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Review of malformed frogs

Abstract

This study reviewed the survey of malformed frogs and the probable causes of their deformities. It analysed the checklist and pattern of malformations in frogs and examined different malformations in frogs of selected articles. It also reviewed the causes of malformation in frogs of different articles. The reviewed showed that limb malformations with 22.41% was the most recorded malformations in frogs with pattern of publications revealed that there was varying trend in article publication which peaked in 2000 and 2023. Different malformations in frogs are abnormal skin, albinism, extra hindlimb, eye malformation. Others are lack of palms, appendages and appendicular, limb malformation, ectrodactyly, brachydactyly and ectrodactyly. The causes of malformations in frogs reviewed includes mutation, parasites, heavy metals, environmental stressors and ultraviolet light. The study concluded that human factors or anthropogenic activities played an important role in malformations in frogs reviewed.

Keywords: frogs, deformities, ectrodactyly, brachydactyly, ectrodactyly

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Introduction

A frog is any member of a diverse and largely carnivorous group of short-bodied, tailless amphibians composing the Order Anura.[1] Warty frog species tend to be called toads, but the distinction between frogs and toads is informal, not from taxonomy or evolutionary history.[2] Anurans mostly lay their eggs in water, breed by producing tadpoles that develop there, and eventually become amphibious adults.[3] They constitute an excellent indicator for monitoring the environment due to their complex life cycles and high sensitivity to environmental changes.[4] Frog populations have declined over the past 20 years due to habitat loss and degradation, increased pollution, and changes in the global climate (Rodriguez and Fernandez, 2005). Malformed frogs are a significant problem in addition to the quick decreases in frog populations.[5] Mass population depletion and odd occurrences like deformities are signs that our environment may be facing crises.[6]

The presence of other toxins in the water, such as heavy metals like copper, xenoestrogens like diethylene glycol, and pesticides like methoxychlor, may result in the development of deformed frogs.[7] Frog deformity can be caused by parasite *Ribeiroia ondatrae* infection in addition to increasing UV radiation and water pollution.[8] Numerous deformed frogs have been reported in the US and Europe.[9–11] Wildlife has an intrinsic strategy to live in the most unlikely situations when faced with xenobiotic pollutants that impact them, such as changes in enzyme activity or protein expression.[12] The aim of this study is to review the survey of malformed frogs and the probable causes of their deformities.

Studies on amphibian malformation

Studies on amphibian limb abnormalities have recently become common in the field of amphibian conservation. These abnormalities can vary from limb malformations to complete limb absence. Many stressors can cause similar responses and a singular cause that links the array of abnormalities is not known. Instead, the several known causes of these abnormalities appear to have variable effects. Malformations are deformities that are caused by environmental factors which prevent normal anatomical development, especially during the larval life-stage. As a result, affected animals can develop too many, or not enough, of certain body parts.[13]

Different authors have reported malformations in frogs and toads. Meteyer et al.[14] recorded abnormalities in northern leopard frogs *Rana pipiens* and it is most commonly found in Minnesota. Their investigation showed that 6.5 % of 13,763 frogs collected were malformed. The malformations observed included missing limbs, missing digits, extra limbs, partial limbs, skin webbing, malformed jaws, and missing or extra eyes. Schoff et al.[15] also recorded the prevalence of skeletal and eye malformations in frogs from North-Central, United States. The results revealed that 2.3% of the total population had eye malformations while 1.6% recorded skeletal malformations. It has also been reported that internal organs can be affected but amphibian malformations noticed by the public are usually those affecting external body parts, such as digits, limbs or the tail in newts and salamanders.[13] A variety of agents are known to cause malformations in amphibians, these include pollutants, parasites, nutritional deficiencies and injury during development. Other possible causes of amphibian deformations are genetic and environmental factors, such as microbial diseases and other disorders, elevation of UV-B radiation and the major chemical agents, most of them found in agribusiness pollution.[17] These may cause homeostatic imbalances that can result in incorrect developments of anurans.[18] Lannoo[19] argued that many sources, both natural and artificial, ranging from fish excrement to overcrowding, are significant when pinpointing causes of the abnormalities. Malformations detected in different anurans inhabiting different microhabitats may denote environmental complications, which also may impact on other organisms and are important to help understanding malformation dynamics.[20]

