REPORT

Sample Design of Biodiversity Monitoring Switzerland (BDM)

Geared to monitoring experts, this report outlines the sample design of Biodiversity Monitoring Switzerland (BDM), emphasizing the sample design of BDM core indicators "Species Diversity in Landscapes" (Z7) and "Species Diversity in Habitats" (Z9). The report expounds the reasoning behind pursuing certain methodological approaches for BDM sample design as opposed to others. It does not contain any detailed technical information or method descriptions. Statistical calculations, methodological assessments, indicator selection, and field survey instructions have been comprehensively covered in the relevant technical reports and manuals.

Explanations focus on the Z7 and Z9 indicators, complemented by information on the sample design of the "Species Diversity in Swiss Watercourses" indicator (Z9-EPT). Other BDM indicators are either computed based on these core indicators or on data supplied by established third-party programs.

In the first part of the report, requirements made on sample design are put in concrete terms as directed by BDM goals and parameters. The second part describes the essentials of BDM sample design, followed by specific sample designs for the Z7, Z9 and Z9-EPT indicators. Finally, the last part provides examples of how new indicators based on BDM data may be defined, and how national BDM data may be densified at the cantonal level.

Contents

Fundamentals

Biodiversity Monitoring Switzerland (BDM) reveals changes in Switzerland's biological diversity over time. Directed by BDM goals and parameters, requirements made on sample design are manifold.

What is Biodiversity Monitoring Switzerland (BDM)?

BDM is a long-term monitoring program initiated by the Federal Office for the Environment (FOEN) and intended to reveal changes in Switzerland's biodiversity. By realizing BDM, Switzerland complies with article 7 of the Rio Convention on Biological Diversity requiring each contracting party to monitor the components of its country's biodiversity.

BDM records Switzerland's biodiversity by means of so-called "indicators" which convey part of the country's biological diversity. There are 34 BDM indicators altogether. Some record the current situation of biodiversity (state indicators), while others describe factors liable to impact biodiversity (pressure indicators), and yet others show measures that may be taken to protect biodiversity (response indicators). Due to this blend, BDM data serve to spotlight relationships between current situations, causes, and measures taken, which may then be subjected to further goal-oriented analysis.

Since 2001, BDM has been capturing its proper field data for the two core indicators "Species Diversity in Landscapes" (Z7) and "Species Diversity in Habitats" (Z9"), both designed to record gradual changes in species diversity. In order to do so, BDM established standardized sampling based on sampling sites and sampling areas distributed all over Switzerland. Standardized sampling makes it possible to report on species diversity in various regions (Z7) and biotopes (Z9) based on specific species groups: vascular plants (Z7, Z9), butterflies (Z7, starting in 2003), breeding birds (Z7), mosses (Z9), and mollusks (Z9). In 2010, additional surveys started for the "Z9-EPT" indicator covering aquatic invertebrates.

For details on the BDM surveying concept and surveying methods please refer to the BDM website (http://www.biodiversitymonitoring.ch/english/konzept/ueberblick.php) or to the following publications: Hintermann et al. 2002, Weber et al. 2004.

Which requirements are met by the chosen sample design?

- Good compatibility with other national and international programs: BDM is compatible with long-running Swiss monitoring programs and designed to adjust—as far as possible—to international and foreign programs that have the same goals.
- High representativeness and reproducibility of findings: BDM is intended to yield statistically valid results that can be duplicated and compared to those found in other areas.
- Diversified possibilities for analysis: Nationwide monitoring programs will primarily allow insights involving the country as a whole. However, insights about smaller spatial units are called for as well.
- Accurate and early detection of species population trends: BDM is designed to detect even comparatively small changes in biodiversity early on and with high statistical probability.
- Flexibility regarding future analyses: Captured data must be suited to allow for providing answers to questions as yet unknown.
- Low cost: Available funds must be used to realize a project that is both feasible and focused on what is essential.
- Long-term orientation: BDM is a long-range monitoring program.

Essentials of the chosen sample design

Why is BDM based on a sampling approach?

Intended to yield results representative for all of Switzerland, BDM data are recorded in sampling areas that are part of a regular sampling grid emanating from a site chosen at random.

Intended to allow representative insights into changes affecting widespread and common species in Switzerland, BDM data are recorded by means of **nationwide surveys**. Sampling areas are located within a regular sampling grid emanating from a site chosen at random.

Surveying methods are designed for repeatedly recording mean species numbers of select species groups at regular intervals in a fixed sampling area or site (paired samples). Data gathered at such a sampling site are part of the sample for an evaluation unit (stratum, e.g. a land-use type such as forests) and may only be interpreted in conjunction with data recorded at other sampling sites of the same evaluation unit. Subject to a minimum number of surveys, this approach generates reliable findings applying to the whole evaluation unit and referring to the development of individual species groups per habitat or per biogeographical space.

However, this surveying method is not explicitly designed to represent the biodiversity of a sampling site's immediate surroundings based on data gathered at that site.

Which programs is BDM compatible with?

Z7 and Z9 sampling networks are compatible with long-running Swiss monitoring programs. Furthermore, the BDM surveying method has been harmonized with international and foreign programs, with results being integrated into European biodiversity indicators.

In order to take advantage of surveying synergies for further analyses, BDM must be adjusted to existing monitoring programs. Such an adjustment, however, is only possible within the statistically permissible framework determined by the requirements made on BDM findings. For this reason, harmonization can—as a matter of principle—only be achieved with systematic surveying networks, which excludes all national and cantonal observation networks containing sampling areas distributed over Switzerland according to different criteria. Yet by applying the concept of post-stratification (see below), findings may be still combined, provided that evaluation units (strata) are large enough (e.g. the Central Plateau, High Alps etc.).

