THE USE OF ELECTRONIC DATA PROCESSING METHODS IN THE FLORA OF VERACRUZ PROGRAM[1]

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AND
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We are living and working in a period when floristic studies far exceed any similar emphasis of the past. They comprise a very significant portion of the systematic studies now underway and appear to be steadily increasing. Even a decade ago floristic studies were not fashionable and, in fact, received considerable criticism from many quarters. It is not intended to imply here that floristics are fashionable today. However, the realization that man is destroying the world before he has taken the opportunity to know and understand the diversity of plants occurring on the earth's surface has had a profound influence on the thinking of many systematic botanists. Many systematists feel a strong moral obligation to document this diversity as best they can before it is too late, and find that floristics offers the most expeditious way to do so. The production of a flora for a given geographical area is a much more difficult task today than it was even a few decades ago. The pressure of time has been mentioned but several additional factors contribute their burdens. Among these is our steadily increasing knowledge of the processes of organic evolution that have to be dealt with and the desire, if indeed not necessity, of understanding the "biology" of the plant groups under study. Also, there are new and urgent demands for increased accuracy of all the data included in the ultimate treatment.

Scientific knowledge grows unevenly and at some point it is most helpful to have this brought together in a synthesized[2] form. A flora can be the vehicle to accomplish this. It should not only be a work of synthesis, which is in itself an accomplishment, but it should also help spawn new and original research. In this way, a floristic study can help to build a new plateau of knowledge upon which other researchers can enlarge. Floras should never be considered as the end point of concern with the plants of a given region but as the beginning.

STEPS IN THE PREPARATION OF A FLORA

During the initial consideration of the Flora of Veracruz, we made a

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[2]Synthesized is used here in the sense of including original data gathering in addition to summarizing previously known information.

general analysis of the usual steps in the preparation of a flora. The basic data and procedures employed seem to vary somewhat from one project to another, just as content and quality vary. In spite of this, most floristic studies do share some common data sources, procedures and problems, each of which is discussed briefly as background information.

Ideally, the ultimate flora would contain all the information known for each taxon regardless of the subject. At the present time, there are serious obstacles to this, one of which is gaining easy access to diverse bibliographic data sources. There are, of course, other problems inherent in gathering data to be used in a flora. Otherwise one might expect that most of the flora of the world would have been covered by this time. The bibliographic problem manifests itself in several ways. All floras begin with some kind of basic bibliography which probably will be most useful at the beginning of the study of a group and again toward the end. These two "peaks" of usage serve somewhat different functions. The first involves an initial search for papers dealing with taxonomy, nomenclature, distribution, etc. These papers, along with specimens, form the basic building block for the development of plant descriptions and keys. The second bibliographic "peak" is usually reached as the rough framework of taxonomic structure has been completed. The usage here tends to be more specialized as the topics tend to be more specialized; for example, the search may be for detailed environmental data, ecology, chemical compounds, etc. One problem inherent in the bibliographic process is relatively simple in theory and difficult in practice: to generate a more or less complete bibliography. The second part of this problem, i.e., the specialized reference, is more complex because considerable *individual* judgment must come into play as to whether to include a paper or not.

The reliability of published information always must be assessed. It is often difficult to determine which taxon the data should be assigned to; for example, many ecological and some phytochemical studies are not backed by voucher specimens. This is also the case with the earlier works in cytology and anatomy. A degree of uncertainty should be anticipated in all descriptive material whether vouchered or not. The ultimate responsibility for proper assessment lies with the individual worker.

Another bibliographic problem concerns the extent to which references are cited in the published flora. The citation of bibliographic references might be considered a part of the description—those dealing with nomenclature certainly are—but many floras have chosen to treat the remainder in a separate category. It is our impression that bibliographic references add significantly to a flora because they furnish the user with a baseline of information to interpret the floristic treatment. Furthermore, we feel that often there is a definite correlation between the number of references cited and the final quality of the work. One should be selective in this matter, however, and not include a reference solely because a particular species is mentioned. It is not especially helpful to have a bibliography

more extensive than the text. In the final analysis, the most difficult problem involving bibliographic resources is to maintain them in such a way as to keep them accessible. This task is compounded as the amount and diversity of information increases and it can be the main reason for not including information that is important.

We doubt that it is necessary to direct much attention to the methods of obtaining original data resources, that is, living plants and herbarium specimens, as most of us are familiar with this aspect of systematic research. Suffice it to say that it is necessary to have a collection of specimens which is representative of the morphological variation and geographic distribution of the taxa.

