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Two centuries of masting data for European beech and Norway spruce across the European continent

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Substantive Area:	Reproductive Strategies < Population Dynamics and Life History < Population Ecology < Substantive Area, Population Ecology < Substantive

	Area, Productivity/Biomass < Ecosystems < Substantive Area, Forestry < Ecosystems < Substantive Area, Plants < Physiological Ecology < Substantive Area, Data < Substantive Area, Databases < Data < Substantive Area, Data paper < Data < Substantive Area
Organism:	Plants, Angiosperms < Plants, Gymnosperms < Plants
Habitat:	Terrestrial < Habitat, Temperate Zone < Terrestrial < Habitat, Deciduous Forest < Temperate Zone < Terrestrial < Habitat, Coniferous Forest < Temperate Zone < Terrestrial < Habitat, Mixed Forest < Temperate Zone < Terrestrial < Habitat
Geographic Area:	Europe < Geographic Area
Additional Keywords:	mast seeding, mast fruiting, pollen, fructification, reproduction, synchrony, tree regeneration

Abstract:

Tree masting is one of the most intensively studied ecological processes. It affects nutrient fluxes of trees, regeneration dynamics in forests, animal population densities, and ultimately influences ecosystem services. Despite a large volume of research focused on masting, its evolutionary ecology, spatial and temporal variability and environmental drivers are still matter of debate. Understanding the proximate and ultimate causes of masting at broad spatial and temporal scales will enable us to predict tree reproductive strategies and their response to changing environment. Here we provide broad spatial (distribution range-wide) and temporal (century) masting data for the two main masting tree species in Europe, European beech (Fagus sylvatica L.) and Norway spruce (Picea abies (L.) H. Karst.). We collected masting data from a total of 347 sources through an extensive literature review and from unpublished surveys. The dataset has a total of 1461 series and 17598 yearly observations from 28 countries and covering a time span of years 1677-2015 and 1791-2015 for beech and spruce, respectively. For each record, the following information is available: identification code; species; year of observation; proxy of masting (flower, pollen, fruit, seed, dendrochronological reconstructions); statistical data type (ordinal, continuous); data value; unit of measurement (only in case of continuous data); geographical location (country, Nomenclature of Units for Territorial Statistics NUTS-1 level, municipality, coordinates); first and last record year and related length; type of data source (field survey, peer reviewed scientific literature, grey literature, personal observation); source identification code; date when data were added to the database; comments. To provide a ready-to-use masting index we harmonized ordinal data into five classes. Furthermore, we computed an additional field where continuous series with length >4 years where converted into a five classes ordinal index. To our knowledge, this is the most comprehensive published database on species-specific masting behaviour. It is useful to study spatial and temporal patterns of masting and its proximate and ultimate causes, to refine studies based on tree-ring chronologies, to understand dynamics of animal species and pests vectored by these animals affecting human health, and it may serve as calibration-validation data for dynamic forest models.

Note: The following files were submitted by the author for peer review, but cannot be converted to PDF. You must view these files (e.g. movies) online.

MASTREE_2016.11.csv

Two centuries of masting data for European beech and Norway spruce across the European continent

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Abstract

Tree masting is one of the most intensively studied ecological processes. It affects nutrient fluxes of trees, regeneration dynamics in forests, animal population densities, and ultimately influences ecosystem services. Despite a large volume of research focused on masting, its evolutionary ecology, spatial and temporal variability and environmental drivers are still matter of debate. Understanding the proximate and ultimate causes of masting at broad spatial and temporal scales will enable us to predict tree reproductive strategies and their response to changing environment. Here we provide broad spatial (distribution range-wide) and temporal (century) masting data for the two main masting tree species in Europe, European beech (*Fagus sylvatica* L.) and Norway spruce (*Picea abies* (L.) H. Karst.). We collected masting data from a total of 347 sources through an extensive literature review and from unpublished surveys. The dataset has a total of 1461 series and 17598 yearly observations from 28 countries and covering a time span of years 1677-2015 and 1791-2015 for beech and spruce, respectively. For each record, the following information is available: identification code; species; year of observation; proxy of masting (flower, pollen, fruit, seed, dendrochronological reconstructions); statistical data type (ordinal, continuous); data value; unit of measurement (only in case of continuous data); geographical location (country, Nomenclature of Units for Territorial Statistics NUTS-1 level, municipality, coordinates); first and last record year and related length; type of data source (field survey, peer reviewed scientific literature, grey literature, personal observation); source identification code; date when data were added to the database; comments. To provide a ready-to-use masting index we harmonized ordinal data into five classes. Furthermore, we computed an additional field where continuous series with length >4 years where converted into a five classes ordinal index. To our knowledge, this is the most comprehensive published database on species-specific masting behaviour. It is useful to study spatial and temporal patterns of masting and its proximate and ultimate causes, to refine studies based on tree-ring chronologies, to understand dynamics of animal species and pests vectored by

these animals affecting human health, and it may serve as calibration-validation data for dynamic forest models.

INTRODUCTION

Masting, i.e., the synchronous and highly variable production of large crops of flowers, fruit or seeds by a population of plants, is a widespread reproductive strategy in tree species (Crone and Rapp 2014, Pearse et al. 2016). It has immediate effects on the regeneration of forest species and cascading effects on the food web, as it provides large quantities of pollen for insects and seeds for frugivore animals (Koenig and Knops 2005). For example, mast years have frequently been linked with animal population dynamics and migrations (Perrins 1965, Boutin et al. 2006). In forestry, masting in trees is critical for scheduling silvicultural treatments (Ascoli et al. 2015). In tree-ring studies, masting usually overlaps and affects the climate signals in tree ring chronologies due to reduced growth in mast years (Mencuccini and Piussi 1995, Koenig and Knops 1998, Drobyshev et al. 2014, Hacket-Pain et al. 2015). Finally, it has important consequences on human health, because of pollen allergies and epidemic diseases vectored by frugivorous (Reil et al. 2015, Bogdziewicz and Szymkowiak 2016).

