

## Conference Paper

# A Global Database of Anomalies in Natural Populations, with an Illustration of Emerging Patterns Focussing on Countries of the Former Soviet Union

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## Abstract

The literature on anomalies from natural populations of amphibians is enormous but widely dispersed and difficult to access. To fill the gap I compiled a global database that covers all extant and fossil amphibian species for which anomalies have been reported. The database focuses on externally visible anomalies. The database is an EXCEL file that provides data on: species, anomalies observed, class of anomalies, sample size, number of abnormal individuals, percentage of abnormal individuals, developmental stage, cause, year of observation, median year, country, location, remarks, and data sources. Using the territory of the former Soviet Union as example we illustrate the publication history, the percentage of urodelan and anuran species of the fauna for which anomalies have been reported, the number of cases reported for the different countries, and the frequency distribution of the number of abnormal individuals.

**Keywords:** Amphibia, anomalies, database, frequency of anomalies, global, publication history, Russia, Soviet Union

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## 1. Introduction

Anomalies in both humans and animals have attracted our attention for centuries and an enormous body of literature has accumulated [1]. Most of the literature is widely dispersed, published in many different languages and often difficult to access, despite a considerable number of reviews [2, 3]. Thus, it is not surprising that most recent publications on the topic consider only a very restricted part of the published literature. This hampers not only progress of knowledge and resolving scientific and non-scientific disputes about the causes of elevated prevalences of anomalies in natural populations, but also addressing and solving the concerns about environmental health.

## OPEN ACCESS

Faced with the lack of a comprehensive overview of the literature to resolve disputes about a major anomaly hotspot [4, 5], I started to collect any publication on anomalies in natural populations of amphibians in the 1980s and conducted a comprehensive review of the topic [1]. While this review builds on a large database, the database has not been published and a description of its content is not yet available. The goal of this publication is to describe the database and its content and to provide exemplary illustrations of patterns of anomalies that emerge from the database for countries of the former Soviet Union.

## 2. Database description

### 2.1. Taxonomic coverage

The database covers all extant and fossil species in the class Amphibia in the Kingdom Animalia for which externally visible anomalies have been reported from natural populations.

### 2.2. Spatial coverage

The database covers all parts of the world that are inhabited by amphibians.

### 2.3. Methods

#### 2.3.1. Review methods

I conducted a comprehensive literature review based on my own extensive literature, the literature on amphibian anomalies compiled by The North American Reporting Centre for Amphibian Malformations, the literature on field herpetology compiled by *Schriftenschau für Feldherpetologie* and a manual search for any anomaly-related indexed word in the *Zoological Record* for 1945-1985 and in *Biosis* for 1945-1985 and 1996-1999. Volumes for other years, *Schriftenschau für Feldherpetologie* and the ISI and SCOPUS databases were searched online using the key words: \*amphib, \*anur, \*urodel and \*gymnophio in combination with \*polymel, \*polydact, \*schizodact, \*polyphalan, \*ectromel, \*amely, \*hemimely, \*phocomel, \*brachymel, \*oligodact, \*adactyl, \*ectrodact, \*brachydact, \*brachyphalang, \*taumel, \*bifurcation, \*dicephaly, \*syndactyl, \*clinodactyl, \*brachycephal, \*microcephal, \*anophthalm,

\*microphthalm, \*macrophthalm, \*cyclopy, (mandibular AND hypoplasia), \*anteversion, \*gigantism, \*edema, \*bloatedness, \*tumour, \*cysts, \*albinis, \*hypomelanic, \*erythris, \*flavis and \*melanic. Furthermore, I attempted to trace any cited reference that might be relevant. For this study, I only extracted data that I could check personally.

The database includes only those publications that I could check myself except for a limited number of papers (primarily more than 100 years old) for which I found verbal citations of relevant parts of the publication, or if at least two later publications cited them consistently, with different details provided so that these authors were likely to have examined the original source independently.

