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# Cancer Prevalence and Etiology in Wild and Captive Animals

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## INTRODUCTION

Despite the evolution of numerous natural cancer suppressor mechanisms (DeGregori, 2011), neoplasia has been recorded in most metazoans (Leroi et al., 2003). Although, a few exceptional species, such as the naked mole-rat (*Heterocephalus glaber*) and sharks have been claimed to be resistant to cancer (Finkelstein, 2005; Tian et al., 2013). Recent studies have, however, shown that even these species may develop cancer (Delaney et al., 2016; Finkelstein, 2005) strongly suggesting that the vast majority of multicellular organisms are indeed susceptible to cancer. The frequent occurrence of cancer in metazoans suggests that neoplasia, similar to pathogens/parasites, may have a significant negative impact on host fitness in the wild (Vittecoq et al., 2013).

This is supported by a recent review of wildlife cancer by McAloose and Newton (2009) demonstrating that high prevalence of cancer in, for example, Tasmanian devils (*Sarcophilus harrisii*) and belugas (*Delphinapterus leucas*) resulted in concomitant significant increase in levels of mortality and reduction in fitness.

Wildlife cancer statistics are, however, highly scattered in the scientific literature and hence challenging to access. Moreover, tumors in wildlife are most commonly detected during postmortem examination and therefore hard to confirm without histopathological examinations. However, even such analyses can be inaccurate because of high levels of autolysis (organ disintegration) (McAloose and Newton, 2009). In addition, individuals harboring tumors often display a decrease in body condition frequently resulting in higher levels of

parasite/pathogen infections and concomitant increased levels in morbidity and mortality (Vittecoq et al., 2013) further impeding a correct analysis of the ultimate cause of death. The combination of the negative effects of cancer and/or pathogen/parasite infections has also been shown to result in increased levels of predation (Vittecoq et al., 2013). In our view, the combination of the problems involved in accurately recording wildlife cancer, the increased risk of succumbing to pathogens/parasites, and/or predation has often led to a somewhat erroneous assumption that although cancer is common in domestic animals, it remains rare in the wild. If, as we suggest, cancer may be a significant determinant of animal fitness it is therefore crucial to determine cancer prevalence in the wild.

The etiology and prevalence of transmissible cancers are presented and discussed in Chapter 12; this chapter will therefore focus on the prevalence and etiology of nontransmissible cancers.

Via thorough searches of the available literature we provide a comprehensive and an updated list of cancer prevalence in wild animals ranging from fish to whales. We also provide a list of cancer recorded in captive animals from French zoological parks and compare our findings to that recorded at other zoological parks. Finally we provide an updated list of cancers recorded as single cases in the wild, as well as in captive animals demonstrating that cancer occurs in nearly every taxonomic order of the animal kingdom.

## CANCER PREVALENCE AND ETIOLOGY IN WILD VERTEBRATES

Although cancers are frequently encountered in wild animals (see Table 2.1 starting on page 13), we were only able to retrieve robust data on cancer prevalence in 31 wild vertebrate species (Table 2.2). We were unable to find information on nontransmissible cancer prevalence in wild invertebrates and consequently this chapter focuses on cancer in wild vertebrates ranging from fish to mammals. In following sections, we provide a summary of cancer etiology and prevalence in each of the five vertebrate groups (Table 2.2).

### Fish

FAO (2010) fisheries and aquaculture department published a report showing that the mean contribution of fish to global diets was 17 kg per person/year, supplying over three billion people with 15% of their animal protein intake. About 45% of the fish consumed were farmed but the remaining 55% of fish were caught in the wild clearly demonstrating the importance of wild fish in the human diet. In spite of their importance to

humans we have only been able to find information on cancer prevalence in 12 wild fish taxa.