Despite the extensive literature on masting ecology, its evolutionary context, spatial and temporal variability, and the related proximate drivers are still a matter of debate (e.g., Kelly et al. 2013, Koenig et al. 2015, Pearse et al. 2014, Pesendorfer et al. 2016). Similarly, the effects of climate warming on masting remain to be fully tested (Schauber et al. 2002, Monks et al. 2016). Understanding proximate and ultimate causes (*sensu* Pearse et al. 2016) of masting on a broad spatial (range-wide) and temporal (century) scale could enable better prediction of these reproductive events (Koenig and Knops 2005). In the light of climate change, the calibration and validation of vegetation models accounting for masting-climate interactions could improve models accuracy in predicting species range shifts (Snell et al. 2014) and support the development of adaptive management strategies.

To date, masting data have been largely available at site and regional level to test hypotheses and to build models, but restrictions occur because of their temporal limitation to only a few decades. Several studies have collected extensive data to study masting behaviour over large geographical areas for many plant species. Valuable datasets which contributed greatly to improve masting studies include those published by Herrera et al. (1998), Koenig and Knops (2000), Kelly and Sork (2002), Schauber et al. (2002) and Kelly et al. (2013). However, these datasets consisted of data from many diverse species resulting in a reduced number of observations at single species level e.g., mean observation number is 179 per species in Koenig and Knops (2000; Table 1). In addition, they have rarely exceeded a span of few decades (range in Herrera et al. 1998, Table A1: 4-33 years; range in Kelly and Sork 2002: 6-35 years). In contrast, long-term studies (> century) based on single species are often not continuous and limited in their geographical extent (e.g., *Fagus sylvatica* L. in Southern Sweden in Drobyshev et al. 2014). These shortcomings have restricted the possibility of testing hypotheses on masting and modelling at adequate spatial and temporal scale.

We collected extensive data on masting of two of the most important masting tree species of the European continent: European beech (*Fagus sylvatica* L.) and Norway spruce (*Picea abies* (L.) H. Karst.). The database covers the complete distribution range of European beech and a large proportion of that of Norway spruce in Europe, extending over a period of two centuries. It provides information on annual flowering, airborne pollen, fruit and seed production and consists of both ordinal and continuous data. We included also two mast year series reconstructed using dendrochronology, and a series of pollen concentration in lake sediments assessed at an annual-resolution. To provide a ready-to-use masting index we harmonized ordinal data into five classes. Furthermore, we computed an additional field where continuous series with length > 4 years where converted into a five classes ordinal index. We collected data from published and unpublished studies. Data sources are fully documented.

Potential uses of this database (here after MASTREE) include testing hypotheses on proximate and ultimate causes of masting, calibration and validation of tree masting models, assessing the effects of climate change on tree reproduction investment, and an enhanced understanding of the effects of masting on tree ring chronologies. Furthermore, MASTREE is a reference masting database that is not restricted to its initial component species or to geographical region.

METADATA

CLASS I. DATA SET DESCRIPTORS

A. Data set identity: The tree masting database (the MASTREE database)

B. Data set identification code: MASTREE_2016.11.csv

C. Data set description

1. Originators: Davide Ascoli, DISAFA, Largo Paolo Braccini 2, 10095 Grugliasco, Torino, Italy and Dipartimento di Agraria, University of Naples Federico II, via Università 100, 80055 Portici, Napoli, Italy; Janet Maringer, Institute for Landscape Planning and Ecology, Keplerstr. 11, 70174 Stuttgart, Germany.

2. Abstract

Tree masting is one of the most intensively studied ecological processes. It affects nutrient fluxes of trees, regeneration dynamics in forests, animal population densities, and ultimately influences ecosystem services. Despite a large volume of research focused on masting, its evolutionary ecology, spatial and temporal variability and environmental drivers are still matter of debate. Understanding the proximate and ultimate causes of masting at broad spatial and temporal scales will enable us to predict tree reproductive strategies and their response to changing environment. Here we provide broad spatial (distribution range-wide) and temporal (century) masting data for the two main masting tree species in Europe, European beech (*Fagus sylvatica* L.) and Norway spruce (*Picea abies* (L.) H. Karst.). We collected masting data from a total of 347 sources through an

extensive literature review and from unpublished surveys. The dataset has a total of 1461 series and 17598 yearly observations from 28 countries and covering a time span of years 1677-2015 and 1791-2015 for beech and spruce, respectively. For each record, the following information is available: identification code; species; year of observation; proxy of masting (flower, pollen, fruit, seed, dendrochronological reconstructions); statistical data type (ordinal, continuous); data value; unit of measurement (only in case of continuous data); geographical location (country, Nomenclature of Units for Territorial Statistics NUTS-1 level, municipality, coordinates); first and last record year and related length; type of data source (field survey, peer reviewed scientific literature, grey literature, personal observation); source identification code; date when data were added to the database; comments. To provide a ready-to-use masting index we harmonized ordinal data into five classes. Furthermore, we computed an additional field where continuous series with length >4 years where converted into a five classes ordinal index. To our knowledge, this is the most comprehensive published database on species-specific masting behaviour. It is useful to study spatial and temporal patterns of masting and its proximate and ultimate causes, to refine studies based on tree-ring chronologies, to understand dynamics of animal species and pests vectored by these animals affecting human health, and it may serve as calibration-validation data for dynamic forest model.

