REPTILES & AMPHIBIANS

Taste the Rainbow: A Review of Color Abnormalities Affecting the Herpetofauna of the British Isles

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Abstract.—Over the years, the terminology in regards to the abnormal coloration of reptiles and amphibians has become more complex with not all authors agreeing on the same terms. This, combined with the diversity of chromatic abnormalities, has led to some confusion, particularly between hobbyists and biologists who tend to use different jargon. In this review, we aim to address this issue by explaining how color within the skin of amphibians and reptiles arises, and evaluating which terminology should be used. This information is then used to explore each of the known chromatic abnormalities observed in amphibians and reptiles before summarizing the known cases from the British Isles. Finally, we also present a number of previously unrecorded instances of color abnormalities in the hope that it promotes further examples to be recorded. Given their rarity in nature, color abnormalities are likely to have a significant impact on the fitness of animals displaying them. Despite our efforts to summarize all the available information on color abnormalities in the herpetofauna of the British Isles, there are still gaps in our knowledge. These could be filled through the effort of a national recording scheme aimed at abnormally colored individuals.

Wild reptiles and amphibians can naturally vary in appearance extensively and it is clear that this diversity puzzled early naturalists with some trying to explain different variations as different species (Bell 1839), such as a red form of the European Adder (*Vipera berus*) described as *V. communis*. There are two drivers of this variation, one being the patternation of the individual and the other its coloration. Abnormal coloration (reviewed herein) can be seen as the base colors of a species differing from those usually seen within nature, caused by mutations such as albinism or melanism (Ferreira et al. 2019). Abnormal patterning is different to this and is usually observed as animals possessing spots or stripes when they usually would not (and vice versa). A species with a large range of pattern diversity is the Common Frog (*Rana temporaria*), which can be maculated, striped, barred or none of these. Common Frogs also have a wide range of potential base colors ranging from olive-green to dark brown (Beebee and Griffiths 2000). The combination of these factors has undoubtedly caused confusion in the past.

The natural variation available within a particular herptile species is often exploited and exaggerated by the pet trade via selective breeding to create 'designer morphs' but also provides the wild population with the means to adapt to different environments, and diversify their visual signaling (McLean et al. 2014; Thorpe and Stenson 2003). Reptiles and amphibians can have several coloration abnormalities that arise through a variety of mechanisms, although these are often of a genetic origin rather than an environmental one (Frost et al. 1986a; Frost et al. 1986b). Abnormal chromatic phenotypes are widespread across both amphibians and reptiles throughout the world, with some more common than others. Not all abnormalities are recorded from all species, perhaps due to their rarity, the disadvantage they cause the affected animal, or because the genes associated with such abnormal coloration are deleterious to developmental pathways (Corn 1986).

Chromatophores are pigment–containing cells that are found in the skin of ectothermic animals such as amphibians and reptiles (Bagnara et al. 1968; Taylor and Hadley 1970). These specialized cells can be grouped together based on the color they reflect under white light. Melanophores contain melanosomes which are filled with melanin, producing a perception of dark color, and iridophores contain crystalline chemochromes which reflect light producing iridescence. Finally, xanthophores contain carotenoids which produce a yellow color (Bagnara et al. 1968). In amphibians, melanophores are found at the base of a dermal chromatophore unit with layers of iridophores and xanthophores above (Bagnara et al. 1968). The structure of reptilian and amphibian skin

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Reptiles & Amphibians ISSN 2332-4961
https://doi.org/10.17161/randa.v30i1.18470

may also contain other pigment cells such as erythrophores and leucophores (Schartl et al. 2016). The abnormalities that lead to axanthic, melanoid, and albino animals are all intrinsic to the neural crest stem cells (Frost et al. 1984; Sawada and Dalton 1979). Due to the cause of these color abnormalities, they are permanent.