BDM is compatible with the following Swiss programs:

- National Forest Inventory (Swiss Federal Institute for Forest, Snow and Landscape Research WSL): The NFI grid is based on the points of intersection of the kilometer lines in the Cartesian coordinate system of the Federal Office of Topography. While the NFI 1 survey included all points of intersection, the NFI 2 survey was limited to only half (points of intersection between even and uneven coordinate figures).
- Range statistics (Federal Statistical Office): Swiss range statistics are based on a nationwide grid of 100-meter cells. Findings refer to a single point or to a 25-ares reference area. The grid is oriented to the Swiss national coordinate system.
- LANAG (Department of construction, transportation and the environment of the canton of Aargau): surveys for the "long-term monitoring of the normal landscape in the canton of Aargau LANAG" follow a sampling plan based on the NFI 2 grid.
- Thurgau biodiversity monitoring (Thurgau regional planning office): Since 2009, the canton of Thurgau has been conducting field surveys based on a densified BDM grid (Z7 kilometer squares).

BDM is compatible with the following international and foreign programs:

- The method used for butterfly surveys has been matched to the monitoring programs of other countries (mainly the U.K. and the Netherlands).
- BDM results are integrated into European biodiversity indicators.

Spatial resolution

The BDM sample has been stratified. For this purpose, Switzerland's expanse was covered with a uniform systematic grid of sampling areas with the network emanating from a site chosen at random. Wherever it was obvious ahead of time that the accuracy achievable with the basic grid would not allow detailed insights into a predefined stratum, complementary sampling areas were added (densification). Network densities were determined based on the best possible compromise between statistical power (measured as the detectability of any change in the mean species diversity of a species group) and surveying cost.

Why was a systematic sampling network chosen?

Following preexisting surveying programs (particularly the National Forest Inventory NFI), BDM was equipped with a **systematic sampling network**. Since the site the grid emanates from has been chosen at random, data captured using that grid may statistically be treated similar to randomized samples. Unlike **randomly distributed samples**, a systematic network of sampling sites has the advantage of keeping regional partial sample sizes in proportion to a region's expanse, regardless of any subsequent new delimitation of that region. What is more, a systematic network maintains sampling sites at a maximum distance of each other, assuring the best possible independence of individual samplings.

Should **regional densification** of the sampling network be required or requested (e.g. multiplying the number of sampling sites in order to obtain findings valid at a cantonal level, as has been done for Thurgau biodiversity monitoring), a systematic network makes it easiest to integrate this option.

As a result of systematic sampling, a grid will comprise areas that are either technically impossible to survey (BDM excludes sampling areas fully located on glaciers, lakes, or inaccessible terrain such as rock) or obviously devoid of any species to be found from the outset (e.g. sealed surfaces in settlements as regards Z9 vascular plants). Such sampling areas will not be surveyed in the field, with analyses taking them into account as **aborts** in the former case and **noughts** (species number=0) in the latter (see table 1). For this reason, the actual sample size is always smaller than the sampling population. Moreover, it also means that BDM is restricted to findings that e.g. disregard glaciers, lakes or rock areas.

Pre- or post-stratification?

Continuous observation covers the development of an object or a species group in time. As scientific insights progress, the experts' understanding of the required kind of data analysis is bound to change. Depending on changes in landscapes, predetermined evaluation units (strata) may change with time as well. For this reason, surveys are conducted based on a uniform systematic sampling network that—given sufficient density—will allow evaluation units to be formed after the fact (**post-stratification**). Such subsequently formed evaluation units are usually proportionate to the sample regarding area size. While this approach offers flexibility for new questions emerging, it also knowingly puts up with the fact that answering questions already defined at this time might possibly involve processing samples that are too large for the purpose.

As opposed to that, **pre-stratification** would be indicated, for example, for targeted effectiveness monitoring founded on analytic questions. In this case, surveys are optimized for existing evaluation units, the advantage being that the number of samples processed is no larger than the one absolutely necessary for yielding the desired insight. However, the flexibility for subsequent formation of evaluation units is lost (stratified-random-sampling vs. design-based-approach, cf. Stevens, 1994).

Which evaluation units does BDM include?

BDM is primarily intended to allow insights into changes in Switzerland's biodiversity as a whole. In addition to nationwide findings, however, insights into developments in individual regions are being strived for as well. So far, the following evaluation units have been established: biogeographical regions, "high altitudes", altitudinal zones, and habitats (types of land use).

- **Biogeographical regions** have been defined according to Gonseth et al. (2001), with the Eastern and Western Central Alps being combined into "Central Alps" for the purpose of computing Z7 and Z9 indicators as well as other indicators based on Z7 and Z9 data (table 2).
- "**High altitudes**" go back to a definition in *Verbreitungsatlas der Farn- und Blütenpflanzen der Schweiz* (Welten & Sutter, 1982), categorizing all sampling areas above the timber line as "mountain areas". In the Alps, such high altitudes rather exactly correspond to thermal zones 1 to 3 as defined by *Wärmegliederung der Schweiz*, making them compatible with the "alpine" zone used for Z9 (= thermal zones 1 to 3).
- Delimitations of **habitats** result from information provided by fieldworkers based on their instructions for mapping types of land use (table 3). Definitions follow a proper key strongly influenced by the criteria catalog of Swiss range statistics (Federal Statistical Office, 1992) and compatible with European CORINE Land Cover requirements (EC DG Environment, 1993).
- As regards forests and grassland/pastures, Z9 data are additionally subdivided by **altitudinal zones** (table 4). BDM altitudinal zones are defined based on *Wärmegliederung der Schweiz* (Schreiber, 1997).

These evaluation units may be redefined for the purpose of particular questions being asked in the future.

Types of landscape or habitat covering only a small share of Switzerland's expanse do not permit valid analyses, but such sites are frequently already covered by specific monitoring programs or effectiveness monitoring.

How was the sample size determined?

Relationship between sample size, statistical power, and accuracy

When planning surveys involving samples, it must be decided what degree of accuracy is required of subsequent findings. The statistical power of such findings (measured as the detectability of any predefined change in mean species diversity) depends on statistical test methods used, the variability of individual values, and the sample size. For Z7 and Z9 indicators, the computation method has already been chosen to be the t-test (see below). Since the variability of individual values is determined by the landscape's heterogeneity and the surveying method used, the only way to control the statistical power is to take account of an appropriately large number of sampling areas. However, the number of sampling areas, i.e. the sample size, has a direct impact on processing cost. Hence, network densities of both indicators are a **compromise between statistical power and surveying cost**.