In walleye (*Sander vitreus*) and Atlantic salmon (*Salmo salar*) retroviruses have been found to initiate cancer development (Coffee et al., 2013). In bicolor damselfish (*Stegastes partitus*) neurofibromatosis-like tumors are most likely caused by an “extrachromosomal DNA virus-like agent” (Coffee et al., 2013) whereas in European smelt (*Osmerus eperlanus*) cancer development have been suggested to be caused by a “herpesvirus-like agent” (Coffee et al., 2013). In northern pike (*Esox lucius*) a corona virus has been suggested to be the cause for the development of lymphosarcoma (Papas et al., 1976). This species also shows substantial seasonal variation in lymphosarcoma prevalence but the underlying etiology is unknown (Papap et al., 1976). In brown bullhead (*Ameiurus nebulosus*), however, the higher levels of liver neoplasms (15%) recorded on one of the lakes investigated have been suggested to be caused by pollution (Baumann et al., 2008). Similarly, a study of English sole (*Parophrys vetulus*) revealed that up to 24% of the fish had developed liver neoplasms of which etiology could be traced to have been caused by pollution/chemical carcinogens (Malins et al., 1987).

Cancer prevalence as high as 20% have been observed in several species, such as gizzard shad (*Dorosoma cepedianum*), northern pike, walleye, bicolor damselfish and in white sucker (*Catostomus commersoni*) cancer may affect up to 59% of the fish (Coffee et al., 2013). However, the epidermal papilloma recorded in the latter taxon appears to result in low mortality (Coffee et al., 2013). In contrast, cancers, such as plasmacytoid leukemia have been shown to result in up to 50% mortality in commercially important taxa, such as Chinook salmon (*Oncorhynchus tshawytscha*; Eaton et al., 1994) and neurofibromatosis-like tumors have been shown to result in 100% mortality in bicolor damselfish (Coffee et al., 2013). Apart from the latter two studies, the remaining studies do not provide any data on the effect of cancer on fish mortality. In spite of this we find it reasonable to suggest that the high tumor frequency observed in several species may have a significant negative impact on fish fitness. Given the importance of fish in the human diet the high cancer prevalence and associated mortality recorded in some fish taxa, clearly demonstrate the need of a substantial increase in research on the effect of cancer on both marine and freshwater fish.

### Amphibians

Although cancer has been reported in numerous amphibians (Balls and Clothier, 1974) we have only been able to find three studies that incorporated data on cancer prevalence in the wild. In the North American leopard frog (*Rana pipiens*) McKinnel (1965) found that

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom<sup>a</sup>

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<b>INVERTEBRATES</b>			
<b>Hydrozoa</b>			
<i>Pelmatohydra robusta</i>	Hydra	Undetermined neoplasia	Domazet-Lošo et al. (2014)
<b>Mollusca</b>			
<i>Arctica islandica</i>	Ocean quahog	Germinoma	Peters et al. (1994)
<i>Argopecten irradians</i>	Atlantic bay scallop	Gonadal neoplasia or germinoma	Peters et al. (1994); Carballal et al. (2015)
<i>Cerastoderma edule</i>	Common cockle	Disseminated neoplasia of unknown origin, gonadal neoplasia, or germinoma	Peters et al. (1994); Barber (2004); Carballal et al. (2015)
<i>Crassostrea gigas</i>	Pacific oyster	Fibroma or myofibroma, gonadal neoplasia, gonadoblastoma, disseminated neoplasia of unknown origin	Peters et al. (1994); Carballal et al. (2015)
<i>Crassostrea virginica</i>	Eastern oyster	Germinoma, gonadoblastoma, disseminated neoplasia of unknown origin	Peters et al. (1994); Carballal et al. (2015)
<i>Ensis magnus (=arcuatus)</i>	Razor clam	Gonadal neoplasia or germinoma	Carballal et al. (2015)
<i>Ensis siliqua</i>	Pod razor	Gonadal neoplasia or germinoma	Carballal et al. (2015)
<i>Macoma balthica</i>	Baltic macoma	Disseminated neoplasia of unknown origin	Carballal et al. (2015)
<i>Macoma calcarea</i>	Chalky macoma	Germinoma, hemic neoplasia	Peters et al. (1994)
<i>Mercenaria campechiensis</i>	Southern quahog	Gonadal neoplasia or germinoma	Carballal et al. (2015)
<i>Mercenaria campechiensis</i> × <i>Mercenaria mercenaria</i> hybrid	Quahog hybrid	Gonadal neoplasia or germinoma	Peters et al. (1994); Carballal et al. (2015)
<i>Mercenaria mercenaria</i>	Hard-shell clam, quahog	Germinoma	Peters et al. (1994); Carballal et al. (2015)
<i>Mya arenaria</i>	Soft-shell clam	Disseminated neoplasia of unknown origin, gonadal neoplasia or germinoma, hemic neoplasia	Carballal et al. (2015); Metzger et al. (2015)
<i>Mytilus edulis</i>	Blue mussel	Focal polypoid hyperplasia of germinal epithelium, germinoma, disseminated neoplasia of unknown origin	Peters et al. (1994); Carballal et al. (2015)
<i>Mytilus edulis (trossulus/galloprovincialis hybrid)</i>	Blue mussel hybrid	Myxomas in vesicular connective tissue	Peters et al. (1994)
<i>Mytilus galloprovincialis</i>	Mediterranean mussel	Gonadal neoplasia or germinoma	Peters et al. (1994); Carballal et al. (2015)
<i>Mytilus trossulus</i>	Bay mussel	Disseminated neoplasia of unknown origin	Peters et al. (1994); Ciocan and Sunila (2005); Ciocan et al. (2006); Carballal et al. (2015)
<i>Ostrea edulis</i>	European flat oyster	Disseminated neoplasia of unknown origin	Barber (2004)
<i>Tiostrea chilensis</i>	Dredge oyster	Germinoma, hemic neoplasia	Peters et al. (1994)
<i>Venerupis aurea</i>	Golden carpet shell	Disseminated neoplasia of unknown origin	Carballal et al. (2015)
<i>Xenostrobus securis</i>	Small brown mussel	Gonadal neoplasia or germinoma	Carballal et al. (2015)
<b>Crustacea</b>			
<i>Lithodes aequispinus</i>	Golden king crab	Probable tegmental gland adenocarcinoma	Morado et al. (2014)
<i>Paralithodes camtschaticus</i>	Red king crab	Midgut tumor, probable tegmental gland adenocarcinoma	Morado et al. (2014)