### 2.3.2. Sampling description: identifying anomalies

Compiling data on anomalies requires deciding what is an anomaly and what not. Even gross morphological anomalies in a given species may be the norm in another one. I followed the approach of Henle et al. [1] to decide what to regard as abnormal and what not. The database also includes data from populations without anomalies, if sample size was at least 50 individuals.

## 2.4. Dataset description

The database comprises two parts: an EXCEL database on anomalies reported from natural populations and a pdf document of the full references of all data sources. The language is English. The database is available upon request, conditional on the database being cited in any publication derived from it and that users add their own published data to the database.

## 2.5. Metadata descriptions

Our database consists of the following 14 columns:

### Species

All species of amphibians are considered. Currently (August 2017) the data cover 509 living species (6 Gymnophiona, 117 Urodela, 386 Anura) and one, 2-4 and 1 fossil

species of Urodela, Anura and Temnospondyli. Nomenclature follows Frost [6] for genera, name changes due to name priorities and synonymies, and for subspecies identified in the source reference that have been elevated to full species rank after the publication of the source reference. Splitting of taxa into several species was followed only if allocation of the data to the new species was obvious from morphological or geographic information provided by the assessed source reference or was already done by other authors. Subspecies names are added if provided by the source publication.

## Anomaly

This column lists the anomalies reported in the source references. The terminology follows Henle et al. [7]. I converted the terminology used in the source publication to this terminology to the extent possible based on a reference to a particular terminology, descriptions or figures of the anomalies mentioned in the source publication. For rarer types of anomalies not covered by terminologies and anomalies that have not been precisely described, I used descriptive terms, such as “digits malformed”. A “–” signifies that no anomalies were observed in the population (only when sample sizes were at least 50 individuals).

## Types of anomalies

The different types of anomalies are grouped into the following categories: Alb (albinism), Black-eyed (uniformly black eyes), Blue [individuals with (patches of) blue colouration], Mela (melanism), Colour (other colour and pattern anomalies), Edema (edema and bloatedness with gas), Sk (skeletal anomalies), Ano (other morphological and anatomical anomalies).

## N total

Total number of assessed individuals for a particular population or location. In case of an uncertain overlap of data among samples and/or authors, I considered only the most recent dataset. Sample sizes may be minimum sample sizes if the data provided in the source publication were insufficiently precise. Entries may also be qualitative, such as “thousands” or “several”. A “?” means that no sample size was provided. Dead individuals were not included in the data extracted from publications.

## N abnormal

Total number of abnormal individuals for a particular population or location. In case of an uncertain overlap of data among samples and/or authors, I considered only the most recent dataset. Individuals injured upon capture were not scored as abnormal and the presence of parasites was scored as an anomaly only if accompanied by explicitly mentioned morphological anomalies induced by the parasite. Entries may be minimum sample sizes if the data provided in the source publication was insufficiently precise. Entries may also be qualitative, such as “dozens” or “several”. A “?” means that no data on the number of abnormal individuals are available. Dead individuals were not included in the data extracted from publications.

## Frequency

Frequency is calculated by  $N \text{ abnormal} / N \text{ total}$ . Cases, in which only the frequency was provided by the source reference, were also included. Entries may also be text, such as “several” or “many”. A “?” means that no data on the percentage of individuals that were abnormal were published.

## Stage

Stage refers to the developmental stages to which the data apply and may comprise several stages or a single one. The following stages are differentiated: clutch, egg, embryo, larva/tadpole, metamorph, juvenile, subadult, adult. Metamorph refers to individuals that are in the final stages of metamorphosis or recently completed metamorphosis. Adults may be differentiated into males and females. I followed the source publication to allocate individuals to stages. If the stage was not provided but it was clear that individuals that had completed metamorphosis were studies, I used “postmetamorph” as entry. A “?” means that the stage was not provided.

## Cause

Cause is text and refers to the cause(s) of the anomalies assumed by the source publication. Only in few cases, the causes suggested in the source publication were tested experimentally. If the source publication was vague on the causes, did not discuss causes or are inconsistent with knowledge from the literature [4], the cause

was scored as “unknown”. A “-” signifies that no anomalies were observed in the population (included only when sample sizes were at least 50 individuals).