D. Key words: mast seeding; mast fruiting; pollen; fructification; reproduction; synchrony; tree regeneration

CLASS II. RESEARCH ORIGIN DESCRIPTORS

A. Overall project description

1. Identity: The tree masting database (the MASTREE database)

2. Originators: Davide Ascoli, DISAFA, Largo Paolo Braccini 2, 10095 Grugliasco, Torino, Italy and Dipartimento di Agraria, University of Naples Federico II, via Università 100, 80055 Portici,

Napoli, Italy; Janet Maringer, Institute for Landscape Planning and Ecology, Keplerstr. 11, 70174 Stuttgart, Germany.

3. Period of study: 2015–2016

4. Objectives:

1. To improve knowledge of masting patterns at a broad spatial and temporal scale.
2. To enable hypotheses testing related to proximate and ultimate causes of masting.
3. To support improvement of vegetation dynamics models.

5. Abstract: same as above.

6. Sources of funding: The paper was partly funded by the "Fondo di Ricerca Locale 2015-2016" of the University of Torino and by the Stiftelsen Stina Werners fond (grant SSWF 10-1/29-3 to I.D.).

B. Specific subproject description

1. Site description: Data were obtained for most of the distribution range of both beech and spruce. The distribution area of beech covered by the database includes the lowland plains in southern Scandinavia (Denmark, Sweden) and northern Germany, Poland and Ukraine to United Kingdom, France and Benelux countries; the colline and the submontane elevation zone (600 – 1,100 m a.s.l.) in Central and Eastern Europe (Austria, Bosnia Herzegovina, Croatia, Czech Republic, Hungary, Romania, Slovakia, Slovenia, Switzerland); the montane-altimontane elevation zones (1,100 – 1,900 m a.s.l.) of Southern Europe (Italy, Greece, Spain) (Bohn et al. 2003). For spruce, the data covers the mountainous regions in Central and Eastern Europe (Austria, Bosnia Herzegovina, Czech Republic, France, Germany, Italy, Romania, Switzerland) and northern Europe (Estonia, Finland, Norway, Poland, United Kingdom, Sweden), and as far as the Russian Federation on the eastern most sites (Bohn et al. 2003).

2. Experimental or sampling design: Data were obtained from published sources, unpublished surveys, and from observations made by the authors. See research methods below.

3. Research methods: We conducted a systematic review of the published data to reconstruct beech and spruce masting. Peer-reviewed journals were searched in ISI Web of Knowledge and Google Scholar. In the case of secondary literature, the original source data was used. Mast data published in reviews were cross-checked for redundancy and the original data source was used whenever possible (e.g., Jenny 1987 in Hilton and Packam 2003). We also searched Google Scholar, Google search engine, OPACplus of the Bavarian Central Library, the global Karlsruhe Virtual Catalog and the Austrian BFW literature database for non-peer-reviewed articles and unpublished data, which were for the most part published or collected by foresters (e.g., Burkhardt 1875). Book searches were also conducted (e.g., Dengler 1944) using Google books. The search terms were beech or spruce masting in an appropriate selection of European languages: Austria, Germany and German speaking Switzerland = Samenjahr, Mastjahr, Ernteaussichten, Blühen and Fruktifizieren; Czech Republic= semenný rok; France, French speaking Switzerland, and Belgium= fainée (specific for beech); Denmark= oldenår; Hungary= bükkmakk (specific for beech); Italy and Italian speaking Switzerland = pasciona; Netherland= mastjaar; Poland= urodzaju nasion; Romania= fructificatie abundenta, an de samamta; Russian= год с обильным плодоношением; Spain= vecería; Sweden= ollonår. Additionally, we contacted experts from governmental and private forest nurseries, ministries for the environment, and research institutes. For each data record, the column *SourceType* reflects the type of source used for data collection (Field survey, Scientific literature, Grey literature, Personal observation), which can also be seen as an indicator of data accuracy (Class IV.B.9). Information on the data sources is coded in the column *SourceCode* and the reference (full reference if published, responsible agency or person if unpublished) is given below (Class IV.B.10). To minimize loss of information from the original source, we have designed the database to include quantitative data on flower, pollen, fruit, seeds, and tree-ring proxies. Masting proxies such as animal population dynamics, seedling age, or disease carriers (e.g., *Hantavirus*) were not included.

4. Project personnel:

Principal investigator: Davide Ascoli

Main associated investigator: Janet Maringer

Contributors: Andy Hacket-Pain, Marco Conedera, Igor Drobyshev, Renzo Motta, Mara Cirolli, Władysław Kantorowicz, Christian Zang, Silvio Schueler, Luc Croisé, Pietro Piussi, Roberta Berretti, Ciprian Palaghianu, Marjana Westergren, Jonathan G.A. Lageard, Anton Burkhard, Regula Gehrig Bichsel, Peter A. Thomas, Burkhard Beudert, Giorgio Vacchiano

CLASS III. DATA SET STATUS AND ACCESSIBILITY

A. Status

1. Latest Update: September 2016

2. Latest Archive data: September 2016

3. Metadata status: The metadata are complete and up to date as September 2016.

4. Data verification: The quality of the data has been carefully reviewed by the authors. Data has undergone substantial checking throughout preliminary statistical analysis (e.g., cross-check for redundancies, spatial correlation, testing of common proximate masting cues). All records are associated to a specific source and a related reference.