(Continued)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (*cont.*)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Paralithodes platypus</i>	Blue king crab	Anaplastic cells on the surface of the antennal gland, probable tegmental gland adenocarcinoma	Morado et al. (2014)
<b>Insecta</b>			
<i>Drosophila melanogaster</i>	Fruit fly	Gut and testis tumors	Salomon and Jackson (2008)
<b>VERTEBRATE</b>			
<b>Fish</b>			
<i>Agonus cataphractus</i>	Armed bullhead	Dermal fibromas, fibrosarcomas	Groff (2004)
<i>Amia calva</i>	Bowfin	Granuloplastic leukemia	Groff (2004)
<i>Anguilla japonica</i>	Japanese eel	Nephroblastoma	Groff (2004)
<i>Astronotus ocellatus</i>	Oscar	Adenocarcinomas	Groff (2004)
<i>Barbus barbus plebejus</i>	Italian barbel	Osteoblastic osteosarcoma	Groff (2004)
<i>Carassius auratus</i>	Goldfish	Fibrosarcoma, pigment cell neoplasm, neurofibromas, schwannomas, focal or multifocal cutaneous erythrophoromas	Groff (2004)
<i>Carassius auratus</i> × <i>Cyprinus carpio</i>	Goldfish hybrid	Gonadal neoplasms	Groff (2004)
<i>Carcharhinus brachyurus</i>	Bronze whaler shark	Proliferative, possibly neoplastic, lesions	Robbins et al. (2014)
<i>Carcharhinus leucas</i>	Bull shark	Cutaneous neoplasms	Robbins et al. (2014)
<i>Carcharias taurus rafinesque</i>	Gray nurse shark	Odontogenic, oral, and gingival neoplasms	Robbins et al. (2014)
<i>Carcharodon carcharias</i>	Great white shark	Proliferative, possibly neoplastic, lesions	Robbins et al. (2014)
<i>Catostomus commersoni</i>	White sucker	Cutaneous papillomas	Groff (2004)
<i>Chaetodon multicinctus</i> and <i>C. miliaris</i>	Butterflyfish hybrids	Pigment cell neoplasms	Groff (2004)
<i>Chologaster agassizi</i>	Spring cavefish	Spontaneous retinoblastomas	Groff (2004)
<i>Corydoras</i> spp.	Cory catfish	Pigment cell neoplasms	Groff (2004)
<i>Cyprinus carpio</i>	Common carp	Gonadal neoplasms, erythrophoromas	Groff (2004)
<i>Danio rerio</i>	Zebrafish	Malignant neoplasms of the intestine	Groff (2004)
<i>Esox lucius</i>	Northern pike	Lymphomas, undifferentiated sarcoma of the integument	Groff (2004)
<i>Esox masquinongy</i>	Muskellunge	Lymphoma	Groff (2004)
<i>Fundulus heteroclitus</i>	Mummichog	Hepatoblastoma	Groff (2004)
<i>Gadus</i> spp.	Alaska pollock	Pseudobranchial adenomas	Groff (2004)
<i>Galeocerdo cuvier</i>	Tiger shark	Cutaneous neoplasms	Robbins et al. (2014)
<i>Ginglymostoma cirratum</i>	Nurse shark	Melanoma	Robbins et al. (2014)
<i>Hemichromis bimaculatus</i>	African jewelfish	Osteochondroma	Groff (2004)
<i>Hippocampus abdominalis</i>	Pot-bellied sea horse	Reticuloendothelial hyperplasia	LePage et al. (2012)
<i>Hippocampus erectus</i>	Lined sea horse	Fibrosarcoma of the brood pouch	LePage et al. (2012)