Studies on Frog Malfunction

Amphibians' population have been recorded to be on the decline since the 1980s. According to Whitfield et al.,[21] this development has led to the current biodiversity crisis. It has also been documented that decrease in the population could be as a result of developmental malformations, especially limb deformities, occurring in amphibians.[22] The authors are of the view that normal rate of abnormalities which was 5% and occur naturally had increased to 15%. Amphibians have moist, permeable skins and shell-less eggs which are directly exposed to the soil, water and sunlight, and can absorb toxic substances present in their surrounding environment.[23] These toxic substances have been known to cause different types of abnormalities in amphibians.[24]

Amphibians are especially sensitive to changes in precipitation, temperature and ultraviolet radiation and their habitats may be influenced strongly by acid precipitation.[25] Thus, amphibians

are considered to be excellent biological indicators of general environmental health and early warning systems to environmental degradation.[23] Abnormalities in frogs have been conducted through surveys and experimental studies. In a study conducted by Farquharson et al.[24] on the impacts of toxin on the four frog species of found in protected areas of Kruger National Park. The results showed that frogs exhibited deformities in different parts of their body. In a field survey conducted by Thigpen et al.,[26] sixteen Fowler's toads, *Anaxyrus fowleri*, and one dwarf American toad, *Anaxyrus americanus charlesmithi* were collected in central Arkansas through direct observation of abnormal toads. Their findings revealed varying degree of abnormalities in both forelimbs and hindlimbs and on both sides of the body. The study concluded that the environment might have caused the abnormalities recorded in the frogs.

Similarly, Mônico et al.[27] reported malformation in three anuran species from a preserved remnant of Atlantic Forest in southeastern Brazil. The frog species investigated are *Crossodactylus timbuhy*, *Proceratophrys schirchi* and *Thoropa miliaris*. The study showed that malformations detected in frogs were hemimelia (long bone shortened with ectrodactyly digit absent) and brachydactyly (digit shortened) in *C. timbuhy* while microphtalmia (small eye) was reported in *P. schirchi* and ectrodactyly in *T. miliaris*. A report on morphological malformation of adult *Itapothyla langsdorffii* in Rebio reserved area, south eastern Brazil, was carried out by Mônico et al.[27] The study reported an individual with a malformed head during the survey period. Lunde and Johnson[13] was of the view that amphibians in well-preserved areas can have natural osteological deformities as a consequence of intrinsic genetic and developmental imperfections. Two hundred and ninety-three *Lithobates* spp. of frogs collected from wetlands in an agricultural region of Nebraska, USA were examined for abnormalities. The frogs showed gonadal anomalies and results revealed that the froglets had ovarian dysgenesis and high rates of testicular oocytes. Ballengee and Sessions[18] provided evidence experimentally supporting the idea that missing limbs in deformed amphibians can be caused by a specific predator. It was reported that dragonfly nymphs use sublethal "selective predation," attacking or capturing tadpoles and gnawing off their protruding hind limbs, often causing permanent limb deformities in frogs that survive to metamorphosis.

Studies have also shown that deformed frogs featuring extra limbs are caused by a parasite, specifically the trematode *Ribeiroia ondatrae*.[28] Ballengee and Session[18] observed that tadpoles with deformities caused by parasites such as extra limbs are largely immobile and do not survive long once they metamorphose. Pollutants such as chemical pollutants have been shown to cause limb deformities in natural populations of amphibians.[29]

Survey of malformation in African frogs

The current widespread deformities among frogs seem to have been linked to recent environmental changes. Numerous amphibian population declines have been attributed to increased mortality rates following infection with the pathogenic chytrid fungus *Batrachochytrium dendrobatidis*.[30] Other factors associated with the amphibian decline phenomenon include habitat loss, climate change, infectious disease, overexploitation, pollution and introduced species.[31] A study to determine the effect of atrazine application on the African clawed frog (*Xenopus laevis*) inhabiting ponds in a maize-growing area MGA and non-maize-growing area NMGA in the Viljoenskroon and Potchefstroom regions of South Africa was investigated by Du Preez et al.[32] The results showed that the herbicide atrazine caused gonadal deformities in frogs.

Amphibians play diverse roles in natural ecosystems and their decline may cause other species to become threatened or may undermine aspects of ecosystem function.[33] Frogs are an important prey source for diverse predators and their tadpoles, which are usually filter feeders, contribute to the stability of water quality in ponds and streams Mohneke et al.,[34] In a study conducted by Ezemonye and Tongo,[35] *Bufo regularis* was evaluated to determine the uptake and effect of environmentally toxicity of Endosulfan and Diazinon pesticides. The results of the authors showed that the pesticides caused dose-dependent deformities and behavioural abnormalities in *Bufo regularis*.