The combination of the two basic resources, bibliography and specimens, leads to the common procedure of preparing keys and descriptions of taxa (admittedly the content varies considerably from flora to flora). In most, however, the description constitutes the main mode of data presentation and accordingly forms the body of the flora. Descriptions of each species consist of some or all of the following categories: the scientific name and some or all of its synonyms, including typification; a morphological description based on data from literature and specimens; diverse data such as chromosome number, phenology, chemical compounds, uses, local name; ecology; illustrations; geographic distribution in the area and in a broader perspective, sometimes with maps. When specimen citations are included they most commonly consist of the collector's name, number, and the locality. In more comprehensive floras, herbarium abbreviations may be included as well. In our opinion, specimen citations add greatly to the usefulness of any flora but most particularly to those of tropical areas.

It is the usual practice to develop generic descriptions from the species treated, unless the generic descriptions are meant to be worldwide in circumscription. Family descriptions are generated in a like manner from generic descriptions. Uniformity of descriptions, even within a single flora where a certain amount of format change may occur, is difficult to obtain. Often this means that descriptions are difficult to compare.

The preparation of keys to all taxa is of prime importance. The keys are necessary to provide access to the proper data (description). Often the keys are the most used part of a flora and they should be constructed with the greatest care and with their frequency of use firmly in mind. Keys are one of the most variable portions of a flora because different criteria may be used for different families; for example, keys based on fruit, flower, leaves, or pollen may have a different diagnostic usefulness in different genera and families, and consequently some are stressed (weighted) while others are not. The most reliable and easily used characteristics should be chosen for the keys.

A related problem is that of compatibility with other floras, i.e., whether they can be used in conjunction with one another without serious data conflict. Frequently a flora of a particular region becomes the base for a

flora either of a smaller area that is a portion of it, or a larger region that includes it. Even though there is a general awareness of this, it is a rare flora that has been planned for such contingencies. The greater the amount of data included in a given flora, the greater the probability that a useful data base will be established.

Finally, the most frustrating procedures in flora preparation are those belonging to all the categories mentioned above, which might be thought of as being routine. Some examples of routine operations are: preparing duplicate labels for recently collected specimens; bibliographic search, particularly in peripheral areas such as the environmental aspects of the area; determination of localities for mapping purposes; and the elaboration of specialized catalogues, such as local names.

In recent years several attempts have been made to solve some of the problems mentioned, with varying degrees of success, by using automatic data processing techniques. After an examination of these efforts, we came to the conclusion that they offered great possibilities, not fully explored, to free the professional botanist from many routine operations. The possibility of increased efficiency, without greatly increased costs, appeared to be a realistic and attainable goal. Several methods were explored before a practical system for the Flora of Veracruz was developed.

The decision to use electronic data processing methods for our flora was made in 1966, when the first pilot projects were completed. These included information retrieval of herbarium specimen data and automatic map production for range distribution. The results of these pilot projects were presented at our Mexico City Symposium on Information Problems in Natural Sciences in 1967 (Gómez-Pompa & Olvera, 1967; Scheinvar, Gómez-Pompa & Alonso, 1967). It is worth mentioning that during the initial developmental stages of our work other floristic projects were stimulated by our approach, results, and personnel (Ahumada, 1967). We are encouraged that in these few years the quality and number of other floristic programs using electronic data processing methods have increased considerably. The approaches for different applications have also increased and diversified (Morse, 1971; Bestchell & Soper, 1970; Scheinvar & Gómez-Pompa, 1969; Crovello & MacDonald, 1970). It is important to realize that many of these techniques were inspired by the pioneer work of Perring (1963) and Soper (1964), which are, to our knowledge the first large scale attempts to use EDP methods for specific floristic projects. Rogers' work on Information Retrieval for Taxonomy (1960) should be mentioned here, even though not floristic in its approach, as it presents many of the basic ideas used for EDP-IR application to floristic studies. It is also worth mentioning the effort of the Smithsonian Institution in this field (Squires, 1966).

Data Processing for the Flora of Veracruz

The possibilities of the kinds and amount of data to be provided in a floristic work are endless and may range from the collection number of a