Estimating sample size

Computing the statistical power and accuracy of monitoring data requires two kinds of estimates: the anticipated variability of species numbers in one surveying period (current states) on the one hand, and the differences between two surveying periods (changes) on the other.

Before BDM became operative, there were no data on the variances of changes in species numbers over time available. For this reason, the confidence interval was projected using spatial variabilities in order to obtain an approximate value. Presupposing changes in species numbers to be continuous and directed, it was assumed that, due to paired samples, the accuracy of findings would be better than the original estimate. In the meantime, it has become obvious that paired samples reduce variability by a factor of at least 2 (Plattner et al., 2004), markedly increasing the statistical power of recorded data as regards changes.

The anticipated statistical power and the required sample size were estimated using traditional formulas for computing the power of t-tests (Zar, 1999). For statistical power, the target value was defined as follows: In nine out of ten cases, it must be possible to detect a difference of 10% in magnitude, which results in a power of 90%.

The required minimum statistical power was estimated for each species group based on biologically conceivable changes. Allowing for the corresponding processing cost, it was subsequently possible to establish Z7 and Z9 sample sizes that are sensitive enough to changes in biodiversity of all the species groups those indicators comprise. These sample sizes amount to roughly 500 sampling areas for the Z7 indicator and roughly 1600 sampling areas for the Z9 indicator (table 1).

Z7 AND Z9 SAMPLE SIZES FOR VASCULAR PLANTS

Indicators	Sampling populations	Numbers of “non-surveyable” areas	Actually processed sample sizes	Data used for the 1st survey 2001-2005
Z7	509	27	482	482
Z9	1830	248	1582	1450

Table 1: Number of Z7 and Z9 sampling areas for vascular plant surveys. The sample size that was actually processed results from the sampling population minus all areas that were excluded in advance (BDM excludes all areas fully located on glaciers, lakes, or inaccessible terrain such as rock). Data used for the 1st BDM survey from 2001 to 2005 include all areas harboring vascular plants or not (noughts) minus areas generating bad data quality or causing aborts in the field.

How was the location of the Z7/Z9 sampling networks determined?

The following requirements were made on sampling networks for the BDM Z7 and Z9 indicators:

- The sample must cover all of Switzerland with a systematic, even grid.
- The grid must be composed of approximately 1600 sites (1800 in the basic grid) for Z9 and approximately 500 sites for Z7 (table 1).
- Z7 and Z9 sampling networks must be mutually compatible, i.e. the two networks are designed to overlap.
- BDM networks must allow the best possible synergies with surveys made for the National Forest Inventory (NFI 2) and with the LANAG surveys already in progress in the canton of Aargau at that time.

For practical reasons, the Z9 grid was determined first. Next, the Z7 sample was established based on a Z9 partial sample.

Cost factors make it mandatory for Z7 sampling areas—which cover 1 square kilometer each—to border directly on a Z9 sampling site, allowing BDM to shorten costly traveling times for Z9 and Z7 surveys. With the Z9 network as a starting point, this again opened up 4 possibilities to lay down the Z7 network.

Given the possibilities outlined above, initial coordinates for the Z7 and Z9 networks were chosen at random by drawing lots. Proceeding from these reference points and bearing in mind the grid’s geometrical specifications, sampling areas and sites were then established nationwide. In order to qualify, more than 50% of any quadrant needed to be located in Switzerland.

How well are regions and habitats represented by the BDM sample?

As an example for the extent to which individual evaluation units are represented by the BDM sample, tables 2 to 4 below show actual Z7 and Z9 sample sizes for the species group of vascular plants.

SAMPLE SIZE BY REGION (Z7)

Biogeographical regions	Northern Alps	Southern Alps	Jura	Central Plateau	Central Alps
Sampling populations	120	78	86	116	109
Plant data used for the 1st survey 2001-2005	114	72	86	116	94

Table 2: Number of Z7 sampling areas per biogeographical region

SAMPLE SIZE BY HABITAT (Z9)

Types of land use	Arable land	Alpine pastures	Unused areas	Settlements	Forests	Grassland
Sampling populations	183	118	185	210	518	356
Plant data used for the 1st survey 2001-2005	161	107	173	179	497	324

Table 3: Number of Z9 sampling areas per type of land use

SAMPLE SIZE BY HABITAT AND ALTITUDINAL ZONE (Z9)

Types of land use by altitudinal zone		colline	montane	subalpine	alpine
Forests	Sampling populations	68	298	137	15
	Plant data used for 1st survey 2001-2005	66	288	129	14
Grassland/pastures	Sampling populations	45	219	92	-
	Plant data used for 1st survey 2001-2005	42	195	87	-

Table 4: Number of sampling areas per altitudinal zone in forests and grassland/pastures for Z9 vascular plants

Temporal resolution

There is a compromise to be found between a temporal resolution that makes sense from a biological point of view on the one hand and the needs of decision makers on the other. Ideally, BDM is capable of drawing up annual reports on the basis of datasets covering time periods of five to ten years.

BDM is interested in changes that may be interpreted as directed development (continuous increase or decrease of recorded values over time). Whether or not a period of time is biologically relevant for such diverse findings depends on the generation period of the organisms being monitored. From this point of view, optimum intervals between surveys would have to differ from one species group to the next. However, the frequency of surveys is limited by available funds. For Z7 and Z9 indicators, a compromise was found by phasing surveys: Only one fifth of all Z7 and Z9 sampling areas is surveyed each year (table 5), resulting in the first paired values being available as of the sixth year. Paired values for the total sample are available after 10 years. Phasing surveys has the following advantages:

- After a certain set-up time, up-to-date reports are possible on an annual basis,
- extreme annual fluctuations will be smoothed,
- marked changes are detectable for the past five years (partial sample), more subtle changes are detectable for the past ten years (total sample),
- annual data are made available for analysis of trends observed for common individual species,
- the required effort will be evenly distributed over several years (important prerequisite for continuity with participating fieldworkers).