Malformation in Nigerian frogs

Nigeria is located within the Guinean rain forest GrF biodiversity hotspot of West Africa. It is located between West and Central Africa.[36] Thus, the country is situated between the biodiversity hotspot of the upper and lower Guinea forest regions.[36] Nigeria boasts of a wide variety of ecosystems ranging from mangroves and rainforests in the south, different savannahs up north, to the Jos plateau in central Nigeria and mountainous habitats in Eastern Nigeria towards the Cameroon border.[37] About 115 species of amphibians have been recorded within the country, two of which are caecilians and one endemic species *Amietophrynus perreti* has been described in the country.[38]

A high biodiversity loss including steep decline in amphibian populations has necessitated assessment of the conservation status of amphibians in Nigeria. The causes of amphibian population declines are diverse and there appears to be no single cause for their decline.[39] Nigeria harbours high biodiversity and endemism consisting of both West and Central African Anuran species.[37] Nigeria is also blessed with amphibian biodiversity which are observed in areas around waterbodies.[40] Though, some regions have been documented to be seriously affected by pollution especially in the Niger Delta region. There is high tendency that anurans especially in that region of Nigeria would have undergo some abnormalities.

Abnormalities in amphibians have been reported around the world in a broad number of taxa,[41] but there is little or no literature on malformation or abnormalities in Nigeria frogs. However, toad abnormalities have been documented to some extent in Nigeria. Akinsanya et al.[42] examined the impacts of trace metals on the African common toad, *Amietophrynus regularis* in Lagos Lagoon. A total of 120 toads of both sexes, alongside 45 soil samples were collected from each of three 3 stations labeled Dumpsite, Lagoon front and Highrise, using hand nets and by hand-picking. The results showed that there were mild tissue alterations in the toads analysed.

Many factors influence the development of morphological abnormalities in amphibians, such as genetic predisposition, heavy metal concentrations, radiation exposure.[43] Synergistic interactions of these factors have also been documented to influence malformations.[44] Rates of abnormalities are considered natural when present in less than 5% of the population (Stocum, 2000). Amphibians play important roles in ecosystem services, medical research and as bio-indicators. Yet, nearly 41% of all existing amphibians are threatened with extinction due to factors such as abnormalities, diseases, human activities.

Methodology

This involved finding citations made on malformations in natural populations of frogs. The literature on malformation of frogs were compiled through various sources of citation. This study also involved extensive collection of literatures related to frog malformations from

different sources such as research gate, academia, Z-library, google scholar etc. Keywords such as frog deformity, malformation, anuran abnormality and frog defects were used to obtain researches published between 1990 and 2023. Examining the occurrence of malformations presents significant difficulties because obvious physical malformations in one species may be the norm in another. Injuries in our counts of malformations were included because they can result in malformed structures and can be challenging to distinguish from other developmental malformations. Only journals that are related to abnormalities were included. Different varying degrees of abnormalities were recorded based on their years of reportage. The frequency of malformations was also analysed with respect to the different frog species and their corresponding references. Causes of the abnormalities and their corresponding abnormalities were also reviewed in order to understand the different causes of anomalies.

Checklist of Malformations in frogs

The checklist of malformation showed that limb malformation was the most recorded malformations. Other malformations that recorded numerical reportage by authors are eye malformation, abnormal skin, hindlimb malformation and ectrodactyly as presented in Table 1. The pattern of publications of different malformations showed that it ranged from 1993 with a peak period in 2000. However, there was a little downward trend in 2003 and 2010. Also, increase in reportage was also observed in 2017 with highest level recorded in 2022 as shown in Figure 1, 2. The percentage of malformations in frog revealed that limb malformation had the highest reported malformation while malformations such as brachydactyly, skin and limb rotation and mouth malformation were among the least reported malformations as presented in Table 2.