When determining the color of an animal in the wild, there are numerous factors that can affect the way it appears in nature. These include the background the animal is being viewed on, the angle at which the animal is being viewed from, the lighting conditions, and the stage at which a reptile is viewed in the slough cycle (which may make some animals appear duller than they actually are). Some coloration abnormalities will also present themselves differently in different species, depending on the life-stage, making the animal appear to be abnormal in color, when upon closer inspection they are in fact not abnormal. Currently the literature and nomenclature regarding color abnormalities are non–consensual. This makes it hard to draw conclusions and comparisons particularly with older literature where detailed descriptions or photographs are not available. Here we summarize each of the irregularities that have been recorded in amphibians and reptiles in the British Isles, from the current body of literature, providing a description and exploring the cause of each, to provide a more consensual viewpoint. We also present multiple new cases, brought to our attention through various means such as online forums or Facebook posts from members of the herpetological community, with a summary of each.

Albinism

Albinism is by far the most easily recognized of the coloration abnormalities encountered in nature. It is characterized by the absence of pigmentation. Even though albinos may have correct chromatophores, they are unable to produce melanins (Bechtel and Bechtel 1981; Frost et al. 1986a). As a consequence, affected animals usually possess a white or pale skin and red or pink eyes (Bechtel and Bechtel 1981). The lack of pigmentation in the iris allows the blood vessels within the eye to be seen. Albinism may reduce the fitness of an affected animal due to their lack of camouflage and vulnerability to ultraviolet radiation (Childs 1953).

Deficiency in the enzyme tyrosinase is a contributing factor in cases of albinism across many taxa (Bechtel and Bechtel 1981), but in some species of reptile, both tyrosinase–positive (T+), and tyrosinase–negative (T–) variants can occur. Tyrosinase–positive specimens tend to exhibit the bold patterning of their 'wild type' counterparts, due in part to their ability to still synthesize melanin (even in reduced quantities), whereas T– specimens appear almost devoid of color and pattern, and are often much lighter in appearance (Gamble et al. 2006). Similarly, hypomelanism (sometimes referred to as xanthic albinism), and amelanism (the total absence of black pigment) are often mistaken as caused by entirely separate genetic mutations but are in fact allelic and are simply variants of T+ albinism (Bechtel and Bechtel 1981). In the case of the Black Rat Snake (*Pantherophis obsoletus obsoletus*), breeding trials showed that two non–allelic forms (meaning that they are not genetic in origin) of incompatible amelanism expressed alongside the above–mentioned allelic T+ mutations (Bechtel and Bechtel 1981). The striking appearance of color and pattern mutations in reptiles, and the seemingly endless possibilities have led to the elevated success of some reptiles in the pet trade and an almost fanatical interest in their genetics. This is especially true when compared to albinism in mammals, which possess only melanophores, leaving albino individuals usually monochrome in appearance (Gamble et al. 2006).

Albinism is by far the most reported chromatic abnormality in the herpetofauna of the British Isles (Table 1). In some cases such as with the Common Frog, albino spawn (transient albinism) may be found; they are visually differentiated from normal spawn due to the contrast in color. Beebee (1985) notes that some albino frogs are a pale yellow in color due to lymph fluid under the skin; this could potentially cause confusion with xanthochromic individuals. Albinism, similarly to leucism (see below), in Smooth Newts (*Lissotriton vulgaris*) is sometimes associated with neoteny (Inns 2009). For more information on the causes of this phenotype please see Frost et al. (1986a; Henle et al. 2017).

Table 1. A summary of the amphibians and reptiles of the British Isles that have been recorded with occurrences of albinism.