TEMPORAL RESOLUTION

Survey year	1	2	3	4	5	6	7	8	9	10	11
1st partial sample											
2nd partial sample											
3rd partial sample											
4th partial sample											
5th partial sample											

Table 5: Key to the phasing of Z7 and Z9 raw data surveys

Partial samples of the total sample are identified based on the coordinates of the sampling areas surveyed. In actual practice, initial survey years are determined by the final digits of the x and y coordinates of all sampling areas covered (table 6).

IDENTIFICATION OF PARTIAL SAMPLES

	Final digits of y coordinates				
Final digits of x coordinates	YY0	YY2	YY4	YY6	YY8
XX1	2001	2005	2004	2003	2002
XX3	2002	2001	2005	2004	2003
XX5	2003	2002	2001	2005	2004
XX7	2004	2003	2002	2001	2005
XX9	2005	2004	2003	2002	2001

Table 6: Identification key for partial samples of the total sample

How are Z7 and Z9 indicators being computed?

Current states of and changes in mean species numbers are computed for various species groups and evaluation units (strata) on an annual basis.

Processing BDM data includes the following statistical calculations:

- Computing means and 95% confidence intervals (based on a t-distribution) for species numbers of various species groups found in sampling areas of Z7 and Z9 indicators (current-state description) for the purposes of different evaluation units. Sampling areas contained in the densified sample are not taken into account for calculations regarding all of Switzerland or the “high altitudes” evaluation unit.
- Computing means and 95% confidence intervals for differences in species diversity within the various species groups of Z7 and Z9 indicators over a period of 5 years (paired sample) for the purposes of different evaluation units. Sampling areas that underwent a change in land use from one survey to the next are not taken into account.

Statistical studies by iRex (Burgdorf, Switzerland) and the WSL (Birmensdorf, Switzerland) showed that, even though computed using different models, estimates of expected values and confidence intervals all remain stable, with differences observed being small. The results of Z7 and Z9 surveys are routinely verified by nonparametric bootstrap.

The above-mentioned studies also looked into the influence of spatial autocorrelation on BDM data. Autocorrelation causes estimates of the accuracy of current states and developments to be conservative since it produces confidence intervals that are larger than possible (and, hence, a potential type-II error). However, results show spatial autocorrelation for Z7 and Z9 data to be very low in general, being somewhat higher in the Z9 stratum of mollusks in forests. Therefore, BDM continues to assume that recorded values fulfill the requirements of stochastic independence.

Sample design for the Z7 indicator

Concise description

Using standardized surveying methods, BDM determines Switzerland's "Species Diversity in Landscapes" by recording vascular plants (since 2001), butterflies (2003) and breeding birds (2001) observed in sampling areas the size of 1 square kilometer each. The Z7 indicator monitors changes in mean species richness, depicting the species diversity created by the mosaic of habitats and transitional zones.

Z7 is computed both for Switzerland as a whole and its individual biogeographical regions, with standalone insights also possible into the "high altitudes" stratum or other large-area parts of the country. The sampling network holds roughly 500 1-km^2 sampling areas, having been densifie in small-area regions such as the Jura and the Southern Alps (figure 1). Located mostly in the high mountains, just under 30 areas are so inaccessible that they cannot be surveyed. Moreover, BDM experts do not sample areas fully located on glaciers or lakes. However, data analysis takes these areas into account, classifying them as "species-free" by definition.

Z7 SPECIES DIVERSITY IN LANDSCAPES

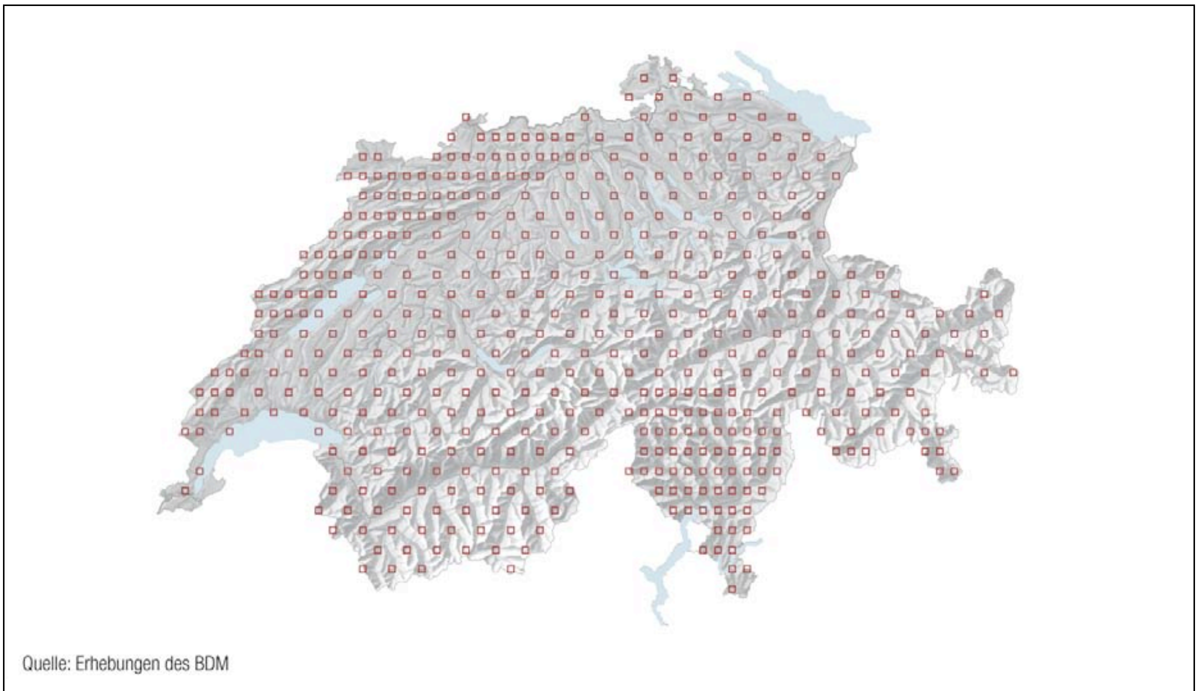

Figure 1: BDM monitors species diversity in landscapes in roughly 500 sampling areas the size of 1 km^2 each. These areas form a sampling network that is evenly distributed over all of Switzerland.