B. Accessibility

1. Storage location and medium: Ecological Society of America data archives. An original data file exists on the server of the University of Torino and University of Napoli, Italy, and University of Stuttgart, Germany.

2. Contact person: Davide Ascoli, DISAFA, Largo Paolo Braccini 2, 10095 Grugliasco, Torino, Italy, and Dipartimento di Agraria, University of Naples Federico II, via Università 100, 80055 Portici, Napoli, Italy. Phone: +39 011 670 5553, Fax: +39 011 670 5544, E-mail: d.ascoli@unito.it, URL: https://www.researchgate.net/profile/Davide_Ascoli

3. Copyright restrictions: None

4. Proprietary restrictions: None

5. Costs: None

CLASS IV. DATA STRUCTURAL DESCRIPTORS

A. Data Set File

1. Identity: MASTREE_2016.11.csv

2. Size: 19 columns and 17598 records (not including header row)

3. Format and storage mode: comma-separated values (.csv). No compression scheme was used.

4. Header information: Headers describe the content of each column and are: ID, Species, Yr, Proxy, VarType, Value, Unit, ORDindex, Country, NUTS1, Location, Coordinates, Start, End, Length, SourceType, SourceCode, AccessionDate, Comments.

5. Alphanumeric attributes: mixed

6. Special characters/fields: in the *Location* and *SourceCode* columns we removed the following special characters: å, à, á, ä, č, è, é, ě, ì, ł, ń, ò, ó, ö, ř, š, ù, ü, ý, ź, ž, to avoid complications in uploading and using the file.

7. Authentication procedure:

The sum of column ORDindex column is 40458. The number of characters in the whole dataset is 1,618,698 (excluding spaces and separations between columns and headers).

B. Variable information

1. Variable definition

Variable name	**Definition**	**Data format**

ID	Unique identifier (see B.2)	Alphanumeric, 9 characters
Species	Species identifier	Character string, up to 4 characters
Yr	Year of observation	Numeric, integer
Proxy	Proxy used to quantify masting (see B.3)	Character string, up to 15 characters
VarType	Variable type: O – categorical ordinal, C – continuous	Character string, up to 1 characters
Value	A number that gives the level of the masting proxy (see B.4)	Numeric, integer
Unit	The unit of measurement of the masting proxy, only if the variable is continuous, i.e., VarType= C	Character string, up to 63 characters (spaces included)
ORDindex	An ordinal index (1 to 5) of the intensity of masting (see B.5)	Numeric, integer
Country	The country where the observation was recorded	Character string, 9 characters (spaces included)
NUTS1	The Nomenclature of Units for Territorial Statistics (NUTS-1) level where the observation was recorded (see B.6)	Alphanumeric, 5 characters
Location	The municipality or specific site (e.g., Nature Reserve) where the observation was recorded (see B.7)	Character string, up to 29 characters (spaces included)
Coordinates	Geographical coordinates (UTM lat/long in degrees, minutes, seconds) of the stand where	Numeric, integer

	data were collected	
Start	First year of a continuous segment of observations	Numeric, integer
End	Last year of a continuous segment of observations	Numeric, integer
Length	Length in years of a continuous segment of observations (see B.8)	Numeric, integer
SourceType	Field survey, Scientific literature, Compilation, Grey literature, Personal observation (see B.9)	Character string, up to 2 characters
SourceCode	Identification code for the source (published or unpublished references) from which the data have been obtained. See B.10 for the complete list.	Character string, up to 74 characters
AccessionDate	Date when the observation was uploaded in the database	Date in month-year format
Comments	Additional comments in free format	Character string, up to 171 characters

Only Unit, ORDindex, Location, Coordinates and Comments include empty cells; the other columns have entries for all rows.

2. ID: unique identifier code

The unique identifier code is composed by 8 or 9 alphanumeric characters.

1st position	Species identifier (FASY = *Fagus sylvatica*; PIAB = *Picea abies*).
2nd, 3rd positions	Country code (AT=Austria, BE=Belgium, BA=Bosnia Herzegovina,

	HR=Croatia, CZ=Czech Republic, DK=Denmark, EE=Estonia, FI=Finland, FR=France, DE=Germany, EL=Greece, HU=Hungary, HR=Croatia, IT=Italy, LU=Luxemburg, NL=Netherlands, NO=Norway, PL=Poland, RO=Romania, RU=Russia, RS=Serbia, SK=Slovakia, SI=Slovenia, ES=Spain, SE=Sweden, CH=Switzerland, UA=Ukraine, UK=United Kingdom).
4^{th} to 7^{th} positions	Numeric code that identifies a series collected with the same method at a single location in a given country (unique combination of the 10^{th}, 11^{th}, 12^{th} columns). The code starts from 0001 for each country. In few long surveys (e.g., SourceCode = UK survey…, SourceCode = AFZ…) location and methods were maintained constant at a specific location although the source publishing the survey changed trough time. In these few cases we inserted the same numeric code (4^{th} to 7^{th} position of the ID) although there might correspond to more than one source.
8^{th} to 9^{th} positions	Alphabetical code that identifies a specific temporal segment of a series (i.e., A, B, C, … , Z, AA, AB, AC, … , AZ). To avoid existing hiatuses in the mast series we divided them into multiple segments, excluding in this way the periods with missing observations. Despite missing years, the structure of the record ID makes it possible to identify discontinuous segments collected using the same method at the same location by exhibiting the same values in the ID positions 4^{th} to 7^{th} but different letters in 8^{th} to 9^{th} positions.

