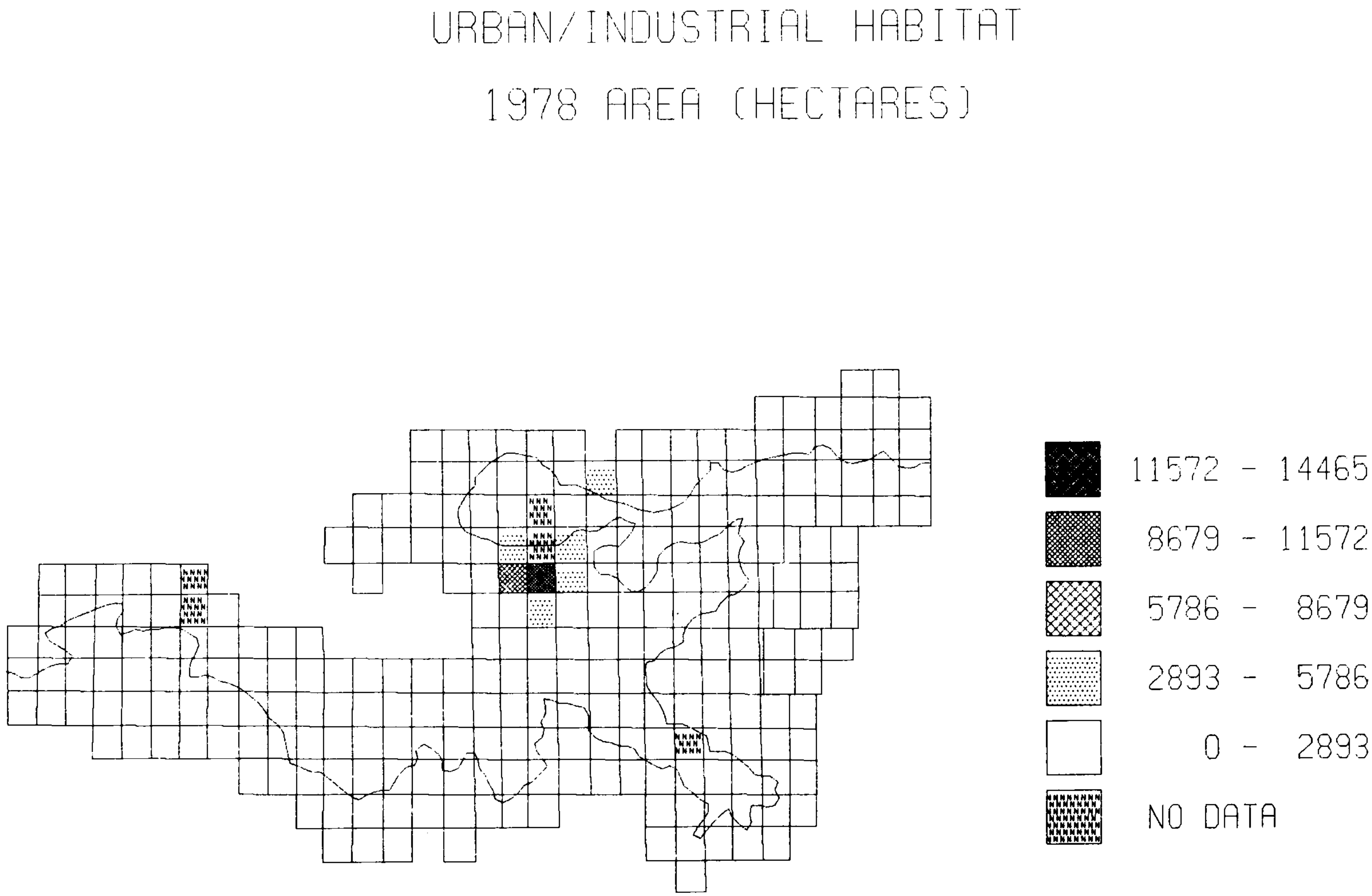


Figure 51. The distribution of MDPR urban/industrial habitat.

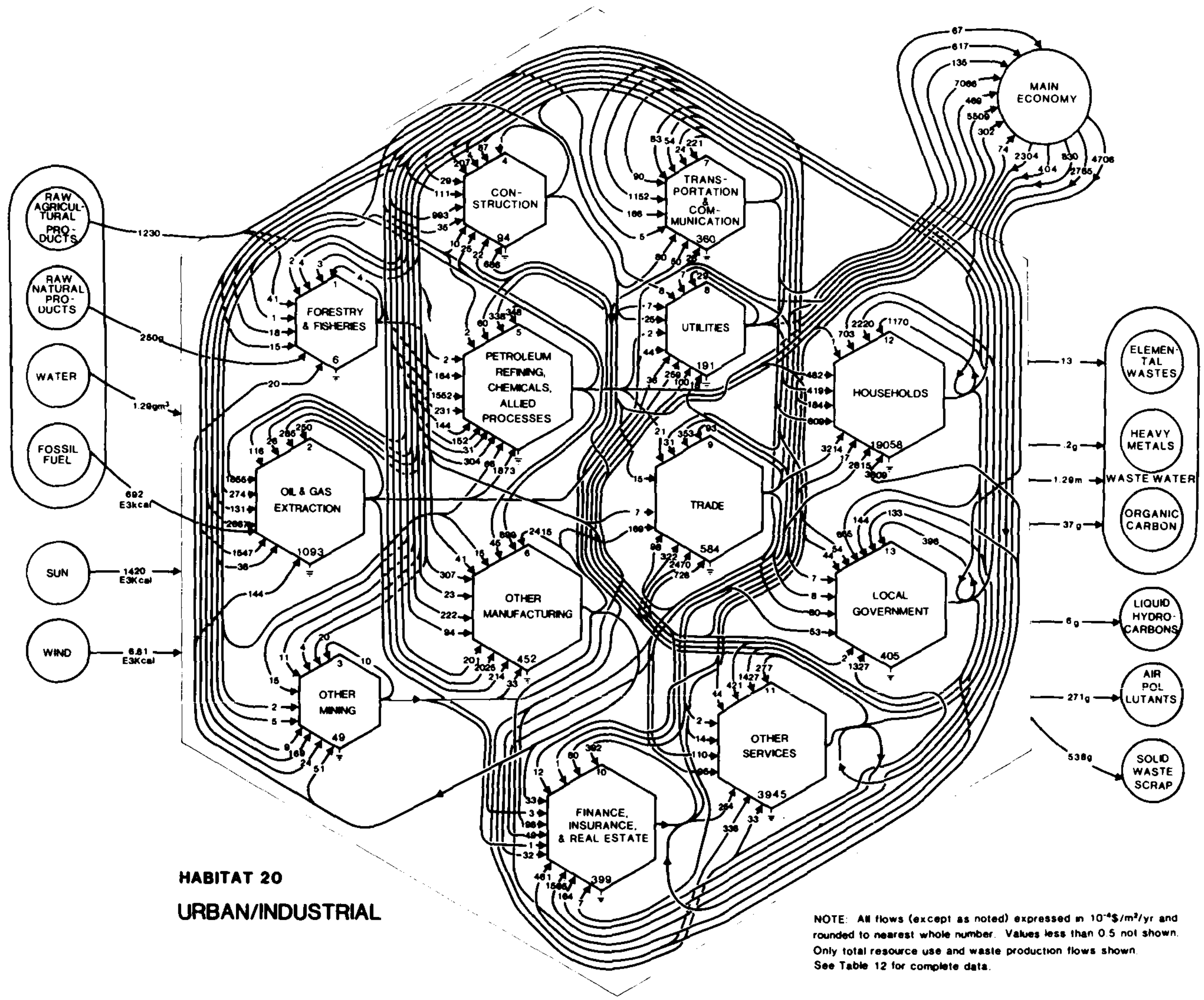


Figure 52. Urban/industrial habitat flow diagram.

HABITAT 20
URBAN/INDUSTRIAL

COMMODITIES		1 FORESTRY AND FISHERIES	2 CRUDE PETROLEUM AND NATURAL GAS	3 OTHER MINING	4 CONSRUCTION	5 CHEMICAL & PETROLEUM REFINING	6 OTHER MANUFACTURING	7 TRANSPORTATION & COMMUNICATION	8 UTILITIES	9 TRADE	10 FINANCE, INSURANCE & REAL ESTATE	11 OTHER SERVICES	12 HOUSEHOLDS	13 LOCAL GOVERNMENT	14 IMPORTS & EXPORTS	15 CHANGE IN STORAGE (GROSS INVESTMENT & INV. CHANGE)	TOTAL	UNITS
FORESTRY & FISHERY PRODUCTS	1	4.24 149.70				2.29	40.86			7.14	0.60		17.34	2.11	73.64	5.71	149.70 149.70	$10^4\,\$/m^2/yr$ $10^4\,\$/m^2/yr$
CRUDE PETROLEUM & NATURAL GAS	2		250.24 10357.80			1873.28		27.62	44.28	0.22	2.53				7066.47	1093.16	10357.80 10357.80	$10^4\,\$/m^2/yr$ $10^4\,\$/m^2/yr$
OTHER MINING	3			9.70 477.70	22.35	60.26	33.49			0.22	0.63		0.57	0.40	301.67	49.01	477.70 477.70	$10^4\,\$/m^2/yr$ $10^4\,\$/m^2/yr$
CONSTRUCTION	4			1.98	0.73 2598.80	65.68	15.49	80.10	24.66	15.31	197.64	33.49		1326.99	469.21	93.97	2598.80 2598.80	$10^4\,\$/m^2/yr$ $10^4\,\$/m^2/yr$
CHEMICALS, REFINED PETROLEUM, & OTHER ALLIED PRODUCTS	5	0.51	38.32	5.31	26.18	348.11 6942.70	44.68	22.76	2.26	21.20	7.33	13.53	481.99	43.63	5509.38	401.08	6942.70 6942.70	$10^4\,\$/m^2/yr$ $10^4\,\$/m^2/yr$
OTHER MANUFACTURED PRODUCTS	6	19.61	144.18	60.80	686.29	338.18	2415.73 7825.00	49.96	6.75	168.67	33.30	336.27	3609.01	144.21	830.21	452.05	8665.21 8665.21	$10^4\,\$/m^2/yr$ $10^4\,\$/m^2/yr$
TRANSPORTATION & COMMUNICATION	7	2.95	285.05	19.61	86.64	304.02	306.98	221.36 2576.33	8.22	97.60	32.48	95.08	609.11	80.34	66.75	360.14	2576.33 2576.33	$10^4\,\$/m^2/yr$ $10^4\,\$/m^2/yr$
ELECTRIC, GAS, WATER & SANITARY SERVICES	8		26.31	3.67	3.53	31.31	22.54	23.63	28.50 1026.90	31.44	11.91	43.96	419.47	53.55	136.11	190.98	1026.90 1026.90	$10^4\,\$/m^2/yr$ $10^4\,\$/m^2/yr$
WHOLESALE & RETAIL TRADE SERVICES	9	4.00	116.11	11.40	206.92	161.91	221.53	53.82	6.80	92.64 5449.30	49.41	110.46	3214.39	8.01	616.92	584.98	5449.30 5449.30	$10^4\,\$/m^2/yr$ $10^4\,\$/m^2/yr$
FINANCE, INSURANCE, & REAL ESTATE SERVICES	10	1.98	1865.39	15.05	28.72	143.71	93.62	83.17	17.63	352.62	392.41 3720.60	254.22	2815.31	52.50	2785.33	399.40	6505.93 6505.93	$10^4\,\$/m^2/yr$ $10^4\,\$/m^2/yr$
OTHER COMMERCIAL SERVICES	11	0.42	130.72	8.85	111.33	230.64	201.34	90.02	36.47	321.94	163.97	276.62 3946.00	2219.54	133.24	403.6	423.50	4348.60 4348.60	$10^4\,\$/m^2/yr$ $10^4\,\$/m^2/yr$
LABOR SERVICES	12	17.77	2667.36	169.35	993.21	1651.90	2024.69	1152.20	256.90	2469.54	1564.99	1427.41	1170.50 19068.40	665.25	2303.78	5228.91	21362.18 21362.18	$10^4\,\$/m^2/yr$ $10^4\,\$/m^2/yr$
GOVERNMENT SERVICES	13	14.96	1546.60	24.35	34.85	163.73	213.63	165.56	99.56	727.68	461.14	420.60	703.29	396.19 404.74	4706.07		5110.81 5110.81	$10^4\,\$/m^2/yr$ $10^4\,\$/m^2/yr$
AGRICULTURAL PRODUCTS	14	41.33			9.90	1.67	898.62	4.64			80.33	2.09	184.49	6.96	1230.03		1230.03 1230.03	$10^4\,\$/m^2/yr$ $10^4\,\$/m^2/yr$
RAW NATURAL PRODUCTS	15	250													250		250 250	$g/m^2/yr$ $g/m^2/yr$
WATER	16		.29806 .27510	.01375 .01269	.00677 .00625	.1735 .16018	.57771 .53321	.00074 .00068	.00015 .00014	.00233 .00215	.00008 .00007	.05857 .05406	.15622 .14419	.00003 .00003	.09948		1.28823 1.28823	$m^3/m^2/yr$ $m^3/m^2/yr$
FOSSIL FUEL	17		692.655												692.655		692.655 692.655	$10^3\,Kcal/m^2/yr$ $10^3\,Kcal/m^2/yr$
ELEMENTAL WASTE	18					5.36	6.995	0.005			0.011	0.343	.591	0.016	13.321		13.321 13.321	$g/m^2/yr$ $g/m^2/yr$
HEAVY METAL	19					.1805	.0157								.1962		.1962 .1962	$g/m^2/yr$ $g/m^2/yr$
ORGANIC CARBON	20		11.259	.519	.283	4.638	9.226	.041	.006	.005	.004	3.243	8.138	.002	37.364		37.364 37.364	$g/m^2/yr$ $g/m^2/yr$
HYDROCARBONS	21		2.8690	.1323		1.5066	.0704	.4689	.1867			.8087		.0040	6.0466		6.0466 6.0466	$g/m^2/yr$ $g/m^2/yr$
AIR POLLUTANTS	22	.0295	21.8860	1.0094		15.5586	8.9518	3.4163	32.4697	.04850			187.5346		270.9044		270.9044 270.9044	$g/m^2/yr$ $g/m^2/yr$
SOLID WASTE & SCRAP	23		2.1337	.0984	.4418	51.1330	143.6905	.7497	.2236	4.7954	.7962	3.4756	328.2619	1.7849	537.5844		537.5844 537.5844	$g/m^2/yr$ $g/m^2/yr$
WIND	24	42.65	2960.62	137.43	195.65	163.00	171.96	193.62	76.50	94.10	67.02	70.41	2418.92	186.21	6770.00		6770.00 6770.00	Kcal/yr Kcal/yr
SUNLIGHT	25	8.9	621.0	28.8	41.0	32.1	36.1	40.6	16.0	19.7	14.1	14.6	507.4	39.5	1420.0		1420.0 1420.0	$10^3\,Kcal/m^2/yr$ $10^3\,Kcal/m^2/yr$

where:

LQ_i = The location quotient for sector i

$TP_{MDPR,i}$ = The taxable payroll for sector i in the MDPR

$TP_{MDPR,total}$ = The total taxable payroll for all sectors in the MDPR

$TP_{LA,i}$ = The taxable payroll for sector i in Louisiana

$TP_{LA,total}$ = The total taxable payroll for all sectors in Louisiana

Table 148 lists the taxable payrolls for each of the 11 sectors used in thi Louisiana and the MDPR, the Standard Industrial Classification (SIC) codes dustries included in the 11 sectors, and the location quotients calculated fc using the above formula. If the location quotient is greater than one, the assumed to be producing more output than needed for local (MDPR) consumpti excess is exported to the rest of the state or other states. If the locatio is less than one, the sector is producing less than that needed for local c and the remainder must be imported.