Achieved statistical power

Achieved statistical power is measured by computing the minimum detectable difference MDD (Zar, 1999). This value indicates the extent of change in mean species diversity at least required to generate statistically ascertained differences between individual samples (in this case between individual yearly results). The target value for statistical power was defined to be 90%, i.e. a difference in the magnitude of 10% is expected to be detectable in nine out of ten tests. Applied to breeding birds in Switzerland, for example, this means that in actual fact, a change in the mean species diversity of 0.7 species has a 90% likelihood to be detected (table 7).

MDD calculations based on current-state data have been made and averaged for each of the 5-year periods of 2003-2007, 2004-2008 and 2005-2009. MDD calculations based on change data have been made for the survey years of 2003 to 2009. Yearly data for 2001 and 2002 have not been taken into account for lack of butterfly data.

ALL SPECIES GROUPS

Species groups	Current-state mean species numbers	Current-state MDD	Change MDD
Vascular plants	239.7	10.7	3.3
Breeding birds	31.1	1.9	0.7
Butterflies	31.6	2.4	1.7

Table 7: Minimum detectable difference (MDD) for current states of and changes in species diversity of vascular plants, breeding birds and butterflies in Switzerland

VASCULAR PLANTS

Biogeographical regions	Current-state mean species numbers	Current-state MDD	Change MDD
Jura	266.4	12.2	9.8
Central Plateau	231.3	18.6	6.4
Northern Alps	264.9	18.4	6.6
Central Alps	206.8	25.3	6.1
Southern Alps	229.1	27.3	5.2

Table 8: Minimum detectable difference (MDD) for current states of and changes in species diversity of vascular plants in individual regions

BREEDING BIRDS

Biogeographical regions	Current-state mean species numbers	Current-state MDD	Change MDD
Jura	39.4	1.9	1.9
Central Plateau	37.1	3.0	1.3
Northern Alps	31.9	3.2	1.3
Central Alps	21.9	4.3	1.3
Southern Alps	23.7	3.5	1.9

Table 9: Minimum detectable difference (MDD) for current states of and changes in species diversity of breeding birds in individual regions

BUTTERFLIES

Biogeographical regions	Current-state mean species numbers	Current-state MDD	Change MDD
Jura	28.2	2.7	3.9
Central Plateau	18.8	2.2	2.7
Northern Alps	37.6	4.0	4.1
Central Alps	38.9	5.8	2.9
Southern Alps	38.9	5.5	3.5

Table 10: Minimum detectable difference (MDD) for current states of and changes in species diversity of butterflies in individual regions

HIGH ALTITUDES

Species groups	Current-state mean species numbers	Current-state MDD	Change MDD
Vascular plants	128.4	22.6	6.1
Breeding birds	7.56	1.6	6.1
Butterflies	20.5	4.5	3.1

Table 11: Minimum detectable difference (MDD) for current states of and changes in species diversity of vascular plants, breeding birds and butterflies at high altitudes (computed disregarding densification starting with 2008 basic data surveys)

Sample design for the Z9 indicator

Concise description

This BDM core indicator has been monitoring the species diversity of vascular plants, mosses and mollusks since 2001. While sampling areas cover 10 m^2 each, standardized area sizes differ from one taxonomic group to the next. Like Z7, Z9 measures changes in mean species richness, albeit in considerably smaller areas. In doing so, the Z9 indicator describes small-scale species diversity found in various habitat types.

Unlike the Z7 indicator which emphasizes nationwide findings, Z9 allocates only a subordinate role to insights into Switzerland's situation as a whole. The Z9 indicator has been explicitly defined to use types of land use (habitats) as reference frames for its findings. Hence, Z9 is computed for different habitats (forests, alpine pastures, grassland, arable land, settlements, mountains) within Switzerland's expanse. Analyses may also focus on forests and grassland in various altitudinal zones. The "settlements" evaluation unit has been densified.

Sampling areas on lakes have been excluded. Due to the sampling areas' small size, areas are—as a general rule—assured to be unequivocally assigned to a land-use type (site mapping). However, the sampling areas' small size also results in certain evaluation units containing noughts (=samples holding zero number of species). The number of sample elements that may actually be processed is further limited by the fact that not all sites or areas are accessible (typically at high altitudes, but in isolated cases e.g. also when access is denied to privately owned land). The Z9 sampling network is composed of roughly 1600 areas, or in other words approximately one sampling site per 25 km^2 (figure 2).