Vernacular name	Scientific name	Reference(s)
Adder	*Vipera berus*	Harris (1936); Leighton (1901)
Barred Grass Snake	*Natrix helvetica*	Baker (2003); Boulenger (1913); Procter (1926)
Common Frog	*Rana temporaria*	Eales (1933); Smallcombe (1938)
Common Toad	*Bufo bufo*	Frazer (1983); Pash et al. (2007)
Great Crested Newt	*Triturus cristatus*	Inns (2009)
Slow Worm	*Anguis fragilis*	Knight (1966)
Smooth Newt	*Lissotriton vulgaris*	Inns (2009); Spooner et al. (2007)

Axanthism

Axanthism is typically encountered as a bluish body color, especially in animals that are usually green; however, affected animals may also be dark in color, if they would normally be pale or brown (Jablonski et al. 2014). The skin of axanthic animals lacks xanthophores, erythrophores and iridophores leaving them unable to reflect red and yellow light, normally as a result of a genetic mutation (Jablonski et al. 2014). This is why axanthic frogs appear blue, due to the absence of yellow pigments in their skin. Axanthic animals also lack iridophores, that produce light–scattering pigments, typically resulting in a darker coloration overall (Jablonski et al. 2014). The eyes of axanthic individuals contain melanophores and iridophores, giving them a dark color (Frost et al. 1984; Frost-Mason and Mason 1996). Some axanthic animals that appear darker than normal in color, particularly reptiles, may be mistaken for those with melanism (Frost-Mason and Mason 1996) but can be differentiated by possessing discernible patterns that are lighter in color (Szkudlarek 2019). Axanthism has been reported to vary in prevalence between populations and evidence from ranids in the United States suggests that it is far more common at higher latitudes (Berns and Uhler 1966), perhaps suggesting some thermoregulatory advantage of the darker blue coloration.

During a routine amphibian survey at a site in Cambridgeshire, United Kingdom (52.2437, 0.0478) in June of 2013, a possibly axanthic Common Toad (*Bufo bufo*) was discovered (Fig. 1). The toad was a uniform dark brown color all over, with some darker striping visible on the hind legs. Introduced Marsh Frogs (*Pelophylax ridibundus*) are occasionally reported as being blue or turquoise in color (Fig. 2), which is consistent with axanthism, although there are no published reports of them being axanthic. In May 2018, a partially axanthic Slow Worm (*Anguis fragilis*) was discovered in south-west London, the first known instance of such (Fig. 3). Axanthism has only been observed in a small number of amphibians and reptiles in England (Table 2). Axanthic frogs have previously been labelled as those showing cyanism (Tyler 1982), but as no native amphibian species are bright green, this may help to explain the scarcity of records from the British Isles. For more information on this phenotype please see Frost et al. (1986b) or Jablonski et al. (2014).

Table 2. A summary of the amphibians and reptiles of the British Isles that have been recorded with occurrences of axanthism.

Vernacular name	Scientific name	Reference(s)
Adder	*Vipera berus*	Bell (1839)
Common Toad	*Bufo bufo*	This review
Marsh Frog	*Pelophylax ridibundus*	This review
Slow Worm	*Anguis fragilis*	This review

Cyanism

Cyanism is characterized by individuals being a vibrant blue color, when they would not normally be. This is possibly caused by a proliferation of cyanophores in the skin. Although they were first identified in fish (Goda and Fujii 1995), cyanophores likely also occur in amphibians and reptiles although further research is needed to confirm this (Bagnara et al. 2007). The causes of cyanism are not known, although they are likely genetic in origin. The blue color of cyanistic individuals therefore almost always occurs as a structural color as it is formed by the scatter of blue wavelengths from the skin

Figure 1. The axanthic Common Toad (*Bufo bufo*) seen in Bar Hill, Cambridgeshire (52.2437, 0.0478) while surveying for Great Crested Newts (*Triturus cristatus*) in 2013. Photograph by Steven Allain.

Figure 2. An axanthic Marsh Frog (*Pelophylax ridibundus*) from RSPB Rainham Marshes, Essex (51.4959, 0.2142) displaying turquoise coloration. Photograph by Neil Phillips.

of the animals (Bagnara et al. 2007). Confusingly, if specimens are found dead, they may be blue in color despite the fact they may not have been so in life. This post–mortem cyanism has been reported in the Sand Lizard (*Lacerta agilis*) but also occurs in other reptile species, with the origin of the color being structural rather than through pigmentation (Rautenberg, 2007). An increase in blue coloration within an individual may be mistaken for cyanism, particularly in individuals of Slow Worm that have an increased number of blue scales (usually seen on the flanks of males) over parts of the animal (Capula et al. 1997), whose numbers increase with age (Simms 1970). Such older individuals are sometimes mistaken for cyanistic ones.

