

VERSION 1.0

USER MANUAL FOR GROUP MANAGEMENT IN PM_x



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About this Manual:

The User Manual for Group Management in PMx was developed as a complement of the User Manual for the software PMx. This version (1.0) is written to describe the characteristics of the Group Management Package (with the group pedigree template and the converter, *group2PMx*) and functionalities of group pedigree analysis in PMx version 1.3.20160708. Periodic changes and revisions will be performed to this User Manual as the functionalities of the Group Management Package and group pedigree analysis in PMx continue to be expanded and updated. This Manual and the Group Management Package are distributed free of charge and are available on: www.vortex10.org/PMx.aspx or <https://sourceforge.net/projects/groupmanagement/>

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Many thanks to the following Manual contributors for useful suggestions:
Paula Tataru
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Citations.

The Group-Management Package and *group2PMx* should be cited as:

Jiménez-Mena, B.; Schad, K.; Hanna, N. & Lacy, R.C. (2016) Pedigree analysis for the genetic management of group-living species. *Ecology and Evolution*, **6**: 3067–3078. doi:10.1002/ece3.1831

Jiménez-Mena, B.; Schad, K. & Lacy, R.C. (2015) User Manual for group management in PMx. Version 1.0. Available from <http://www.vortex10.org/PMx.aspx> or <https://sourceforge.net/projects/groupmanagement/>

The PMx software should be cited as:

Ballou, J.D., Lacy, R.C., & Pollak, J.P. (2014) PMx: Software for demographic and genetic analysis and management of pedigreed populations (Version 1.3.20150713). Chicago Zoological Society, Brookfield, Illinois, USA. Available from <http://www.vortex10.org/PMx.aspx>

Lacy, R.C.; Ballou, J.D. & Pollak, J.P. (2012) PMx: Software package for demographic and genetic analysis and management of pedigreed populations. *Methods in Ecology & Evolution* 3:433-437.

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SECTION 1: Introduction

One of the main aims of zoos and aquariums is to contribute to the conservation of biodiversity by retaining as much genetic diversity of the species as possible, as well as maintaining the sustainability of their *ex situ* collections. This is generally done by registering the information about each individual in the population, their parentage and breeding pairs. Using this pedigree information to design the breeding programs, it is possible to manage the population. However, there are numerous species/taxa that i) cannot be individually identified and ii) are typically managed in tanks/groups and thus the control of matings is complicated (Wang, 2004). Many groups of amphibians, reptiles, fishes, birds and also mammals, such as primates and ungulates (Wang, 2004; Smith, 2010), are group-living organisms. In order to optimally manage these kinds of organisms and address their challenges, zoos and aquariums have worked on extending the use of pedigree analysis for managing groups, in so called *group management* (Leus *et al.*, 2011).

The software PMx (Ballou *et al.*, 2014; Lacy *et al.*, 2012) allows the conservation community to perform demographic and genetic analysis of populations from which pedigree data are available. This program was created to analyze pedigree data from individual records as registered and stored in SPARKS (ISIS, 2012) and PopLink (Faust *et al.*, 2012), but also allows for the analysis of data from group-living organisms. The package described in this manual helps storing and importing group data into PMx. This package consists of:

- (i) a **data entry sheet in Excel** that allows registration of group data, and
- (ii) **group2PMx**, a converter that transforms the Excel file into a .csv file readable by PMx.

Note that the data entry sheet in Excel can also be used for individual records in addition to groups. This will allow conservation managers outside the zoo and aquarium community (without access to SPARKS or PopLink) to have a user-friendly template in Excel in which to register the individuals of the population and still perform an analysis in PMx.

Given a complete and accurate pedigree, individual management is the best strategy to manage a population. In general, one should be aware that group management will not be as accurate as individual management, but it is better than not managing the population at all and thus becomes the recommended strategy for managers of these types of organisms.

Getting started

System requirements

group2PMx.exe is written in Python 2.7 . It has been tested on Windows XP and 7. *group2PMx* can run on 32-bit or 64-bit processors. For Linux users, the Python script is provided. See the PMx Manual for information about the system requirements of PMx (Traylor-Holzer, 2011).

Installation

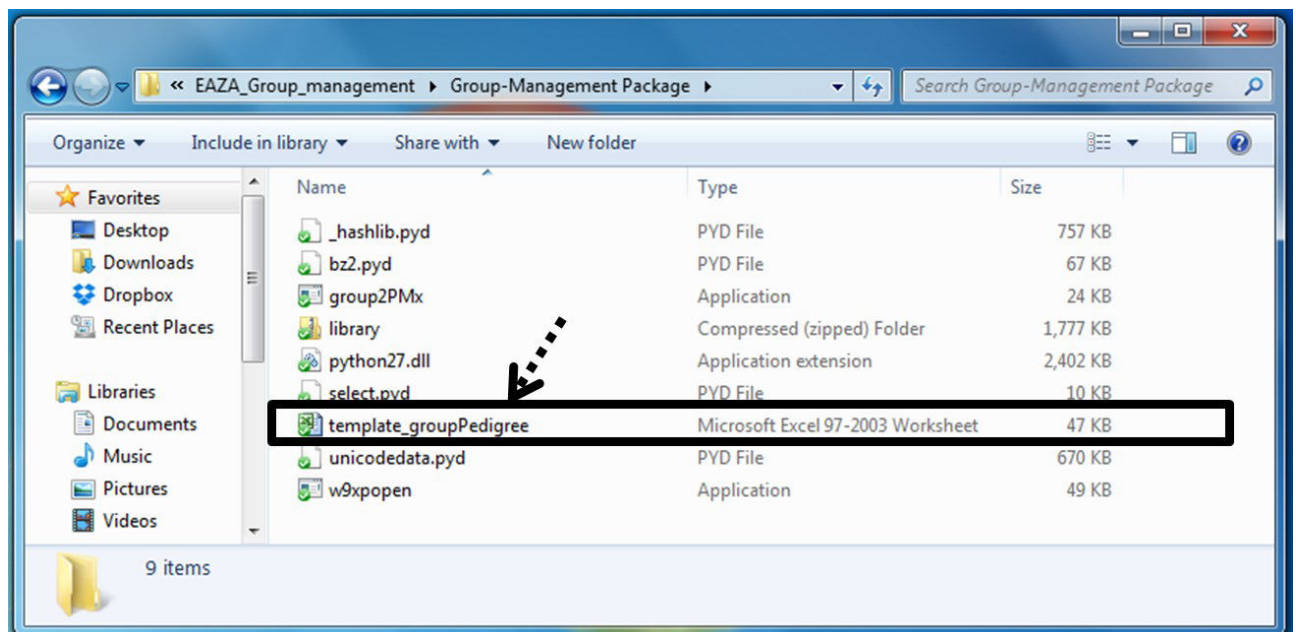
The package is freely available from the website: www.vortex10.org/PMx.aspx, or <https://sourceforge.net/projects/groupmanagement/> Click “Save File” and choose the folder where to store it in your computer. Unzip the .zip file.

SECTION 2: the group data entry sheet template

The group data can be stored in the group data entry sheet template provided in the Group Management Package. In this section, we describe the structure of the data entry sheet and how to fill it in with the group data collected from the population to be managed.

Location

The Excel spreadsheet *template_groupPedigree* is found in the main folder of the Group-Management Package.



Structure of the data entry sheet

Note that the format for some data fields in PMx is more flexible than what is described below. However, to avoid confusion it is better to use the rules given here. For a more complete description of the various formats that can be used with PMx, refer to the PMx manual (Traylor-Holzer, 2011).

Header section (lines 3-12; blue background)

The first lines/rows of the spreadsheet correspond to the header where information about the dataset and analysis can be filled in (i.e., species, dates, authorships, etc.). Each line begins with '*'. The structure must not be modified. As stated in the spreadsheet, the user can add other header lines, if useful, and these should always start with '#'. These header lines are ignored by PMx but can be useful for the manager for clarification.