The next step is to prepare a direct requirements matrix for the MD using the Louisiana transactions table (Table 147) and the MDPR location This table appears as Table 149. Each entry in this table was calculated following formula:

if $LQ_i > 1.0$ then $a_{i,j} = x_{i,j}/x_j$

if $LQ_i < 1.0$ then $a_{i,j} = LQ_i*(x_{i,j}/x_j)$

where:

$a_{i,j}$ = direct requirement of sector i product by sector j per $ of total output in the MDPR- these are the entries in Table 149.

$x_{i,j}$ = total transaction from sector i to sector j in LA - these are the entries in Table 147

x_j = the total output of sector j in LA - these are the row totals in Table 147

LQ_i = the location quotients shown in Table 148

For example, the input of forestry and fisheries products (sector dollar of output of other manfacturing (sector 6), or $a_{1,6}$ in Tabl was calculated as:

$a_{1,6}$ = 0.9134 * (21.2/3711.4) = 0.00522 $/$ total output

The final step to arrive at the estimates in Table 146 involved scaling the direct requirements per dollar of total output for the MDPR shown in Table 149 to represent a unit urban/industrial land area in the MDPR. This was done based on the intensity (in \$/sq m) of economic activity of the 11 sectors in Louisiana in 1967, as shown in Table 150. Each entry in the upper 11 rows of Table 146 is the product of the corresponding element in Table 149 (in \$/\$ total output) and the appropriate output intensity (in \$ total output/sq m) from Table 150 For example, forestry and fisheries products input to other manufacturing (1,6,I) was calculated as:

0.00522 \$/\$ * 0.78250 \$/sq m = 40.85 E-4 \$/sq m

The gross change in storage column in Table 146 was calculated as a percentage of total output, based on national average values listed in Table 151. The export/import column was then calculated as a residual--the difference between the total uses of each commodity in the MDPR and the amount produced by local processes. For example, the MDPR Forestry and Fisheries sector produces 149.7 E-4 \$/sq m/yr (Table 150) but local uses (the sum of the entries in the upper line of row 1 in Table 146, except exports and imports) totals 76.06 E-4 \$/sq m/yr. The difference (or residual) of 73.64 E-4 \$/sq m/yr is thus available for export and appears as the entry (1,14,0) in Table 146.

Labor services and government services.

12,1,I through 13,15,0 Labor and government service inputs to MDPR urban/industrial processes (Table 152) were estimated as percentages of total value added based on a breakdown derived from national averages. Total value added per dollar of total output by sector was calculated using the data sources and methods already noted. These estimates appear as a row in Table 149. The entries in the labor and government service input rows of Table 146 were calculated by multiplying the \$ value added/\$ total output estimate (from Table 149) by the fraction of value added attributable to labor and government, respectively (from Table 152), by the \$ total output/sq m estimates from for the appropriate sector (from Table 150). For example, the estimate for labor service input to forestry and fisheries (12,1,I) was calculated as:

0.33521 \$/\$ * 0.3541 * 0.01497 \$/sq m = 17.77 E-4 \$/sq m

Agricultural products.

14,1,I through 14,14,0 Data on agricultural products inputs to the MDPR urban/industrial sectors was included in the input-output data sources cited above. Agriculture was not included as an urban/industrial process since a separate habitat model was prepared for it. Methods of estimating agricultural inputs follow those already mentioned. Input of agricultural products in \$ input/ \$ total output were calculated and appear in Table 149. Multiplying these estimates by the \$ total output/sq m estimates from Table 150 for the appropriate sector yields the estimates in Table 146. For example, agricultural products inputs to other manufacturing (14,6,I) were calculated as:

0.11484 \$/\$ * 0.78250 \$/sq m = 898.62 E-4 \$/sq m

Raw natural products.

15,1,I Total input of raw forestry and fisheries products in 1967 was estimated as 206 g/sq m/yr. Forestry products are unimportant in the MDPR. Total fish and shellfish landed in Louisiana in 1967 was 639.7 E6 lb or 290.16 E6 kg (NOAA 1967) The MDPR represents about 66% of the total wetlands in Louisiana (959,240 ha out of a total of 1,446,740 ha, see Table 1 and Gosselink et al. 1979) so it was estimated that about 191.5 E6 kg of fish and shellfish were landed in the MDPR in 1967. Dividing this by the total MDPR urban/ industrial land area (estimated at 76,500 ha in 1967 from interpolation of Table 3) yields 2.50 E3 kg/ha or 250 g/sq m/yr

Water.

16,1,I through 16,14,0 Table 153 contains estimates of water use and waste water production intensities (in cu m/$ total output) for the MDPR urban/industrial sectors. The water input and output estimates in Table 23 were calculated by multiplying these estimates by the $ total output/sq m of the appropriate sector from Table 150. For example, the estimate for water input to chemicals and refined petroleum (16,5,I) was calculated as:

0.24997 cu m/$ * 0.69427 $/sq m = 0.17355 cu m/sq m

The estimate for water output for the same process (16,5,0) was calculated as:

0.23072 cu m/$ * 0.69427 $/sq m = 0.16018 cu m/sq m

Fossil fuel.

17,2,I Fossil fuel input to the crude petroleum and natural gas extraction sector was estimated to be 692.535 E3 kcal/sq m/yr. The national average domestic fossil fuel input per dollar of total output of the crude petroleum and natural gas sector for 1967 was 40.050 E15 Btu/15.031 E9 $ (U. S. Bureau of Census 1974). Converting this to kcal (0.251 kcal/Btu) yields 668.78 E3 kcal/$. Multiplying this by the value intensity of oil and gas extraction in the MDPR from Table 150 (1.0357 $/sq m/yr) yields an estimated fossil fuel input of 692.655 E3 kcal/sq m/yr. This input is distributed by the oil and gas extraction sector to the other sectors in the MDPR or exported.

Elemental wastes.

18,1,0 through 18,13,0 These values were calculated by multiplying the waste production coefficient from Table 154 (in kg/$) times the total sector dollar output (in $/sq m) from Table 150. For example, elemental waste production from households (18,12,0) was estimated as:

0.00031 kg/$ * 1.90584 $/sq m = 0.591 g/sq m

Heavy metals.

19,1,0 through 19,13,0 These values were calculated by multiplying the waste production coefficient from Table 154 (in kg/$) by the total sector dollar output (in $/sq m) from Table 150. For example, heavy metal production from chemicals and refining (19,5,0) was estimated as:

0.00026 kg/$ * 0.69427 $/sq m = 0.1805 g/sq m

Organic carbon.

20,1,0 through 20,13,0 These values were calculated by multiplying the waste production coefficient from Table 154 (in kg/$) by the total sector dollar output (in $/sq m) from Table 150. For example, organic carbon production from households (20,12,0) was estimated as:

0.00427 kg/$ * 1.90584 $/sq m = 8.138 g/sq m

Hydrocarbons.

21,1,0 through 21,13,0 These values were calculated by multiplying the waste production coefficient from Table 154 (in kg/$) times the total sector dollar output (in $/sq m) from Table 150. For example, hydrocarbon production from crude petroleum and natural gas (21,2,0) was estimated as:

0.00277 kg/$ * 1.03578 $/sq m = 2.869 g/sq m

Air pollutants.

22,1,0 through 22,13,0 These values were calculated by multiplying the waste production coefficient from Table 153 (in kg/$) by the total sector dollar output (in $/sq m) from Table 150. For example, air pollutant production from crude petroleum and natural gas (22,2,0) was estimated as:

0.02113 kg/$ * 1.03578 $/sq m = 21.886 g/sq m

Solid waste.

23,1,0 through 23,13,0 These values were calculated by multiplying the waste production coefficient from Table 153 (in kg/$) by the total sector dollar output (in $/sq m) from Table 150. For example, solid waste production from other manufacturing (23,6,0) was estimated as:

0.18363 kg/$ * 0.78250 $/sq m = 143.6905 g/sq m

Wind.

24,1,I through 24,13,I Available wind power in the MDPR averages about 90 watts/sq m/yr (Considine 1976) or 6.77 E5 kcal/sq m/yr. Of this amount, only a small percentage is actually absorbed by any given sq m of surface. Although no precise measurements have been made, it was estimated that about 1% of the available wind power is absorbed, or about 6.77 E3 kcal/sq m/yr. This total was distributed to the urban/industrial sectors according to their relative land intensity from Table 155. For example, wind input to forestry and fisheries (24,1,I) was estimated as:

6.77 E3 kcal/sq m * 0.0063 sq m/sq m = 42.65 kcal/sq m

Sunlight.

25,1,I through 25,13,I The MDPR averages about 1.42 E6 kcal/sq m/yr solar radiation at the surface (Knapp 1980). This total was distributed to the urban/industrial sectors according to their relative land intensity from Table 155. For example, solar input to households (25,12,I) was estimated as:

1.42 E6 kcal/sq m * 0.3573 sq m/sq m = 507.4 E3 kcal/sq m

Table 147. Louisiana total transactions table (millions of $ 1967).[a]

	1	2	3	4	5	6	7	8[b]	9	10	11	PCE[c]	G'vt[d]	FD[e]	Total Output
1 Forestry and fisheries	2.2	0	0	0	1.2	21.2	0	0	3.7	0.3	0	8.2	-1.0	35.2	71.0
2 Oil and gas extraction	0	118.7	0	0	888.5	0	13.1	21.0	0.1	1.2	0	--	--	3,870.1	4,912.7
3 Other mining	0	0	4.6	10.6	28.6	15.9	0	0	0.1	0.3	0	0.7	-0.2	166.0	226.6
4 Construction	0	152.0	1.1	0.4	36.5	8.6	44.5	13.7	8.5	109.8	18.6	--	629.4	209.5	1,232.6
5 Chemicals and petro refining	0.9	67.9	9.4	44.6	616.5	79.1	40.3	4.0	37.5	13.0	24.0	228.6	20.7	2,106.4	3,292.9
6 Other manufacturing	9.3	68.4	24.1	325.5	160.4	1,145.8	23.7	3.2	80.1	15.8	159.5	1,806.6	68.4	-179.4	3,711.4
7 Transportation and communication	1.4	135.2	9.3	41.1	144.2	145.6	105.0	3.9	46.3	15.4	45.1	288.9	38.1	202.5	1,222.0
8 Utilities	0	37.3	5.2	5.0	44.4	32.0	33.5	40.4	44.6	16.9	62.3	199.0	25.4	-59.4	486.6
9 Trade	2.0	58.0	5.7	103.4	75.9	110.7	26.9	3.4	46.3	24.7	55.2	1,524.6	3.8	544.0	2,584.6
10 Finance, insurance and real estate	1.0	937.1	7.6	14.5	72.6	47.4	42.0	8.9	178.1	198.2	128.4	1,335.3	24.9	-1,231.3	1,764.7
11 Other services	0.2	62.0	4.2	52.8	109.4	95.5	42.7	17.3	152.7	77.8	131.2	1,052.7	63.2	9.4	1,871.1
Total intermediate inputs	17.0	1,636.6	71.2	597.9	2,178.2	1,701.1	371.7	115.8	598.80	473.4	624.3	6,444.6	872.7		
Industries not located in Louisiana	10.6	501.7	31.9	95.1	154.0	331.1	108.0	84.3	91.3	52.1	150.3	553.5	82.0		
Agriculture	19.6	0	0	4.7	0.8	426.2	2.2		0	38.1	1.0	87.5	3.3		
Value added	23.8	2,774.4	123.5	[illegible]34.9	959.9	1,252.5	740.1	286.5	1,895.3	1,201.1	1,095.5	1,954.1	961.7		
Total inputs	71.0	4,912.7	226.6	1,232.6	3,292.9	3,711.4	1,222.0	486.6	2,584.6	1,764.7	1,871.1	9,039.4	1,919.7		

[a] Aggregated from data in Hargrave and Burford 1973.

[b] Utilities disaggregated from transportation and communication on the basis of their relative total dollar output.

[c] Personal consumption expenditures.

[d] Local government.

[e] Other final demand + net exports.

Table 148. Taxable payrolls (in thousands of $1972) and location quotients for the MDPR urban/industrial sectors.

Sector	SIC Codes included	Taxable LA	Payrolls MDPR	Location quotient
1. Forestry & fisheries	7-9	5015	2490	0.9134
2. Oil & gas extraction	13	98900	56411	1.0493
3. Other mining	14	24727	21402	1.5923
4. Construction	15-17	146921	68175	0.8537
5. Chemicals & refining	28-30	101349	14752	0.2678
6. Other manufacturing	19-27,31-39	262497	179830	1.2603
7. Trans. & comm.	41-48	123236	88222	1.3170
8. Utilities	49	29605	5384	0.3346
9. Trade	52-59	332343	171447	0.9491
10. Finance	60-67	93847	47906	0.9391
11. Other services	70-89	191804	110544	1.0603
TOTALS		1410244	766563	

[a]Households and government were assumed to have a location quotient of 1.00.
[b]MDPR parishes as defined by Larson et al. 1980.

Table 149. MDPR direct requirements matrix ($/$ total output).[a]

From sector	To sector 1	2	3	4	5	6	7	8	9	10	11	Personal consumption expenditures	Local government
1 Forestry and fisheries	.02830	--	--	--	.00033	.00522	--	--	.00131	.00016	--	.00091	.00052
2 Oil and gas extraction	--	.02416	--	--	.26982	--	.01072	.04316	.00004	.00068	--	--	--
3 Other mining	--	--	.02030	.00860	.00868	.00428	--	--	.00004	.00017	--	.00003	.00010
4 Construction	--	.02641	.00414	.00028	.00946	.00198	.03109	.02404	.00281	.05312	.00849	--	.32786
5 Chemicals and petro refining	.00339	.00370	.01111	.00969	.05014	.00571	.00883	.00220	.00389	.00197	.00343	.02529	.01078
6 Other manufacturing	.13099	.01392	.10635	.26408	.04871	.30872	.01939	.00658	.03099	.00895	.08524	.19986	.03563
7 Transportation and communication	.01972	.02752	.04104	.03334	.04379	.03923	.08592	.00801	.01791	.00873	.02410	.03196	.01985
8 Utilities	--	.00254	.00768	.00136	.00451	.00288	.00917	.02778	.00577	.00320	.01114	.02201	.01323
9 Trade	.02674	.01121	.02387	.07962	.02188	.02831	.02089	.00663	.01700	.01328	.02800	.16866	.00198
10 Finance, insurance and real estate	.01323	.17913	.03150	.01105	.02070	.01199	.03228	.01718	.06471	.10547	.06444	.14772	.01297
11 Other services	.00282	.01262	.01853	.04284	.03322	.02573	.03494	.03555	.05908	.04407	.07012	.11646	.03292
Total Intermediate inputs	.22519	.30121	.26452	.45086	.51124	.43405	.25323	.17113	.20355	.23980	.29496	.71290	.45584
Industries not located in MDRP	.16354	.13405	.19267	.11133	.19701	.11364	.13932	.24007	.06314	.05798	.11903	.06124	.04148
Agriculture	.27606	--	--	.00381	.00024	.11484	.00180	--	--	.02159	.00053	.00968	.00172
Value added	.33521	.56474	.54281	.43400	.29151	.33747	.60565	.58880	.73331	.68063	.58548	.21618	.50096
Total inputs	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.0000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000

[a]Based on the Louisiana total transactions table (Table 147) adjusted to the MDPR using the location quotients given in Table 148.

Table 150. Total sector outputs in 1967 and output per unit of urban/industrial land.[a]

Sector	$ Value of LA Output (E6 $1967)	Output per unit total urban/ind. land ($1967/sq m)
1. Forestry & fisheries	71.0	.01497
2. Oil & gas extraction	4912.7	1.03578
3. Other mining	226.6	.04777
4. Construction	1232.6	.25988
5. Chemicals & refining	3292.9	.69427
6. Other manufacturing	3711.4	.78250
7. Trans. & comm.	1222.0	.25764
8. Utilities	486.6	.10259
9. Trade	2584.6	.54493
10. Finance	1764.7	.37206
11. Other services	1871.1	.39450
12. Households	9039.4	1.90584
13. Government	1919.7	.40474

[a]1967 urban/industrial land area in 1967 estimated as 4.743 E9 sq m (Louisiana State Planning Office 1981. Total for 1972 adjusted to 1967).

Table 151. Investment coefficients for the MDPR urban/industrial sectors based on national values for 1967.