## Year

Year refers to the years in which data had been collected. If a range is presented, the range represents the start and the end of the survey period but sampling may have not occurred in each year. If the year of sampling was not provided in the source, the year of publication was entered.

## Median Year

Median year is the median of the years in which data were collected. If only the starting year and final year were available, we assumed that sampling was carried out annually to calculate the median. If the number of sampling years was an even number, we used the last sampling year of the first half of the sampling years instead of the median.

## Country

Country identifies the country in which data had been collected. The designation of geographical entities in the database does not imply the expression of any opinion whatsoever on the part of the data compiler concerning the legal status of any country, territory or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

## Location

Location follows the site acronyms or site names used in the cited publication(s). This information is included to facilitate tracing of the data in the source reference(s) and was used in the data quality check to identify data that apply to the same location/population, allowing also the identification of cases in which a source did not cite other publications on the same location/population.

## Remarks

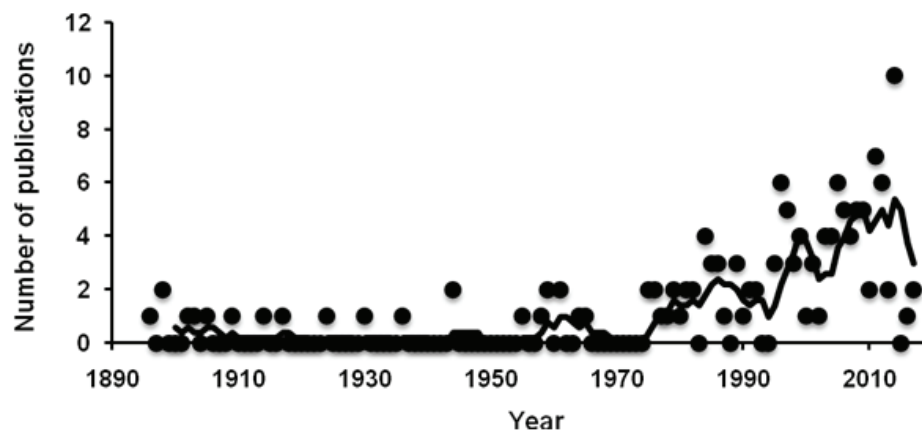
Remarks provide additional information on the study, such as additional details on the anomalies reported, the number of sites surveyed, comparison to other sites or species studied in the same site or about suggested causes.

## Source

Source is the citations of the publications from which the data on anomalies and/or on potential causes were extracted. The publications that were used for the collation of the database are available as a separate pdf document that includes all publications on amphibian anomalies that I have collated.

## 3. Exemplary illustrations of patterns

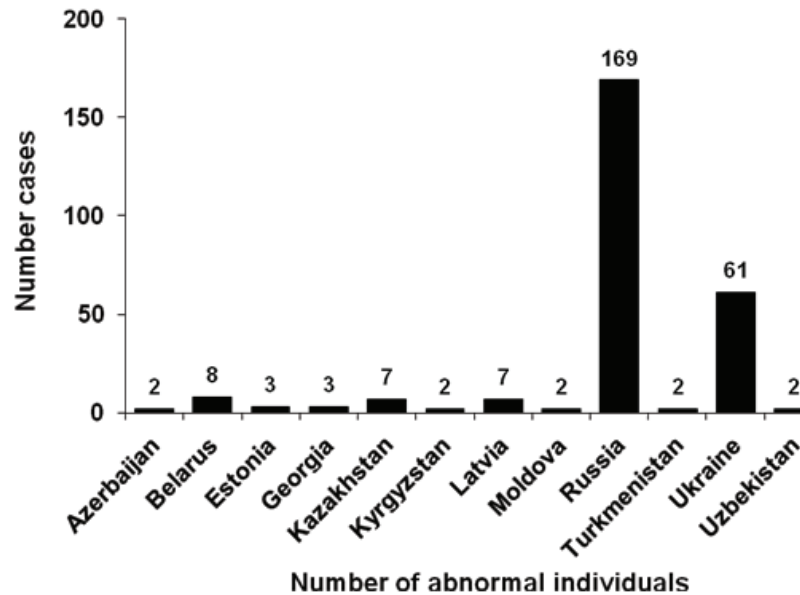
I present examples of patterns that I extracted from the database for countries of the former Soviet Union. The database covers data from 143 publications that reported anomalies for this geographic region. Figure 1 provides an overview of the history of these publications. The first publication dates back to 1896 [8]. I found few publications for the period until the 1970ies. Since then, the number of publications steadily increased. This increase is slower than the global increase that started in the 1950s and was exponential since the 1980s [1].