The header lines included in the spreadsheet template are:

- **ID:** Descriptive header – this is a description about your studbook, but is optional (e.g., Salamander groups studbook)
- **Scientific name:** the scientific/Latin name of the species in this studbook
- **Common name:** the common name of this species in this studbook
- **Exported on:** the date you are analyzing the data
- **Software version:** this is always filled with “group data sheet” to differentiate this analysis from others coming from SPARKS. The spreadsheet template is already filled with this information and nothing should be changed. In case the spreadsheet is used to record individual-based populations (e.g. users from outside the zoo community), this field can be changed to “individual-based population data sheet” if applicable
- **Scope:** the regional association or geographic region in which the studbook is maintained (e.g., EAZA, international)
- **Current to:** the date in which the entire studbook is updated to
- **Compiled by:** the Studbook Keeper’s name and institution

Lines required for PMx (lines 15-23; purple background)

The line below *#Name of the fields* and *# FIELDS* (indicated below) should not be erased or modified as it makes reference to the entered data of the group/individual and is needed for the correct function of PMx. Note that the line *# FIELDS* specifies the sequence of data fields in all individual records, so it is critical that it be included and correct. Each semicolon separates a different column (“;” indicates an entry in a new cell in the Excel spreadsheet); we will use this notation throughout the document.

*FIELDS: ID; Entity; Size; Sire; Dam; Sex; ReproStat; Selected; Living; BirthType; DOB; DOBest; DOD; DODest; Location; Rearing; BirthLoc; BProgram; BCountry; Necr1; LocalID; Program; Country; Transponder; Tag; Tattoo; Color; AsstRep

Note that the #FIELDS line contains the actual names of the column information from the Group/Individual entries (from line 25) that PMx is actually analysing. To help the user, the headers in Group/Individual entries (from line 25) have been modified accordingly to make the dataset clearer. For example, the entry “Included in Genetic Analysis” corresponds in #FIELDS to “Selected”.

Several header lines (with first cell as *MULT, *MULTPROBS and *MOVE) describe the format of lines that specify the structure of the parentage data and move records sections. These lines begin with ‘*’ and are ignored by PMx.

Group/Individual entries (from line 25)

Each group/individual record must be registered in one line. The data fields’ names from above that are filled in red are required by PMx and thus should be filled for each group/individual. The field columns in blue are not essential and PMx can work without this information. The fields must remain in the given order (see above *Lines required for PMx*). There cannot be any blank lines in this section; a commented line (a lineline starting with #) can be used instead.

The required entries (in Red) are:

- **ID:** The identifier used for a group/individual throughout the project, typically the studbook number. To avoid errors in computations in PMx, it is required that a group name must start with the letter “G”; the rest is flexible to the User. For instance, a group can be named using the word “GROUP” (lowercase or uppercase) followed by letters (“A”, “B”, etc.). A space can be added between GROUP and the letter, (e.g., “GROUP G”). Whichever option is chosen (“GROUPG”, “GROUP G”, “GroupG”, “Group_G”), it must be consistent throughout the pedigree because PMx would recognize “GROUPG” and “GROUP G” as different groups.
- **Entity:** This field should be filled with “GROUP” when group-managing a population. If the Entity field is left blank, PMx assumes that the line is an individual.
- **Size:** The number of individuals forming the group. If the Size field is left blank, PMx assumes this to be 1.
- **Sire:** For individuals, this entry corresponds to the unique ID of the sire (male parent), or “WILD” or “UNK” if the individual is wild caught or has an unknown origin. For groups, this entry has a different meaning and corresponds to the breeding type that has generated the creation of the group. The options are “GROUP”, “MERGE”, “SPLIT” (see Section 5 for an explanation of each of these terms). For these, an extra line indicating the parental group name is required to be inserted in the Parentage data section (see below). As for individuals, this entry can also be “WILD” if the group is wild caught.
- **Dam:** For individuals, this corresponds to the unique ID of the dam (female parent), or “WILD” or “UNK” if the dam is wild caught or unknown, respectively. For groups, this entry must always be filled by “GROUP” (see

below the explanation for this term) and an extra line indicating the parental group name is required to be inserted in the Parentage data section (see below). Other options are: "WILD" if the group/individual is wild caught.

- **Sex:** The gender of a group/individual. The options are "Female", "Male", "Hermaphrodite", "Abnormal", "Asexual", "Unknown" (or "U") or "Both". When a group is formed by all females or all males, the sex should be indicated as "Female" or "Male". Whenever the sex is not known or individuals of both sexes are mixed together, the sex should be indicated as "Unknown" or "Both".
- **Reproductive Status:** The reproductive status of a group/individual. The options are: "Fertile" (living individuals that are presumed capable of breeding), "Contracepted" (living individuals contracepted), and "Sterilized" (individuals permanently sterilized). If group/individuals are not listed as "Contracepted" or "Sterilized" in the studbook, they will appear as Fertile in PMx by default, which may or may not be accurate.
- **Included in Genetic Analysis:** This entry indicates if this group/individual is able to be part of the breeding program. The options are "True" or "False". "True" means that the group/individual is alive and have the ability to reproduce now or sometime in the future; "False" means that the group/individual are no longer able to reproduce, due to being dead, Lost to Follow Up (LTF), permanently sterilized, post-reproductive, or any other reason.
- **Living:** This indicates whether or not the group/individual is currently living or, alternately, no longer exists in the population. The options are: "True" or "False".
- **BirthType:** The birth origin of the group/individual. The options are: "Wild Born", "Captive Born", "Other", or "Unknown".
- **Date of Birth:** The date of birth or hatch of the group/individual, formatted in the following specific format:

yyyymmdd

(e.g., 15 March 2011 should be entered as 20110315).

- **Estimate for Date of Birth:** The date of birth estimate indicates the resolution to which the birth date can be estimated, if it is not a known date. Fields are coded as "Exact" (a blank or "None" is also treated as exact), "U" (for an unknown date), "Y" or "Year" (known only to year), "M" or "Month" (known only to month), or "D" or "Day", with each of Y, M, and D optionally followed by an integer to indicate the number of years, months, or days to which a date is known (e.g., +/- 2 months would be entered as "M2").
 - **Date of Death:** The date of death is the date of the group/individual's actual death even if this occurred outside of the project date span. Date fields in text files must be formatted as for Date of Birth in the following specific format:
- yyyymmdd
- (e.g., 15 March 2011 should be entered as 20110315).
- **Estimate for Date of Death:** The date of death estimate is the resolution to which the death date can be estimated, if it is not a known date. Same format as Estimate for Date of Birth (see above).
 - **Location Mnemonic:** The current (or last in the case of not living group/

individual) location of the group/individual. The location is usually indicated by the institution's ISIS mnemonic (i.e the mnemonic is "MADRID Z" for Zoo Aquarium de Madrid). If a group/individual left the scope of the project (e.g., was transferred outside the region or association), then Location may not reflect the current living place. It can be left blank.

The optional entries (in Blue) can be deleted by the user if they are not going to be used (and updating the line below *#Name of the fields*, see above *Lines required for PMx*). They are not used for any calculations within PMx, but they can be used for filtering and sorting which animals are displayed in tables in PMx. These optional entries are:

- **Rearing:** The rearing type of the group/individual. The options are: "Parent", "Hand", "Foster", "Peer", "Supplemental", "Unknown", "None", "Colony"/"Group".
- **Birth Location:** The location of birth or hatch of the group/individual. This can be the institution's ISIS mnemonic (e.g., "MADRID Z" for Zoo Aquarium de Madrid).
- **Breeding program at birth:** The breeding program that the group/individual belongs to at the time of birth.
- **Country of birth:** The country of birth or hatch of the group/individual.
- **Necropsy note:** This necropsy note indicates any comment related to the necropsy.
- **LocalID:** The local ID of the group/individual used by the institution indicated in the Location field.
- **Program:** The breeding program that the group/individual is currently part of.
- **Country:** The current country where the group/individual is located.
- **Transponder:** The transponder number of the group/individual used by the institution indicated in the Location field.
- **Tag:** The tag description of the group/individual used by the institution indicated in the Location field.
- **Tattoo:** The tattoo description of the group/individual used by the institution indicated in the Location field.
- **Color:** The color phase or pattern observed and recorded for the group/individual.
- **Assisted Reproduction:** This indicates if any type of assisted reproduction was used to breed the group/individual. The options are: "NotAsstRep" (no assisted reproduction was used) or "AsstRep" (assisted reproduction was used).

Parentage data section

Depending on the information given in Sire/Dam, some extra information is needed. If a group is formed by a GROUP, MERGE, or SPLIT (and therefore, Sire = GROUP, MERGE, or SPLIT and Dam=GROUP; see Section 5), information about the parental groups/individuals' ID and the number of individuals contributed by each group must be inserted in this section (note that there are several currently acceptable formats). Instead of the actual count number, it is possible to use a proportion to show how

much of the parental group is included here (e.g., 0.3).