Sector	Gross capital formation + net inventory change as a fraction of total output for the U.S. in 1967[a]
1. Forestry & fisheries	.03816
2. Oil & Gas extraction	.10554
3. Other mining	.10259
4. Construction	.03616
5. Chemicals & refining[b]	.05777
6. Other manufacturing	.05777
7. Trans. & comm.	.13979
8. Utilities	.18616
9. Trade[c]	.10735
10. Finance	.10735
11. Other services	.10735
12. Households	.27436
13. Government	.34262

[a]From Costanza 1979.
[b]All manufacturing assumed to have the same coefficient.
[c]Trade and services assumed to have the same coefficient.

Table 152. Estimated value added distribution among urban/industrial sectors.[a]

Sector	Fraction of value added to labor	Fraction of value added to government	Remainder
1. Forestry & fisheries	.3541	.2982	.3477
2. Oil & Gas extraction	.4560	.2644	.2796
3. Other mining	.6531	.0939	.2530
4. Construction	.8806	.0309	.0885
5. Chemicals & refining[b]	.7668	.0809	.1523
6. Other manufacturing	.7668	.0809	.1523
7. Trans. & comm.	.7384	.1061	.1555
8. Utilities	.4286	.1648	.4066
9. Trade[c]	.6180	.1821	.1999
10. Finance	.6180	.1821	.1999
11. Other services	.6180	.1821	.1999
12. Households	.2841	.1707	.5452
13. Government	.3281	.1954	.4765

[a]From Costanza 1979.
[b]All manufacturing assumed to have the same coefficients.
[c]Trade and services assumed to have the same coefficients.

Table 153. Resource use and waste production coefficients.[a]

Sector	Water input[b] cu m/$	Waste water cu m/$	Solid waste kg/$	Air pollutants kg/$
1. Forestry & fisheries	-	-	-	.00197
2. Oil & gas extraction	.28776	.26560	.00206	.02113
3. Other mining	.28776	.26560	.00206	.02113
4. Construction	.02607	.02406	.00170	-
5. Chemicals & refining	.24997	.23072	.07365	.02241
6. Other manufacturing	.73750	.68070	.18363	.01144
7. Trans. & comm.	.00286	.00264	.00291	.01326
8. Utilities	.00151	.00139	.00218	.31650
9. Trade	.00428	.00395	.00880	.00009
10. Finance	.00021	.00019	.00214	-
11. Other services	.14848	.13705	.00881	-
12. Households[c]	.08197	.07566	.17224	.09840
13. Local government	.00087	.00080	.00441	-

[a]Aggregated from data in Nissan et al. (1980), except households.

[b]Estimated as 108.34% of waste water output based on the average consumptive use factor for manufacturing (U.S. Bureau of Census 1974).

[c]Water input estimated as total municipal use in Louisiana in 1978 (482.8 E6 gal/day or 667 E6 cu m/yr) divided by the dollar value of household production in 1967 (9039.4 E6 $, see Table 147) times the ratio of 1978 population to 1967 population in Louisiana (3978 E3/3581 E3 = 1.11, Louisiana State Planning Office 1981). This yields 0.08197 cu m/$. Waste water output was assumed to be the same percentage of water input as for the other sectors. This yields 0.07566 cu m/$. Solid waste from households estimated as 92 E9 kg/yr for the U.S. in 1974 (Considine 1976) divided by the total U.S. population in 1974 (211.381 E6, Louisiana State Planning Office 1981) divided by the per capita household production in Louisiana in 1967 (9039.4 E6 $/yr / 3581 E3 people = 2.524 E3 $/capita/yr, from Table 147 and the Louisiana State Planning Office 1981). This yields 0.17244 kg/$. Total auto emmissions average 68 g/mi (U.S. Council on Environmental Quality 1979). Based on an average of 10,000 mi/car/yr and 1.308 E6 cars registered in Louisiana in 1967 (Louisiana State Planning Office 1981) an estimate for total household related air pollution of 8.89 E8 kg/yr was derived. Dividing this by Louisiana household production in 1967 (9039.4 E6 $, see Table 147) yields 0.09840 kg/$/yr.

Table 154. Waste production coefficients.[a]

Sector	Elemental wastes kg/$[b]	Heavy metals kg/$[c]	Organic waste kg/$[d]	Hydro-carbons kg/$[e]
1. Forestry & fisheries	-	-	-	-
2. Oil & gas extraction	-	-	.01087	.00277
3. Other mining	-	-	.01087	.00277
4. Construction	-	-	.00109	-
5. Chemicals & refining	.00772	.00026	.00668	.02241
6. Other manufacturing	.00894	.00002	.01179	.00009
7. Trans. & comm.	.00002	-	.00016	.00182
8. Utilities	-	-	.00006	.00222
9. Trade	-	-	.00001	-
10. Finance	.00003	-	.00001	-
11. Other services	.00087	-	.00822	.00205
12. Households[f]	.00031	-	.00427	-
13. Local government	.00004	-	.00005	.00001

[a]Aggregated from data in Nissan et al. 1980, except households.

[b]Includes chlorine, nitrogen, sulfides, fluoride, and phosphate.

[c]Includes zinc, cadmium, iron, chromium, aluminum, copper, nickel, and lead.

[d]Includes biological oxygen demand (BOD), chemical oxygen demand, suspended and settled solids.

[e]Includes oil and grease, phenols, aldehydes, and other hydrocarbons.

[f]Household elemental waste production based on the chemical characteristics of domestic treated waste water. Total nitrogen and phosphorus in secondary treatment and combined sewer overflow was 450.1 E6 lb/yr or 168 E6 kg/yr for the nation in 1978 (U.S. Council on Environmental Quality 1979). Dividing this by the 1978 U.S. population (218.228 E6 people) yields 0.7698 kg/capita/yr. Dividing this by the Louisiana annual household production per capita in 1967 (2.524 E3 $/capita) (Table 153) yields 0.000305 kg/$/yr. Organic carbon output from households is based on average annual discharge of BOD and suspended solids in secondary treatment and combined sewer overflows in 1978 (6.304 E9 lb/yr or 2.353 E9 kg/yr) (U.S. Council on Environmental Quality 1979). Dividing by the U.S. population in 1978 yields 10.78 kg/capita/yr. Dividing by the Louisiana annual household production per capita in 1967 yields 0.00427 kg/$.

Table 155. Land intensity coefficients.[a]

Sector	Land use category	Relative land intensity (sq m/sq m)
1. Forestry & fisheries		.0063
2. Oil & gas extraction	Extractive	.4373
3. Other mining		.0203
4. Construction	Open & Other	.0289
5. Chemicals & refining		.0226
6. Other manufacturing	Industrial	.0254
7. Trans. & comm.	Trans., Comm.,	.0286
8. Utilities	& Utilities	.0113
9. Trade		.0139
10. Finance	Commercial &	.0099
11. Other services	Services	.0104
12. Households	Res. + Mixed + Clustered	.3573
13. Local government	Institutional	.0278
	TOTAL	1.0000

[a]Land areas for the land use categories listed were obtained for 1972 from the Louisiana State Planning Office 1981. These were distributed among the appropriate sectors according to the relative dollar outputs of the sectors (Table 150).

HYDROLOGIC UNIT MODELS

At the hydrologic unit level of resolution, habitats are the functional units. Flows of water and their loads of dissolved and suspended nutrients and organic matter, animal migrations, harvests of economically important plants and animals, and flows of urban and agricultural waste products are the primary connections between habitats. Although each hydrologic unit is physiographically distinct, there are similar patterns of interhabitat connections via waterflow and other pathways among all basins. Money flows and purchased goods and services connect urban/industrial habitats with the national economy. Figure 1 shows the seven MDPR hydrologic units.

Hydrologic flows through a basin are generally from upland habitats to aquatic habitats. Tidal exchange also influences flows to and from habitats in estuarine areas. Nutrients and organic matter are carried by the flow of water. Products from upland and wetland habitats are washed into open water bodies--a matter of great importance to natural ecosystem functions and human perturbations of these functions.

The major feedback from the downstream habitats to the urban/industrial habitat is the harvest of marketable species--fish, game, and furbearers--from wetland and aquatic habitats. Non-marketed services that are provided by MDPR habitats are also important. These include waste assimilation, hurricane and flood protection, nursery ground and migratory bird access, as well as aesthetics and recreation.

A brief description of each hydrologic unit, a flow diagram, and a table showing the areal extent of each habitat in the hydrologic unit for the years 1955 and 1978 follow below. Care must be taken in interpreting the area changes shown in these tables since differences exist in the classification and resolution of the 1955 and 1978 data.

A computer model was developed to estimate the flows of water, nutrients, and organic matter within a hydrologic unit. The model is a water budget/water routing model. The hydrologic unit is divided into subunits which consist of habitats or groups of habitats. A water budget is then calculated for each subunit. Exchanges of nitrogen, phosphorus, and total organic matter between habitats in the model are calculated by multiplying water flows by concentrations of these materials in outflowing water.

Application of the hydrologic unit model to the Barataria hydrologic unit is outlined in Appendix A. Calculation of flows within the other basins was not attempted because of lack of adequate information on water flows between habitats in these hydrologic units.

1. MISSISSIPPI SOUND

The Mississippi Sound hydrologic unit occupies the eastern flank of the deltaic plain and is approximately the same size as its western counterpart, the Vermilion Basin. Table 156 lists the areas of each of the 20 habitats in this hydrologic unit in 1955 and 1978 and the change in habitat areas from 1955 to 1978.

The Mississippi Sound is not a typical deltaic hydrologic unit. There are no broad marshes and swamps, the shore is the Pleistocene shoreline, and the barrier island are rather permanent features. Because of the lack of extensive wetlands and a low level of oil activity, there are relatively few canals. Further, canals do not seem to have played an important hydrologic role compared to more typical deltaic basins. Practically all aquatic habitat is estuarine open water, therefore, there is a high

Table 156. Habitat areas for the Mississippi Sound hydrologic unit.

No.	Habitat Description	Area (ha) 1955	Area (ha) 1978	Change (ha) (1978-1955)
1	Agriculture	25901	10930	-14971
2	Beach and dune	2340	1973	-367
3	Bottomland hardwood	16917	17157	240
4	Brackish marsh[a]		14702	
5	Canal	107	402	295
6	Cypress/tupelo	13547	13421	-126
7	Fresh aquatic bed	19	62	43
8	Fresh marsh	2578	1451	-1127
9	Fresh open water	389	790	401
10	Fresh scrub/shrub	214	404	190
11	Mangrove	-	-	-
12	Mud flat	248	152	-96
13	Nearshore gulf	42774	41849	-925
14	River, stream, bayou	1980	1827	-153
15	Estuarine aquatic bed	537	4265	3728
16	Estuarine open water	147877	146402	-1475
17	Salt marsh[a]	26859	10899	-1258
18	Spoil	196	943	747
19	Upland forest	27258	31014	3756
20	Urban/industrial	6591	17686	11095
	Total	316332	316329	

[a]Brackish marsh was not delineated on the 1955 maps, but was included with salt marsh as "non-fresh marsh." Therefore, the value for change in salt marsh was set equal to the change in total non-fresh marsh.

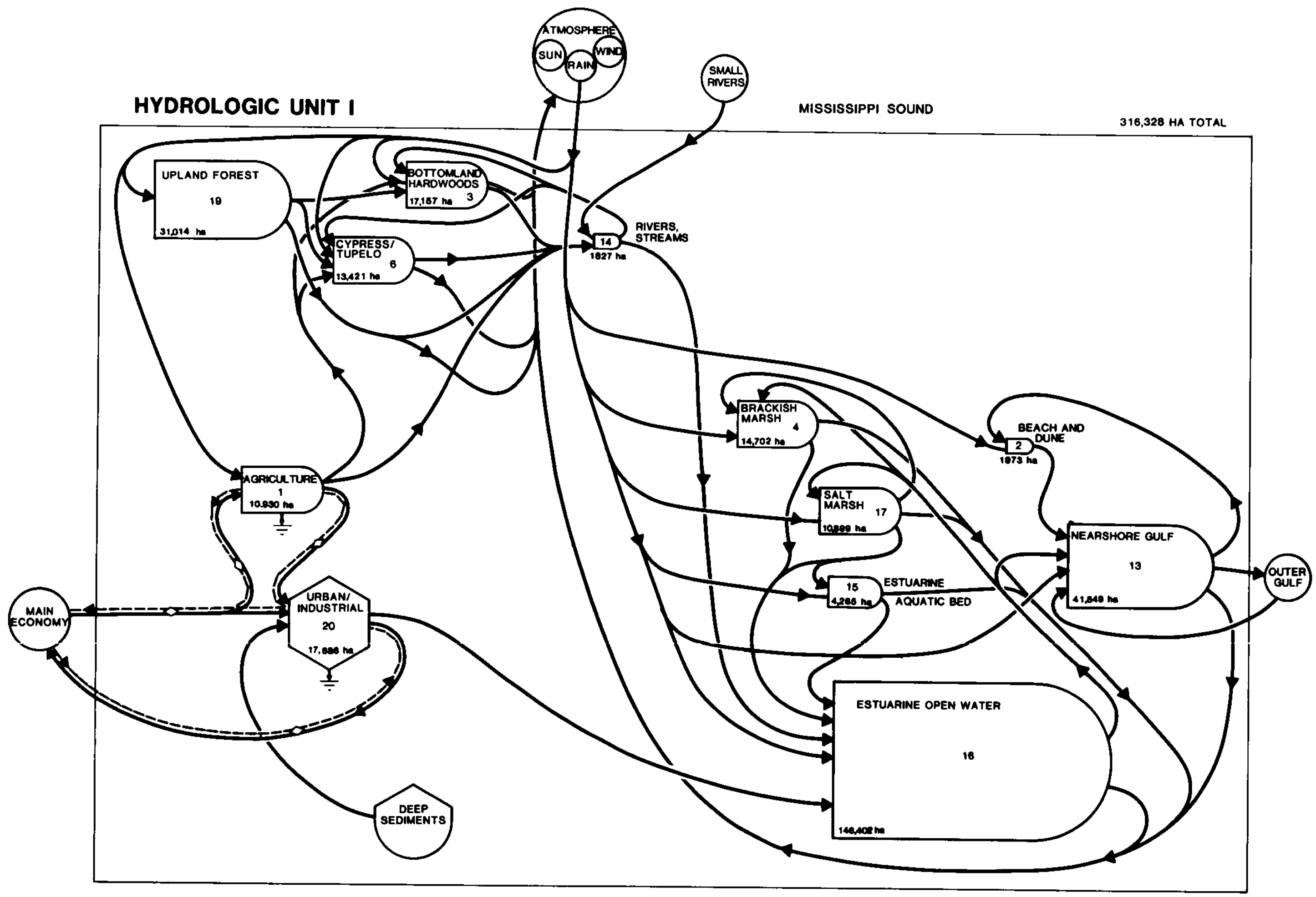


Figure 53. Mississippi Sound hydrologic unit flow diagram.

connectivity between estuarine open water and all other habitats. Since all major urban areas are located on the coast, water flows from this habitat are directly into estuarine open water. The other two upland habitats (upland forest and agriculture) flow primarily into rivers and to a much lesser extent into swamps which form fringes along the rivers. The flow diagram for Mississippi Sound is shown in Figure 53.

2. PONTCHARTRAIN

The Pontchartrain hydrologic unit is the largest of the seven basins within the MDPR as defined by the state coastal zone boundary. It occupies most of the eastern bank of the Mississippi River. Table 157 lists the areas of each of the 20 habitats in this hydrologic unit in 1955 and 1978, and the change in habitat areas from 1955 to 1978.

Essentially all open water in the Pontchartrain hydrologic unit is classified as estuarine open water. This includes Lake Maurepas which is primarily a freshwater lake. Thus, as with Mississippi Sound, there is a high connectivity between estuarine open water and all other habitats. Because of the large urban area at New Orleans and on the North Shore, all urban water flows in the model are routed into estuarine open water. There are industrial and smaller urban areas along the Mississippi River, but most discharges from these areas flow outside the hydrologic unit into the river. Agriculture and upland forest flows are similar to those in the Barataria hydrologic unit, in that they flow into canals and wetlands. The Pontchartrain flow diagram is shown in Figure 54.