**Figure 1:** Temporal pattern of publications reporting or reviewing anomalies in natural populations of amphibians in the territory of the former Soviet Union, with 5-years running average. Database accessed on 12.9.2017.

Most of the data available were collected in Russia and the Ukraine. For all other countries only few data have become available (Fig. 2). Besides less field research

efforts in these countries, this is presumably also due to higher difficulties to find and access local and regional publications from these countries.



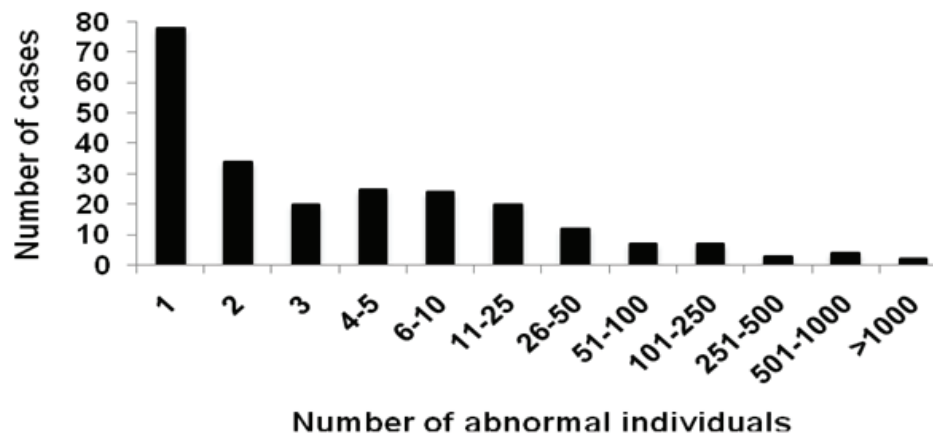
**Figure 2:** Number of cases reported from the countries of the former Soviet Union. Database accessed on 12.9.2017.

The database covers nine species of urodeles and 22 species of anurans from the territory of the former Soviet Union, whereas the number of species known for this region is 15 and 33, respectively [9]. Thus, the fraction of species, for which anomalies were reported, was very similar between anurans and urodeles ( $X^2 = 0.2$ ;  $\alpha > 0.8$ ). This differs from the data compiled by Lannoo [10] for North America, where for a larger fraction of the known species of anurans anomalies were reported compared to urodeles. He interpreted this pattern as indicating a higher sensitivity of urodeles to obtain anomalies. In contrast, globally the fraction is higher for urodeles [1]. However, one cannot derive any conclusion on a different sensitivity from these data, because such an inference requires the strong assumption that both anuran and urodele species were exposed to the same teratogenic factors and that the same percentage of species and the same (average) number of populations have been assessed with sufficiently large sample sizes. These assumptions are certainly violated.

Most of the observed cases reported are single abnormal individuals (Fig. 3). However, there is also a considerable number of cases, in which more than ten abnormal individuals were found and two cases, in which even more than 1000 individuals were abnormal. The frequency distribution of the number of cases observed for different numbers of abnormal individuals is similar to that for North America, whereas in



Europe, the percentage of cases that involve a single abnormal individual is considerably higher.



**Figure 3:** Frequency distribution of the number of abnormal individuals observed in natural populations. Database accessed on 12.9.2017.

In conclusion, the database contains valuable information that allows extracting a range of patterns of reported anomalies for various regions and globally. However, care is needed in interpreting the patterns and rigorous standards for data collection is required to improve the power that is provided by such global databases.

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