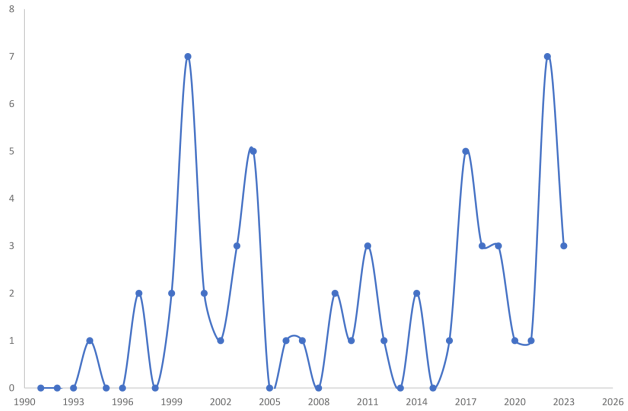

Figure 1 Pattern of Publications Reportage of Malformations in Frogs.

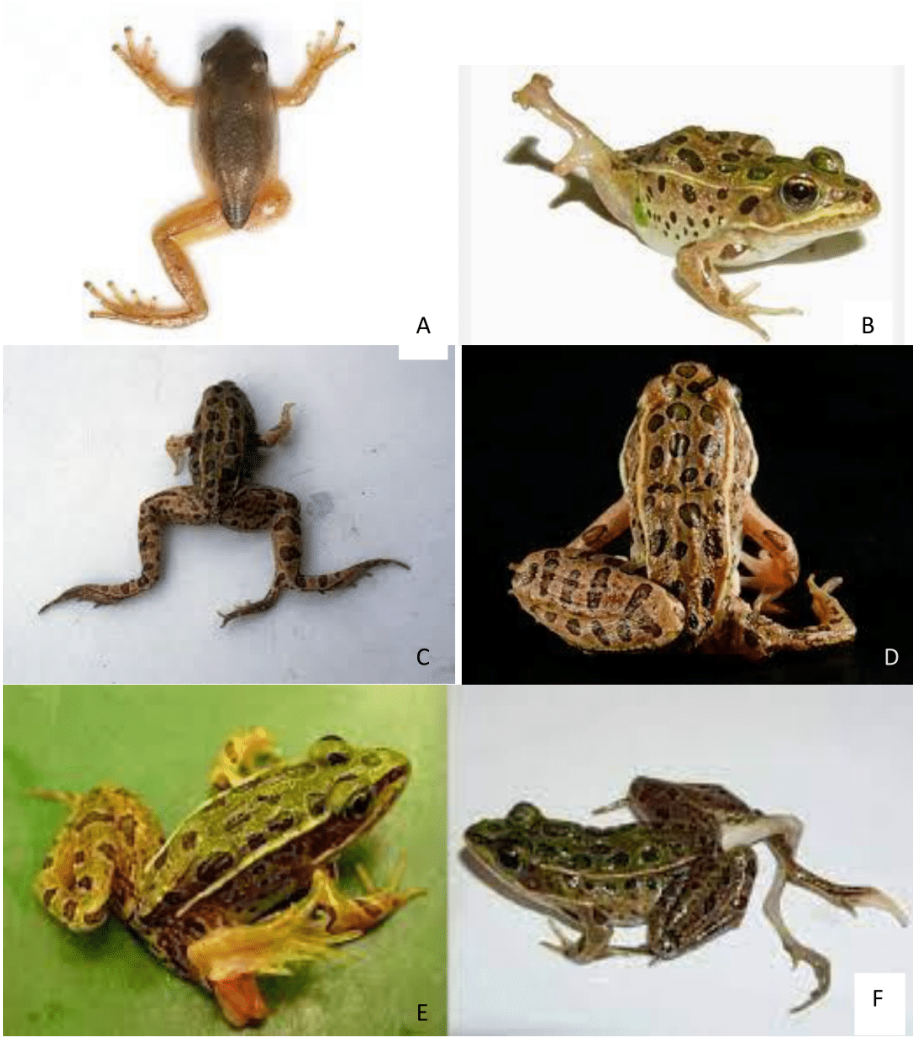

Figure 2 Some common malformations observed in frogs; A: Missing limb. B: Incompletely formed hindlimbs. D: malformed hindlimb. C, E and F: Extra limb.

Malformations in different frogs

Different malformations were recorded in different frogs by different authors as shown in Table 3. Frog species such as *Amolops chunganensis*, *Rana clamitons*, *Scinux squalirostris, Rana marina* were reported with different malformations. The malformations included abnormal skin, albinism, hindlimb malformation, limb abnormalities etc. others are absence of eyes or eye malformation, split-leg malformation, polydactyly, missing digits of varying severity. These digits severity recorded are oligodactyly, ectrodactyly and brachydactyly. The frequency of malformations showed that different authors recorded frequency of occurrence that varied from 0.01% in *Rana temporaria* to 100% in *Rana hanluica*.