3. MISSISSIPPI RIVER DELTA

The Mississippi River Delta hydrologic unit is the modern "birdsfoot" delta of the Mississippi River. Table 158 lists the areas of each of the 20 habitats in this hydrologic unit in 1955 and 1978, and the change in habitat from 1955 and 1978.

The overriding water flow in the Mississippi Delta is that of the river. The major flow is from river to estuarine open water. There are small flows to fresh marsh and fresh open water during overbank flooding. There is no salt marsh habitat. All upland flows have the same routing into canals, swamps, and the river's distributary channels, but these flows are extremely low compared to the flow of the river. The Mississippi Delta flow diagram is shown in Figure 55.

4. BARATARIA

The Barataria hydrologic unit occupies the area immediately to the west of the Pontchartrain Basin. It is bounded on the north and east by the Mississippi River and on the south and west by Bayou Lafourche. This bayou, which is currently small and sluggish, formerly contained most of the flow of the Mississippi River before it was abandoned by the river about 300 years ago. The Lafourche Delta system was dominant between 1000 and 600 years before present. Sediments within the eastern region of the Barataria Basin have also been contributed by the St. Bernard and Plaquemines Delta complexes (Kolb and van Lopik 1958).

Since the abandonment of the Lafourche Delta system and the total leveeing of the Mississippi River, the Barataria Basin has become sediment-starved, its seaward edge has regressed, and many of its marshes have broken up and been replaced by open water. One of the principal distinctions of the Barataria hydrologic unit is that it receives

Table 157. Habitat areas for the Pontchartrain hydrologic unit.

No.	Habitat Description	Area (ha) 1955	Area (ha) 1978	Change (ha) (1978-1955)
1	Agriculture	45008	23949	-21059
2	Beach and dune	1737	988	-749
3	Bottomland hardwood	20986	15042	-5944
4	Brackish marsh[a]		129487	
5	Canal	3551	7366	3815
6	Cypress/tupelo	91553	73903	-17650
7	Fresh aquatic bed	409	1809	1400
8	Fresh marsh	36855	14519	-22336
9	Fresh open water	24232	1714	-22518
10	Fresh scrub/shrub	764	2460	1696
11	Mangrove	63	208	145
12	Mud flat	975	245	-730
13	Nearshore gulf	76505	74721	-1784
14	River, stream, bayou	2367	1412	-955
15	Estuarine aquatic bed	-	1420	1420
16	Estuarine open water	740222	797036	56814
17	Salt marsh[a]	185018	45793	-9738
18	Spoil	2191	9453	7262
19	Upland forest	31393	36110	4717
20	Urban/industrial	27987	55116	27129
	Total	1291816	1292751	

[a]Brackish marsh was not delineated on the 1955 maps, but was included with salt marsh as "non-fresh marsh." Therefore, the value for change in salt marsh was set equal to the change in total non-fresh marsh.

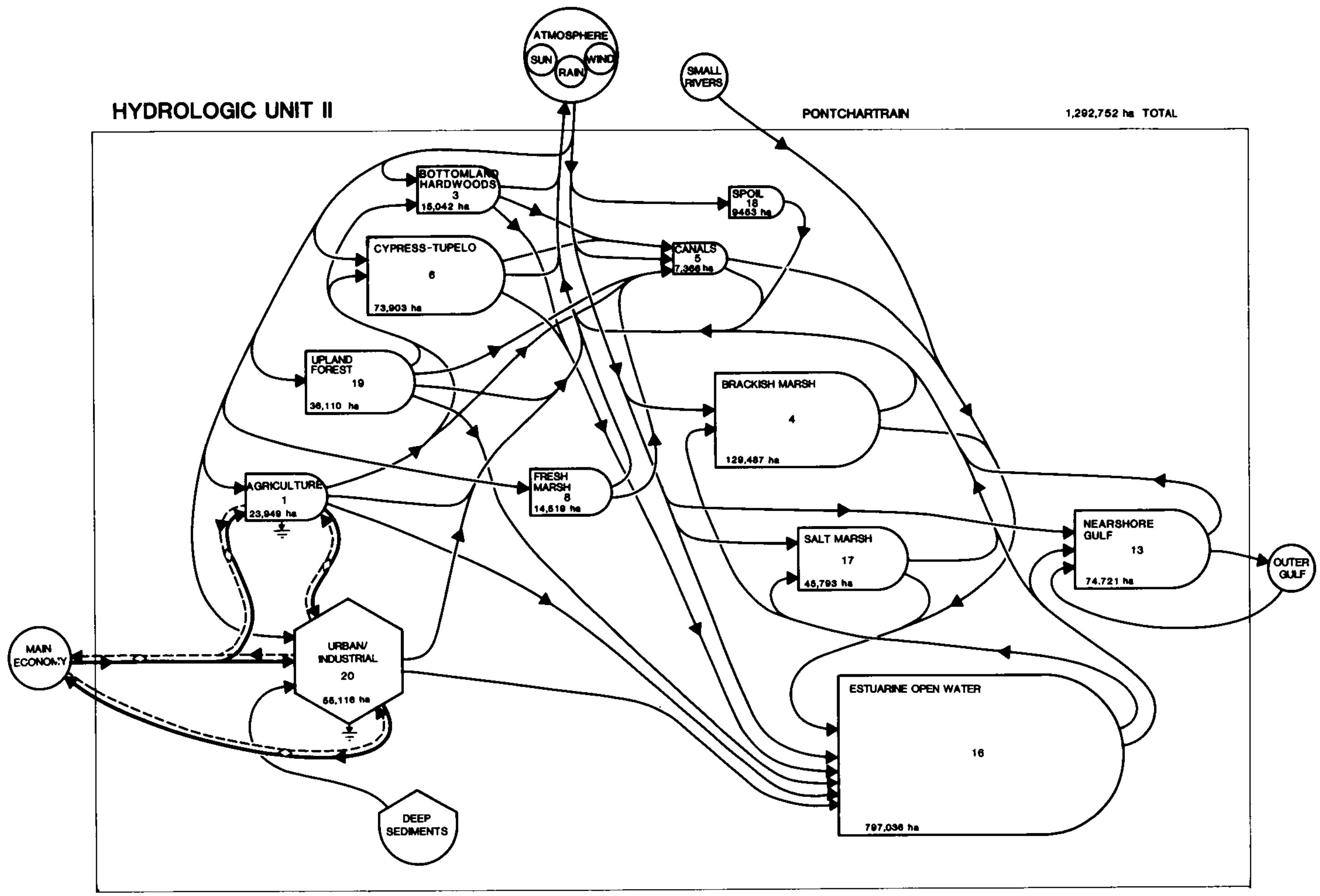


Figure 54. Pontchartrain hydrologic unit flow diagram.

Table 158. Habitat areas in the Mississippi River Delta hydrologic unit.

No.	Habitat Description	Area (ha) 1955	Area (ha) 1978	Change (ha) (1978-1955)
1	Agriculture	37	81	44
2	Beach and dune	277	37	-240
3	Bottomland hardwood	2595	3247	652
4	Brackish marsh[a]		10386	
5	Canal	1291	1270	-21
6	Cypress/tupelo	1615	279	-1336
7	Fresh aquatic bed	0	1099	1099
8	Fresh marsh	54266	16397	-37869
9	Fresh open water	7890	16658	8768
10	Fresh scrub/shrub	955	504	-451
11	Mangrove	0	1	1
12	Mud flat	2193	3434	1241
13	Nearshore gulf	0	0	0
14	River, stream, bayou	26345	26287	-58
15	Estuarine aquatic bed	0	293	293
16	Estuarine open water	171046	185279	14233
17	Salt marsh[a]	0	0	10386
18	Spoil	866	3491	2625
19	Upland forest	0	54	54
20	Urban/industrial	1979	2058	79
	Total	271355	270855	

[a]Brackish marsh was not delineated on the 1955 maps, but was included with salt marsh as "non-fresh marsh." Therefore, the value for change in salt marsh was set equal to the change in total non-fresh marsh.

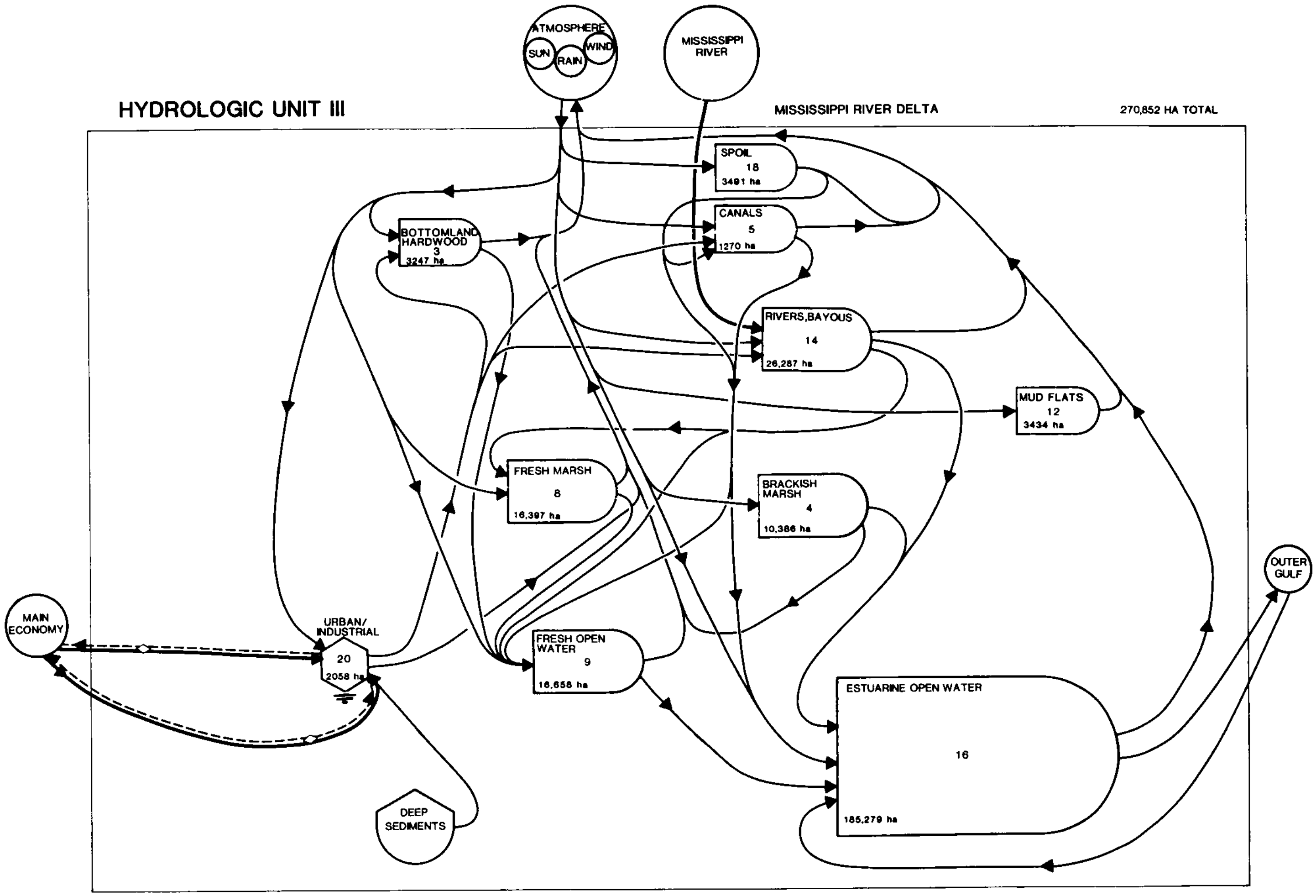


Figure 55. Mississippi River Delta hydrologic unit flow diagram.

no riverine input. The Barataria unit is hydrologically connected only to the Mississippi Delta Basin, and most water inputs come from rainfall and from the outer gulf, with only minor lateral interbasin exchange via the Intercoastal Waterway.

Table 159 lists the areas of each of the 20 habitats in this hydrologic unit in 1955 and 1978, and the change in habitat areas from 1955 and 1978.

The MDPR hydrologic unit represents the portion of the Barataria basin in the MDPR study area for which area measurements are available. The habitat makeup of the MDPR hydrologic unit differs from the habitat makeup of the entire basin primarily in its greater proportion of estuarine open water and its smaller proportions of fresh marsh, swamp forest, upland, urban/industrial, and agricultural habitats.

The most extensive wetland habitats by area in the Barataria hydrologic unit are brackish and salt marshes. Estuarine open water covers the largest area in the unit.

The urban habitat in the Barataria hydrologic unit includes industrial and urban areas on the fingerlike natural levee areas on both sides of the basin. Agricultural habitat is also limited to natural levee areas in the Barataria hydrologic unit. Sugar cane is the dominant cash crop.

Water movement in the hydrologic unit is primarily from uplands and wetland habitats to aquatic zones, and from fresh to brackish, and from brackish to saline aquatic zones.

Under completely natural conditions, almost all upland runoff would enter one of the wetland habitats and then flow into streams or open water bodies. However, because of extensive canalization and spoil deposits, most runoff is first channelized into canals. Based on existing information (Kemp and Day, in press; Hopkinson and Day 1980a, 1980b), it was estimated that runoff entering the swamp from the upland zone (agriculture, upland forest, and urban/industrial) is apportioned as follows: 72% to canals, 25% to the swamp, and 3% to bayous. It was estimated that upland runoff to the fresh water zone is 25% to fresh marsh and 75% to fresh open water. It was assumed that all upland runoff to the brackish and saline zones enters estuarine open water.

Although there are canals throughout the basin, in the model flow from canals is 95% to fresh open water and 5% to extuarine open water. This reflects the higher density of canals in the fresh areas and maintains water flows in the model closer to actual water flows in the basin.

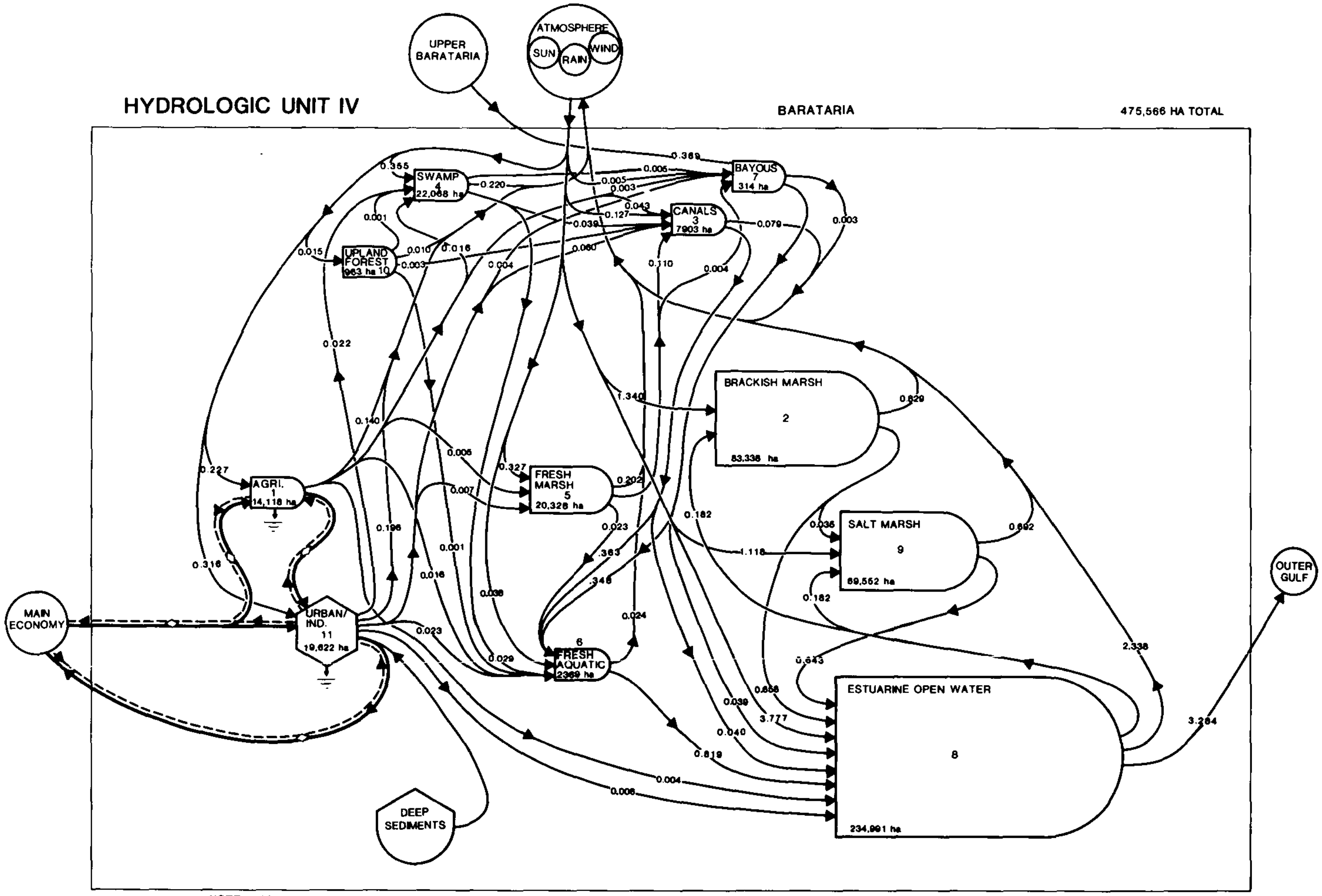
Because of minor distributary ridges within the basin and numerous spoil banks, there is little direct water exchange between different wetland zones. The major exchanges in the hydrologic unit model are between specific wetland habitats and the adjacent open water habitat. Only minor flows of water between brackish and salt marshes are included in the model. Groundwater exchange was assumed to be negligible.