Cyanism can be distinguished from such pattern–related polymorphisms by a uniform blue coloration throughout the whole body, with some darker elements still visible, due to the presence of melanophores. In the summer of 2018, a cyanistic *A. fragilis* (Fig. 4) was discovered beneath an artificial cover object in Treborth, Bangor (53.2170, -4.1717). On 1 June 2020, a cyanistic female Viviparous Lizard (*Zootoca vivipara*) was seen in a residential garden in Biggleswade, Bedfordshire climbing a garden fence (Fig. 5). Despite being quite conspicuous, it is likely that the *Z. vivipara* was trying to find a more optimal spot to bask. To our knowledge these are the first records of cyanistic individuals from both species and the only cyanistic reptiles currently known throughout the British Isles (Table 3). There are currently no other explanations as to the bright blue color of the *A. fragilis* and *Z. vivipara*, despite the lack of current information regarding the presence of cyanophores in reptilian skin.

Table 3. A summary of the reptiles of the British Isles that have been recorded with occurrences of cyanism. No amphibians within the British Isles have so far been recorded with cyanism.

Vernacular name	Scientific name	Reference(s)
Slow Worm	*Anguis fragilis*	This review
Viviparous Lizard	*Zootoca vivipara*	This review

Erythrism

Erythrism leads to the color of affected animals being red due to an excessive deposition of erythrophores (which produce red and orange pigments) in the skin, with various shades and degrees of intensity possible (Moore and Ouellet 2014). Erythrophores are present in skin of both amphibians and reptiles (Schartl et al. 2016), indicating that both groups are susceptible to erythrism. The eyes of erythristic animals may or may not be affected but in some cases are red, too, as the lack of melanosomes allows their blood vessels to be visible such as with albinistic animals. Cases of erythrism in the literature have been reported more in reptiles than amphibians, although not every case is recorded. For example photographs of erythristic individuals of *A. fragilis* from throughout England have previously been posted on forums and social media sites. However, erythrism in *A. fragilis* has never been formally reported, at least to our knowledge. The causes of erythrism in other species can be linked to diet (Hudon and Mulvihill 2017) or unknown causes (Bukaciński and Bukacińska 1997); however, in reptiles and amphibians there is likely a genetic component demonstrated by selective breeding in captive animals.

Figure 3. An axanthic Slow Worm (*Anguis fragilis*) showing incomplete axanthism discovered in south-west London in 2018. Photograph by Jim Foster.

Figure 4. A cyanistic Slow Worm (*Anguis fragilis*) encountered on a routine survey at Treborth, Wales (53.2170, -4.1717), found underneath a cover object. Photograph by Luke O'Sullivan.

Figure 5. A cyanistic Viviparous Lizard (*Zootoca vivipara*) seen in a Biggleswade garden. Photograph by Caroline Sims.

Figure 6. An erythristic Slow Worm (*Anguis fragilis*) from Northamptonshire (52.5778, -0.5548) in May 2020. Photograph by Nicholas Milton.

Table 4. A summary of the amphibians and reptiles of the British Isles that have been recorded with occurrences of erythrism.

Vernacular name	Scientific name	Reference(s)
Common Frog	*Rana temporaria*	Beebee and Griffiths (2000); West and Allain (2020)
Sand Lizard	*Lacerta agilis*	This review
Slow Worm	*Anguis fragilis*	This review

Figure 7. An erythristic Sand Lizard (*Lacerta agilis*) from Dorset. Photograph by David Bird.

Figure 8. A hypomelanistic Slow Worm (*Anguis fragilis*). Photograph by Josh Harwood.