<i>Hippocampus kuda</i>	Yellow sea horse	Renal adenoma, renal round cell tumor, exocrine pancreatic carcinoma, intestinal carcinoma	LePage et al. (2012)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (cont.)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Hippocampus kuda</i> and <i>Phyllopteryx taeniolatus</i>	Sea horse hybrids	Cardiac rhabdomyosarcoma, renal adenocarcinoma, renal adenoma, lymphomas, exocrine pancreatic carcinoma, intestinal carcinoma	LePage et al. (2012)
<i>Ictalurus nebulosus</i>	Brown bullhead	Hepatobiliary neoplasms	Groff (2004)
<i>Ictalurus punctatus</i>	Channel catfish	Osteosarcoma	Groff (2004)
<i>Kryptolebias marmoratus</i>	Mangrove rivulus	Chondrosarcomas, hemangiomas, hemangioendotheliomas, hemangioendotheliosarcomas	Groff (2004)
<i>Lepomis</i> sp.	Sunfish	Cutaneous carcinoma	Groff (2004)
<i>Limanda limanda</i>	Common dab	Papillomas	Groff (2004)
<i>Microgadus tomcod</i>	Atlantic tomcod	Hepatic neoplasm	Groff (2004)
<i>Morone saxatilis</i>	Striped bass	Nephroblastomas	Groff (2004)
<i>Mustelus canis</i>	Smooth dogfish	Cutaneous neoplasms	Groff (2004)
<i>Nebrius ferrugineus</i>	Tawny nurse shark	Cutaneous osteoma	Groff (2004)
<i>Oncorhynchus kisutch</i>	Coho salmon	Plasmacytoid leukemia (marine anemia), lymphomas	Groff (2004)
<i>Oncorhynchus mykiss</i>	Rainbow trout	Hepatobiliary neoplasms, nephroblastoma, adenopapillomas, lymphomas	Groff (2004)
<i>Oncorhynchus tshawytscha</i>	Chinook salmon	Plasmacytoid leukemia (marine anemia)	Groff (2004)
<i>Oryzias latipes</i>	Medaka	Lymphohematopoietic neoplasms, cutaneous lymphoma, adenomas, adenocarcinomas, retinoblastomas, teratoid medulloepitheliomas, neoplasms of embryonal origin, or teratomas	Groff (2004)
<i>Osmerus eperlanus</i>	European smelt	Papillomas and squamous cell carcinomas	Groff (2004)
<i>Osmerus mordax</i>	Rainbow smelt	Papillomas and squamous cell carcinomas	Groff (2004)
<i>Pagrus major</i>	Japanese seabream	Leukemia	Groff (2004)
<i>Perca flavescens</i>	Yellow perch	Ovarian and testicular leiomyomas and fibroleiomyomas	Groff (2004)
<i>Phyllopteryx taeniolatus</i>	Weedy sea dragon	Rhabdomyosarcoma	LePage et al. (2012)
<i>Plecoglossus altivelis</i>	Ayu	Rhabdomyoma	Groff (2004)
<i>Plectropomus leopardus</i>	Coral trout	Melanomas	Sweet et al. (2012)
<i>Poecilia formosa</i>	Amazon molly	Pigment cell neoplasms (or chromatophoromas)	Groff (2004)
<i>Poecilia reticulata</i>	Guppy	Epidermal cystadenoma, adenomas, adenocarcinomas, neoplasms of embryonal origin, or teratomas	Groff (2004)
<i>Pomacentrus partitus</i>	Bicolor damselfish	Neurofibromas, schwannomas	Groff (2004)
<i>Prionace glauca</i>	Blue shark	Cholangiocarcinoma, testicular mesothelioma, odontogenic, oral, and gingival neoplasms	Groff (2004); Robbins et al. (2014)
<i>Pseudopleuronectes obscurus</i>	Flatfish	Papillomas (wild)	Groff (2004)
<i>Pterophyllum scalare</i>	Angelfish	Labial fibromas (odontomas)	Groff (2004)