Rana pipiens recorded 86% hindlimb malformation while 81% malformation of the limb was reported in *Rana catesbeina*. The tree summary of different abnormalities in frogs showed that limbs malformation and its associated severity were the most reported malformations while eye malformation was the least recorded abnormalities as shown in Figure 3&4.

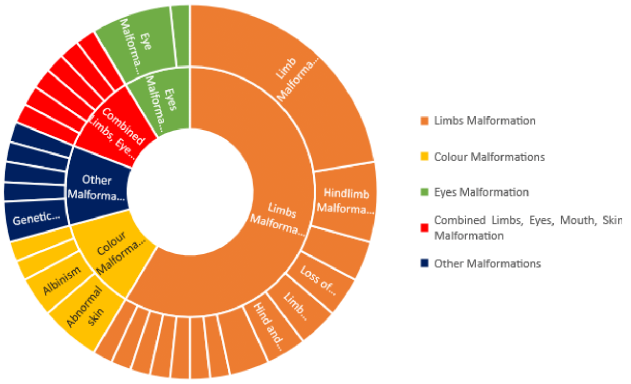

Figure 3 Tree Summary of Malformations in Reported Frogs.

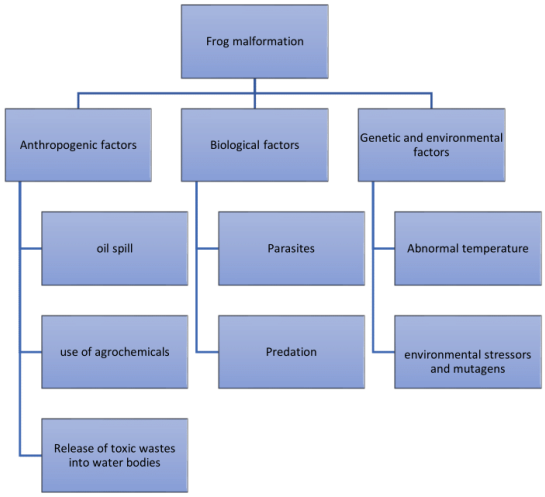

Figure 4 Causes of frog abnormalities.

Causes of Abnormalities

The parasite *Ribeiroia ondatrae* has been observed to cause limb malformation in frogs. Heavy metals also cause eye malformation while polymely is caused by chemicals or mutagenic factors. Limbs and ocular malformation, lack of palms, appendages exostosis to appendicular and skin abnormalities are caused by environmental stressors, organic pollutants and agricultural chemicals and mechanical perturbation respectively as shown in Table 4.

Table 1 Checklist of Different Malformations in Frogs and its Reported Year(s)

S/N	Abnormalities	Number Reported	Year(s) Reported
1.	Abnormal skin	3	2023, 2023, 2023
2.	Absence of Eyes	1	2022
3.	Albinism	2	2002, 2003
4.	Brachydactyly (Shortening of Digits)	1	2017
5.	Colour Anomalies	1	2022
6.	Digit malformation	1	2004
7.	Ectrodactyly (Loss of Tarsal Bones)	2	1994, 2018
8.	Extra Hindlimb	1	2010
9.	Eye Malformation	4	2003, 2004, 2009, 2011
10.	Genetic Abnormalities	2	2000, 2007
11.	Hind and Forelimbs Malformation	2	2001, 2022
12.	Hindlimb Malformation	4	1997, 2000, 2017, 2022
13.	Lack of Palms, Appendages Exostosis to Appendicular	1	2020
14.	Limb Abnormalities	2	1997, 2009
15.	Limb Malformation	13	1999, 2000, 2003, 2004, 2006, 2014, 2017, 2017, 2018, 2018, 2019, 2019, 2021
16.	Limbs and Digits	1	2022
17.	Limbs and Ocular Malformation	1	2022
18.	Loss of Limbs	2	2011, 2022
19.	Malformation of the limbs and mouth	1	2000
20.	Malformation of the limbs, Spine, Eyes and Skin	1	2011
21.	Micrognathia of the Mandible	1	2004
22.	Missing Eyes, Malformed hindlimbs	1	2000
23.	Missing limbs, Eyes and mandibles	1	2000
24.	Mouth malformation	1	2000
25.	Oligodactyly (Missing Digits)	2	2004, 2012
26.	Polydactyly (Extra Digits)	1	2019
27.	Skeletal Abnormalities	1	2017
28.	Skin and Limb Rotation	1	2014
29.	Split-leg Malformation	1	1999
30.	Testicular Anomalies	1	2016
31.	Transient Albinism	1	2001