A computer model of water flow in the Barataria hydrologic unit is presented in Appendix A. The Barataria flow diagram is shown in Figure 56. Note that the habitat numbers in this flow diagram correspend to those in Table A.4.

Table 159. Habitat areas for the Barataria hydrologic unit.

No.	Habitat Description	Area (ha) 1955	Area (ha) 1978	Change (ha) (1978-1955)
1	Agriculture	13772	14118	346
2	Beach and dune	802	423	-379
3	Bottomland hardwood	10449	7735	-2714
4	Brackish marsh[a]		79483	
5	Canal	4274	7903	3629
6	Cypress/tupelo	15784	11652	-4132
7	Fresh aquatic bed	28	669	641
8	Fresh marsh	106688	19388	-87300
9	Fresh open water	25392	1700	-23692
10	Fresh scrub/shrub	0	1660	1660
11	Mangrove	0	601	601
12	Mud flat	161	26	-135
13	Nearshore gulf	0	0	0
14	River, stream	716	314	-402
15	Estuarine aquatic bed	0	2283	2283
16	Estuarine open water	175406	232682	57276
17	Salt marsh[a]	108942	65358	35899
18	Spoil	3007	8985	5978
19	Upland forest	1580	963	-617
20	Urban/industrial	8279	19622	11343
	Total	475280	475565	

[a]Brackish marsh was not delineated on the 1955 maps, but was included with salt marsh as "non-fresh marsh." Therefore, the value for change in salt marsh was set equal to the change in total non-fresh marsh.



NOTE: Habitat numbers and areas correspond to those shown in Table A.4

Figure 56. Barataria hydrologic unit flow diagram.

5. TERREBONNE

The Terrebonne hydrologic unit is bounded on the east by Bayou Lafourche and on the west by the Atchafalaya River. Table 160 lists the areas of each of the 20 habitats in this hydrologic unit in 1955 and 1978, and the change in habitat areas from 1955 to 1978.

Unlike hydrologic units in the eastern part of the deltaic plain, there is considerable water exchange among adjacent hydrologic units in the western part of the region. There is a strong input from the Atchafalaya to Terrebonne. The two pathways for this input are via canals (representing the flow through the Avoca Island channel into fresh marshes) and via estuarine open water (representing the water flow into Fourleague Bay). As with the other units, practically all open water is estuarine. Thus, there are connections with most other habitats. Routing from the three upland habitats is the same and is very similar to the Barataria hydrologic unit.

The flow diagram for the Terrebonne hydrologic unit is shown in Figure 57.

6. ATCHAFALAYA

The Atchafalaya hydrologic unit consists of the coastal portion of the Atchafalaya River system. Like the Mississippi River Delta unit, the Atchafalaya unit is an active, prograding delta experiencing net sediment deposition. Table 161 lists the areas of each of the 20 habitats in this hydrologic unit in 1955 and 1978, and the change in habitat areas from 1955 to 1978.

As with the Mississippi Delta, the major flow is that of the Atchafalaya River to estuarine open water. There are significant flows from estuarine open water into the adjacent Terrebonne and Vermilion basins. Routing from the three upland habitats is the same with the major part of flows into canals. There is no brackish or salt marsh in this unit. The Atchafalaya flow diagram is shown in Figure 58.

7. VERMILION

The Vermilion hydrologic unit is the westernmost unit in the MDPR. Its drainage area is mainly coastal, but it extends inland of the MDPR boundary. Table 162 lists the areas of each of the 20 habitats in this hydrologic unit in 1955 and 1978, and the change in habitat areas from 1955 to 1978.

The basin is similar to the Terrebonne hydrologic unit. There are significant inputs from the Atchafalaya Basin. Essentially all open water is estuarine, so that there are connections between estuarine open water and most other habitats. Flows from uplands are routed similarly and the most important flow is into canals. The Vermilion flow diagram is shown in Figure 59.

Table 160. Habitat areas for the Terrebonne hydrologic unit.

No.	Habitat Description	Area (ha) 1955	Area (ha) 1978	Change (ha) (1978-1955)
1	Agriculture	5100	6639	1539
2	Beach and dune	821	611	-210
3	Bottomland hardwood	1114	955	-159
4	Brackish marsh[a]		92010	
5	Canal	2541	6808	4267
4	Cypress/tupelo	24530	20628	-3902
7	Fresh aquatic bed	88	1844	1756
8	Fresh marsh	141691	69423	-72268
9	Fresh open water	4218	12119	7901
10	Fresh scrub/shrub	0	3235	3235
11	Mangrove	0	2133	2133
12	Mud flat	684	110	-574
13	Nearshore gulf	0	0	0
14	River, stream, bayou	1406	2060	654
15	Estuarine aquatic bed	0	5461	5461
16	Estuarine open water	253139	288093	34954
17	Salt marsh[a]	140546	57866	9330
18	Spoil	2114	6214	4100
19	Upland forest	253	298	45
20	Urban/industrial	1278	2680	1402
	Total	579523	579187	

[a]Brackish marsh was not delineated on the 1955 maps, but was included with salt marsh as "non-fresh marsh." Therefore, the value for change in salt marsh was set equal to the change in total non-fresh marsh.

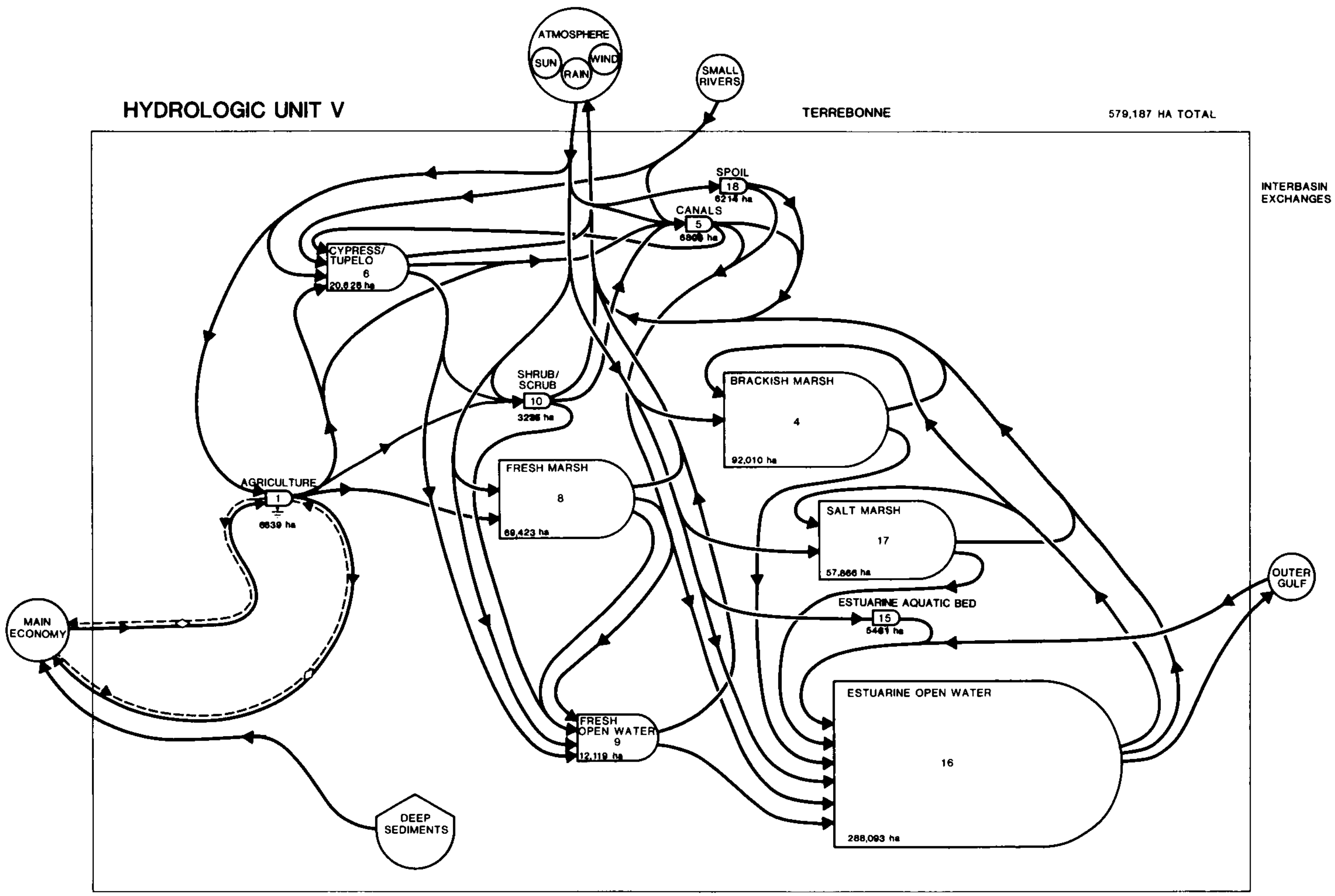


Figure 57. Terrebonne hydrologic unit flow diagram.

Table 161. Habitat areas for the Atchafalaya hydrologic unit.

No.	Habitat Description	Area (ha) 1955	Area (ha) 1978	Change (ha) (1978-1955)
1	Agriculture	742	1043	301
2	Beach and dune	0	4	4
3	Bottomland hardwood	44	2	-42
4	Brackish marsh[a]		0	
5	Canal	825	1695	870
6	Cypress/tupelo	17185	18079	894
7	Fresh aquatic bed	7	601	594
8	Fresh marsh	9960	23855	13895
9	Fresh open water	1496	1705	209
10	Fresh scrub/shrub	69	797	728
11	Mangrove	0	12	12
12	Mud flat	1000	811	-189
13	Nearshore gulf	0	0	0
14	River, stream, bayou	3046	5324	2278
15	Estuarine aquatic bed	0	1	1
16	Estuarine open water	102272	97876	-4396
17	Salt marsh[a]	16232	0	-16232
18	Spoil	1060	2025	965
19	Upland forest	115	163	48
20	Urban/industrial	387	575	188
	Total	154440	154568	

[a]Brackish marsh was not delineated on the 1955 maps, but was included with salt marsh as "non-fresh marsh." Therefore, the value for change in salt marsh was set equal to the change in total non-fresh marsh.

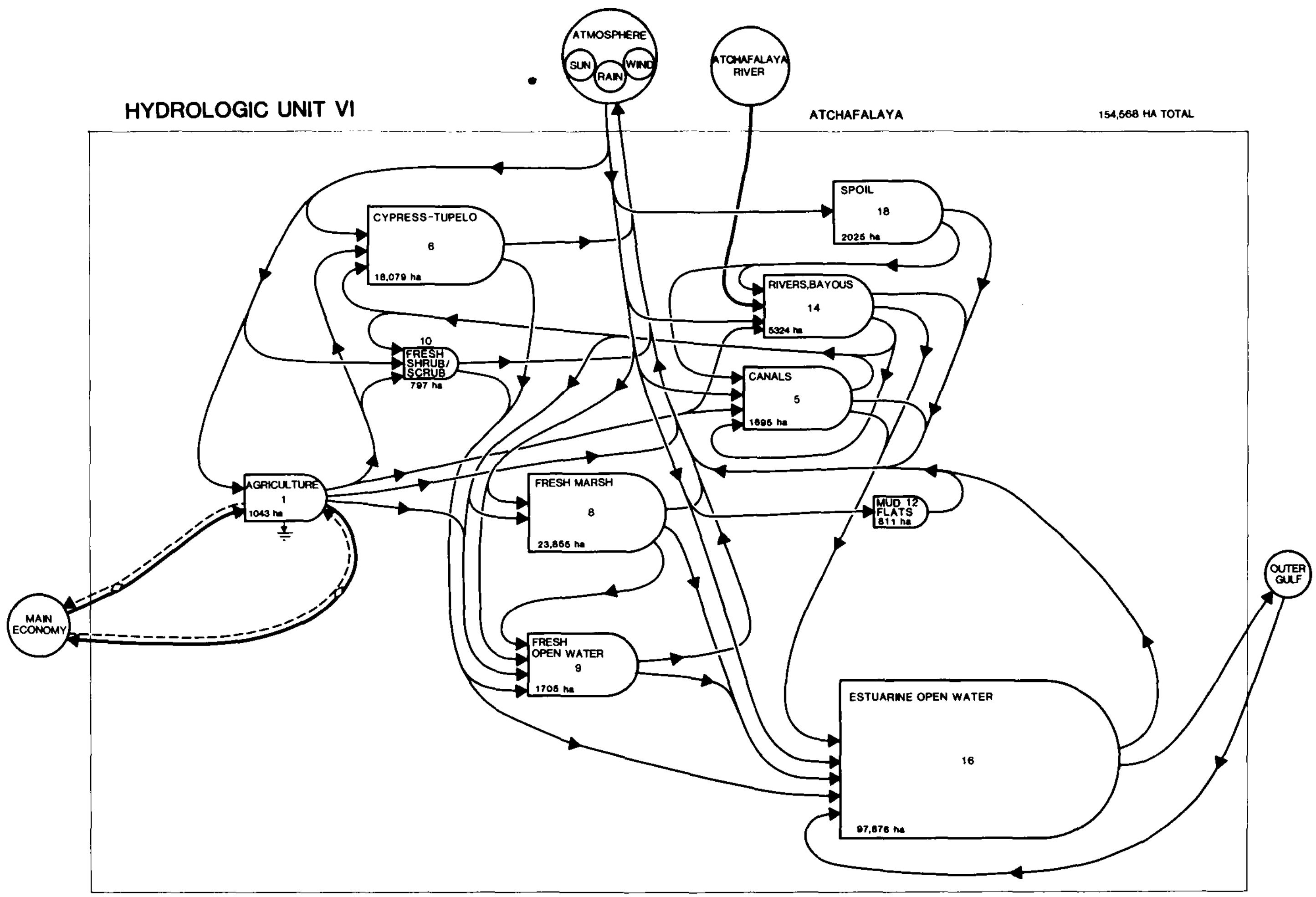


Figure 58. Atchafalaya hydrologic unit flow diagram.

Table 162. Habitat areas for the Vermilion hydrologic unit.