The format should be:

```
*IDAM: name of the group/individual; dam1ID; prob1  
*IDAM: name of the group/individual; dam2ID; prob2
```

where the *dam IDs* are the IDs of the parental groups and *prob* is the number of individuals or probability (proportional contribution) of each parental group. For example, if GroupM has been formed with 5 and 6 individuals from GroupAAR and GroupCPH, respectively, the parentage line is as follows:

```
*IDAM: GroupM; GroupAAR; 5  
*IDAM: GroupM; GroupCPH; 6
```

Instead of listing all parental groups and their contributions on separate lines, we can write the same information in a more condensed format using *IDAMS (with an 'S') and *IDAMPROBS:

```
*IDAMS: name of the group/individual; dam1ID; dam2ID  
*IDAMPROBS: name of the group/individual; prob2; prob2
```

And the example,

```
*IDAMS: GroupM; GroupAAR; GroupCPH  
*IDAMPROBS: GroupM; 5; 6
```

Note that "IDAM" does not explicitly refer to the sex of the individuals; it just indicates the parental group from which the group/individual was generated. In the case of a SEXUAL MERGE (see Breeding Systems for groups in Section 5) we use both *IDAM (and *IDAMS) and *ISIRE (or *ISIRES). In this case we actually know that a specific group has only males and another specific group has only females, and we are using both groups to create the new offspring group. Then the user can indicate the extra lines for the parents as follows:

```
*IDAM: name of the group/individual; damID; prob  
*ISIRE: name of the group/individual; sireID; prob
```

Or equivalently:

```
*IDAMS: name of the group/individual; dam1ID; dam2ID  
*IDAMPROBS: name of the group/individual; prob2; prob2  
*ISIRES: name of the group/individual; sire1ID; sire2ID  
*ISIREPROBS: name of the group/individual; prob2; prob2
```

If the number of individuals that form the group or probabilities are not specified (in

either style above), they are assumed to be equal across all possible group sires or dams.

Move records section

The record of individuals moved in and out of populations can be inserted in this section with the format indicated below:

*MOVE: ID; Date of Event; Estimate for Date of Event; Move Event to New Situation; Date Event Ends; Estimate for Date Event Ends; Move Event Leaving Situation; Location Mnemonic; Notes

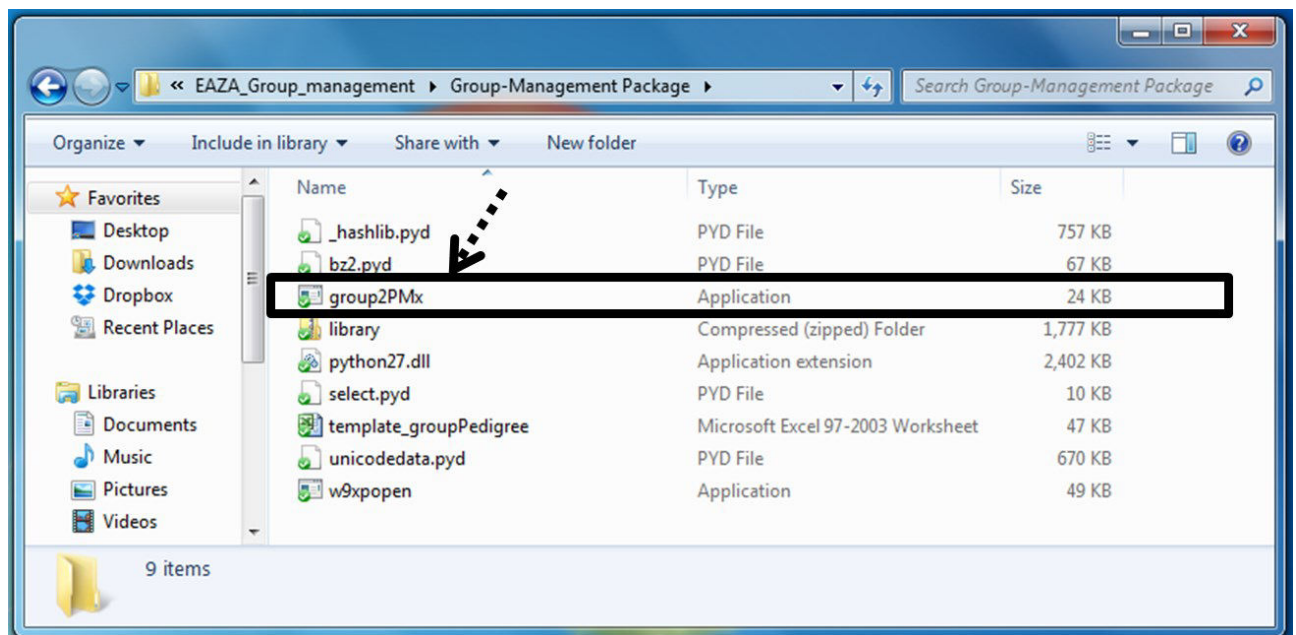
- **ID:** The group/individual identifier.
- **Date of Event:** The date of the “move/transfer” event. The date fields coded as specified above for “Date of Birth” and “Date of Death” in the section of Group/Individual entries.
- **Estimate for Date of Event:** The resolution to which the “Date of Event” can be estimated, as detailed before for “Estimate for Date of Birth” and “Estimate for Date of Death” in the section of Group/Individual entries.
- **Move Event to New Situation:** This entry indicates how the individual or group entered the population. The options are: “*birth*”, “*capture*”, “*found*” (individual/group that appeared in the exhibit and no one knows how it got there, *e.g.*, an unobserved birth, a wild animal that got into the exhibit, etc.), “*import*” (individual/group obtained from another institution), “*leftentry*” or “*entry*” (individual/group that entered the population sometime after its birth, but it is not recorded previously in the studbook. Differs from “*Import*” in which there is no specification about where it came from).
- **Date Event Ends:** The date when the group/individual left the population. The date fields coded as specified above for “Date of Birth” and “Date of Death” in the section of Group/Individual entries.
- **Estimate for Date Event Ends:** The resolution to which the DateOut date can be estimated, as detailed before for “Estimate for Date of Birth” and “Estimate for Date of Death” in the section of Group/Individual entries.
- **Move Event Moving Situation:** This indicates how the group/individual left the population. The options are: “*death*”, “*release*” (individual/group released into the wild), “*lost*” (there is any information about the individual/group), “*export*” (sent out of the population to some location that is not included in the studbook), “*rightexit*” or “*exit*” (removed from the population by an unspecified means), or “*alive*”. In the case of groups, whenever an individual is being merged with a group or other individuals, it should be specified as “*exit*”.
- **Location Mnemonic:** The new location of the group/individual, indicated by the institution’s ISIS mnemonic.
- **Notes:** The notes can be any additional text about this group/individual.

SECTION 3: Importing the group pedigree data into PMx (group2PMx)

In this section, we describe how to convert the Excel data entry sheet filled with the pedigree data into a file readable by PMx. The user needs to run *group2PMx*, which with just one click will easily convert the data.

Location

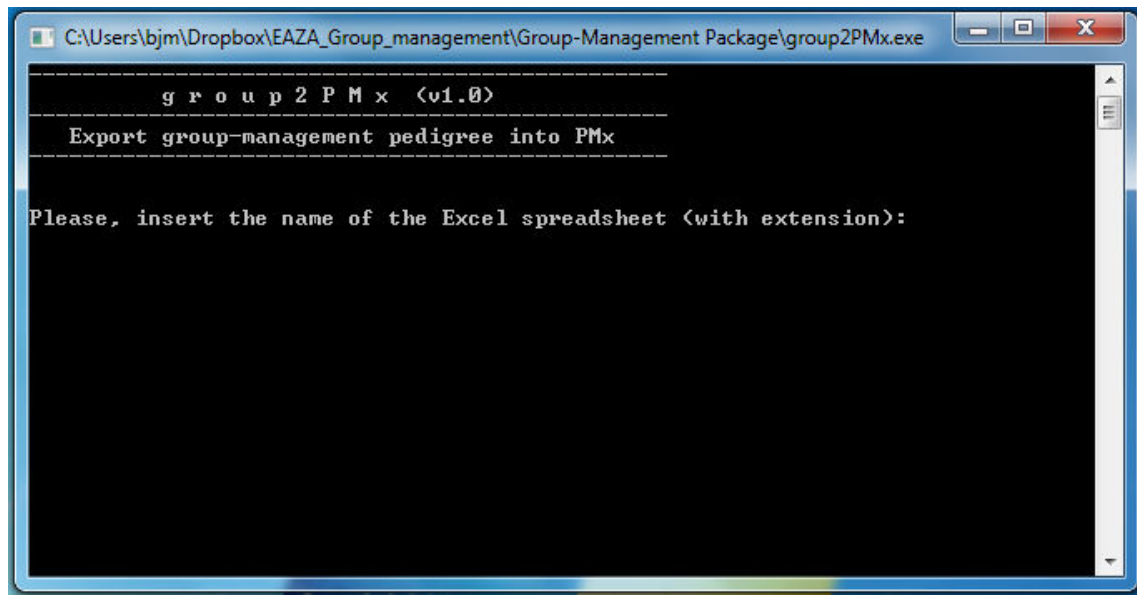
The executable *group2PMx* is located in the Group Management Package.