Table 2 Malformation Percentage of Reported Frogs

S/N	Abnormalities	Number Reported	Percentage of Reported Malformation
1.	Abnormal Skin	3	5.17
2.	Absence of Eyes	1	1.72
3.	Albinism	2	3.45
4.	Brachydactyly (Shortening of Digits)	1	1.72
5.	Colour Anomalies	1	1.72
6.	Digit Malformation	1	1.72
7.	Ectrodactyly (Loss of Tarsal Bones)	2	3.45
8.	Extra Hindlimb	1	1.72
9.	Eye Malformation	4	6.9
10.	Genetic Abnormalities	2	3.45
11.	Hind and Forelimbs Malformation	2	3.45
12.	Hindlimb Malformation	4	6.9
13.	Lack of Palms, Appendages Exostosis to Appendicular	1	1.72
14.	Limb Abnormalities	2	3.45
15.	Limb Malformation	13	22.41
16.	Limbs and Digits	1	1.72
17.	Limbs and Ocular Malformation	1	1.72
18.	Loss of Limbs	2	3.45
19.	Malformation of the Limbs and Mouth	1	1.72
20.	Malformation of the Limbs, Spine, Eyes and Skin	1	1.72
21.	Micrognathia of the Mandible	1	1.72
22.	Missing Eyes, Malformed Hindlimbs	1	1.72
23.	Missing Limbs, Eyes and Mandibles	1	1.72
24.	Mouth Malformation	1	1.72
25.	Oligodactyly (Missing Digits)	2	3.45
26.	Polydactyly (Extra Digits)	1	1.72
27.	Skeletal Abnormalities	1	1.72
28.	Skin and Limb Rotation	1	1.72
29.	Split-Leg Malformation	1	1.72
30.	Testicular Anomalies	1	1.72
31.	Transient Albinism	1	1.72
Total		58	100

Table 3 Different Malformations of Frogs and its Frequencies

S/N	Malformation	Frequency of Malformation occurrence	Number of frogs sampled	Frog species	References
1.	Abnormal Skin	59.09%	22	*Amolops chunganensis*	Sun et al.[45]
2.	Cutaneous fusion, rotation of limbs, ectromely	30.70%	86	*Rana luteiventris*	Roberts and Dickinson[46]
3.	Cutaneous fusion, polymely; presumably also torsion of limbs, ectromely	100%	4	*Lithobates septentrionalis*	Hoppe[47]
4.	Albinism	100%	3	*Rana temporaria*	Miura et al.[48]
5.	Albinism	50%	4	*Rana septentrionalis*	Johnson et al.[49]
6.	Transient Albinism	0.50%	9,473	*Pelodytes punctatus*	Rivera et al.[50]
7.	Colour Anomalies	100%	2	*Rana arvalis*	Katz[51]
8.	Extra Hindlimb	100	1	*Litoria aurea*	Seabrook-Davison et al.[52]
9.	Eye Malformation	65%	54	*Rana pipiens*	Helgen et al.[53]
10.	Eye Malformation	7.10%	694	*Linnodynastes fletcheri*	Spolyrich et al. (2011)
11.	Eyes Malformation	1.40%	1131	*Rana pipiens*	Schoff et al.[15]
12.	Eye Malformation	0.07%	7,260	*Lithobates sylvaticus*	Eaton et al.[54]
13.	Absence of Eyes	100%	1	*Xenophrys major*	Lalremsanga[55]
14.	Polydactyly	3.20%	869	*Lithobates septentrionalis*	Vandenlangenberg et al.[11]
15.	Genetic Abnormalities	25%	46	*Eleutherodactylus sp*	Heinicke et al.[56]
16.	Hind and Forelimbs Malformation	4.28%	513	*Rana catesbeiana*	Johnson et al.[8]
17.	Hindlimb Malformation	0.10%	74	*Corythamantis greeeningi*	Silva-Soares et al.[57]

Table 3 Continued...