Z9 SPECIES DIVERSITY IN HABITATS

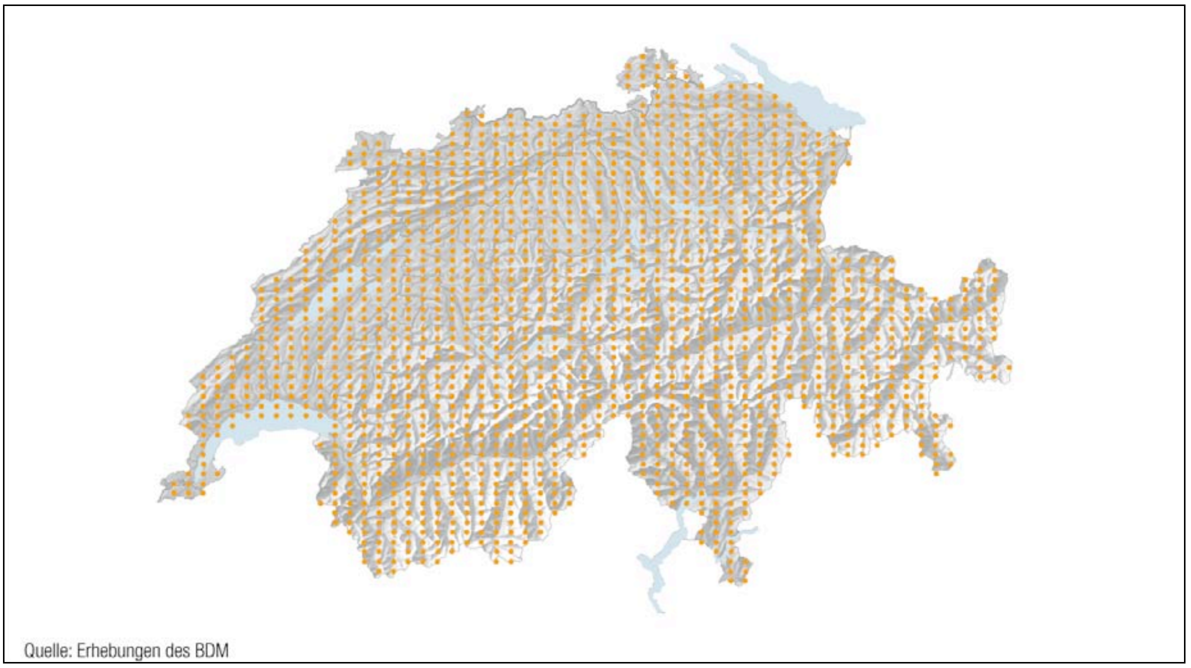

Figure 2: BDM monitors species diversity in habitats in roughly 1600 sampling areas of 10 m^2 each. These sites are evenly distributed over all of Switzerland, with sampling areas on lakes excluded.

Achieved statistical power

Achieved statistical power is measured by computing the minimum detectable difference MDD (Zar, 1999). This value indicates the extent of change in mean species diversity at least required to generate statistically ascertained differences between individual samples (in this case between individual yearly results). The target value for statistical power was defined to be 90%, i.e. a difference in the magnitude of 10% is expected to be detectable in nine out of ten tests. Applied to vascular plants in Swiss forests, for example, this means that in actual fact, a change in the mean species diversity of 0.8 species has a 90% likelihood of giving rise to statistically ascertained differences (table 12).

MDD calculations based on current-state data have been made and averaged for each of the 5-year periods of 2003-2007, 2004-2008 and 2005-2009. MDD calculations based on change data have been made for the survey years of 2003 to 2009.

VASCULAR PLANTS

Habitats	Current-state mean species numbers	Current-state MDD	Change MDD
Forests	21.6	1.6	0.8
Grassland	34.6	2.1	1.1
Arable land	14.9	1.8	2.2
Settlements	19.0	3.7	1.9
Alpine pastures	41.4	3.7	1.7
Unused areas	21.5	3.2	1.1

Table 12: Minimum detectable difference (MDD) for current states of and changes in species diversity of vascular plants in various habitats

MOSSES

Habitats	Current-state mean species numbers	Current-state MDD	Change MDD
Forests	15.7	1.1	0.7
Grassland	6.5	1.1	0.6
Arable land	1.6	0.5	0.6
Settlements	5.0	1.0	0.9
Alpine pastures	18.5	2.4	1.6
Unused areas	13.6	1.8	1.2

Table 13: Minimum detectable difference (MDD) for current states of and changes in species diversity of mosses in various habitats

MOLLUSKS

Habitats	Current-state mean species numbers	Current-state MDD	Change MDD
Forests	9.3	0.9	0.6
Grassland	6.2	0.7	0.6
Arable land	3.7	0.8	0.6
Settlements	6.2	1.3	0.9
Alpine pastures	3.5	1.0	1.1
Unused areas	3.4	1.1	0.7

Table 14: Minimum detectable difference (MDD) for current states of and changes in species diversity of mollusks in various habitats

VASCULAR PLANTS IN FORESTS

Altitudinal zones	Current-state mean species numbers	Current-state MDD	Change MDD
colline	18.1	3.9	2.3
montane	19.7	2.1	1.1
subalpine	27.1	3.0	1.5
alpine	22.1	13.7	1.9

Table 15: Minimum detectable difference (MDD) for current states of and changes in species diversity of vascular plants in forests in various altitudinal zones

VASCULAR PLANTS ON GRASSLAND

Altitudinal zones	Current-state mean species numbers	Current-state MDD	Change MDD
colline	27.5	4.8	3.4
montane	32.6	2.4	1.4
subalpine	45.0	4.2	2.4

Table 16: Minimum detectable difference (MDD) for current states of and changes in species diversity of vascular plants on grassland in various altitudinal zones

MOSSES IN FORESTS

Altitudinal zones	Current-state mean species numbers	Current-state MDD	Change MDD
colline	10.9	2.3	1.5
montane	14.5	1.3	0.9
subalpine	20.2	2.1	1.5
alpine	20.6	9.5	7.5

Table 17: Minimum detectable difference (MDD) for current states of and changes in species diversity of mosses in forests in various altitudinal zones

MOSSES ON GRASSLAND

Altitudinal zones	Current-state mean species numbers	Current-state MDD	Change MDD
colline	3.6	1.5	1.3
montane	5.3	1.1	0.6
subalpine	11.7	2.8	1.6

Table 18: Minimum detectable difference (MDD) for current states of and changes in species diversity of mosses on grassland in various altitudinal zones

MOLLUSKS IN FORESTS

Altitudinal zones	Current-state mean species numbers	Current-state MDD	Change MDD
colline	11.0	2.8	1.9
montane	10.6	1.2	0.8
subalpine	6.5	1.2	1.1
alpine	3.2	3.0	6.1

Table 19: Minimum detectable difference (MDD) for current states of and changes in species diversity of mollusks in forests in various altitudinal zones

MOLLUSKS ON GRASSLAND

Altitudinal zones	Current-state mean species numbers	Current-state MDD	Change MDD
colline	7.6	2.0	1.9
montane	6.3	0.9	0.7
subalpine	5.0	1.3	1.4

Table 20: Minimum detectable difference (MDD) for current states of and changes in species diversity of mollusks on grassland in various altitudinal zones

Sample design for the Z9-EPT indicator

Concise description

The Z9 indicator for aquatic macroinvertebrates (abbreviated to “Z9-EPT”) covers three orders of insects: *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies) and *Trichoptera* (caddisflies), describing current states of and changes in species diversity in Switzerland’s watercourses. Surveys for this indicator have begun in 2010.