3. Proxy: proxy used to reconstruct masting

The 4^{th} columns reports the type of proxy used to quantify beech and spruce masting. The database is designed to collect as much information as possible; consequently, we included:

1. Flowering: mass flowering is a common and direct indicator of masting (e.g., Schauber et al. 2002). However, cancelling factors of masting such as late frost may occur during or after flowering inhibiting the pollination or subsequent fruit and seed development (Kelly and Sork 2002).
2. Pollen: a strong positive relationship has been found between beech and spruce airborne pollen and seed crop (e.g., Pidek et al. 2010, Kasprzyk et al. 2014). Quantity of pollen directly affects pollination efficiency and thus the percentage of sound seeds (Nilsson and Wastljung 1987, Norton and Kelly 1988, Koenig et al. 2015).
3. Fruit/Cone: a strong linear relationship has been found between fruits of beech and spruce and their respective seeds (e.g., Ascoli et al. 2015).
4. Seed: the most common indicator to assess masting (Pearse et al. 2016).
5. Dendro: dendrochronological reconstruction of mast years, based on the split calibration-verification of the growth depressions in regional master chronologies (Drobyshev et al. 2014).
6. Pollen_sediment: Similar as point 2 (airborne pollen), but using pollen influx data from varved (laminated at annual resolution) lake sediments as masting indicator.

4. Value: value of the proxy

The 6th column reports the value of the masting proxy. According to the original source, the value is expressed as a continuous value (VarType=C) or as an ordinal scale ranging from 1 to 5 (VarType=O).

Continuous data accounted for 32% of the observations in the database. If the measure is expressed as a continuous number, the original annual value as reported by the published or unpublished source is reported (in the case of data published in scientific journals, any available Figure or Table number from which data were taken is indicated in the column "Comments").

Ordinal data accounted for the remaining 68% of observations. As with previous attempts at creating masting databases using ordinal data (Koenig and Knops 2000, Kelly and Sork 2002), we faced the problem of varying number of categories (range 3-9) when recording masting data from different sources. Following the approach of Koenig and Knops (2000), we harmonized the number of classes for all ordinal series, adopting a five class standard, as this had been used by several pre-existing official surveys (e.g., United Kingdom survey, European Aerobiological Network – EAN, Italian State Forest Service – CFS), in many scientific papers (e.g., Jenny 1987, Hilton and Packam 2003, Watcher 1964) and in the longest recorded series (i.e., Hase 1964). The five ordinal categories express the annual masting levels are as follow: 1 – very poor mast; 2 – poor; 3 – moderate; 4 – good; and 5 – full mast year.

Here after, we provide some examples of how we harmonized ordinal data to this five class system.

Series ID: FASYDE0051A; SourceCode: Maurer 1964

Maurer (1964) presented data of seed masting on a three-class scale and expressed the mast events as poor, half-mast, and full-mast. We converted this three-class scale to the five-class one assigning poor to class 1; half-mast to class 3; full-mast to class 5, as suggested by Koenig and Knops (2000).

Series ID: from FASYDE0098A to FASYDE0182A and from PIABDE0090A to PIABDE0136A; SourceCode AFZ Year(issue n.)

The German survey published by the Allgemeine Forst Zeitschrift für Wald und Forstwirtschaft (AFZ) uses a four-class scale. The annual intensity of flowering and the yield of seeds of the previous year are published in the ‘Allgemeine Forstzeitschrift’ (later ‘AFZ der Wald’). Since 1991, the intensity of flowering is systematically categorized in: class 1: no mast year (0-10% blossoms); class 2: local mast (11-30% blossoms); class 3: half mast (31-60% blossoms); class 4: full mast (>60% blosssoms). In some cases, flowering is reported as “half to full mast” (i.e., 3rd to 4th AFZ class). The data were transformed to the five-class system assigning “no mast year” to class 1, "local mast year" to class 2, "half mast year" to class 3, "half to full mast year" to class 4 and a "full mast year" to class 5.

Series ID: from FASYAT0051A to FASYAT0278A; SourceCode: BFW archive

The Austrian survey is based on a 4 class system similar to the German one. However, the categories are given in ascending order from 1: full mast to 4: no mast (Nather 1962). For the database, the Austrian classification (AS) system was transferred into the common five classes where 4-AS is 1 (very poor mast), 3-AS and 2-AS are 3 (moderate mast), and 1-AS is 5 (full mast). Based on practical difficulties of differentiateing between categories 2-AS and 3-AS, these were combined in one class. If masting was reported as 1-2-AS these observations were assigned to class 4.

Series ID: FASYUK0022A; SourceCode: Perrins 1965

Perrins (1965) presented data of seed masting on a nine-class scale and expressed the mast events as nil, nil-poor, poor, poor-moderate, moderate, moderate-good, good, good-abundant, abundant. We converted the nine-class scale to the five-class one assigning "nil" to class 1; "nil-poor, poor" to class 2; "poor-moderate, moderate" to class 3; "moderate-good, good" to class 4; "good-abundant, abundant" to class 5.

Series ID: FASYBE0008A and FASYSE0005A; SourceCode: Latte et al. 2016 and Drobyshev et al. 2014

In case of sources reporting single observations of full-mast years (e.g., Latte et al. 2016, page 199: "*However, for three mature beech stands located in the same locality, 1995, 2000, 2002, 2004 and 2011 were qualified as heavy mast years*"), or dendrochronological reconstruction based on annual tree ring growth depressions in regional master chronologies (Drobyshev et al. 2014), we assigned an ordinal value equal to class 5.