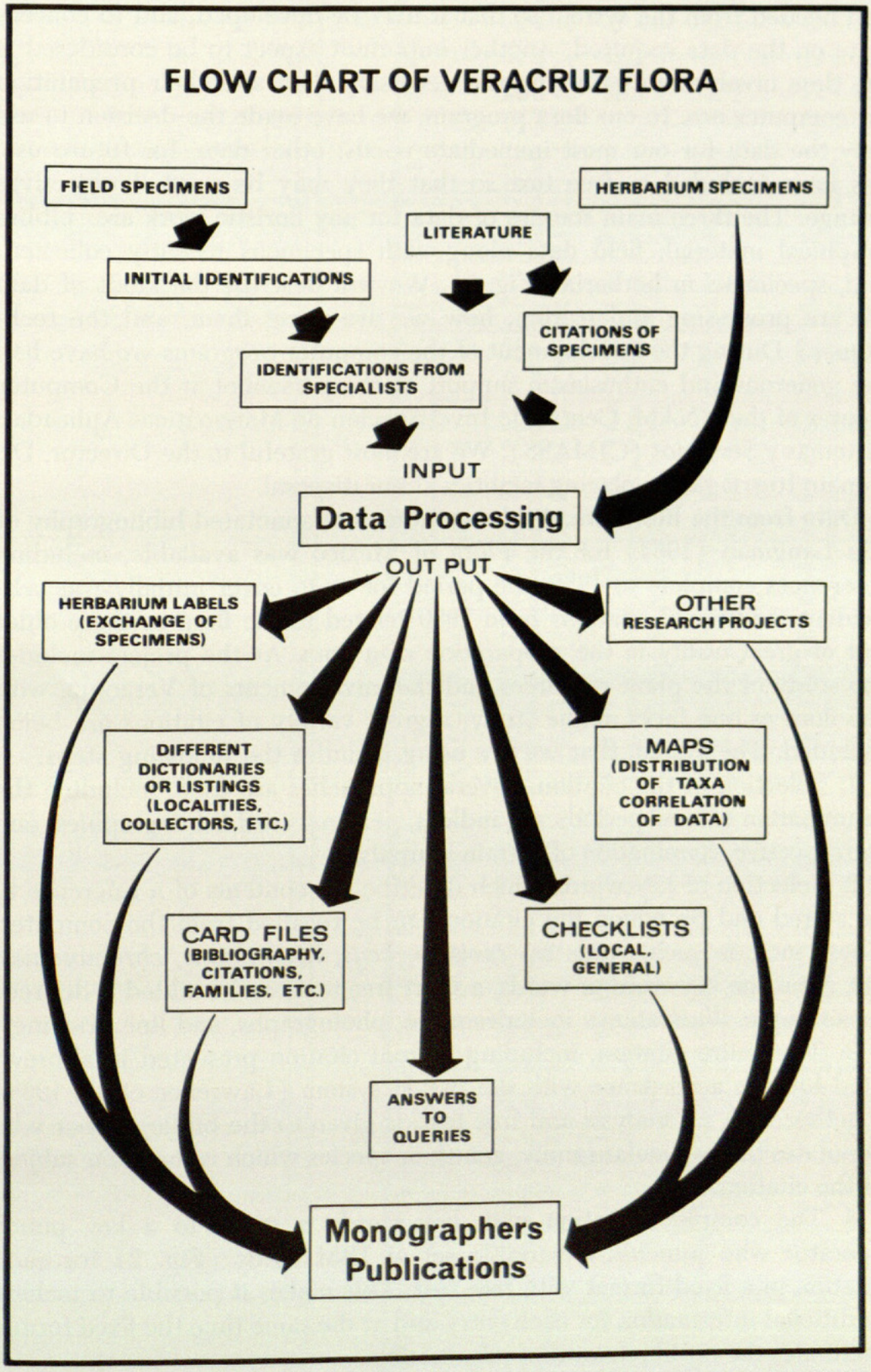

FIG. 1. Flow chart of the Flora of Veracruz.

specimen from a certain locality to the number of ovules in the ovary of a certain species collection. The main problem is to decide what is wanted and needed from the system so that it may be developed, and to concentrate on the data required. Another important aspect to be considered is the time involved in gathering the necessary data and their preparation for computer use. In our flora program, we have made the decision to use only the data for our most immediate needs; other data, for future use, has been included in free text so that they may be used if objectives change. The three main sources of data for any floristic work are: bibliographical material; field data along with specimens recently collected; and, specimens in herbaria (Fig. 1). We will describe the kinds of data we are processing and storing, how we are using them, and the techniques.[3] During the development of the computer programs we have had the generous and enthusiastic support of the personnel at the Computer Center of the UNAM, Centro de Investigación de Matemáticas Aplicadas, Sistemas y Servicios (CIMASS). We are most grateful to the Director, Dr. Renato Iturriaga, for placing facilities at our disposal.

Data from the literature. As the monumental annotated bibliography of Ida Langman (1964) for the Flora of Mexico was available, including references complete to 1950, the period for us to cover initially was self-evident; additional citations from 1950 related to the flora or those older but of great utility in the preparation of a flora. As the project includes the study of the plant resources and the environments of Veracruz, with the flora as one facet of the study, a great variety of citations are being included. The system that we are using includes the following steps:

1. Selection of the citation. Several approaches are used, including the examination of new periodicals, indices, personal card bibliographies, and retrospective examination of certain journals.