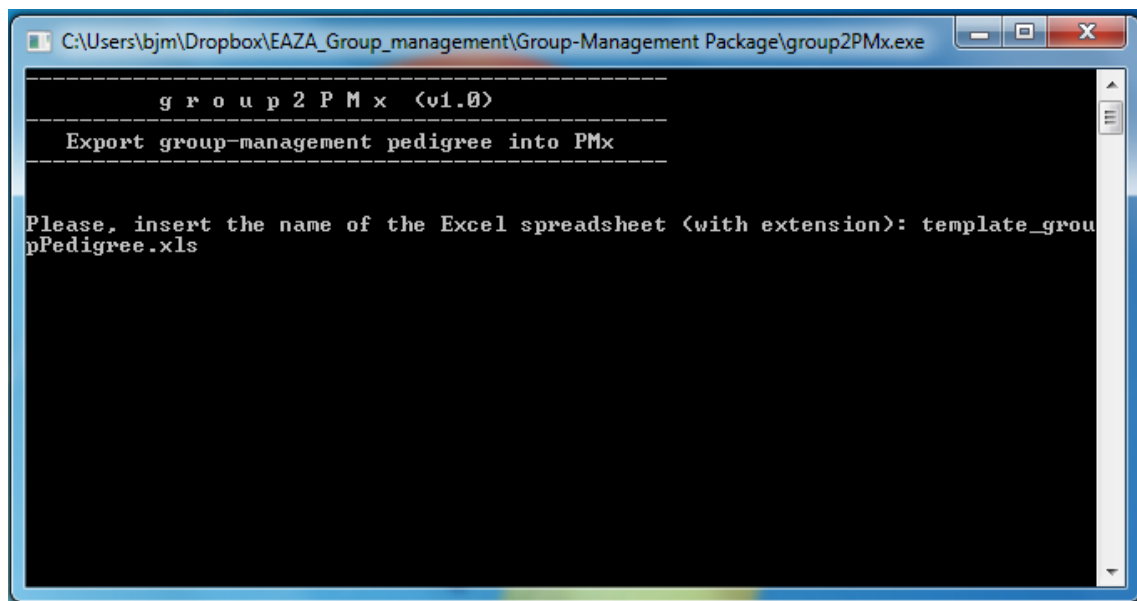
The folder contains other files apart from the *template_groupPedigree* Excel template and the *group2PMx* executable; these files are required by the converter and should not be deleted or moved.

Steps to convert the pedigree file

Double-click on *group2PMx*. A black screen will appear where you need to specify the name of the spreadsheet file (do not forget the extension: .xls, .xlsx, etc).

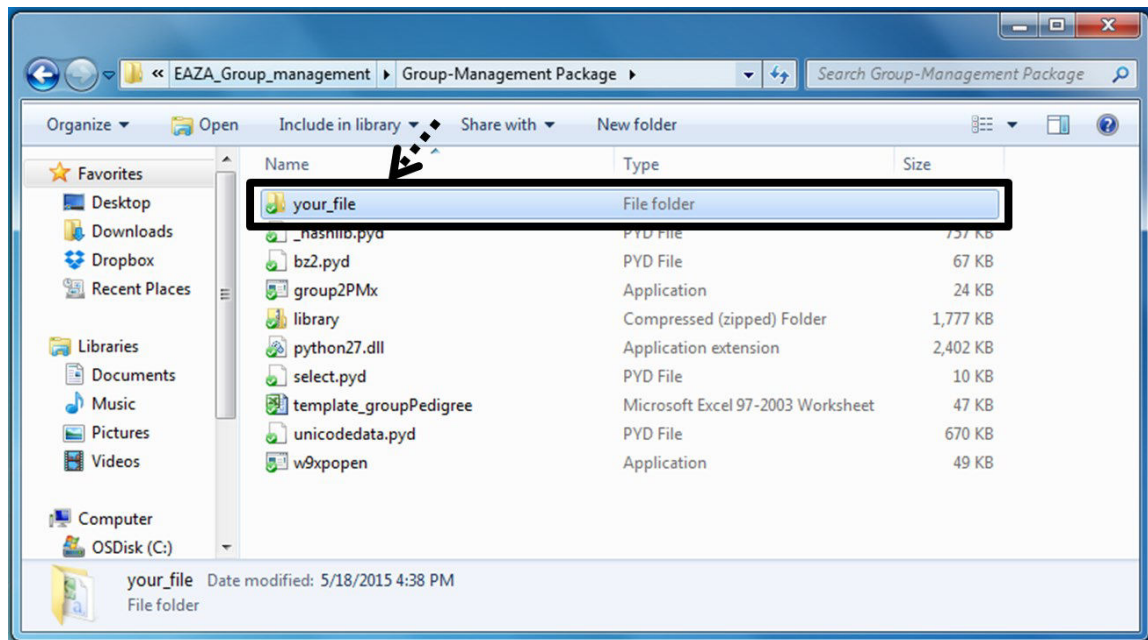


If the spreadsheet is in the same folder as the executable, the user can just provide the name of the file and the extension (for example: "template_groupPedigree.xls"). If the spreadsheet is in another folder than the executable, the relative path should be provided (for example: C:\Documents\ ... \template_groupPedigree.xls).

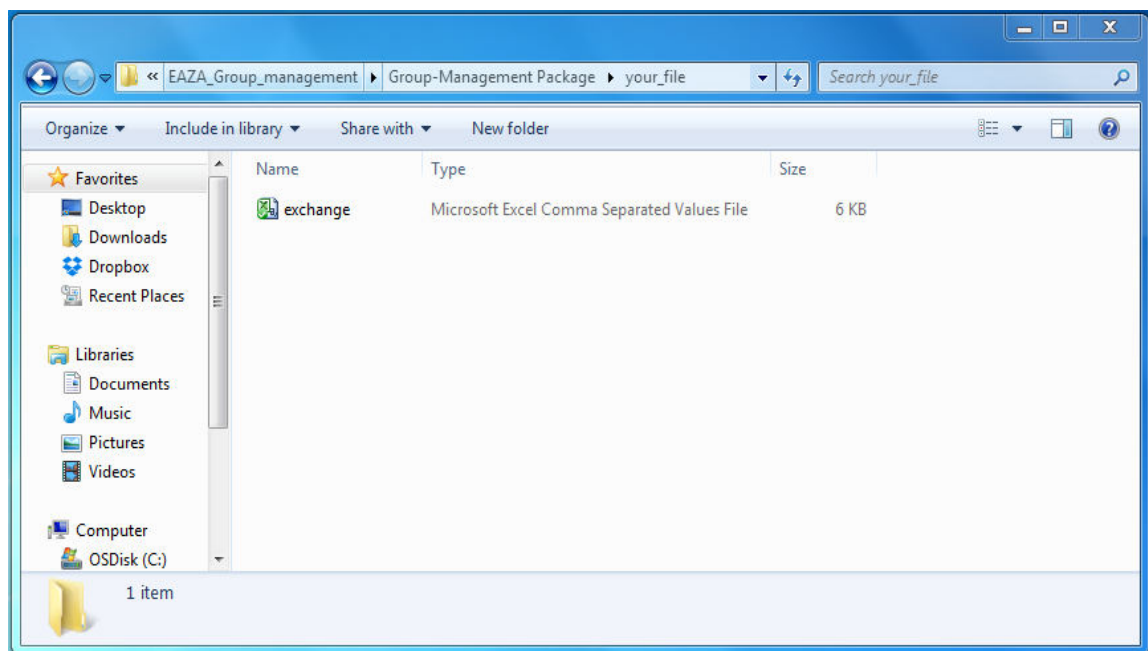


Output file

After specifying the correct path and name of the file, a subfolder, "your_file", should have been created. If the subfolder does not appear, try to reload the main folder.



The exchange file generated by *group2PMx* should be inside the subfolder “your_file”.