5. Ordinal masting index

The 8th column is a ready-to-use ordinal index of masting in 5 classes (class 1=very poor; class 5: very abundant) which includes all ordinal series (note: for ordinal series, ORDindex reports the same value displayed in the column Value) and all continuous series longer than four years, after being converted into the 1 to 5 ordinal scale. The procedure for data conversion from continuous to ordinal is described below.

i) For each ordinal series (VarType=O) with length > 4 years, we calculated the relative frequencies of the five ordinal masting classes; ii) for each species separately, we computed the mean relative frequency of each class across all series; iii) we re-classified each continuous series (VarType=C) with length > 4 years into 5 classes, using as percentile cut-offs the mean relative frequencies of the respective species.

Mean relative frequencies used for the conversion were:

Beech = class 1: 0.352; class 2: 0.279; class 3: 0.189; class 4: 0.082; class 5: 0.098

Spruce = class 1: 0.425; class 2: 0.237; class 3: 0.161; class 4: 0.080; class 5: 0.097

6. NUTS1: Nomenclature of Units for Territorial Statistics

The 10th column reports the code of the Nomenclature of Units for Territorial Statistics (NUTS-1) administrative level where data were collected. Non-EU countries where beech masting data were recorded (i.e., Russia, Ukraine, Serbia, Croatia, Bosnia and Herzegovina) were also included in the database with dummy NUTS-1 codes. When the source did not provide sufficient information to assign the observation to a specific NUTS-1, we give the country code followed by "#", e.g., AT#, DE#, UK#. In the case of the German masting survey, we assigned each region of the survey to the most overlapping NUTS-1 level.

7. Location

The 11th column reports more detailed geographical information than the NUTS-1 level (e.g., region, municipality, Nature Reserve name). In some cases, observations were made from different stands at the same general location, without further specific locational information (i.e., coordinates). In these cases we report the name of the location followed by the stand number (e.g., Asiago_stand1, Asiago_stand2, … , Asiago_stand5). If there was no geographic information apart from the NUTS-1 level, the location cell was left empty, i.e., the NUTS-1 level represents the only geo-referencing for the observation.

8. Length

The 15th column results from the difference between the last and first year of a continuous segment in a given series plus one (i.e., End – Start + 1). It refers to the length of any single segment of a series (see the ID description Class IV.B.2). It is equal to 1 in case of one or more discontinuous single year observations at a specific location, or when continuous series present missing data, resulting a segment of length 1 year (e.g., as recorded in the Hase 1964 series for the Schleswig-Holstain location in the years 1685, 1687, 1712, 1714, 1720, 1730, 1734, 1742, 1744, 1746, 1838 and 1843).

9. SourceType

The 16th column describes the general methods of gathering the information and the related accuracy. Four possible cases are considered:

FS = Field survey. Published or unpublished data obtained from an official survey. The data collection followed the same method for several years on permanent sites.

SL = Scientific literature. Published data obtained from a scientific, peer-reviewed journal.

GL = Grey literature. Published data obtained from a research produced outside of the academic publishing (e.g., administrative reports, Masters thesis).

PO = Personal observation. Data from visual estimation or personal experience.

The first and second categories are considered the most accurate information, while the others are viewed as less accurate.

10. SourceCode

The 17th column provides a code that refers to the data source (SourceCode). Complete references are listed below. Note that the references include field surveys, published articles, grey literature and personal observations.

Source Code	**Full reference**
Abt. Waldbau Ib	Abteilung Waldbau I b der Forstlichen Bundesversuchsanstalt Mariabrunn in Schönbrunn. 1960. Waldsamen-Ernteaussichten für 1960/61. Fachzeitschrift für das gesamte Forstwesen; Mitteilungsbl. D. forstl. Forstvereine u. Standesorganisation Österreichs.- Wien: Österr. Agrarverlag. Band 71 (19-20): 225-226.
AFZ 1954(31/32)	Siegl, H. 1954. Prognosen der Waldsamenernte 1954. Allgemeine Forstzeitschrift. 31/32: 333.
AFZ 1955(33/34)	von Schönborn, A. 1955. Prognosen der Waldsamenernte 1955. Allgemeine Forstzeitschrift. 33/34: 381.
AFZ 1956(35/36)	von Schönborn, A. 1956. Prognosen der Waldsamenernte 1956. Allgemeine Forstzeitschrift. 35/36: 453.
AFZ 1957(39)	von Schönborn, A. 1957. Prognosen der Waldsamenernte 1957. Allgemeine Forstzeitschrift. 39: 460-462.
AFZ 1958(33)	von Schönborn, A. 1958. Prognosen der Waldsamenernte 1958. Allgemeine Forstzeitschrift. 33: 472/473.
AFZ 1959(40)	von Schönborn, A. 1959. Prognosen der Waldsamenernte 1959. Allgemeine

	Forstzeitschrift. 40: 703-705.
AFZ 1960(40)	von Schönborn, A. 1960. Prognosen der Waldsamenernte 1960. Allgemeine Forstzeitschrift. 40: 584-586.
AFZ 1961(35)	von Schönborn, A. 1961. Prognosen der Waldsamenernte 1961. Allgemeine Forstzeitschrift. 35: 518-520.
AFZ 1962(38)	von Schönborn, A. 1962. Prognosen der Waldsamenernte 1962. Allgemeine Forstzeitschrift. 38: 597-599.
AFZ 1963(38)	von Schönborn, A. 1963. Prognosen der Waldsamenernte 1963. Allgemeine Forstzeitschrift. 38: 586-588.
AFZ 1964(36)	von Schönborn, A. 1964. Prognosen der Waldsamenernte 1964. Allgemeine Forstzeitschrift. 36: 539-542.
AFZ 1965(45)	von Schönborn, A. 1965. Prognosen der Waldsamenernte 1965. Allgemeine Forstzeitschrift. 36: 539-542.
AFZ 1967(41)	von Schönborn, A. 1967. Prognosen der Waldsamenernte 1967. Allgemeine Forstzeitschrift. 41: 695-698.
AFZ 1968(41)	von Schönborn, A. 1968. Prognosen der Waldsamenernte 1968. Allgemeine Forstzeitschrift. 41: 719-722.
AFZ 1969(44)	von Schönborn, A. 1969. Prognosen der Waldsamenernte 1969. Allgemeine Forstzeitschrift. 44: 862-865.
AFZ 1970(39)	von Schönborn, A. 1970. Prognosen der Waldsamenernte 1970. Allgemeine Forstzeitschrift. 39: 814-818.
AFZ 1971(42)	v. Schönborn, A. 1971. Prognosen der Waldsamenernte 1971. Allgemeine Forstzeitschrift. 42: 877-879.
AFZ 1972(36)	Eicke, G. 1972. Prognosen der Waldsamenernte 1972. Allgemeine Forstzeitschrift. 36: 717-718.