Currently only a limited number of erythristic amphibians and reptiles are known from the British Isles (Table 4) including those presented herein. On 25 May 2020, an erythristic Slow Worm was found in Fineshade Wood, Northamptonshire (52.5778, -0.5548) underneath an artificial cover object (Fig. 6). Similarly, an erythristic Sand Lizard was encountered in the summer of 2008 during a destructive habitat search in Dorset (Fig. 7), although tissue samples to confirm this may be required. Beebee and Griffiths (2000) state that orange and red colored *R. temporaria* have turned up frequently in southern Britain. Some of these frogs were likely erythristic while others were brightly colored females in the

Table 5. A summary of the reptiles of the British Isles that have been recorded with occurrences of hypomelanism. No amphibians within the British Isles have so far been recorded with hypomelanism.

Vernacular name	Scientific name	Reference(s)
Barred Grass Snake	*Natrix helvetica*	Baker (2014)
Slow Worm	*Anguis fragilis*	Hails (2017); this review
Viviparous Lizard	*Zootoca vivipara*	Gleed-Owen (2005); Palmer (2005)

breeding season exhibiting pattern plasticity. The taxonomic breadth across which erythrism occurs in reptiles and amphibians is likely greater in nature than currently recognized in the literature. For example, erythristic Smooth Snakes (*Coronella austriaca*) have been recorded from elsewhere in their range (Maèát et al. 2016), but not yet from the British Isles.

Hypomelanism

Hypomelanism is a condition in which there is a reduced pigmentation compared with that seen in the wild type. Animals exhibiting hypomelanism have their visual acuity significantly affected (Balkema and Dräger 1991), in a similar way to albinistic individuals as a direct result of the absence of melanin, a photo–protectant (Brenner and Hearing 2007). As with cases of albinism, survivability is reduced due to conspicuous coloration (Gezova et al. 2018). A hypomelanistic Slow Worm (*Anguis fragilis*) was discovered in June 2020 during a private reptile translocation at a site in Sussex (Fig. 8). Other than this, a small number of amphibians and reptiles have been recorded as being hypomelanistic in the British Isles (Table 5), although the true number of specimens with this color aberration is probably higher.

Leucism

Leucism is characterized by partial loss of pigmentation in the skin of an animal, which gives them a white or pale color (Bechtel 1991). Individuals may superficially resemble albinos but their eyes are dark in color, helping to distinguish between the two (Bechtel 1991). In some cases, eyes of leucistic animals are visible through their skin, due to the lack of pigmentation in the surrounding tissues (Harkness and Allain 2020). Leucism means reduction or loss of all types of pigment, whereas albinism is just the lack of melanin. For example, leucistic snakes have reduced numbers of iridophores and likely few or no melanophores and xanthophores (Bechtel 1991). As with albinism (above), the loss of camouflage caused by leucism may increase the likelihood of predation (Krecsák 2008). Leucism within Smooth Newts (*L. vulgaris*) is often associated with neoteny; both are linked to damage or developmental problems with the pituitary gland (Frazer 1983).

Leucism was recorded in several amphibians and reptiles throughout the British Isles (Table 6). It is likely that some individuals reported as being albinistic are indeed leucistic and vice versa. Care has been taken to discern these. In April 2015, a leucistic female *B. bufo* was observed in amplexus with a normally colored male in a residential garden in Leeds (Fig. 9).

Melanism

Melanism is often seen as the opposite abnormality to albinism, where the affected individuals are black in color. Melanism is one of the most commonly reported color aberration in reptiles and is caused by the darkening of normal

Figure 9. A leucistic female Common Toad (*Bufo bufo*) in amplexus with a normally colored male, photographed in April 2015. Photograph by Mark Darwell.

Figure 10. A piebald Common Toad (*Bufo bufo*) from Cumbria showing approximately 30% normal coloration, with the rest being much paler in color. Photograph by Sam Griffin.

Table 6. A summary of the amphibians and reptiles of the British Isles that have been recorded with occurrences of leucism.