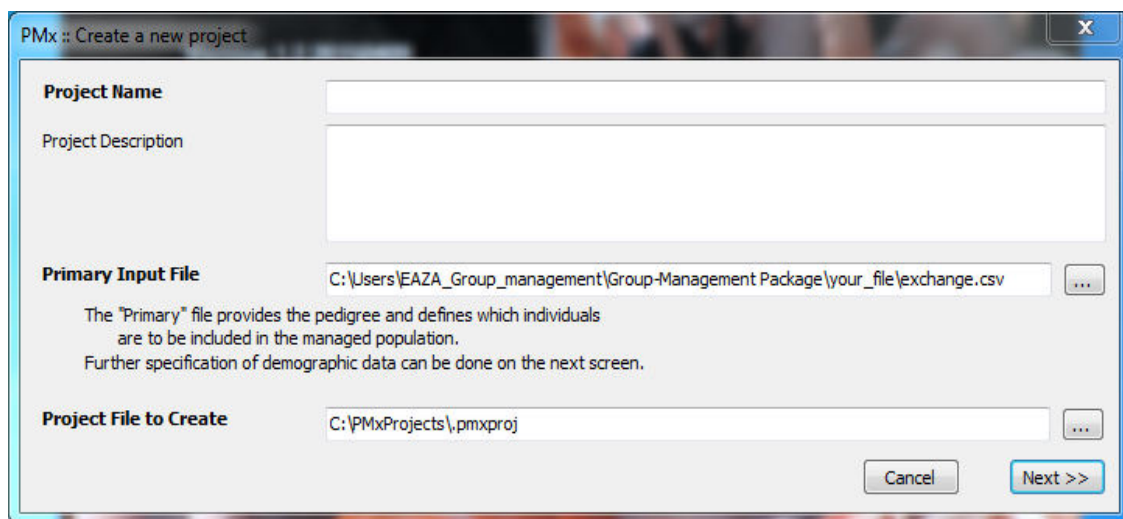
SECTION 4: Creating a project in PMx from the converted file

Here we summarize the steps to start using PMx with our data and how to create a project. The information found below has been obtained and adapted from the PMx manual (Traylor-Holzer, 2011).

1. The software PMx and the Manual, if not installed yet, can be downloaded from: <http://www.vortex10.org/PMx.aspx>
2. Once PMx is installed on your computer, open it.



3. Select *New Project* and create a project name.
4. The exchange.csv file can now be used directly in PMx as the “Primary input file”. Then click on *Next*.



5. No *Demography* or *Additional Optional Input File* needs to be specified because enough information is already contained in the spreadsheet (the *Primary Input File - exchange.csv*). See Traylor-Holzer (2011) to read more about other Input files.
6. Click on *Create*. Once PMx opens to the initial **Project Notes** screen, select *File* > *Save Project*.

PMx :: Create a new project

Demography Input Files (Optional -- specify files if the population view for demography is to be different than for genetics)

☐ Life tables in .PRN format

Female

Male

☐ Move records in .CSV format

for Demography

for Genetics

☐ Move records in .MOV format

☒ Apply moves to both Demographic and Genetic views ☐ Apply moves to Demographic view only

Additional Optional Input Files

Census

Associations

<< Back Cancel Create

SECTION 5: Navigating into pedigree analysis of group management

Understanding group management

Like individual management, group management is based on the theory of population genetics. It is important to note that once we define a group containing some individuals, we no longer speak about individuals, but instead about a virtual set of genes coming from those individuals. That is exactly the definition of a 'group' in group management: a gene pool of the genes from the individuals. The information about which genes belong to which individual is not used. Any entity can form a group, i.e. with any ploidy (e.g. haploid, diploid, tetraploid). For convenience, here we describe all of the concepts in terms of groups that consist of diploid individuals.

When we include several individuals/groups in the same enclosure to form a new group (for example, 'GROUPA', formed by individuals with studbook IDs 5, 6, 7, 8, 9 and 10), assuming all the individuals are different from one another and are diploid, the individuals contribute their genes to the gene pool as in Figures 2 and 3.

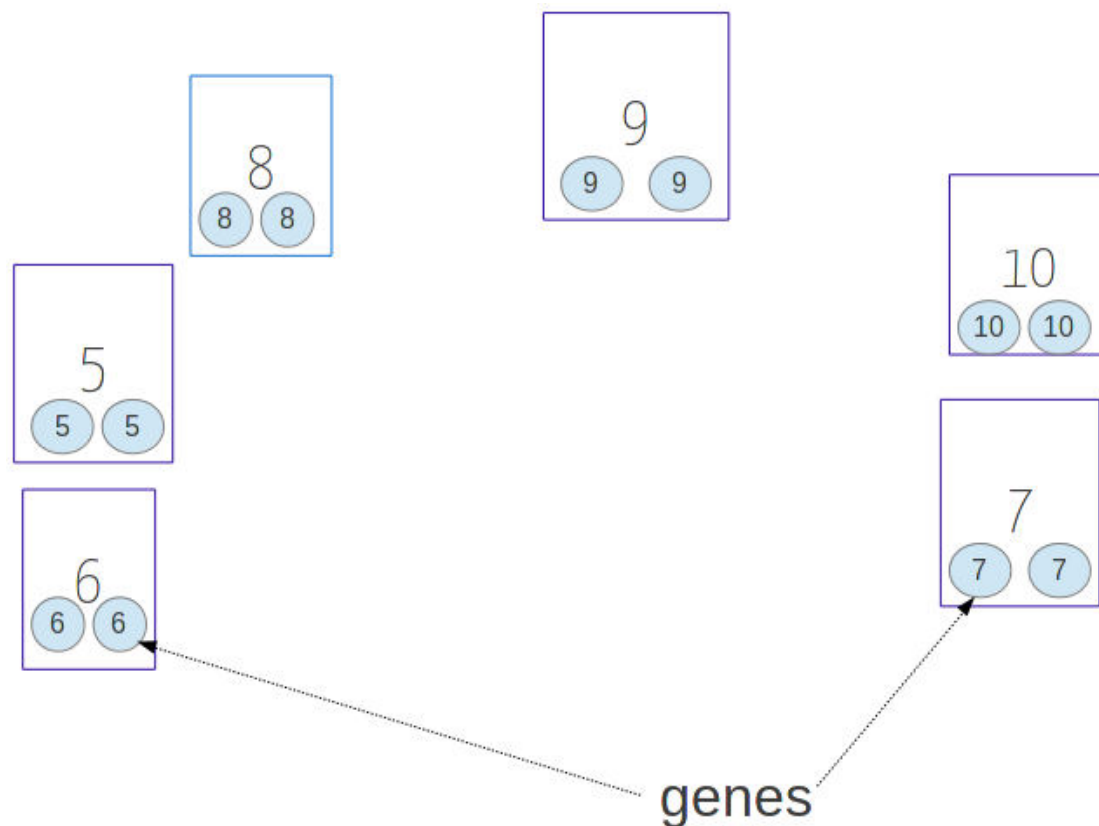


Figure 2: basic scheme representing the genes of the individuals 5, 6, 7, 8, 9, 10