2. Selection of key words which describe the contents of a reference to be stored and by which the citation can be recalled from the computer. These include such words as: *revision, keys, illustrations, chromosomes,* etc. After the key word or words, a short free text can be added if desired; for example, *illustrations:* includes maps, photographs, and line drawings.

3. The entire citation, including journal citation presented in abbreviated form in accordance with the B-P-H system (Lawrence et al., 1968) together with its analysis and free text, is given to the bibliographer who annotates the particular family, genus, or species which is the main subject of the citation.

4. The complete citation with key words is given to a key punch operator who punches a variable set of IBM cards (Fig. 2) for each citation in a fixed format with free text. This makes it possible to include additional information for each entry and at the same time the fixed format facilitates the rapid retrieval of information.

5. The punched cards are edited and the information is transferred to

[3]Details of the format and programs are not included here.

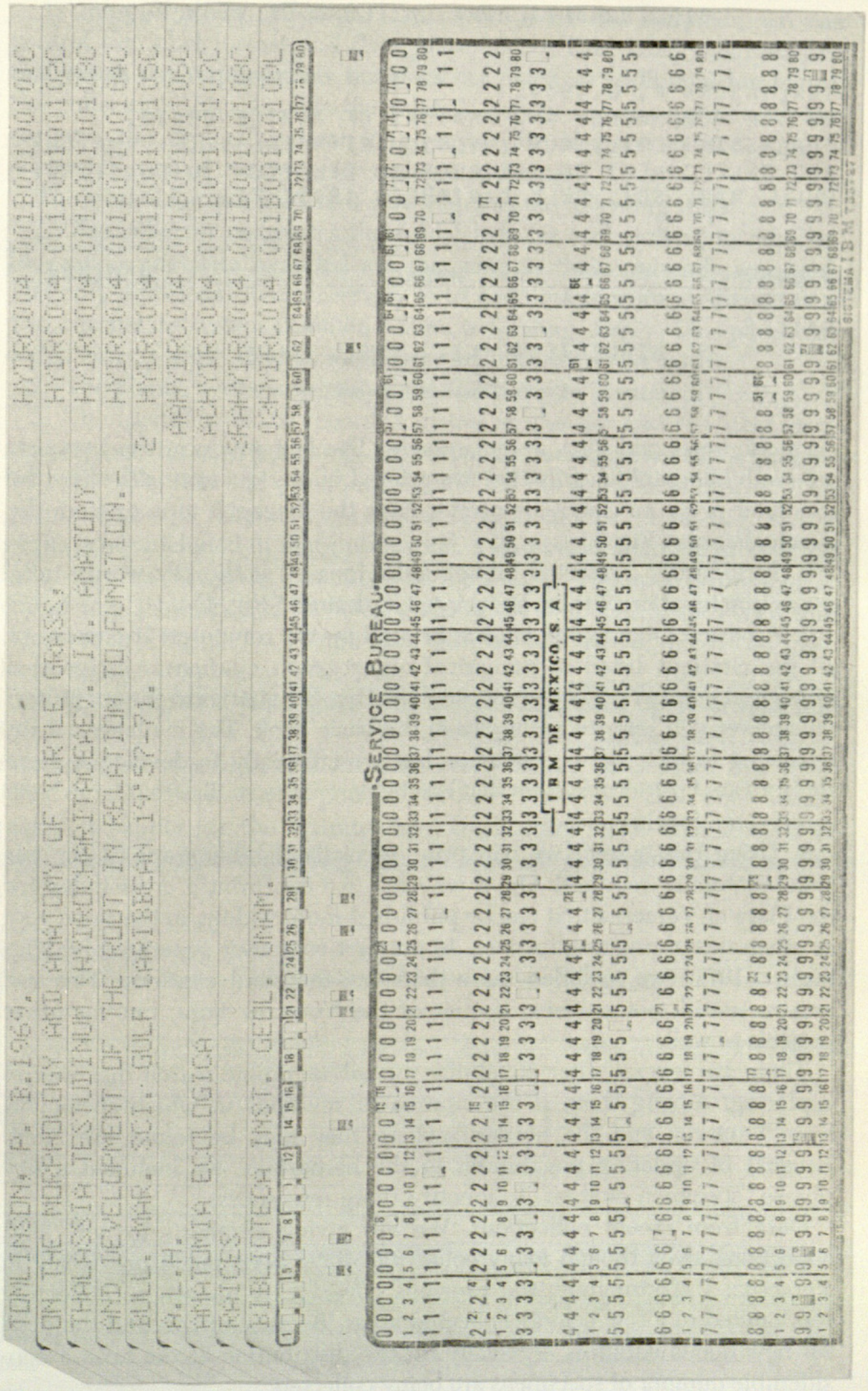

FIG. 2. Complete set of punched cards for one bibliographic entry.