S/N	Malformation	Frequency of Malformation occurrence	Number of frogs sampled	Frog species	References
18.	Hindlimb Malformation	7.40%	203	*Rana clamitans*	Quellet et al.[58]
19.	Hindlimb Malformation	86%	182	*Rana pipiens*	Meteyer et al.[14]
20.	Hindlimb Malformation	100%	1	*Euphlyctis kalasgramensis*	Siammawii et al.[59]
	Lack of Palms, Appendages and Appendicular	1.80%	10,909	*Rana limnochacis*	Huang et al.[60]
21.	Limb Abnormalities	1%	350	*Lithobates catesbeianus*	Volpe and Rosenbaum[61]
22.	Limb and Ocular Malformation	50%	100	*Odorrana graminea*	Yeung and Yang[62]
23.	Limb Malformation	81%	1,436	*Rana catesbeina*	Sower et al.[63]
24.	Limb Malformation	1%	4115	*Rana temporaria*	Piha et al.[64]
25.	Limb Malformation	79%	101	*Rana septentrionalis*	Gardiner and Hoppe[65]
26.	Limb Malformation	100%	1	*Scinux squalirostris*	Jorgewich-Cohen et al.[66]
	Hindlimb Malformation and Fused Toes	100%	1	*Boana cinerascens*	Pommer-Barbosa et al.[67]
27.	Limb Malformation	100%	1	*Euphylyctis cyanophlyctis*	Jaman et al.[68]
28.	Limb Malformation	100%	1	*Rana boylii*	Alvarez et al.[69]
29.	Limb Malformation	13.30%	102	*Pelophylax esculentus*	Nekrasova and Kuibida[70]
30.	Limb Malformation	25%	12	*Isthmohyla rivularis*	Hedrick and Cossel[71]
31.	Limb Malformation	100%	1	*Rana marina*	Zuluaga-Isaza et al.[72]
32.	Limb Malformation	0.70%	150	*Euphlyctis Cyanophlyctis*	Jilani et al.[73]
33.	Limb Malformation	7.90%	5100	*Rana pipiens*	Vandenlangenberg et al.[11]
34.	Limb Malformation	68.14%	113	*Rana pipiens*	Garber et al.[74]
35.	Limb Malformation	100%	2	*Crossodactylus timbuhy*	Monico et al. (2019)
36.	Limb Abnormalities	25%	200	*Rana cascadae*	Bowerman et al.[75]
37.	Limbs and Digits Malformation	13.30%	30	*Pelophylax esculentus*	Kryvoltsevych et al.[76]
38.	Loss of Limbs	8.20%	428	*Linnodynastes tasmaniensis*	Spolyrich et al. (2011)
39.	Ectrodactyly (Missing Digit)	25%	1537	*Neobactrachus centralis*	Read and Tyler (1994)
40.	Absence of Limbs	2%	158	*Rheobates palmatus*	Molina-Betancourt et al.[77]
41.	Brachydactyly (Shortening of Digits)	100%	2	*Leptodactylus podicipinus*	Dos santos et al.[78]
42.	Malformation of the Limbs and Mouth Malformation	0.39%	9,987	*Acris crepitons*	Gray[79]
43.	Digit Malformation	2%	21,000	*Rana sylvatica*	Eaton et al.[54]
44.	Ectrodactyly (Loss of Tarsal Bones)	5.38%	665	*Rana arvalis*	Ibragimova and Nakonechayi[80]
45.	Malformation of the Limbs, Spine, Eyes and Skin	35.30%	273	*Pelophylax saharicus*	Hassine et al.[81]
46.	Micrognathia of the Mandible	9%	238	*Rana aurora*	Bettaso[82]
47.	Missing Eyes, Malformed Hindlimbs	2.00%	3598	*Rana pipiens*	Converse et al.[83]
48.	Missing Limbs, Eyes and Mandibles	0.39%	10,000	*Acris creptans*	Gray[79]
49.	Mouth Malformation	11%	252	*Rana utricularia*	Burger and Snodgrass[84]
50.	Oligodactyly (Missing Digits)	0.82%	5,243	*Lithobates sylvaticus*	Eaton et al.[54]
51.	Oligodactyly (Missing Digits)	78.5	1171	*Lithobathes catesbeianus*	Rowe et al.[85]
52.	Polydactyly (Extra Digits)	5.50%	110	*Pelophylax ridibundus*	Svinin et al.[86]
	Skeletal Abnormalities	2.50%	854	*Cyclorana mainia*	Read et al.[87]
53.	Skin and Limb Rotation	1.90%	848	*Ferjervarya limnocharis*	Hegde and Krishnanurthy[88]
54.	Split- Leg Malformation	3.20%	31	*Rana Sphenocephala*	Mc Callum[89]
55.	Testicular Anomalies	61%	193	*Pelophylax esculentus*	Litvinchuk[90]