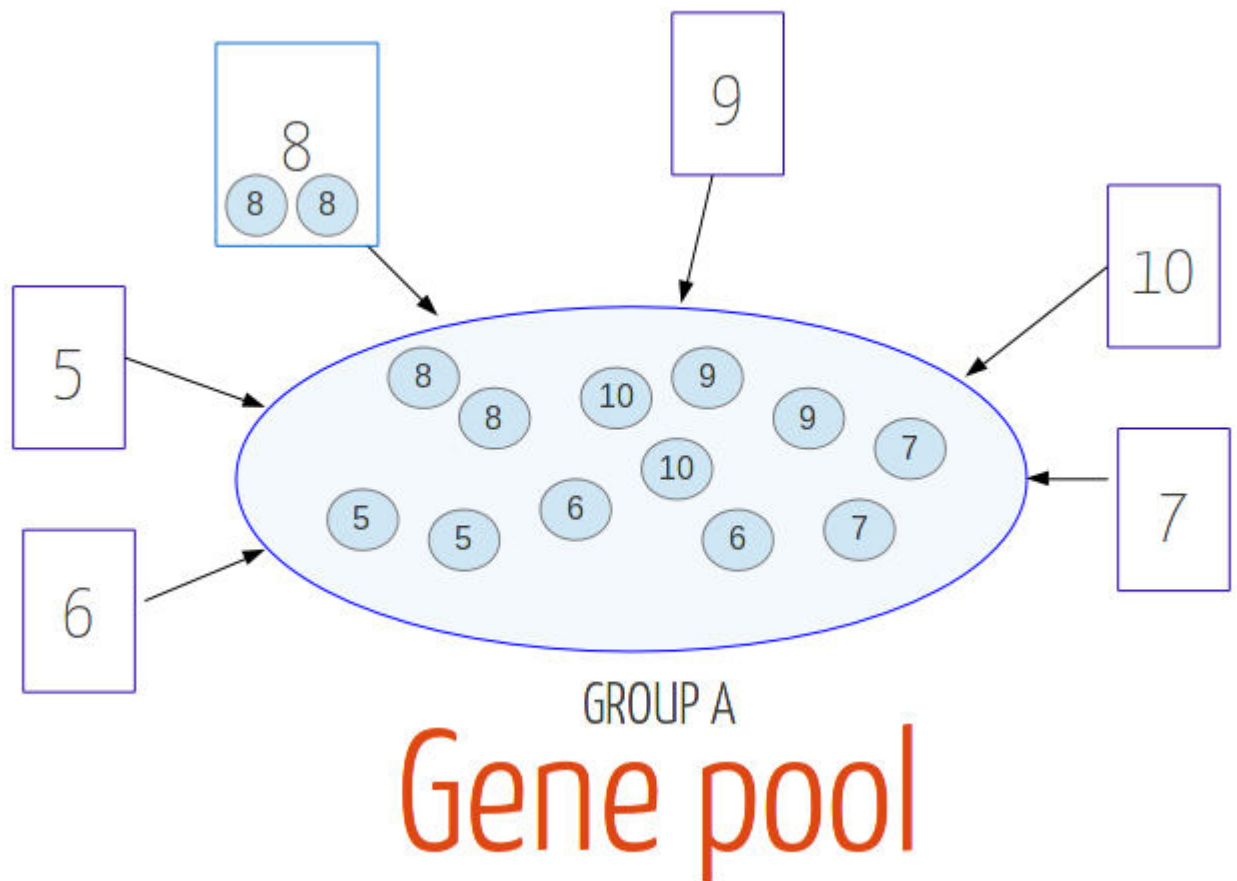


Figure 3: representation of the individuals contributing to form the gene pool that corresponds to groupA. The six individuals are diploid and contribute with two genes to the gene pool. Just for representation, we indicate individual 8 with the two genes on it.

Breeding systems of groups

Computations of genetic parameters for groups in PMx are different depending on the breeding system used to form the offspring group.

The different breeding systems are MERGE, SPLIT and EXTRACT, detailed below.

MERGE

In general, this term refers to the union of individuals or existing groups to form a single group.

We present five management situations where the field 'Sire' should be filled in with MERGE:

- Merge of individuals: let's study the pedigree example represented in Figure 4.

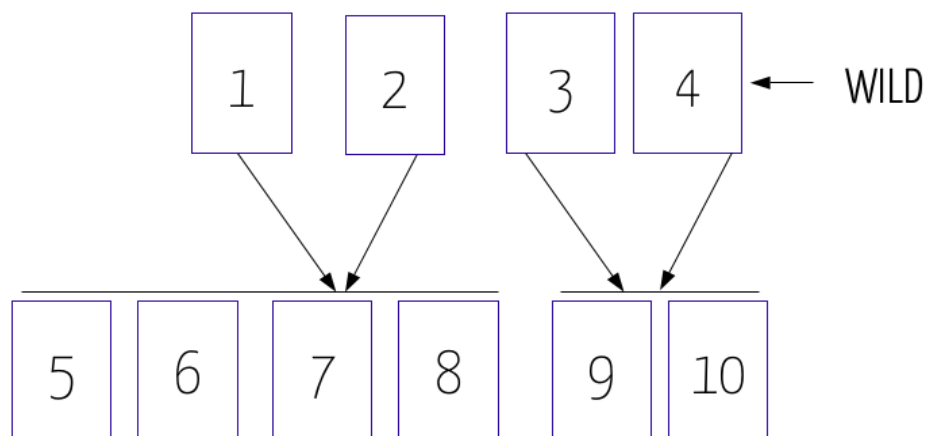


Figure 4: example of a pedigree describing the relationship between ten individuals with ID 1-10. Individuals are represented by square symbols. Generations are connected by a vertical line.

Wild-origin individuals 1, 2, 3, and 4 have given birth to offspring 5, 6, 7, 8, 9, and 10 (Figure 4). Let's imagine we want to form a group with all the offspring and name it 'GROUPA' (Figure 5).

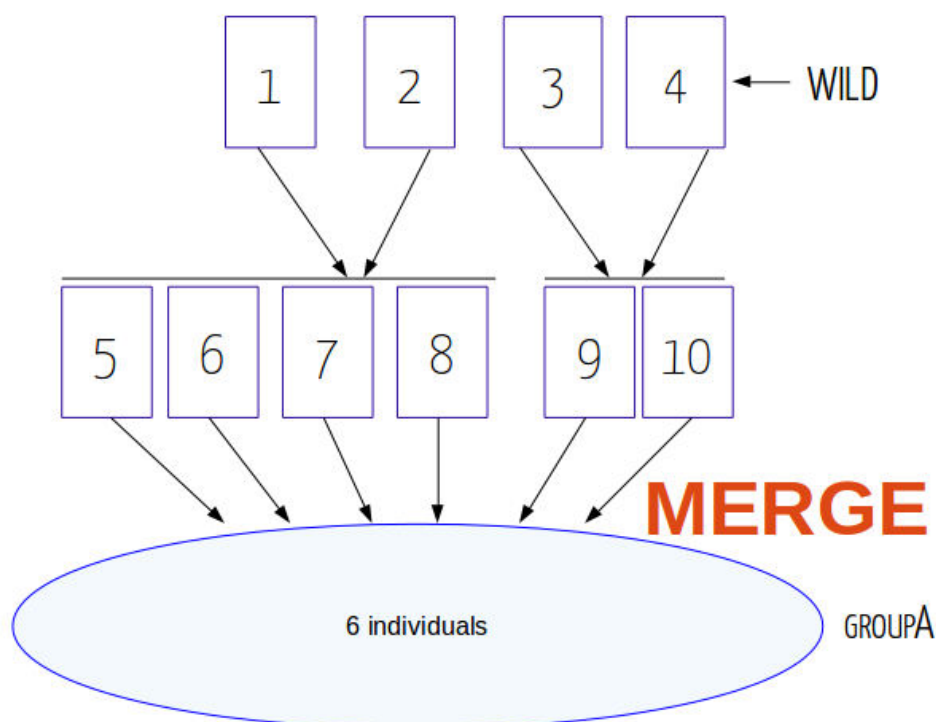


Figure 5: pedigree example in which the individuals 5, 6, 7, 8, 9, 10 are merged to form 'GROUPA'

The data from Figure 5 would be entered in the condensed form as follows:

GROUPA; GROUP; 6; MERGE; GROUP; ...

*IDAMS: GROUPA; 1; 2; 3; 4

*IDAMPROBS: GROUPA; 2; 2; 1; 1

Or

GROUPA; GROUP; 6; MERGE; GROUP; ...

*IDAM: GROUPA; 1; 2

*IDAM: GROUPA; 2; 2

*IDAM: GROUPA; 3; 1

*IDAM: GROUPA; 4; 1

Note that it would also work to first create individuals 5, 6, 7, 8, 9, and 10 from their parents, and then create GROUPA by merging those 6 individuals (each described as a “Dam” of GROUPA).

The above entries use number of individuals, but they can be transformed to probabilities by dividing by 6, the total size of 'GROUPA'.

GROUPA; GROUP; 6; MERGE; GROUP; ...

*IDAMS: GROUPA; 1; 2; 3; 4

*IDAMPROBS: GROUPA; 0.33; 0.33; 0.16; 0.16

EXIT

As a consequence of the merge, the individuals of Figure 5 included in 'GROUPA' (5, 6, 7, 8, 9, 10) are no longer identifiable. Therefore, we need to include 'MOVE' lines indicating that the individuals have “Exited” the population. Below is an example of one of the MOVE lines (one line per individual for more information about the information to add in the “MOVE” line, see *Section 2 -extra lines “MOVE” line*). The date corresponds to the date in which 'GROUPA' was formed.

IMOVE: 3; ; ; 20060302; ; Exit;

- Merge of two or more groups: in Figure 6, 'GROUPC' is formed as a merge of two groups ('GROUPA' and 'GROUPB'). The sum of the individuals from 'GROUPA' and 'GROUPB' will form the total of 'GROUPC'.