BIBLIOGRAFIA PARA LA FLORA DE VERACRUZ

TOMLINSON, P. B.1969.
ON THE MORPHOLOGY AND ANATOMY OF TURTLE GRASS,
THALASSIA TESTUDINUM (HYDROCHARITACEAE). II. ANATOMY
AND DEVELOPMENT OF THE ROOT IN RELATION TO FUNCTION.-
BULL. MAR. SCI. GULF CARIBBEAN 19:57-71.

A.L.H. HYDRC B001001
ANATOMIA ECOLOGICA
RAICES

BIBLIOTECA INST. GEOL. UNAM.

FIG. 3. Printed bibliographic card.

magnetic tapes and discs for processing. The first products the botanists see are bibliographic cards that are printed in any quantity either by the computer or by an electronic printer from the magnetic tape or from the punched cards (Fig. 3).

6. Periodically a selected bibliography for any of the key words, taxa, or any combination of them are printed as desired (Fig. 4).

7. A basic bibliographic book is printed by the computer. It consists of all the citations listed in numerical order (each citation is assigned a sequential number). This serves as a reference for queries to the computer: the answer will refer to a number in the basic book. The main reason for retrieving in this way is economic, but we are ready to develop a more sophisticated retrieval system that can be derived from files that have been constructed for this purpose.

8. Using this system we can print specialized bibliographies for our collaborators as required. Or, if we wish, we can print a cross index for the Flora of Veracruz that can be published more widely, in the same way as other abstracting publications. In our first computer generated bibliography (1971) we included more than one thousand citations. This has proven useful, not only for studies of the Veracruz flora, but for other projects as well.

There are several other possibilities in bibliographic search that we are exploring. Among these is the citation of revisions in which specimens from Veracruz and the herbaria where they may be found are cited. Because of updating possibilities in the herbarium, we included a key phrase "specimen citation" to identify these references.

Data from recent collections. We are giving emphasis to new field collections, even though many collections have been made previously in Veracruz. Unfortunately, the previous coverage is uneven as collecting was limited to a few heavily collected areas. Because of this and the need for new documentation, especially for the distribution of the taxa, a considerable number of specimens are being collected.

As most of these collections are made under our auspices, we can control the label format and data presented. A field label was designed that meets our requirements but does not place an additional burden on the collectors (Fig. 4). The field labels consist of an original and two carbons; the original is kept in a master file and one carbon copy is allotted to each of the two cooperating institutions.

The system for specimen data flow requires the following steps:

1. The collector completes the field labels for each collection number. In general, the data included are the same as those normally recorded. The only additional item necessary is to code the locality according to a grid coordinate system (Gómez-Pompa & Nevling, 1967). This particular coded entry permits the automatic printing of distribution maps.

2. The plants, with accompanying field labels, are identified.

3. The identification is recorded in the master file and the label data are prepared for card punching. This involves the assignment of a number for each collection and a numerical code for the genus and species. The genus number is derived from Dalla Torre & Harms (1900–07). If the genus is not included in that publication, a number is assigned arbitrarily, following the last generic number of the family. The species number is completely arbitrary and we keep a check list of species names with this information (Fig. 5). All important data fields must be filled, e.g., collector's name, number, and date, etc.

4. The completed label then goes to the key punch operator and the information on each label is transferred to IBM cards. Each card is numbered in sequence, and for each entry on the label there is a card (Fig. 6). All information is punched in free text within each field which makes it simple for the operator and for revision. The final item is a replication number containing the number of duplicate labels to be printed.

No. REC. INF.		FAM.
NOMBRE CIENTIFICO		
PAIS	ESTADO	MUNICIPIO
LOCALIDAD		
		MAPA
LATITUD	LONGITUD	ALTITUD
TIPO VEGETACION		PRIM. ☐ SEC. ☐
INF. AMBIENTAL		
SUELO		
ASOCIADA		
ABUNDANCIA	FORMA BIOLOGICA	TAMAÑO
AN. ☐ PERENNE ☐	OTROS DATOS	
FRUTO		FLOR
NOMBRE LOC.		FECHA COL.
USOS		DET.
COL.		No.

ORIGINAL

FIG. 4. Field label.