No.	Habitat Description	Area (ha) 1955	Area (ha) 1978	Change (ha) (1978-1955)
1	Agriculture	41366	40772	594
2	Beach and dune	197	202	5
3	Bottomland hardwood	2283	1989	-294
4	Brackish marsh[a]		77902	
5	Canal	1956	4005	2049
6	Cypress/tupelo	21486	20503	-983
7	Fresh aquatic bed	0	172	172
8	Fresh marsh	12438	20233	7795
9	Fresh open water	117	1138	1021
10	Fresh scrub/shrub	4374	4126	-248
11	Mangrove	0	0	0
12	Mud flat	730	352	-378
13	Nearshore gulf	0	0	0
14	River, stream, bayou	335	280	-55
15	Estuarine aquatic bed	4	597	593
16	Estuarine open water	172345	174754	2409
17	Salt marsh[a]	95340	2541	-14897
18	Spoil	1104	2466	1362
19	Upland forest	2331	2089	-242
20	Urban/industrial	2145	4364	2219
	Total	358551	358485	

[a]Brackish marsh was not delineated on the 1955 maps, but was included with salt marsh as "non-fresh marsh." Therefore, the value for change in salt marsh was set equal to the change in total non-fresh marsh.

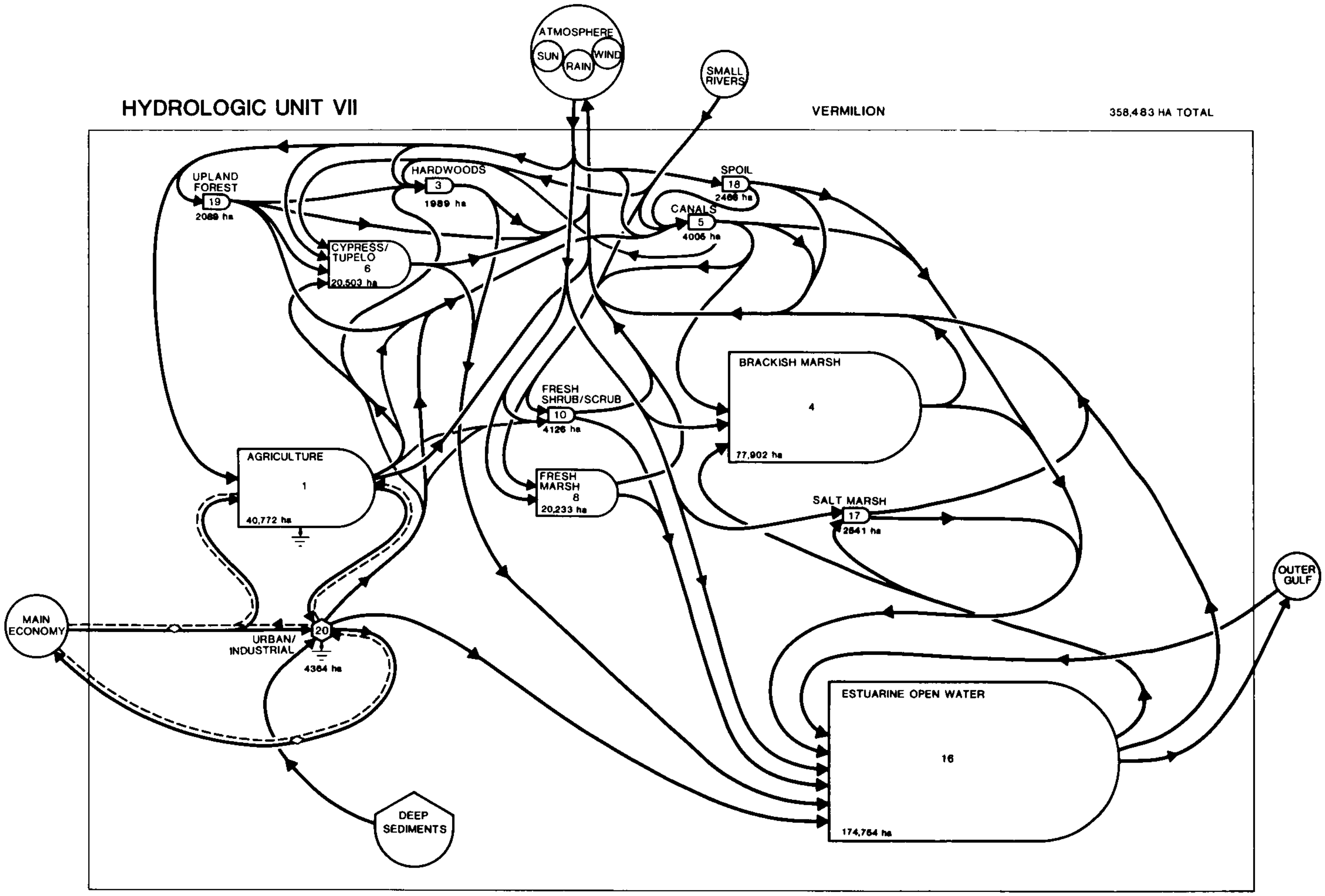


Figure 59. Vermilion hydrologic unit flow diagram.

REGIONAL MODEL

The conceptual model of the Mississippi River Deltaic Plain Region is illustrated in Figure 60. The model emphasizes the seven hydrologic units, symbolized as rectangles whose size is proportional to the size of the basins within the region. Each basin rectangle symbolizes a drainage basin model presented in the previous sections. The regional model also illustrates the primary forcing functions that drive the region, i.e., the external economy, the Mississippi River and several other coastal rivers, the outer gulf system, and atmospheric inputs. The model also illustrates the major interconnections among the basins and their forcing functions. A quantified input-output table was not prepared at the regional level, since the hydrologic unit tables were too imprecise.

The reader should be aware that the size of some of the MDPR hydrologic units is artificially small because of the use of the State coastal zone boundary in defining the study area. This political boundary excludes important functional portions of some basins, particularly the Atchafalaya and Barataria Basins. The validity of the regional and basin level conceptual models is not affected by this problem, because those excluded portions of the coastal zone are treated as external entities that have inputs into the designated coastal region.

The specific configuration of the regional model shows the present state of an area that is the result of long term geological processes: alluvial (depositional) and marine (erosional) processes in combination with a gradual rise in sea level. Because of periodic switches in the course of the major distributary of the Mississippi River (about once every 500 years), the areas of different basins have waxed and waned.

The main economy is pumping a great amount of energy into the maintenance of the present course of the Mississippi River. This is shown by the arrow at the intersection of the Mississippi and Atchafalaya Rivers (Figure 60). This arrow also symbolizes flood control and navigational projects on both rivers. All of these programs require increasing monetary inputs. The U.S. Army Corps of Engineers is committed to these major programs that directly affect the entire MDPR. Only 30% of the flow of the Mississippi River is currently allowed to enter the Atchafalaya River, despite the natural tendency of the Atchafalaya to capture a greater percentage. In addition, a massive flood control program was instituted for the entire lower Mississippi system, following the disastrous flood of 1927. This program includes continuous manmade levees along the river and a series of dams in the upper tributaries. Navigation is facilitated by artificially dredged deepwater channels from the Gulf of Mexico upstream to Baton Rouge.

As a result of these management programs, the MDPR is experiencing a net sediment deficit, presumably for the first time in its 4500-year history. This deficit is due to a combination of containment of river between the levee banks, the discharge of the major sediment load off the Continental Shelf, and the trapping of sediment by manmade dams along the tributaries of the upper Mississippi.

A major shift in sediment load from the eastern to the western end of the MDPR is occurring. The new Atchafalaya Delta system is building rapidly, and freshwater marsh habitat within that basin is increasing (Table 161). In most of the other basins, wetland habitats are eroding into estuarine open water habitats at an accelerating rate.

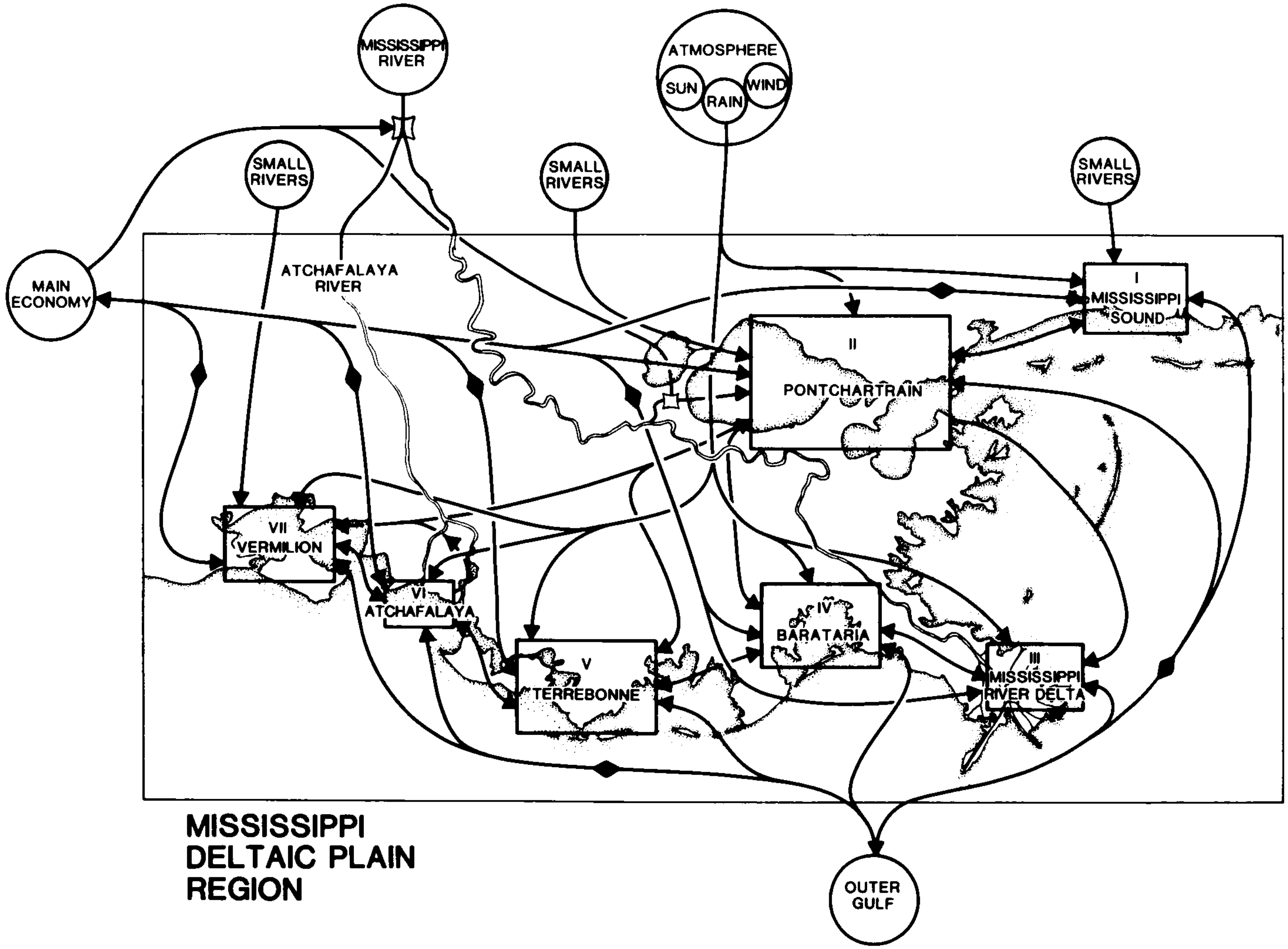


Figure 60. Mississippi Deltaic Plain Region flow diagram.

As shown in Figure 60, the only basins that normally receive direct water and sediment inputs from the Mississippi River are the Atchafalaya and the Mississippi River Delta basins. Mississippi River sediment inputs to other basins occur indirectly through marine processes (erosion and redeposition). The Pontchartrain hydrologic unit is exceptional in that during extreme flood stages the Bonnet Carre Spillway is opened, introducing significant quantities of sediment and freshwater into western Lake Pontchartrain. Some of this input, in turn, flows into the Mississippi Sound basin via Lake Borgne.

Exchanges between hydrologic units in the MDPR include such diverse commodities as fresh water, sediment, migrating animals, agricultural and manufactured goods, and airborne and waterborne waste products.

The main economy of the United States receives major supplies of fossil fuels, refined petroleum, and petrochemicals from the MDPR, as shown by the arrows from all of the basins (Figure 60). It also receives other mineral resources such as sulfur and salt, agricultural commodities such as refined sugar and lumber, and the largest fishery harvest in the country.

Atmospheric inputs to the MDPR symbolize the subtropical climate and high rainfall that characterize the area. This forcing function, along with tidal and other marine influences from the outer gulf, drives the high rates of primary and secondary production by coastal organisms. This production results in a high rate of organic deposition to the sediments, which normally allows undisturbed wetland habitats to keep pace with the slowly rising sea level. Atmospheric inputs also strongly affect the regional agricultural system in terms of the choice of cash crops. Residential energy consumption and a variety of cultural practices are also dictated by climate. These in turn strongly affect economic activities, and the type of coastal zone management decisions that are made.

CONCLUSIONS AND RECOMMENDATIONS

Any attempt to codify, characterize, or quantify the complex workings of natural and economic systems necessarily involves approximations. In this study, various degrees of approximation were necessary because of the wide array of information sources employed and the varying quality, coverage, and precision of the assembled data. Based on the results of this study, the following general conclusions and recommendations can be drawn concerning the quality and availability of ecological data in the MDPR:

(1) Most of the available ecological data is site-specific, and oriented toward a particular habitat. Therefore, the habitat level data were generally of the highest quality. Very little direct information on transfers between habitats was available. The hydrologic unit level information, therefore, was much less precise. In this study a method to calculate interhabitat exchanges of water was formulated and applied to the Barataria hydrologic unit, since this unit had the best (although still very limited) hydrologic data. Because the information necessary to derive results was not available to a very high degree of precision, little confidence can be placed in the quantification of hydrologic unit level exchanges at this time. An important area for further research is therefore the measurement of interhabitat exchanges, especially of water, since water is the transport medium for several other materials.

(2) Certain habitats have been studied more intensively than others, and this is reflected in the level of detail and precision achieved in the habitat models. Only eight of the original 20 habitats defined for this study had sufficient data to warrant preparation of quantified I-O tables. These were, roughly in order of decreasing overall quality, salt marsh, cypress-tupelo swamp, urban/industrial, brackish marsh, fresh marsh, agriculture, estuarine open water, and fresh open water. The remaining 12 habitats require significant additional research effort if they are to be characterized at similar levels of quantitative detail.

(3) Even a perfectly specified input-output table does not convey everything there is to know about an ecological system. They are useful mainly as static summary characterizations of the average quantitative connections betweeen system components, and are only a first step toward complete understanding. Information on ecosystem changes over time (which is available in some detail for a few components of a few habitats) is averaged out in an I-O presentation. Use of the I-O format does not imply that information on dynamic behavior is unimportant, but rather that it not available for enough parameters to allow a comprehensive quantitative treatment. Additional research is needed to remedy this situiation. The Long Term Ecological Research (LTER) studies currently in progress in various parts of the country provide such dynamic information. An LTER project for coastal Louisiana would greatly aid a detailed ecological characterization.

(4) The uneven quality of information is a fundamental recurring problem throughout this and other studies that attempt a quantitative synthesis from a wide variety of data sources. The reader is required to sift through long descriptions of the detailed calculations in order to form an opinion about the relative quality of the estimates. A system to communicate to the reader a summary assessment of the degree of precision associated with each estimate would be a useful device. For example, a grading scheme that attached a letter grade (A through E) to each estimate based on the analyst's assessment of the quality of the primary information and the number and accuracy of the assumptions necessary to derive the estimate from the primary information, might serve this purpose.

APPENDIX A

BARATARIA HYDROLOGIC UNIT COMPUTER MODEL

A computer model was developed to estimate flows of water, nutrients, and dissolved and suspended organic matter between habitats in the Barataria hydrologic unit.

Input information for the Barataria hydrologic unit consisted of:

(1) Land area of each habitat in 1978 (Table 159).
(2) Average monthly rainfall (Table A.1)
(3) Average monthly evapotranspiration (Table A.1)
(4) Average monthly water levels in each habitat (Table A.2)
(5) Runoff or river inflow from outside the hydrologic unit (Table A.3)
(6) Aggregation of habitats into major habitat groups for which hydrologic connections can be estimated (Table A.4).
(7) Estimates of distribution of runoff from each habitat (Table A.5).
(8) Estimates of nitrogen, phosphorus, and total organic matter concentrations in surface water runoff from each habitat (Table A.6).