AFZ 1973(43)	Eicke, G. 1973. Prognosen der Waldsamenernte 1973. Allgemeine Forstzeitschrift. 43: 969-972.
AFZ 1974(36)	Eicke, G. 1974. Prognosen der Waldsamenernte 1974. Allgemeine Forstzeitschrift. 36: 784-785.
AFZ 1975	Eicke, G. 1975. Prognosen der Waldsamenernte 1975. Allgemeine Forstzeitschrift. 907-908.
AFZ 1976	Eicke, G. 1976. Prognosen der Waldsamenernte 1976. Allegemeine Forstzeitung. 926-928.
AFZ 1978	Eicke, G. 1978. Prognosen der Waldsamenernte 1978. Allgemeine Forstzeitschrift. 998-999.
AFZ 1979	Eicke, G. 1979. Prognosen der Waldsamenernte 1979. Allgemeine Forstzeitschrift. 1005-1006.
AFZ 1981(37)	Eicke, G. 1981. Prognosen der Waldsamenernte 1981. Allgemeine Forstzeitschrift 37, pp. 948
AFZ 1982(37)	Eicke, G. 1982. Prognosen der Waldsamenernte 1982. Allgemeine Forstzeitschrift. 37: 1118.
AFZ 1983(37)	Eicke, G. 1983. Prognosen der Waldsamenernte 1983. 37: 950-951.
AFZ 1984(36)	Eicke, G. 1984. Das Blühen der Waldbaumarten 1984. Allgemeine Forstzeitschrift. 36: 888.
AFZ 1985(33)	Eicke, G. 1985. Das Blühen der Waldbaumarten 1985. Allgemeine Forst Zeitung. 33: 855-856.
AFZ 1986(33)	Eicke, G. 1986. Das Blühen der Waldbaumarten 1986. Allgemeine Forstzeitschrift 33: 812-813.
AFZ 1987(39)	Eicke, G. 1987. Das Blühen der Waldbäume 1987. Allgemeine Forstzeitschrift. 39: 1005-1007.

AFZ 1988(33)	Eicke, G. 1988. Das Blühen der Waldbäume 1988. Allgemeine Forstzeitschrift. 33: 901.
AFZ 1989(32)	Eicke, G. 1989. Das Blühen der Waldbäume 1989. Allgemeine Forstzeitschrift. 32: 833-835.
AFZ 1990(32)	Eicke, G. 1990. Das Blühen der Waldbäume 1990. Allgemeine Forst Zeitung. 32: 811-814.
AFZ 1991(17)	Eicke, G. 1991. Das Blühen der Waldbäume 1991. Allgemeine Forstzeitschrift. 17: 858-860.
AFZ 1992(17)	Eicke, G. 1992. Das Blühen der Waldbäume 1992. Allgemeine Forstzeitschrift. 17: 886-887.
AFZ 1993(18)	Eicke, G. 1993. Das Blühen der Waldbäume 1993. Allgemeine Forstzeitschrift. 18: 916-91.7
AFZ 1994(18)	Eicke, G. 1994. Das Blühen der Waldbäume 1994. Allgemeine Forst Zeitung. 18: 978-979.
AFZ 1995(18)	Eicke, G. 1995. Das Blühen der Waldbäume 1996. AFZ der Wald. 18: 958-959.
AFZ 1996(18)	Eicke, G. 1996. Das Blühen der Waldbäume 1996. AFZ der Wald 18, 982-983
AFZ 1997(18)	Eicke, G. 1997. Das Blühen der Waldbäume 1997. AFZ der Wald. 18: 958-956
AFZ 1998(18)	Eicke, G. 1998. das Blühen der Waldbäume 1998. AFZ der Wald. 18: 926-927.
AFZ 1999(16)	Schneck, D. 1999. Das Blühen der Waldbäume 1999. AFZ der Wald. 16: 828-829.
AFZ 2000(16)	Schneck, D. 2000. Das Blühen der Waldbäume 2000. AFZ der Wald. 16:

	844-845.
AFZ 2001(16)	Schneck, D. 2001. Das Blühen der Waldbäume 2001. AFZ der Wald. 16: 812-813.
AFZ 2002(16)	Schneck, D. 2002. Das Blühen der Waldbäume 2002. AFZ der Wald. 16: 820-821.
AFZ 2003(16)	Schneck, D. 2003. Das Blühen der Waldbäume 2003. AFZ der Wald. 16: 816-817.
AFZ 2004(16)	Schneck, D. 2004. Das Blühen der Waldbäume. AFZ der Wald. 16: 848-849.
AFZ 2005(16)	Schneck, D. 2005. Das Blühen der Waldbäume. AFZ der Wald. 16: 836-837.
AFZ 2006(16)	Schneck, D. 2006. Das Blühen der Waldbäume. AFZ der Wald. 16: 852-853.
AFZ 2007(16)	Schneck, D. 2007. Das Blühen der Waldbäume. AFZ der Wald. 16: 844-845.
AFZ 2008(16)	Schneck, D. 2008. Das Blühen der Waldbäume. AFZ der Wald. 16: 844-845.
AFZ 2009(16)	Schneck, D. 2009. Das Blühen der Waldbäume 2009. AFZ der Wald. 16: 844-845.
AFZ 2010(16)	Schneck, D. 2010. Das Blühen der Waldbäume 2010. AFZ der Wald. 16: 4-5.
AFZ 2011(16)	Schneck, D. 2011. Das Blühen der Waldbäume 2011. AFZ der Wald. 16: 4-5.
AFZ 2012(16)	Schneck, D. 2012. Das Blühen der Waldbäume 2012. AFZ der Wald. 16: 4-5.
AFZ 2013(16)	Schneck, D. 2013. Das Blühen der Waldbäume 2013. AFZ der Wald. 16: 18-19.
AFZ 2014(16)	Schneck, D. 2014. Das Blühen der Waldbäume 2014. AFZ der Wald. 16: 27-28.
AFZ 2015(16)	Schneck, D. 2015. Das Blühen der Waldbäume 2015. AFZ der Wald. 16: 9-

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Anderson 1949	Anderson, M. L. 1949. Some observations on Belgian forestry. Empire Forestry Review. 28(2): 117-130.
Andersson 1965	Andersson, E. 1965. Cone and seed studies in Norway spruce (*Picea abies* (L.) Karst.). Studia Forestalia Suecica. 23: 1-278.
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Ardo & Lindquist 1947	Ardö, P. and B. Lindquist .1947. Om Laspeyresia grossana Haw. som skadedjur i de nordväst-europeiska bokskogarna, 36. Swedish Institute for Forest Research, Stockholm. Online: http://pub.epsilon.slu.se/view/series/Meddelanden_fr=E5n_Statens_skogsforskningsinstitut.creators_name.html (Access 2016-06-30)
Arpa Toscana	Agenzia regionale per la protezione ambientale della Toscana (ARPAT). 2015. Dati concentrazioni pollini e spore fungine in Toscana - anni 1996-

	2015. (http://www.arpat.toscana.it/datiemappe/dati/dati-concentrazioni-pollini-e-spore-fungine-in-toscana)
Ascoli et al. 2013	Ascoli, D., Castagneri, D., Valsecchi, C., Conedera, M. and G. Bovio. 2013. Post-fire restoration of beech stands in the Southern Alps by natural regeneration. Ecological Engineering. 54: 210-217.
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Ascoli; Personal observation	Ascoli, D.; Personal observation
ASP Bayern	Bayerisches Amt für forstliche Saat- und Pflanzenzucht Kontinuität und Wandel (Bavarian Office for Forest Seeding and Planting Continuity and Change)
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Matejka 2015	dormancy of beechnuts in individual stand groups with varying climatic conditions within a single unit of approval. Journal of Forest Science. 61(9): 382-392.
BFW archive	Department of Forest Genetics, Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW), Vienna, Austria
BFW online	Department of Forest Genetics, Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW). 2015. Pollen-Samenproduktion österreichischer Waldbäume. (http://bfw.ac.at/rz/pollen.main?bart_in=01.0&jahr_in=2009)
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Brodovych; Personal observation	Brodovych, R. I.; Personal observation
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Cermak & Jezek 2005	Čermák, P. and J. Ježek. 2005. Effect of tree seed crop on small mammal populations and communities in oak and beech forests in the Drahany Upland (Czech Republic). Journal of Forest Science. 51(1): 6-14.
CFS_UTB_Peri	Corpo Forestale dello Stato, Ministero delle Politiche Agricole, Alimentari e Forestali, Ufficio territoriale per la Biodiversità di Verona - CNBF di Peri, Italiano
CFS_UTB_Pieve Santo Stefano	Corpo Forestale dello Stato, Ministero delle Politiche Agricole, Alimentari e Forestali, Ufficio territoriale per la Biodiversità di Pieve Santo Stefano, Italiano
Chalupka & Giertych 1973	Chalupka W. and Giertych M. 1973. Seed years in *Picea abies* (L.) Karst. Arbor. Kornickie. 18: 183-186.
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10. Comments

For some data, a brief comment provided by the data compiler may be included in the 18th column. In the case of continuous data from scientific and the grey literature, we report the table or figure number (if available) from which we extracted data values.

CLASS V. SUPPLEMENTARY DESCRIPTORS

A. Data acquisition

Data forms: n/a

Location of completed data forms: n/a

Data entry/verification procedures: Data were introduced in a spreadsheet from published references and unpublished series. The main compilers (Ascoli and Maringer) reviewed all individual series to homogenise criteria and to detect any inconsistencies.

B. Quality assurance/quality control procedures: see Authentication procedure (Class IV).

C. Related material: n/a

D. Computer programs and data processing algorithms:

The file can be read using different statistical, database or spreadsheet software. The command line to read it in R version 3.2.5 (R Development Core Team 2016) reads:

```
dataFrameName <- read.csv("MAST_2016.11.csv")
```

E. Archiving: n/a

F. Publications using the data set: The full data set has not yet been used in any publication. Several papers using the database are in preparation by the same authors.

G. History of data set usage: n/a (the data has not yet been used by any secondary user).

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