RANUNCULACEAE
****

ANEMONE MEXICANA HBK.	RANUN	21	1
CLEMATIS CARACASANA DC.	RANUN	22	4
CLEMATIS DIOICA L.	RANUN	22	1
CLEMATIS GROSSA BENTH.	RANUN	22	2
CLEMATIS SERICEA HBK.	RANUN	22	3
DELPHINIUM AJACIS L.	RANUN	19	1
RANUNCULUS CYMBALARIA PURSH	RANUN	26	7
RANUNCULUS DICHOTOMUS MOC. & SESSE	RANUN	26	1
RANUNCULUS GEOIDES HBK.	RANUN	26	2
RANUNCULUS HOOKERI SCHLECHT.	RANUN	26	6
RANUNCULUS MACRANTHUS SCHEELE	RANUN	26	3
RANUNCULUS PERUVIANUS PERS.	RANUN	26	8
RANUNCULUS PILOSUS HBK.	RANUN	26	4
RANUNCULUS SIBBALDIOIDES HBK.	RANUN	26	5
THALICTRUM GIBBOSUM LEC.	RANUN	28	1
THALICTRUM STRIGILLOSUM HEMSL.	RANUN	28	2

FIG. 5. Family listing from checklist prepared by computer.

5. After editing and any necessary revision of the cards, a file is generated according to a prepared program, and the labels are produced for the duplicate specimens (Fig. 7).

6. With the information stored on the files it is possible to do many things with the aid of the computer: update the checklist; construct listings of collectors, localities, collector's numbers, etc. With appropriate software, a closed information system can be prepared if needed. We intend to print a basic collection book periodically with the collection data arranged numerically with a cross index at the end for the most important items.

7. The basic collection book serves as the *base* for queries to the computer. The answer is obtained faster and more cheaply by referring to the numbers in the book. This method of information retrieval is economical: the coding is done by the computer, the search for specific information is faster, it eliminates the inclusion of information that is not reliable; *all* the information is kept for future use in case a need for it develops. More sophisticated systems can be developed from this one if desired.

8. The use of the locality files (gazetteer) permits the automatic printing of distribution maps by a plotter.

9. If the data are to be used for a specific research project, programs can be written especially for that purpose. There are numerous possible ways of presenting data in relation to specimens, such as voucher specimens for chemical, genetic, and ecological studies that are being done in the flora program or that are mentioned in the literature. Our system is open and we can add as many data cards to any collection as necessary, including bibliographic citations. Errors can be corrected in the archives at any time and will assist in keeping the data current.