The program utilizes this information to calculate estimates of total runoff from each habitat and the distribution of that runoff to the other habitats. The basis for the program is the water balance equation given below:

$$DS(I,T) = RH(I,T) - ETH(I,T) + RI(I,T) + \Sigma\, RIH(J,I,T) - RO(I,T) \qquad (1)$$

where:

$DS(I,T)$	=	change in storage of water in habitat I from time T - 1 to time T (cu km)
$RH(I,T)$	=	total rain water input to habitat I from time T - 1 to time T (cu km)
$ETH(I,T)$	=	total evapotranspiration from habitat I from time T-1 to time T (cu km)
$RI(I,T)$	=	total runin from outside the hydrologic unit to habitat I from time T - 1 to time T (cu km)
$\Sigma\, RIH(J,I,T)$	=	sum of the inputs from all other habitats to habitat I from time T - 1 to time T (cu km)
$RO(I,T)$	=	total runoff from habitat I from time T - 1 to time T (cu km)

This equation lists all the major inputs and outputs of water to and from each habitat on the right side (rain - evapotranspiration + runoff inflow + inputs from all other habitats - runoff outflow) and states that their sum equals the change in water stored in the habitat for a particular time interval (a month in this case). It was assumed that there are no significant exchanges of groundwater.

Data were available to directly estimate rainfall, evapotranspiration, and runoff from outside the Barataria hydrologic unit. Total rainwater input by habitat was estimated from average monthly rainfall totals (Sklar 1980) and habitat area data. Evapotranspiration was estimated for the Barataria Basin by Sklar (1980) using the Thornthwaite method (Thornthwaite and Mather 1955). While evapotranspiration undoubtedly varies from habitat to habitat, no data are currently available from the study area, so an average evapotranspiration rate was assumed to apply to all habitats. This data, along with rainfall data for the Barataria basin are listed in Table A.1. Change in storage of water was estimated from average monthly water level data by habitat (Table A.2) and the land area of each habitat in the hydrologic unit. The upper basin is the only source of external runoff or riverine input since the entire basin is fed almost exclusively by rainfall. Incoming runoff from outside the hydrologic unit was derived from a calculation of upper Barataria basin runoff (Sklar 1982) and is shown in Table A.3.

The 20 habitats were further aggregated to 11 types. Habitat aggregations and 1978 habitat areas for the Barataria hydrologic unit are shown in Table A.4. Further aggregation of the 20 habitats into 11 major habitat associations allowed the model to route water only between major vegetative zones (e.g., agriculture, swamp, fresh marsh, brackish marsh, salt marsh, estuarine open water) rather than between very similar and often hydrologically indistinguishable habitats (e.g., fresh aquatic bed, fresh open water) for which no data on hydrologic connections exists. Aggregations were performed on the basis of hydrologic similarity. When habitat were small in area (spoil, beach and dune, mangroves) they were aggregated with the major habitat in the vegetative zone in which they ocurred. Spoil was aggregated with swamp and different marsh types on the basis of the relative areas of those major habitats.

To solve the water balance equations, an expression for the inflow from the other habitats in terms of the total runoff from the habitats is necessary. To accomplish this, a matrix of water transfer coefficients, which indicates the fraction of the total runoff from each habitat that flows to each other habitat, is required. Combining the measurable terms in equation (1) to:

$$Y(I,T) = RH(I,T) - DS(I,T) - ETH(I,T) + RI(I,T) \qquad (2)$$

and rewriting the interhabitat flow expression in terms of the total runoff and the water transfer coefficients:

$$RIH(I,J,T) = C(I,J) * RO(I,T) \qquad (3)$$

yields:

$$Y(I,T) + \Sigma\, C(J,I) * RO(J,T) = RO(I,T) \qquad (4)$$

where C(J,I) = the fraction of the total runoff from habitat J that flows to habitat I

Rewriting this in matrix notation for all n habitats yields the following equation for each T:

$$R - CR + Y \qquad (5)$$

where: R is a N x 1 vector of total runoff by habitat for time T
Y is an N x 1 vector of measurable water balance terms by habitat for time T
C is an N x N matrix of water transfer coefficients.

Equation (5) can be solved for R in terms of C and Y as:

$$\begin{aligned} R - CR &= Y \\ R(I-C) &= Y \\ R &= Y\,(I-C)^{-1} \end{aligned} \qquad (6)$$

Equation (6) yields an estimate of total runoff by habitat for each time interval for which estimates of Y are available. The (I-C) matrix can be thought of as the

Table A.1. Average monthly rainfall and evapotranspiration for the Barataria hydrologic unit (Sklar 1980).

Month	Rainfall (cm)	Evapotranspiration (cm)
Jan.	12.83	2.54
Feb.	12.17	2.92
Mar.	13.41	5.05
Apr.	11.40	8.00
May	13.03	11.81
June	13.41	13.74
July	18.34	15.67
Aug.	16.36	14.88
Sept.	14.86	11.60
Oct.	8.99	6.88
Nov.	11.23	3.81
Dec.	14.71	2.59
TOTAL	160.74	99.49

Table A.2. Estimated average monthly water levels (listed as cm above surface unless noted) for wetland and aquatic habitats in the Barataria hydrologic unit

Month	Salt marsh[a]	Cypress-tupelo[b]	Fresh marsh[c]	Brackish marsh[d]	Estuarine open water[e]	Fresh Open water[e]
Jan.	-29.0	9.4	6.3	-11.4	648.8	39.6
Feb.	-17.1	18.7	6.6	-5.3	644.0	38.7
Mar.	-9.5	10.6	13.3	1.9	644.3	47.2
Apr.	0.6	33.7	21.2	10.9	653.5	53.9
May	10.0	31.1	25.2	17.6	654.7	59.7
June	10.6	14.9	19.7	15.2	644.3	49.7
July	7.9	12.5	15.7	11.5	645.3	43.6
Aug.	8.5	10.7	20.6	14.6	659.3	47.2
Sept.	14.3	36.3	30.4	22.4	673.9	50.9
Oct.	-7.4	0.0	24.9	8.8	673.6	49.1
Nov.	-13.5	11.6	11.7	-0.9	658.7	38.7
Dec.	-24.7	10.5	13.0	-5.9	658.4	52.7

[a]From Baumann (1980). Cm above or below marsh surface.
[b]From Conner, unpublished data. Cm above swamp surface.
[c]From U. S. Geological Survey gauging data. Assumed marsh surface 30 cm above mean sea level.
[d]Interpolated as the average of salt and fresh marsh.
[e]Cm above mean sea level from U. S. Geological Survey gauging data.

Table A.3. Runoff entering from outside the Barataria hydrologic unit (Sklar 1980).[a]

Month	Runoff (cm)	Runoff (sq km)
Jan.	3.21	0.050
Feb.	3.43	0.053
Mar.	3.42	0.053
Apr.	2.58	0.040
May	1.86	0.029
June	1.31	0.020
July	1.10	0.017
Aug.	0.92	0.014
Sept.	1.01	0.016
Oct.	0.92	0.014
Nov.	1.46	0.023
Dec.	2.57	0.040
TOTAL	23.80	0.369

[a]Based on upper Barataria basin area of 1545 sq km.

Table A.4. Habitat aggregations and areas for the Barataria hydrologic unit model.

No.	Habitats	1978 Area (ha)
1.	Agriculture	14,118
2.	Brackish marsh, spoil	83,338
3.	Canal	7903
4.	Cypress-tupelo, bottomland hardwood, scrub/shrub, spoil	22,068
5.	Fresh marsh, spoil	20,328
6.	Fresh open water, fresh aquatic bed	2369
7.	River, stream, bayou	314
8.	Estuarine open water, estuarine aquatic bed, mudflat, nearshore gulf	234,991
9.	Salt marsh, spoil, mangrove, beach and dune	69,552
10.	Upland forest	963
11.	Urban/industrial	19,622
TOTAL		475,566

direct and indirect hydrologic connections between habitats. If all the habitats were hydrologically independent of each other, the C matrix would be all zero and the runoff would be strictly a function of Y.

A central problem of this approach is, therefore, estimating the C matrix. Data on water flow between habitats were used to generate the C matrix. Water flow data unavailable for Barataria Basin were estimated from maps and the authors' knowledge of basin hydrology. Estimates of the water flow between 11 major habitats in the Barataria hydrologic unit are shown in Table A.5.

One additional estimate is necessary to utilize this method. At the downstream end of each hydrologic unit, there is runoff to the open gulf. Thus, an "external area" for estuarine open water to exchange with. In the model an external area equal to 25% of the estuarine open water area was used.

Based on the above data and estimates, the program can solve equation (6) once for each month. These estimates are then summed over the year to generate a total annual water transfer matrix, which lists estimates of the total amount of water (cu km) transferred between each habitat and each other habitat annually. Using these estimates and the estimates of nitrogen, phosphorus, and TOM concentrations in outflowing water by habitat listed in Table A.6, these commodity exchanges for the Barataria hydrologic unit were estimated. The results of the model calculations are shown in the input-output table for the Barataria hydrologic unit (Table A.7).

Hydrologic Unit Model Computer Program Listing

Below is a listing of the WATFIV computer program used to estimate the water and material transfers for the hydrologic unit input-output tables.

```
C$JOB
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C   THIS MODEL ESTIMATES THE MONTHLY WATER FLOWS BETWEEN N HABITATS
C   IN A HYDROLOGIC UNIT.    IT IS BASED ON WATER BALANCE
C   CONSIDERATIONS COMBINED WITH DATA ON THE SURFACE AREA AND
C   DISTRIBUTION OF THE HABITATS.
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C         BARATARIA HYDROLOGIC UNIT
C
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      DIMENSION A(11),R(12),ET(11,12),RI(11,12),WL(11,12)
      DIMENSION DS(11,12),RH(11,12),ETH(11,12),RIH(11,11,12),RO(11,12)
      DIMENSION C(11,11), Y(11,12), RSUM(11), CT(11,11),CTINV(11,11)
      DIMENSION TRO(11,11),TN(11),TP(11),TOM(11),SED(11)
      DIMENSION WKAREA(300), EXSUM(11), TT(5,11,2),TOTTT(5,2)
      DIMENSION RIYR(11),RYR(11),ETYR(11)
      INTEGER T
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C   REQUIRED INPUTS ARE:
C      1. AREA OF EACH HABITAT (IN HA)-- A(I)
C      2. EXTERNAL AREA HYDROLOGICALLY CONNECTED TO HABITAT I--EXSUM(I)
C      3. ALLOWABLE CONNECTIONS MATRIX (IE WATER CAN FLOW FROM
C         UPLAND FOREST TO SWAMP BUT NOT BACK)-- IC(I,J)
C      4. RAINFALL BY MONTH (IN CM/MO)-- R(T)
C      6. EVAPOTRANSPIRATION BY MONTH BY HABITAT TYPE-- ET(I,T)
```

```
C       7. RUNIN FROM OUTSIDE THE AREA BY MONTH BY HABITAT TYPE
C          (IN CU KM/MO)-- RI(I,T)
C       8. WATER LEVEL BY HABITAT BY MONTH (IN CM)-- WL(I,T)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
1       FORMAT(11F10.3)
2       FORMAT(2X,11I1)
3       FORMAT(11I1)
        N=11
        IA=11
        IDGT=3
        DO 10 I=1,N
        RIYR(I)=0
        RYR(I)=0
        ETYR(I)=0
10      CONTINUE
        PRINT,'SURFACE AREA OF HABITATS--HA'
        READ(5,*) (A(I),I=1,N)
        WRITE(6,*) (A(I),I=1,N)
        PRINT,'EXTERNAL AREA HYDROLOGICALLY CONNECTED TO HABITATS--HA'
        READ(5,*) (EXSUM(I),I=1,N)
        WRITE(6,*) (EXSUM(I),I=1,N)
        PRINT,'RAINFALL BY MONTH--CM/MO'
        READ(5,*) (R(T),T=1,12)
        WRITE(6,*) (R(T),T=1,12)
        PRINT,'EVAPOTRANSPIRATION BY HABITAT BY MONTH--CM/MO'
        DO 30 I=1,N
        READ(5,*) (ET(I,T),T=1,12)
30      WRITE(6,*) (ET(I,T),T=1,12)
        PRINT,'RUNIN BY HABITAT BY MONTH--CU KM/MO'
        DO 40 I=1,N
        READ(5,*) (RI(I,T),T=1,12)
40      WRITE(6,*) (RI(I,T),T=1,12)
        PRINT,'WATER LEVEL BY HABITAT BY MONTH--CM'
        DO 50 I=1,N
        READ(5,*) (WL(I,T),T=1,12)
50      WRITE(6,*) (WL(I,T),T=1,12)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C    CERTAIN ASSUMPTIONS ARE NECESSARY TO OBTAIN RESULTS.
C    THESE INCLUDE:
C       1. THE SOIL IS ALWAYS SATURATED.
C       2. THERE IS NO NET TIDAL EXCHANGE
C
C    A WATER BALANCE EQUATION FOR EACH HABITAT CAN BE
C    FORMULATED AS FOLLOWS:
C
C       DS(I,T) = RH(I,T) - ETH(I,T) + RI(I,T) + SUMI(RIH(J,I,T))
C                 - RO (I,T)
C
C    WHERE
C       DS(I,T) = CHANGE IN STORAGE OF WATER IN HABITAT I FROM
C                 TIME T-1 TO TIME T
C               = ((WL(I,T)-WL(I,T-1))/100000)*A(I)
C       RH(I,T) = TOTAL RAIN WATER INPUT TO HABITAT I FROM TIME
C                 T-1 TO TIME T
C               = (R(T)/100000)*A(I)
C      ETH(I,T) = TOTAL EVAPOTRANSPIRATION BY HABITAT I FROM
C                 TIME T-1 TO TIME T
```

```
C              = (ET(I,T)/100000)*A(I)
C      RI(I,T) = TOTAL RUNIN FROM OUTSIDE THE AREA TO HABITAT I
C                FROM TIME T-1 TO TIME T
C   RIH(J,I,T) = RUNIN FROM HABITAT J TO HABITAT I FROM
C                TIME T-1 TO TIME T
C              = C(J,I)*RO(J,T)
C      RO(I,T) = RUNOFF FROM HABITAT I FROM TIME T-1 TO
C                TIME T
C       C(I,J) = WATER TRANSFER COEFFICIENT FROM HABITAT I
C                TO HABITAT J
C              = IC(I,J)*(A(J)/TA)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      DO 60 I=1,N
      DO 60 T=1,12
      K=T-1
      IF(K.EQ.0)K=12
      DS(I,T)=((WL(I,T)-WL(I,K))/10000000.)*A(I)
      RH(I,T)=(R(T)/10000000.)*A(I)
      ETH(I,T)=(ET(I,T)/10000000.)*A(I)
      RO(I,T)=0.
60    CONTINUE
      DO 70 I=1,N
      DO 70 T=1,12
           RIYR(I)=RIYR(I)+RI(I,T)
           RYR(I)=RYR(I)+RH(I,T)
           ETYR(I)=ETYR(I)+ETH(I,T)
70    CONTINUE
      PRINT,'CHANGE IN STORAGE BY HABITAT BY MONTH--CU KM/MO'
      DO 80 I=1,N
80    WRITE(6,*) (DS(I,T),T=1,12)
      PRINT,'TOTAL RAINFALL INPUT BY HABITAT BY MONTH--CU KM/MO'
      DO 81 I=1,N
81    WRITE(6,*) (RH(I,T),T=1,12)
      PRINT,'TOTAL EVAPOTRANSPIRATION BY HABITAT BY MONTH--CU KM/MO'
      DO 82 I=1,N
82    WRITE(6,*) (ETH(I,T),T=1,12)
      PRINT, 'ANNUAL RUNIN BY HABITAT'
      DO 83 I=1,N
83    WRITE(6,*) RIYR(I)
      PRINT, 'ANNUAL RAINFALL BY HABITAT'
      DO 84 I=1,N
84    WRITE(6,*) RYR(I)
      PRINT, 'ANNUAL EVAPOTRANSPIRATION BY HABITAT'
      DO 85 I=1,N
85    WRITE(6,*) ETYR(I)
      DO 90 I=1,N
90    RSUM(I)=EXSUM(I)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C  READ IN RUNOFF ALLOCATION MATRIX
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      DO 130 I=1,N
130   READ(5,*) (C(I,J),J=1,N)
      PRINT,'INTERCONNECTIONS MATRIX'
      DO 140 I=1,N
140   WRITE(6,1) (C(I,J),J=1,N)
```