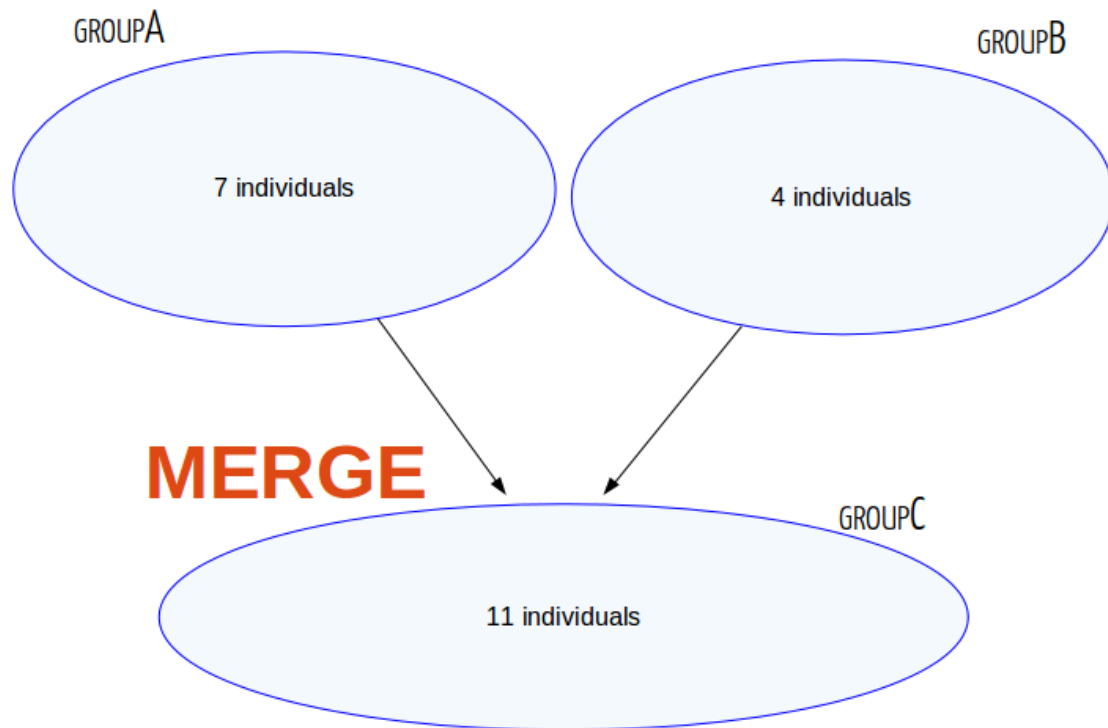


Figure 6: pedigree example in which two groups are merged to form 'GROUPC'

We will indicate this in our Excel sheet (using the condensed form) as:

```
GROUPC; GROUP; 11; MERGE; GROUP; ...  
*IDAMS: GROUPC; GROUPA; GROUPB  
*IDAMPROBS: GROUPC; 7; 4
```

In another example (Figure 7), 'GROUPG' is formed as a merge of three groups ('GROUPD', 'GROUPE' and 'GROUPF'). As before, the sum of the individuals from 'GROUPD', 'GROUPE' and 'GROUPF' will form the total of 'GROUPG'.

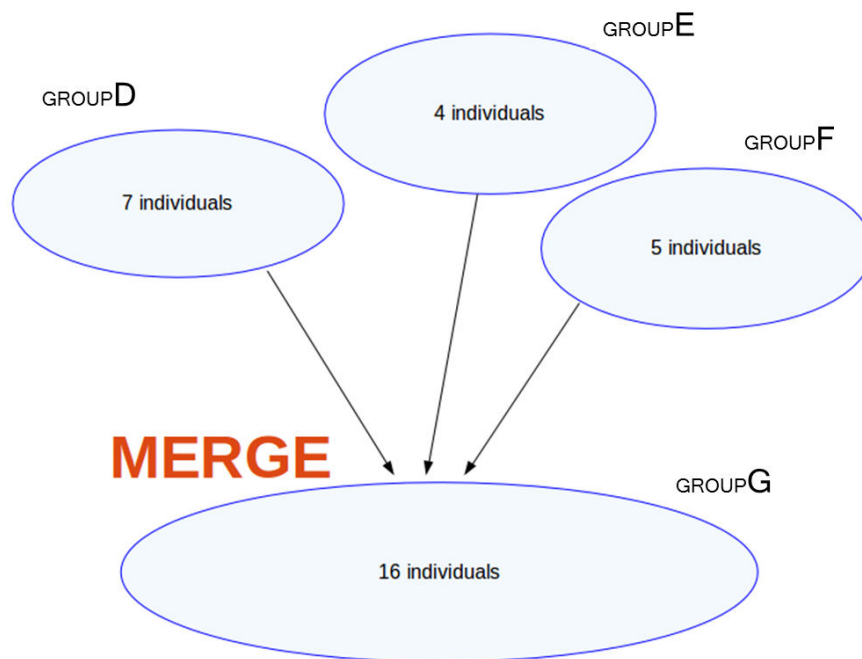


Figure 7: pedigree example in which three groups are merged to form 'GROUPG'

We will indicate this in our Excel sheet as:

```

GROUPG; GROUP; 16; MERGE; GROUP; ...
*DAMS: GROUPG; GROUPD; GROUPE; GROUPF
*IDAMPROBS: GROUPG; 7; 4; 5
  
```

- Merge of an all-male group with an all-female group: this is a particular case of merging two groups, where we know with certainty that one of the groups is formed by all males, and the other group is all females. This is called a *sexual merge*. For example, if in Figure 6, GROUPA contains only males and GROUPB contains only females, we have

```

GROUPC; GROUP; 11; MERGE; GROUP; ...
*IDAM: GROUPA; 7
*ISIRE: GROUPB; 4
  
```

- Merge of an individual with an already existing group: As we can see in the pedigree example from Figure 8, an individual (with ID=3) is introduced into 'GROUPA', creating 'GROUPB'.

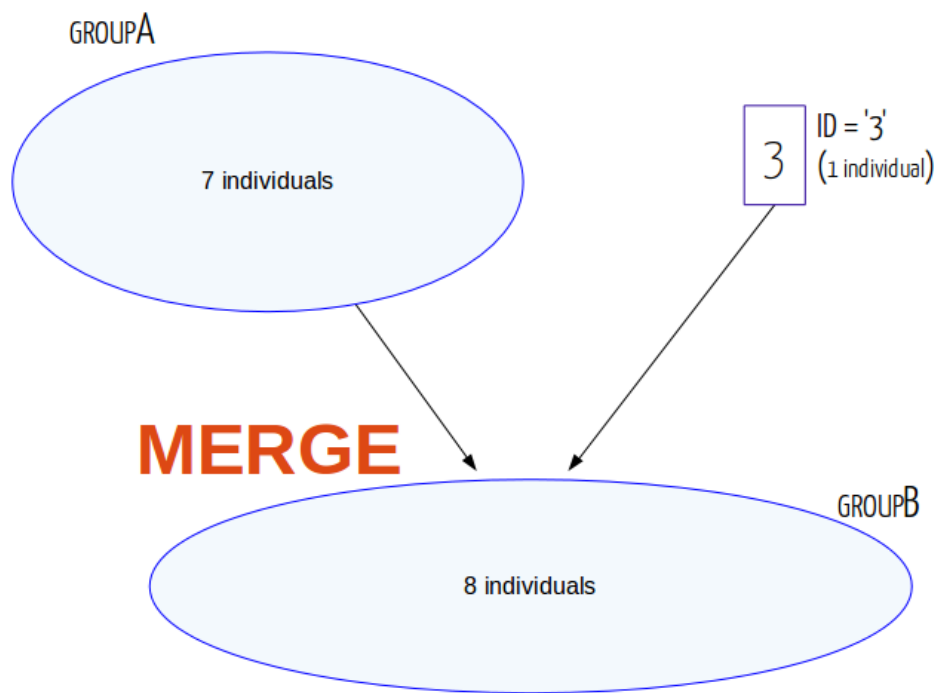


Figure 8: pedigree example in which one group and a single individual are merged to form 'GROUPB'

In the Excel data entry sheet, we can indicate this by:

```
GROUPB; GROUP; 8; MERGE; GROUP; ...
*IDAMS: GROUPB; GROUPA; 3
*IDAMSPROB: GROUPB; 7; 1
```

SPLIT

This term refers to the situation in which a group reproduces and gives birth to a new generation of individuals, or when part of a group is separated from a parental group to form another group or an independent individual.