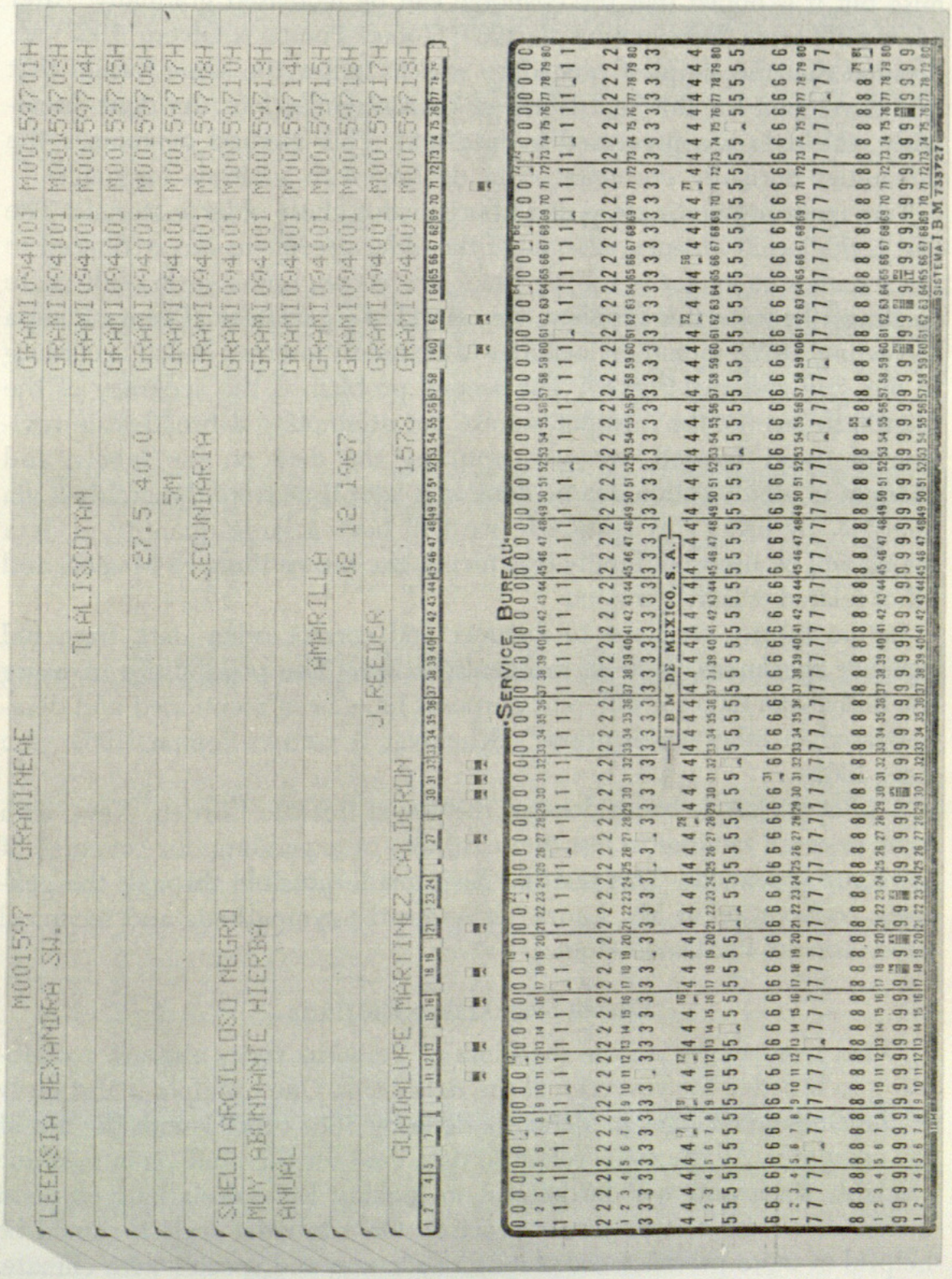

FIG. 6. Punched cards for one specimen label.

The most important source of data for any floristic project is the specimens deposited in herbaria. Representation of a particular floristic area varies from herbarium to herbarium and this poses a serious information restriction. The organization of the herbaria of the world is such that it makes it impossible to use all the information (specimens) available from an area. We have begun a retrospective search for specimen data in our respective institutions (UNAM and Harvard) and in herbaria with personnel interested in cooperating. This procedure represents a compromise but it is hoped that the coverage can be increased gradually. After a few pilot trials (Scheinvar et al., 1967; Gómez-Pompa & Olvera, 1967) we decided that the simplest procedure was to follow the same format that was developed for the field labels of current collections. As done previously, the data are presented in free text. This method overcomes the difficulties normally encountered in dealing with multiple languages.

Two main problems are posed in organizing these older materials. The first is the locality names, as some of the older specimens are attributed to place names no longer in use, or which are known under several alternate spellings. To solve this problem, we compiled a gazetteer (Gómez-Pompa & Nevling, 1970) including localities of botanical interest, coded according to our grid system (Fig. 8). The second problem is the accuracy of the identifications: at the moment we are not attempting a broad-scale revision of these. Instead, we are capturing the data on the labels, and changes in identification can be done at a later time from the archives via teletype. By using this approach, we will have a large quantity of data which will be useful in family treatments, the future Flora of Mexico, and other related research projects.

In the future, we hope to uncover and correct other data from old voucher specimens, such as misidentifications. The possibilities of using the herbarium data for different purposes have been mentioned and demonstrated in other publications (Scheinvar & Gómez-Pompa, 1969; von Reis, 1962).

A pilot project is being done at the Royal Botanic Garden, Kew, with some selected families to test the feasibility of expanding our coverage of Veracruz specimens. This test has been made possible through the generous cooperation of Ms. Laura Vit under the sympathetic and technical supervision of Dr. David Hunt.

Other Specialized Projects

Other research projects in the Flora of Veracruz series also are contributing to broaden the coverage of the data bank. One example is the study of the climatic changes in Veracruz done by Soto (1969) with the aid of the computer. All the meteorological data used for this study is in machine readable form and will be helpful in looking for correlations of plant distribution with certain climatic factors. On a broader scale it should be helpful in more precisely correlating vegetation and species with climate.

INSTITUTO DE BIOLOGIA
HERBARIO NACIONAL DE LA UNIVERSIDAD DE MEXICO (MEXU)

NO.REC.INF. D001826 COMPOSITAE

EUPATORIUM COLLINUM D.C.

CATEMACO
CARRETERA COYAME

MAPA 22.0 57.0
ALT. 300M
ACAHUAL VEG.SECUNDARIA

SUELO ARCILLA Y GRAVA

ABUND.REGULAR HIERBA REPADORA TAM.2.50M
ANUAL LAS FLORES SON AROMATICAS

BLANCA
03/02/1969

COL.GUADALUPE MARTINEZ CALDERON NO. 1848

INSTITUTO DE BIOLOGIA
HERBARIO NACIONAL DE LA UNIVERSIDAD DE MEXICO (MEXU)

NO.REC.INF. D001880 COMPSOITAE

EUPATORIUM COLLINUM DC.