Table 4 Causes of Different Malformations Reported in Frogs

S/N	Abnormalities	Causes	References
1	Albinism	Spontaneous Tyrosinse Mutation	Miura et al.[48]
2	Oligodactyly	Trematode Parasite	Kaiser[91]
3	Eye Malformation	Heavy Metals	Fort et al.[92]
4	Genetic Abnormalities	*Batrachochytrium dendrobatidis*	Savage et al.[93]
5	Hindlimbs Malformation	*Ribeiroia ondatrae*	Levey[94]
6	Polymely	Chemicals or mutagenic factors	Ohler and Dubois[95]
7	Polydactyly	*Strigea robusta*	Svinin[96]
		Ribeiroia ondatrae	Johnson et al.[97]
8	Skin Abnormalities	Cutaneous injuries/alterations in water quality	Pessier[98]
9	Loss of Limbs	Predators	Ballenge and Sessions[18]
10	Limb Malformation	Parasitic Trematode (*Ribeiroia ondatrae*)	Johnson et al.[99]
12	Skin and Limb Rotation	Mechanical Perturbation	Hecker and Sessions[100]
13	Limbs and Ocular Malformation	Environmental stressors	Ankley et al.[101]
14	Lack of Palms, Appendages Exostosis to Appendicular	Organic pollutants and Agricultural chemicals	Huang et al.[60]
15	Skeletal Abnormalities	Environmental stressors	Reeves et al.[102]
17	Extra Hindlimb	*Ribeiroia ondatrae*, Pesticides or Ultraviolet light	Kaiser[103]

Conclusion

Malformation of frogs have been a major interest since the 1990s when some students observed some malformed frogs when on tour.[103] This gave rise to more focus and prompted researchers to examine malformations in frogs and its causes since the 1990s. The reviewed malformations of frogs of this current study showed that 1990s was the period of most documented reports on malformed frogs which peak in 2000. According to Loeffler et al.,[104] the investigation of malformations in frogs has underscore the wide range in the different malformations in frogs. Most of the observed malformations reviewed in this study were limb, eye, and skin malformations. Also, varying degree in severity of limb malformations was also recorded such as ectrodactyly, polymelia, brachydactyly etc. Polymelia and ectrodactyly in different frog species have been documented to be caused by parasite trematode worm from genus *Ribeiroia*.[97,105] This parasite physically or chemically disrupts the developing limb, jaw or eye fields.[106] Albinism which was documented in frogs is caused by several different genes.[107]

Also, limb malformations were the most documented frog malformations by different authors. Thus, available data suggests that limb malformations could be used as a baseline malformation for frogs of different species. Evidence has shown that water contamination, pesticides, herbicides, petrochemicals and UV radiation could results to abnormities in frogs (Johnson *et al.,* 2000).[108] This reviewed also showed that malformations in frogs were documented among different species of frogs and evidence showed that malformation in different frogs are not species specific. Different causes of malformations have been documented for different frog species. Although no single cause has been found to explain all frog malformations. However, mutation, parasite, environmental stressors, organic pollutants have been recorded as causes of malformation in frogs.[75,102] These chemicals are known to act as retinoids which are potent regulators of development in the vertebrate brain, eye, mandible and limbs.[15] In conclusion, this study gave an insight into the malformation of frogs from 1990 to 2023. The study reviewed that limb malformation was the most occurred abnormalities among the different frogs. The study concluded that human factors or activities played an important role in frog malformations. Although malformations in frogs cannot be completely stopped, there is need to completely reduce anthropogenic activities which may mitigate the problem. Further researches need to be carried out to determine the exact cause of each deformity that has been observed in frogs and it is recommended that the indiscriminate dumping of toxic waste, use agrochemicals such as pesticides, and harmful chemicals should be discouraged and made illegal.[109–116]

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Conflicts of interest

The author declares there is no conflict of interest.

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