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C   THE WATER BALANCE EQUATION CAN BE RESTATED AS:
C
C      RO(I,T) = C(J,I)*RO(J,T) + (RH(I,T) - DS(I,T) - ETH(I,T)
C                + RI(I,T))
C
C   COMBINING THE LAST FOUR TERMS ON THE RIGHT:
C
C        Y(I,T) = RH(I,T) - DS(I,T) - ETH(I,T) + RI(I,T)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
       DO 150 I=1,N
       DO 150 T=1,12
150    Y(I,T)=RH(I,T)-DS(I,T)-ETH(I,T)+RI(I,T)
       PRINT,'RAIN-DELTA STORAGE-ET+RUNIN = Y(I,T)--CU KM/MO'
       DO 160 I=1,N
160    WRITE(6,*) (Y(I,T),T=1,12)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C   WE NOW HAVE THE WATER BALANCE EQUATION IN THE FORM:
C
C       RO(I,T) = C(J,I)*RO(J,T) + Y(I,T)
C
C   OR IN MATRIX FORM FOR EACH TIME INTERVAL:
C
C       R = CR + Y
C
C   WHICH CAN BE SOLVED FOR R AS:
C
C       R = Y*INV(I-C)
C
C   THE WATER TRANSFERS BETWEEN HABITATS CAN THEN BE
C   CALCULATED FROM THE ELEMENTS OF THE R VECTOR AND C MATRIX AS:
C
C      RIH(I,J,T) = C(I,J) * RO(I,T)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
       PRINT, 'CT(I,J)'
       DO 180 I=1,N
       DO 180 J=1,N
       IF(I.EQ.J)GO TO 170
       CT(I,J)=-C(J,I)
       GO TO 180
170    CT(I,J)=1-C(I,J)
180    CONTINUE
       DO 190 I=1,N
190    WRITE(6,*) (CT(I,J),J=1,N)
       CALL LINV2F (CT,N,IA,CTINV,IDGT,WKAREA,IER)
       PRINT,'INVERSE CONNECTIONS MATRIX'
       DO 200 I=1,N
200    WRITE(6,*) (CTINV(I,J),J=1,N)
       DO 210 T=1,12
       DO 210 I=1,N
       DO 210 J=1,N
       RO(I,T)=RO(I,T)+Y(J,T)*CTINV(I,J)
210    CONTINUE
       DO 220 T=1,12
       DO 220 I=1,N
       DO 220 J=1,N
220    RIH(I,J,T) = C(I,J) * RO(I,T)
```

```
      PRINT,'TOTAL RUNOFF BY HABITAT BY MONTH--CU KM/MO'
      DO 230 I=1,N
230   WRITE(6,*) (RO(I,T),T=1,12)
      DO 240 I=1,N
      DO 240 J=1,N
      TRO(I,J)=0.
      DO 240 T=1,12
240   TRO(I,J)=TRO(I,J)+RIH(I,J,T)
      PRINT,'TOTAL ANNUAL WATER TRANSFER MATRIX--CU KM/YR'
      DO 250 I=1,N
250   WRITE(6,*) (TRO(I,J),J=1,N)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C  THIS SECTION MULTIPLIES THE TOTAL WATER TRANSFER ESTIMATES
C  BY NUTRIENT AND OTHER MATERIAL CONCENTRATIONS TO
C  ESTIMATE THE FLOWS OF THESE MATERIALS BETWEEN HABITATS
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      READ(5,*) (TN(J), J=1,N)
      PRINT,'NITROGEN CONCENTRATIONS BY HABITAT--GN/CU M'
      WRITE(6,*) (TN(J), J=1,N)
      READ(5,*) (TP(J),J=1,N)
      PRINT,'PHOSPHOROUS CONCENTRATIONS BY HABITAT--GP/CU M'
      WRITE(6,*) (TP(J),J=1,N)
      READ(5,*) (TOM(J),J=1,N)
      PRINT,'ORGANIC MATTER CONCENTRATIONS BY HABITAT--GTOM/CU M'
      WRITE(6,*) (TOM(J),J=1,N)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C   NEXT, CALCULATE MATERIAL TRANSFERS BASED ON WATER
C   TRANSFERS AND MATERIAL CONCENTRATIONS
C   COMMODITIES ARE: 1. WATER --CU KM/YR
C                    2. NITROGEN--E6 KG/YR
C                    3. PHOSPHORUS--E6 KG/YR
C                    4. TOTAL ORGANIC MATTER--E6 KG/YR
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      DO 270 I=1,5
      DO 270 J=1,N
      DO 270 K=1,2
270   TT(I,J,K)=0.
      DO 280 J=1,N
C  CALCULATE COMMODITY INPUTS BY HABITAT FROM OTHER HABITATS
      DO 290 L=1,N
      TT(1,J,1)=TT(1,J,1)+TRO(L,J)
      TT(2,J,1)=TT(2,J,1)+(TRO(L,J)*TN(J))
      TT(3,J,1)=TT(3,J,1)+(TRO(L,J)*TP(J))
290   TT(4,J,1)=TT(4,J,1)+(TRO(L,J)*TOM(J))
C  ADD INPUTS FROM OUTSIDE THE HYDROLOGIC UNIT (EG. RAIN, RUNIN)
      DO 300 T=1,12
      TT(1,J,1)=TT(1,J,1)+RH(J,T)+RI(J,T)
      TT(2,J,1)=TT(2,J,1)+(RH(J,T)*.23)+(RI(J,T)*8.78)
      TT(3,J,1)=TT(3,J,1)+(RI(J,T)*.58)
300   TT(4,J,1)=TT(4,J,1)+(RI(J,T)*10.5)
C  CALCULATE COMMODITY OUTPUTS BY HABITAT
      DO 310 L=1,N
      TT(1,J,2)=TT(1,J,2)+TRO(J,L)
      TT(2,J,2)=TT(2,J,2)+(TRO(J,L)*TN(J))
      TT(3,J,2)=TT(3,J,2)+(TRO(J,L)*TP(J))
310   TT(4,J,2)=TT(4,J,2)+(TRO(J,L)*TOM(J))
C  ADD OUTPUTS TO OUTSIDE THE HYDROLOGIC UNIT (EG. ET)
```

```
      DO 320 T=1,12
320   TT(1,J,2)=TT(1,J,2)+ETH(J,T)
280   CONTINUE
C  PRINT COMMODITY BY PROCESS I-O TABLE- STANDARD FORMAT
      PRINT,'COMMODITY BY PROCESS I-O TABLE FOR HYDROLOGIC UNIT IV'
      DO 330 I=1,4
      DO 330 K=1,2
330   WRITE(6,*) (TT(I,J,K),J=1,N)
C  CALCULATE TOTAL COMMODITY INPUTS AND OUPUTS FOR HYDRO UNIT
      DO 340 I=1,4
      DO 340 K=1,2
      TOTTT(I,K)=0.
      DO 340 J=1,N
340   TOTTT(I,K)=TOTTT(I,K)+TT(I,J,K)
      PRINT,'TOTAL COMODITY INPUTS AND OUTPUTS FOR HYDRO UNIT'
      DO 350 K=1,2
350   WRITE(6,*) (TOTTT(I,K),I=1,5)
     STOP
     END
C$ENTRY
```

Table A.5 Percent runoff allocation matrix for the Barataria hydrologic unit.[a]

From / To	1	2	3	4	5	6	7	8	9	10	11	Export
1. Agriculture			0.50	0.18	0.06	0.19	0.03	0.05				
2. Brackish Marsh								0.95	0.05			
3. Canal						0.90		0.10				
4. Swamp			0.80			0.17	0.03					
5. Fresh Marsh			0.80			0.17	0.03					
6. Fresh Open Water								1.00				
7. River, Stream, Bayou						0.90		0.10				
8. Estuarine Open Water	0.05								0.05			0.90
9. Salt Marsh								1.00				
10. Upland Forest			0.50	0.18	0.06	0.19	0.03	0.05				
11. Urban/Industrial			0.50	0.18	0.06	0.19	0.03	0.05				

[a]Column heading numbers refer to habitats listed at left. Runoff is read as the percent of total runoff from habitat at left to habitat to top.

Table A.6. Total nitrogen, total phosphorus, and total organic matter concentrations in surface water runoff from eleven habitats in the hydrologic unit models.

	Habitat										
	1	2	3	4	5	6	7	8	9	10	11
Total Nitrogen (gN/cu m)	0.92[a]	1.70[b]	2.79[c]	2.43[c]	1.66[d]	1.60[e]	0.001[f]	0.720[g]	1.22[b]	0.12[a]	1.43[a]
Total Phosphorus (gP/cu m)	0.18[a]	0.10[b]	0.98[c]	0.45[c]	0.11[d]	0.27[e]	0.002[f]	0.27[g]	0.10[b]	0.004[a]	0.10[a]
Total Organic Matter (gTOM/cu m)	10.00[h]	14.70[i]	12.10[e]	14.10[e]	26.70[j]	11.60[e]	0.02[f]	7.10[k]	9.00[i]	1.00[h]	10.00[h]

[a] Hopkinson (1978). Calculated using 1.6 m rain/yr.
[b] Ho and Schneider (1976). Station No. 7.
[c] Kemp and Day (1981).
[d] Ho and Schneider (1976). Station No. 7.
[e] Day et al. (1977). Total organic carbon (TOC) converted to gdw TOM by multiplying by 1.724 (Wilson and Staker 1932). TOC estimated at Station A.
[f] Estuarine open water habitat model. Table 86.
[g] Estuarine open water habitat model. Table 87.
[h] Estimated.
[i] Cramer (1978). TOC converted to gdw TOM by multiplying by 1.724. (Wilson and Staker 1932).
[j] Cramer et al. (1981). TOC converted to gdw TOM by multiplying by 1.724 (Wilson and Staker 1932). Canal TOM estimated from Walker Canal Station. Fresh marsh TOM estimated as the average of Goose Point and New Orleans East Stations.
[k] Happ et al. (1977). TOC converted to gdw TOM by multiplying by 1.724 (Wilson and Staker 1932). Average of all Upper Barataria Bay Stations.

Table A.7. Input-output table for Barataria hydrologic unit.

HYDROLOGIC UNIT IV BARATARIA

COMMODITIES		PROCESSES: AGRICULTURE 1	BRACKISH MARSH 2	CANALS 3	SWAMP 4	FRESH MARSH 5	FRESH OPEN WATER 6	RIVERS, STREAMS, BAYOUS 7	ESTUARINE OPEN WATER 8	SALT MARSH 9	UPLAND FOREST 10	URBAN/INDUSTRIAL 11	IMPORTS & EXPORTS 12	TOTAL	UNITS
WATER	1	0.227	1.522	0.482	0.393	0.340	0.842	0.390	5.987	1.335	0.015	0.316		11.849	km³/yr
		0.227	1.522	0.482	0.393	0.340	0.842	0.390	2.703	1.335	0.015	0.316	3.284	11.849	km³/yr
NITROGEN	2	0.052	0.618	1.020	0.175	0.096	1.296	3.241	2.460	0.546	0.004	0.073		9.561	mt/yr
		0.060	1.178	1.125	0.422	0.228	1.310	0.000	0.263	0.857	0.001	0.174	3.943	9.561	mt/yr
PHOSPHORUS	3	0.000	0.182	0.348	0.017	0.001	0.217	0.214	0.597	0.022	0.000	0.000		1.598	mt/yr
		0.016	0.069	0.395	0.078	0.015	0.221	0.001	0.099	0.065	0.000	0.012	0.627	1.598	mt/yr
TOTAL ORGANIC MATTER	4	0.000	2.682	4.295	0.540	0.341	9.330	3.875	15.690	1.954	0.000	0.000		41.161	mt dry wt/yr
		0.873	10.186	4.881	2.446	3.665	9.498	0.001	2.591	5.788	0.006	1.216	2.444	41.161	mt dry wt/yr

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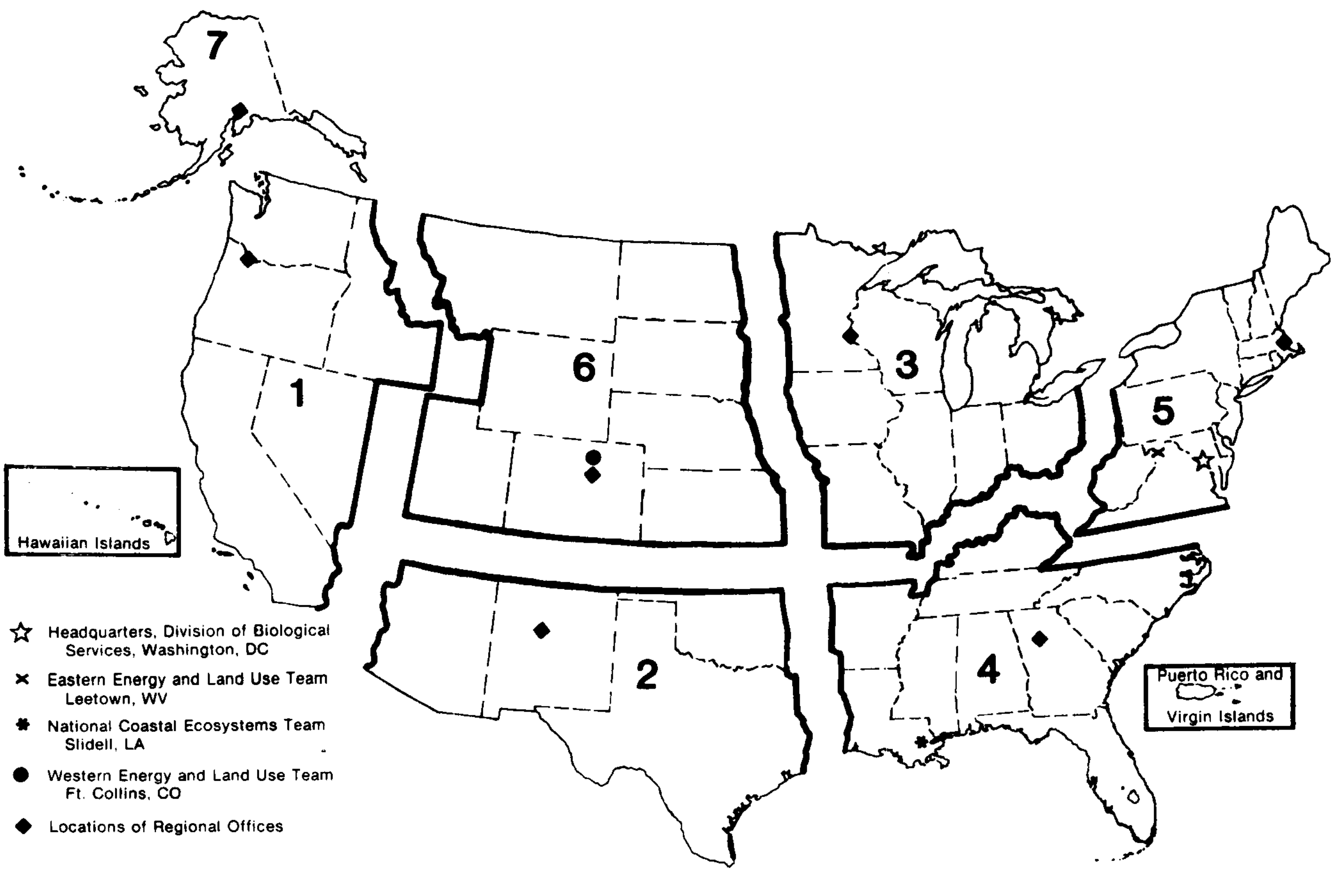

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