CATEMACO
CARRETERA A COYAME

MAPA 21.5 55.5
ALT. 300M
ACAHUAL VEG.SECUNDARIA

SUELO ARCILLA Y GRAVA

ABUND.REGULAR HIERBA TREPADORA TAM.2.50M
LAS FLORES SON AROMATICAS

BLANCA
03/02/1969

COL.GUADALUPE MARTINEZ CALDERON NO. 1848

INSTITUTO DE BIOLOGIA
HERBARIO NACIONAL DE LA UNIVERSIDAD DE MEXICO (MEXU)

NO.REC.INF. D001826 COMPOSITAE

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CARRETERA COYAME

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ALT. 300M
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SUELO ARCILLA Y GRAVA

ABUND.REGULAR HIERBA REPADORA TAM.2.50M
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SUELO ARCILLA Y GRAVA

ABUND.REGULAR HIERBA REPADORA TAM.2.50M
ANUAL LAS FLORES SON AROMATICAS

BLANCA
03/02/1969

COL.GUADALUPE MARTINEZ CALDERON NO. 1848

FIG. 7. Duplicate labels prepared by computer.

IDOLO	MAPA 67.0/21.0
IDOLO ISLA DEL	MAPA 66.5/20.5
IGNACIO ALTAMIRANO	MAPA 51.0/25.5
IGNACIO DEL ROSARIO	MAPA 38.0/26.5
IGNACIO DE LA LLAVE	MAPA 26.0/42.0
IGNACIO MUNOS	MAPA 52.0/25.0
IGUANARA	MAPA 14.0/65.0
INDEPENDENCIA	MAPA 46.0/27.0
INDEPENDENCIA	MAPA 44.0/25.0
INDEPENDENCIA	MAPA 39.5/24.5
INDIO	MAPA 15.0/53.0
INFIERNILLO	MAPA 32.0/40.5
INFIERNILLO	MAPA 26.0/40.5
ISLA BLANQUILLA	MAPA 33.5/41,0
ISLA DE BURROS	MAPA 71.0/18.5
ISLA DE ENMEDIO	MAPA 32.0/43.0
ISLA DE JUAN ROSAS	MAPA 50.5/23.5
ISLA DE LOS PAJAROS	MAPA 68.0/21.0
ISLA DE LOBOS	MAPA 67.5/24.0
ISLA DEL FRONTON	MAPA 72.5/17.5
ISLA DEL TORO	MAPA 69.0/19.5
ISLA FRIJOLES	MAPA 68.5/21.0
ISLA MARTINICA	MAPA 70.5/18.5
ISLA MATACABALTOS	MAPA 68.5/20.0
ISLA PAJAROS	MAPA 33.0/41.0
ISLA SACRIFICIOS	MAPA 33.0/41.0
ISLA SALMENDRA	MAPA 31.5/43.0

FIG. 8. Partial page of gazetteer with grid system coding.

Conclusion

Our experience with using electronic data processing methods for a flora project generally is very favorable. We have proof that it is very helpful and the evidence suggests that it will be even more helpful in the near future. We have been able to produce duplicate herbarium labels, bibliographic cards, bibliographic indices, checklists, maps, gazetteers, specialized data for specific research projects (Gómez-Pompa, in press) and have created a data bank that will be of great usefulness in the future. One of the things we have accomplished is to have a flexible and simple system, which is useful from the beginning. Our system is not expensive (very little computer time is required) and it will be of maximum help to the researchers of our flora who prepare family treatments. Our final objective is to write the Flora and a side product of it will be the creation of a data bank for future programs.

Machines used. During the development of our work, we have had access to a variety of machines that have been used to perform different portions of our data processing program. From the beginning we used the computers available at the UNAM computer center (CIMASS): a CDCG20 and a CDCG15 but in the last three years we have been using a Burroughs 5500 and a 6500.

For primary data input, we have used IBM 80 column punched cards. The maintenance of the files has been by means of a teletype unit. We have used an IBM 447 tabulator machine and a UNIVAC printer for inexpensive printing of certain files and for printing labels and bibliographic cards when the high speed printer of the computer was not available.

For making distribution maps, we have used a CALCOMP machine linked to an IBM computer. This machinery, as well as help and advice, was supplied by the Mexican Oil Company (PEMEX) to whom we are most grateful. The outline of our map was prepared by an OSKAR machine of the UNAM computer center.

Programming. Specific programs have been prepared for the Flora by our different programmers in the last few years. During this time we have had the advice of the staff of CIMASS who have shown a continuing interest in our project. We are indebted especially to Juan Antonio Toledo for his advice and dedication to this program. We would be very happy to give advice on this subject to any floristic project interested in our results.

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