Vernacular name	Scientific name	Reference(s)
Barred Grass Snake	*Natrix helvetica*	Boulenger (1913)
Common Frog	*Rana temporaria*	Nicholson (1997)
Common Toad	*Bufo bufo*	This review
Great Crested Newt	*Triturus cristatus*	Baker (2006)
Natterjack Toad	*Epidalea calamita*	Beebee and Griffiths (2000)
Slow Worm	*Anguis fragilis*	Harkness and Allain (2020); Jablonski and Purkart (2018)
Smooth Newt	*Lissotriton vulgaris*	Smith (1964)

pigmentation, due to increased melanin production by melanocytes in the stratum basale skin layer (Bechtel 1995). Some ecological hypotheses have been raised to try to explain the adaptiveness of melanism. For example, a darker color may provide a thermoregulatory advantage when basking on a lighter background (Strugariu and Zamfirescu 2009; Jambrich and Jandzik 2012). Where these thermoregulatory advantages are negligible, Gvoždík (1999) hypothesized that frequency of melanistic individuals may be mainly driven by predation pressure or habitat type. There is some evidence that melanistic individuals are subject to increased predation risk from visually–orientated predators (Andren and Nilson 1981). However, there is also evidence that melanism can increase inconspicuousness and therefore reduce predator attacks, especially in complex habitats (Gvoždík 1999; Nash et al. 2016 and references therein). In sampled populations female *Z. vivipara* were found to be less frequently melanistic than males, possibly as a function of their increased need to bask during pregnancy where they could more likely be predated by visual predators, despite the thermoregulatory advantage melanism would provide (Jambrich and Jandzik 2012).

Melanism has been reported to be relatively frequent in certain geographical areas or under certain environmental conditions for some species, such as *V. berus* (Strugariu and Zamfirescu 2009). Melanistic adders are often associated with high latitudes and mountainous areas that tend to have colder climates, though they can be found at lower altitudes, too (Thiesmeier and Voelkl 2002). Interestingly, melanistic adders are thought to obtain their black coloration only in later life, during their second or third year, and neonates that are born melanistic are much rarer (Forsman 1995). This requires further investigation to confirm whether or not this is the case. Melanistic specimens tend to reach larger sizes than their normally colored conspecifics, perhaps as a result of increased thermoregulatory ability due to the darker coloration (Strugariu and Zamfirescu 2009). Melanism has been reported in three of the snakes found in the UK, Adders (*V. berus*), Barred Grass Snakes (*N. helvetica*) and Smooth Snakes (*C. austriaca*) with the occurrence broadly reflecting the species' natural ranges (Nash et al. 2016). There are reports of melanistic *Z. vivipara* and *A. fragilis* within the British Isles (Table 7) but melanistic *L. agilis* are yet to be recorded (Beebee and Griffiths 2000), with melanism in *Z. vivipara* being more common. Melanistic individuals of *L. agilis* have been recorded elsewhere in their range (Smolinský 2016), so it may only be a matter of time until a melanistic individual is recorded in a British population. For whatever reason, melanistic amphibians are present in the wild but underreported (Alho et al. 2010; Lunghi et al. 2017), despite the occurrence of melanism in nature and the potential benefit such coloration could provide.

Piebaldism

Piebaldism, also known as partial or regional albinism, is characterized by a series of non–patterned, unpigmented (white or pale) spots distributed on a pigmented background, without any change in the color of the eyes (Kornilios 2014). It

Table 7. A summary of the amphibians and reptiles of the British Isles that have been recorded with occurrences of melanism.

Vernacular name	Scientific name	Reference(s)
Adder	*Vipera berus*	Boulenger (1913); Leighton (1901)
Barred Grass Snake	*Natrix helvetica*	Halfpenny and Bellairs (1976); Worsnip (1978)
Natterjack Toad	*Epidalea calamita*	Cooke et al. (1983); Hall and Nissenbaum (1988)
Slow Worm	*Anguis fragilis*	Gleed-Owen (2012)
Smooth Snake	*Coronella austriaca*	Pernetta and Reading (2009)
Viviparous Lizard	*Zootoca vivipara*	Smith (1964); Simms (1970)

Table 8. A summary of the amphibians and reptiles of the British Isles that have been recorded with occurrences of piebaldism.