The aquatic Z9 sample comprises 574 sampling sites chosen by means of a systematic sampling grid and precisely mapped by their coordinates. Proceeding this way makes sure that any findings on current states of and changes in EPT species diversity in Swiss watercourses are reproducible and statistically valid. The sampling concept is based on watercourses from 2nd order streams up, including culverted watercourses. As a general rule, standing waterbodies, 1st order streams, and watercourses surpassing a predefined width, depth or steepness are not sampled for methodological reasons. In other words, the sample is intentionally restricted to small streams. The Z9-EPT surveying method has been developed and harmonized with the “Macrozoobenthos Level I” module on benthic macroinvertebrates of the EAWAG’s Modular Stepwise Procedure (MSK; Stucki, 2010).

Z9-EPT sampling grid density corresponds to Z7 sampling grid density for the cantons of Jura and Tessin (densified Z7 sampling grid). However, the Z9-EPT sampling grid does not emanate from the same site as the Z7 sampling grid in order to prevent EPT sampling sites from overlapping with Z7 sampling sites. For sampling site selection, BDM experts proceeded to locate a watercourse that intersects with the demarcation of a Z7 kilometer square. Starting at the lower left-hand corner of a kilometer square and advancing in a clockwise direction, the first intersection between a kilometer square and a watercourse is defined as the beginning of the corresponding Z9-EPT sampling area. If, allowing for tolerable small-scale displacements, a sampling area does not fulfill the sampling population’s criteria, selection will move on to the next watercourse intersecting with the kilometer square’s demarcation.

The number of planned sampling areas per biogeographical region is as follows: Jura: 42; Central Plateau: 155; Northern Alps: 180; Western Central Alps: 54; Eastern Central Alps: 84; Southern Alps: 59 (figure 3). Since it will take the first field survey to reveal whether certain sampling areas actually hold a watercourse fulfilling permissible population criteria, the final number of sampling areas will be slightly lower.

The total sample is stratified by altitude, ecomorphology, and by the width or order of a watercourse.

Z9-EPT SPECIES DIVERSITY IN WATERCOURSES

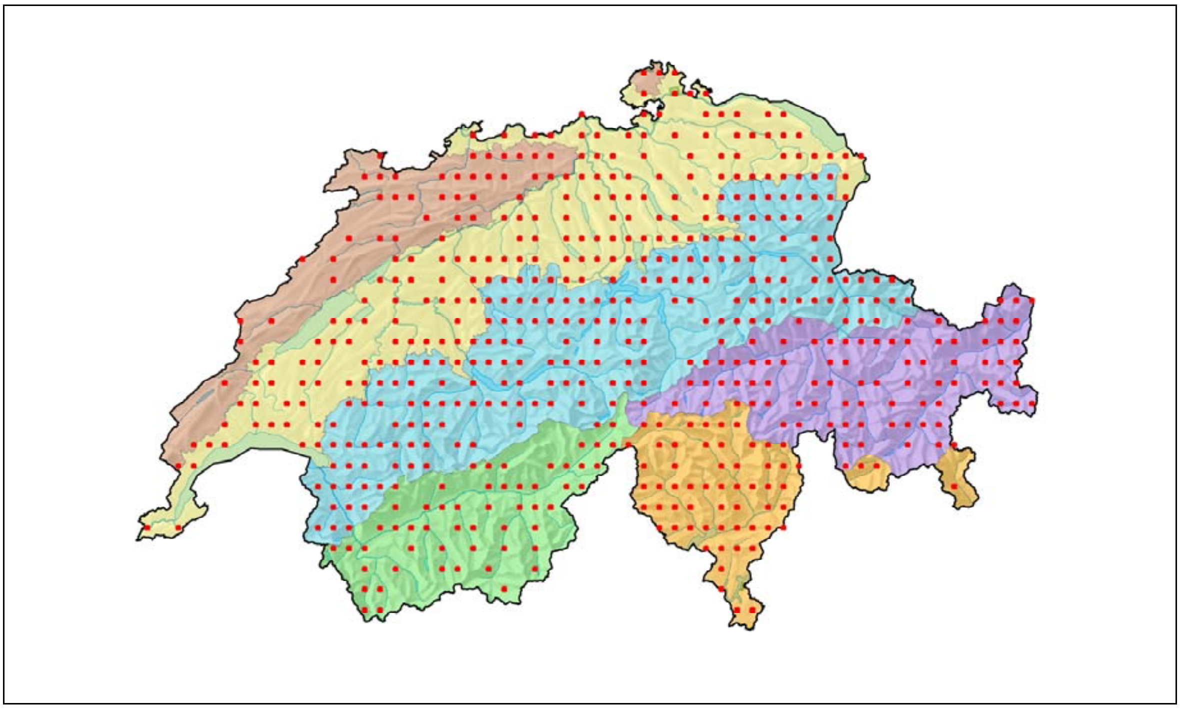

Figure 3: BDM monitors species diversity in watercourses in 574 sampling areas. The illustration shows the distribution of sampling sites by biogeographical region.

Achieved statistical power

As Z9-EPT surveys have not started until 2010, calculations of achieved statistical power are not available yet. Using field data from 2009, however, the indicator's expected statistical power has been calculated per survey and year.

Achieved statistical power is measured by computing the minimum detectable difference MDD (Zar, 1999). This value indicates the extent of change in mean species diversity at least required to generate statistically ascertained differences between individual samples (in this case between individual yearly results).