- The group is formed by reproduction of a parental group. The offspring can either stay in the same enclosure as the parental group (and then the original group will increase in size) or be separated to form a new independent group.

If the offspring stay in the same parental group, the size of the new group (formed by the parents and offspring) has increased. Let's imagine GROUPA, formed by 5 individuals, is the parental group. GROUPA reproduces and gives birth to 4 offspring that stay in the same enclosure as the parents. Now we have GROUPA_OFFS with a total size of 9 individuals. This is indicated in the Excel sheet as:

```
GROUPA_OFFS; GROUP; 9; SPLIT; GROUP; ...
*IDAM: GROUPA_OFFS; GROUPA; 9
```

GROUPA is eliminated as it does no longer exist:

*IMOVE: GROUPA; ; ; 20070302; ; Exit;

If the offspring are separated from the parents into a new group, we indicate it as creating a new group (GROUPB):

GROUPB; GROUP; 4; SPLIT; GROUP; ...

*IDAM: GROUPB; GROUPA; 4

- Split a group to form two separated groups: Let's assume that from 'GROUPA', we want to extract 3 individuals and form 'GROUPB'. 'GROUPA' is no longer the same group with the same genetic material, so we denote this new “stage” of 'GROUPA' as a new group 'GROUPC' containing the remaining individuals from 'GROUPA' and eliminate 'GROUPA'.

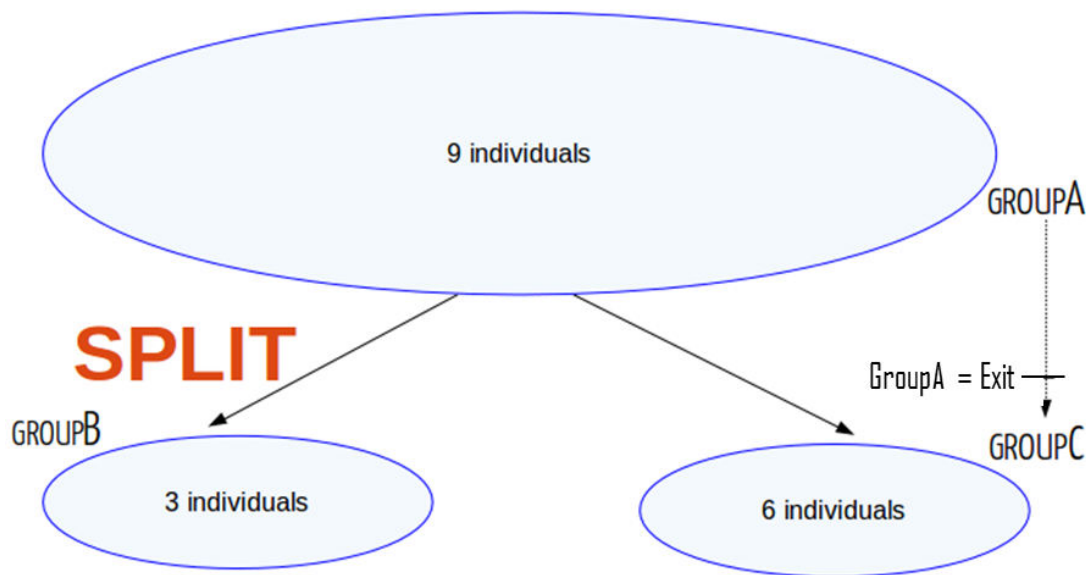


Figure 9: pedigree example in which a group ('GROUPB') is formed by a split from 3 individuals from 'GROUPA'.

In our Excel sheet, we indicate the split of 'GROUPA' in 'GROUPB' and 'GROUPC' as:

GROUPB; GROUP; 3; SPLIT; GROUP; ...

GROUPC; GROUP; 6; SPLIT; GROUP; ...

*IDAM: GROUPB; GROUPA; 3

*IDAM: GROUPC; GROUPA; 6

IMOVE: GROUPA; ; ; 20070302; ; Exit

- Split a single individual from a group: we will indicate this by the term EXTRACT (see EXTRACT section below).

EXTRACT

This term refers to an individual that has been separated or extracted from the group it belonged to. This new entity will be assumed to be an individual by PMx.

Let's study this case with the example represented in Figure 10.

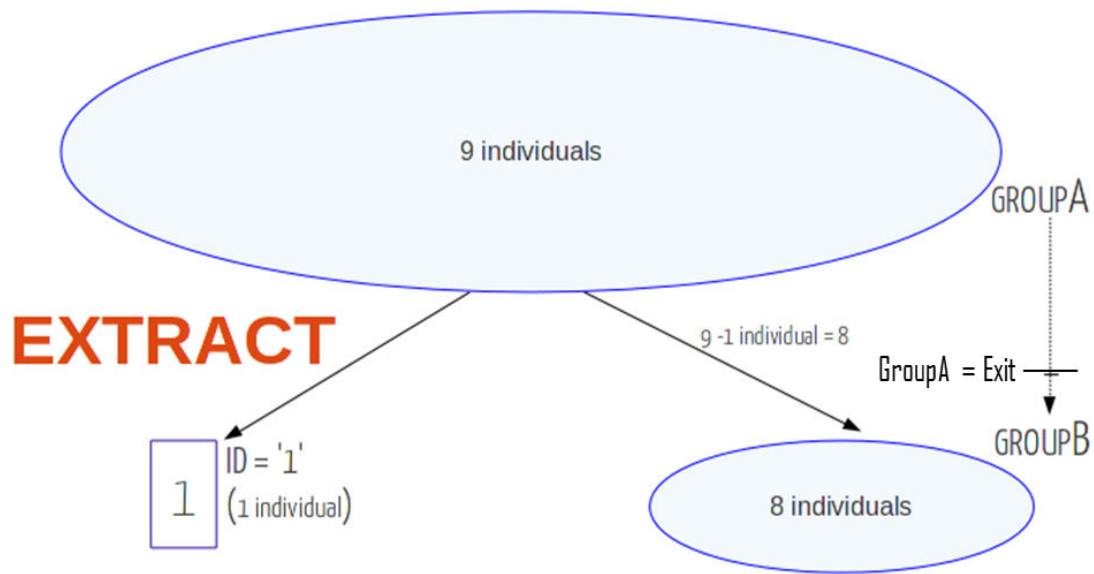


Figure 10: pedigree example in which an individual is created by an extraction from 'GROUPA'

The individual "1" is extracted from 'GROUPA'. 'GROUPA' no longer has the same genetic information, thus, we create another group ('GROUPB') which is smaller than 'GROUPA' by 1 individual, and eliminate 'GROUPA':

```
1; INDIVIDUAL; 1; EXTRACT; GROUPA; ...
GROUPB; GROUP; 8; SPLIT; GROUP; ...
*IDAM: GROUPB; GROUPA; 8
IMOVE: GROUPA; ; ; 20080305; ; Exit;
```

Note that if GROUPA is left to exist in the data set (i.e., not recorded as EXIT), and GROUPB is never formed, then the remaining GROUPA after the removal of the individual will be assumed to have not changed genetically and to still be of size = 9 diploid individuals.

Bibliography

Ballou, J. D., Lacy, R. C. and Pollak, J. P. (2011) PMx: software for demographic and genetic analysis and management of pedigreed populations (Version 1.0). Chicago Zoological Society, Brookfield, Illinois. IL, USA.

Faust, LJ, Bergstrom, YM, Thompson, SD & Bier, L. (2012) PopLink Version 2.4. Lincoln Park Zoo. Chicago, IL.

ISIS (2012). SPARKS (single population analysis and records keeping system) version 1.66. Eagan, MN: International Species Information System.

Lacy, R. C., Ballou, J. D., & Pollak, J. P. (2012). PMx: software package for demographic and genetic analysis and management of pedigreed populations. *Methods in Ecology and Evolution*, 3(2), 433-437.

Leus, K., Traylor-Holzer, K., & Lacy, R. C. (2011). Genetic and demographic population management in zoos and aquariums: recent developments, future challenges and opportunities for scientific research. *International Zoo Yearbook*, 45(1), 213-225.

Smith (2010). Genetic management of groups. Thesis. University of Maryland, US.

Traylor-Holzer, K. (2011). PMx Users Manual, Version 1.0. IUCN SSC Conservation Breeding Specialist Group, Apple Valley, MN, USA.

Wang, J. (2004). Monitoring and managing genetic variation in group breeding populations without individual pedigrees. *Conservation Genetics*, 5(6), 813-825.