Vernacular name	Scientific name	Reference(s)
Common Frog	*Rana temporaria*	Baker and Biddle (2020)
Common Toad	*Bufo bufo*	This review
Great Crested Newt	*Triturus cristatus*	Sewell (2007)
Slow Worm	*Anguis fragilis*	This review

normally arises through developmental anomalies in pigment cell differentiation, not necessarily involving genetic mutations (Acevedo et al. 2009) although there is also evidence for genetic heritability (Baker and Biddle 2020). This chromatic anomaly is rare in amphibians with only a handful of records published, including three caudate species and one anuran from North America (Whipple and Collins 1990; Neff et al. 2015). Though this rarity, however, may also be a function of inconsistencies in color abnormality nomenclature (such as partial leucism or partial albinism). Piebaldism is more common in reptiles where it has been reported in lizards (Rocha and Rebelo 2010), snakes (Kornilios 2014) and amphisbaenians (Kazilas et al. 2018) in the wild. In Europe, records are rare despite the fact that unusually colored frogs have sometimes caught the nation's attention (Beebee 1997).

A small number of cases of piebaldism within the herpetofauna of the British Isles exist (Table 8), although there are not many. Here we provide reports of two more species bringing the total to four, most of which are amphibians. The first of these is a piebald *B. bufo* from Cumbria encountered in September 2016 (Fig. 10). The individual shows less than a third of its normal coloration and is instead covered with blotches of a lighter shade, typical of piebald animals. The other case is the only recorded reptile with piebaldism in the British Isles, in this instance *A. fragilis* found in 2020 (Fig. 11). The Slow Worm is very reminiscent of the piebald Anatolian Worm Lizard (*Blanus strauchi*) described by Kazilas et al. (2018). It is plausible that such abnormalities would not have such a strong selection pressure in regards to predation in a fossorial species, compared to cursorial ones (Kornilios 2014).

Xanthism

Xanthism (also called xanthochromism or flavism) is a condition characterized by the affected animals being abnormally yellow in color; as with albinos, their eyes are usually red due to the lack of melanophores (Mitchell 1994). In fish, it has been suggested that xanthophores might go into overproduction with melanophores or other pigment cells absent (Angus and Blanchard 1991). Xanthism is thought to have a genetic basis which can explain its presence across a wide taxonomic spectrum (Angus and Blanchard 1991). This color anomaly is a form of amelanism, where the skin lacks all skin pigments except for xanthophores which contain xanthine (Mendonça et al. 2020). Xanthism is regarded by some as the opposite abnormality to axanthism (see above) as both relate to the number of xanthophores present in the skin. Previously xanthochromic frogs have been mistaken as albinistic individuals (Allain and Goodman 2017), what may be in part due to the lack of consensual literature on the topic. Xanthism has been observed in both amphibians and reptiles (Mendonça et al. 2020; Mitchell 1994), although the literature is scarce at best.

Figure 11. A piebald Slow Worm (*Anguis fragilis*) found inhabiting a garden among woodlice. Photograph by Emma-Jane Thompson.

Figure 12. A xanthic Great Crested Newt (*Triturus cristatus*) discovered on a routine monitoring survey for the species. Photograph courtesy of FPCR Environment & Design Ltd.

Table 9. A summary of the amphibians of the British Isles that have been recorded with occurrences of xanthism. No reptiles within the British Isles have so far been recorded with xanthism.

Vernacular name	Scientific name	Reference(s)
Common Frog	*Rana temporaria*	Allain and Goodman (2017)
Great Crested Newt	*Triturus cristatus*	This review

This chromatic abnormality is mainly recorded in cryptic or nocturnal snake species (Mendonça et al. 2020) whereas in diurnal species, there would be a stronger negative selection pressure against such coloration due to the loss of cryptic coloration protecting from visual predators. Just as with albinism and leucism, xanthism may reduce the fitness of the affected animal (Krecsák 2008).