The minimum detectable difference achievable with a 90% power based on a sample of n=115 (corresponds to the number of sampling areas surveyed per year) is 2.4 species when data are processed per sampling area. This means that, comparing different evaluation units, differences in mean species numbers of 2.4 species would have a 90% likelihood of being discovered.

Flexibility with regard to future analyses

BDM sample design is also expected to make it possible for data to be used for finding answers to new questions that have not even arisen yet at this time. The following two sections offer descriptions of two indicators based on Z7 and Z9 indicator data.

Z8 indicator "Population Size of Common Species"

The Z8 indicator documents changes in the populations of widespread or common species in Switzerland. Common species are of great ecological significance: They make up the major share of the living biomass, they provide important ecosystem services, and they supply an abundant food resource for other organisms. Characterized by large populations and wide distributions, they shape the appearance not only of their habitats, but also of landscapes as a whole.

Common species frequently colonize habitats that are part of the "normal landscape", or they are so undemanding that they are able to live in a wide range of different habitats. Consequently, increases or decreases in the populations of such species allude to the quality of the "normal landscape". If common species become more common and more widely distributed at the expense of rare species, this development has a negative impact on biodiversity, since it trivializes and homogenizes species communities in habitats.

So far, common species have hardly been monitored at all. Yet Z7 and Z9 indicators both provide sampling networks that reflect Switzerland's "normal landscape". Even though there are no frequency data recorded in the field for either Z7 or Z9, insights into species frequencies are possible. Based on a species' presence in or absence from Z7 and Z9 sampling areas, its frequency can be calculated. Species found with a frequency of at least 3% are considered common.

For additional information on this indicator please go to:
http://www.biodiversitymonitoring.ch/english/indikatoren/z8.php

Z12 indicator "Diversity of Species Communities"

The number of species occurring in a sampling area cannot be the one and only measure of biodiversity. While high or increasing numbers of species are basically a good thing, such an increase must not be brought about by alien or undemanding species able to settle in throughout a wide range of habitats, since that may cause typical and specialized species of a particular habitat to be gradually displaced. If such a process were allowed to continue, the long-term outcome would be increasingly similar species communities composed of common species, and that is tantamount to qualitative impoverishment of our landscapes and habitats.

For this reason, BDM was looking for an indicator capable of evidencing and describing biotic homogenization or diversification, if indeed either of these developments were to take place in Switzerland. Z12 meets this requirement. Newly developed and first computed in 2008, this indicator monitors the way species communities diversity develops nationwide, in individual regions, and in various habitats.

In doing so, Z12 is entirely based on data recorded for Z7 and Z9 and covers all species groups and strata surveyed for these two indicators.

The Z12 indicator is designed to monitor temporal changes in the mean Simpson's Index (similarity value) calculated based on all pairwise comparisons of species lists compiled in all sampling areas during a complete survey (5 years) of the BDM total sample. The greater the similarity between species communities in sampling areas, the lower the indicator value, and vice versa.

Hence, the Z12 indicator describes similarities of species communities independently of the species richness observed in surveyed sampling areas. As a result, BDM is able to document and evaluate changes in species diversity and changes in the similarity of species compositions as two different phenomena.

For additional information on this indicator please go to:
http://www.biodiversitymonitoring.ch/english/indikatoren/z12.php

Amplifications at a cantonal level

For reasons of funding, BDM is normally restricted to findings regarding the country as a whole, at best additionally subdivided by biogeographical region. Detailed insights into the development of species diversity in cantons, districts or communities are not possible. However, the BDM sampling concept has deliberately been designed in such a way as to allow cantons to densify the nationwide sampling network, enabling them to gain higher-resolution insights into their particular areas of interest.

Aargau biodiversity monitoring (LANAG)

The canton of Aargau has been monitoring the development of species diversity in landscapes since 1995, starting with surveys of breeding birds. In 1996, surveys of mollusks and vascular plants were added to the program, to be followed by butterflies in 1998. Data on the four species groups are recorded in 517 sampling areas evenly distributed all over the canton. Analogously to BDM, roughly a fifth of all areas is sampled each year, causing a total survey of the canton as a whole to last five years.

Habitat types correspond to those used by Biodiversity Monitoring Switzerland. In addition, fieldworkers log comments on agricultural and forestry use of sampling areas. Further information about land use, location, etc. is obtained from other sources (such as the Aargau Geoportal or the National Forest Inventory) if needed.

Survey data are evaluated by computing the so-called "Kessler Index" (named after a local nature conservation pioneer). Currently, the Kessler Index is at 109 points, or 8 points higher than in 2000.

Completed by an indication of accuracy, mean species numbers for the canton as a whole, certain habitats and regions are determined on an annual basis.

http://www.ag.ch/alg/de/pub/natur_landschaft/erfolgskontrolle/lanag.php (information in German only)

Thurgau biodiversity monitoring

In the canton of Thurgau, the BDM sample comprises nine 1-km^2 sampling areas (Z7) and forty 10-m^2 sampling areas (Z9). Due to the small size of the Thurgau sample, species diversity at a cantonal level cannot be evaluated based on BDM basic data alone. For this reason, the cantonal government ordered the existing BDM sampling network to be densified.

The canton of Thurgau expects this densification to yield trend observations of cantonal species diversity, giving authorities the opportunity to compare results in both a regional and a national context. In addition to improved interpretation options, this approach is aimed at revealing species diversity developments at an early stage.

As requested by the Thurgau government, the densification was based on the surveying methods applied for the BDM Z7 indicator "Species Diversity in Landscapes", depicting the kind of species diversity that is created by the mosaic of habitats and transitional zones (see above).

This "habitat mosaic species diversity" was meant to take center stage, since this is where the majority of questions arise, making it possible to produce synergy effects with the Thurgau Landscape Development Concept LEK. Furthermore, the densification was designed to allow survey data to be broken down by the canton's three major types of land use, i.e. forests, agricultural land with or without networking function, and land zoned for development.

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