Within the British Isles, xanthism has only been recorded in amphibians (Table 9), although it has likely been misattributed to albinism in some species (including reptiles) in the past. In April 2015, as part of an ecological survey targeting Great Crested Newts (*Triturus cristatus*), a xanthic individual was found (Fig. 12). The newt's eyes were paler in color than usual although not entirely red and the body was a pale-yellow color. The areas of the newt that would usually be yellow or orange such as the 'rings' on the toes are particularly vibrant. There are, however, some dark spots on the tail and pigmentation over the crest, which is consistent with other xanthic individuals (Mendonça et al. 2020).

Discussion

As well as reviewing a variety of color abnormalities in the herpetofauna of the British Isles from the literature, we also present a number of new cases with photographs to illustrate these examples. This review is not a complete synopsis as new records of such abnormalities are constantly being reported, although it is the first to summarize all currently available information. It is hoped with this review, that other members of the herpetological community will begin to record the color abnormalities of herpetofauna they encounter, and take the necessary steps to fill in the gaps we have identified. Although this review encompasses the entirety of the British Isles, there is a strong bias towards records in England with a lack of others throughout the rest of this potential geographic range, especially Scotland and Ireland. This may be due to a number of factors including the densities of amphibian and reptile species in those geographic locations and a reduced number of surveyors in those areas where records are lacking.

One of the reasons why some abnormalities may have not been recorded is their rarity in nature due to the increased risk of predation (Krecsák 2008). However, this is unlikely to affect species that are nocturnal or fossorial as their lighter color cannot be detected as easily by visually-orientated predators in low-light conditions (Kornilios 2014). For diurnal species, surviving long enough to be encountered by a human surveyor or to breed may be the biggest challenge, depending on the abnormality. There is also the possibility that some abnormalities simply can't exist without damaging pathways critical for the development and survival of the affected animal (Corn 1986). Some of the abnormalities listed may not affect the whole body (depending on their cause) and so affected individuals may have patches of normally colored skin/scales, such as is the case of the axanthic Slow Worm (Fig. 3) reported herein.

With all this potential variation, it is important to explore potential advantages it may provide to individuals. Aside from the thermoregulatory advantages already mentioned, experiments have shown that color polymorphism may be important in social interactions (Vercken and Clobert 2008). The extreme cases we report and describe herein are rare in nature for a number of reasons. For populations of some species such as *C. austriaca* and *L. agilis* that have experienced major population bottlenecks, the genes for such abnormalities may no longer naturally occur in British populations. This may also be true for populations of introduced species, which originated from a small number of founders. Albinism (Ćurić 2019) and hypomelanism (Kolenda et al. 2017) have been recorded in Aesculapian Snakes (*Zamenis longissimus*) within their native range, indicating that there may be a possibility of encountering such color anomalies in the introduced populations of Great Britain.

National surveys of unusually colored amphibians have been carried out in the past, the best example being Nicholson (1997). That survey documented the distribution of albino or partially albino frogs throughout Great Britain, with most of them recorded in southern England. It is likely that leucistic, albino, and xanthic frogs were all included in the survey and listed as albino, the problem being that eye color in most cases was not mentioned. As highlighted above, this is one of the more reliable ways to determine which color anomaly an animal displays. There is also evidence of piebald frogs and a single erythristic individual which was recorded with both red eyes and red skin (Nicholson 1997). These cases highlight the issues of such national surveys without a consensus on nomenclature, definitions, and diagnostics. There is a need for such a national survey to be replicated, with a wider taxonomic spread, which would hopefully produce some significant results given the power of citizen scientists. This would help to explore not only the number of species affected by such abnormalities, but also their geographic spread.

Acknowledgements

We would like to thank everybody who contributed their photos and accompanying information for this review, without them it would not have the same level of impact. We would also like to thank Rob Ward and Jim Foster from the Amphibian and Reptile Conservation Trust for their helpful comments and suggestions throughout the writing and researching of this review.

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