(Continued)



TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (*cont.*)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Salmo salar</i>	Atlantic salmon	Fibrosarcomas of the swimbladder, cutaneous papillomas, sarcomas	Groff (2004)
<i>Sparus aurata</i>	Gilt-head bream	Osteochondroma	Groff (2004)
<i>Stizostedion vitreum</i>	Walleye	Dermal sarcomas	Groff (2004)
<i>Tilapia spp.</i>	Tilapia	Adenocarcinomas, lymphomas	Groff (2004)
<i>Xiphophorus maculatus</i>	Southern platyfish	Melanoma, neoplasms of embryonal origin, or teratomas	Groff (2004)
<i>Xiphophorus maculatus</i> and <i>X. helleri</i>	Platyfish and swordtail hybrid	Pigment cell neoplasms	Groff (2004)
<b>Amphibians</b>			
<i>Ambystoma tigrinum</i>	Tiger salamander	Tumorous growths, type not specified	Rose (1976); Rose and Harshbarger (1977)
<i>Bufo japonicus</i> × <i>Bufo raddei</i>	Toad hybrids	Renal cell carcinomas	Masahito et al. (2003)
<i>Calotriton arnoldi</i>	Montseny brook newt	Pigmented skin tumors, melanophoroma, chromatophoromas	Martinez-Silvestre et al. (2011)
<i>Litoria aurea</i>	Green and golden bell frog	Nephroblastoma, carcinoma	Ladds (2009)
<i>Litoria caerulea</i>	Green tree frog	Renal adenocarcinoma, cutaneous papilloma and fibropapilloma of the maxillary region and upper lip, hepatoma, metastatic pancreatic adenocarcinoma, coelomic adenoma	Ladds (2009)
<i>Litoria infrafrenata</i>	Giant (white-lipped) tree frog	Lymphoma, renal tubular adenoma, squamous cell carcinoma, papilloma, sebaceous gland carcinoma	Ladds (2009)
<i>Litoria lesueurii</i>	Lesueur's frog	Melanoma	Ladds (2009)
<i>Paramesotriton hongkongensis</i>	Hong Kong warty newt	Seminoma	Chu et al. (2012)
<i>Xenopus laevis</i>	African clawed frog	Various types, the most common being hepatomas, ovarian tumors, and teratomas	Balls and Clothier (1974); Robert et al. (2009); Hardwick and Philpott (2015)
<b>Reptiles</b>			
<i>Acanthophis antarcticus</i>	Death adder	Leukemic lymphoma, melanoma	Mader (1996); Ladds (2009)
<i>Acrantophis madagascariensis</i>	Madagascar boa	Squamous cell carcinoma, biphasic neoplasm	Bera et al. (2008); Steeil et al. (2013)
<i>Acrochordus javanicus</i>	Elephant trunk snake	Fibroma	Mader (1996)
<i>Agkistrodon contortrix</i>	Southern copperhead	Myeloid leukemia, cholangiocarcinoma, hemangiosarcoma	Catão-Dias and Nichols (1999)
<i>Agkistrodon halys breviceaudus</i>	Korean mamushi	Adenocarcinoma, neurofibrosarcoma	Mader (1996)
<i>Agkistrodon piscivorus</i>	Cottonmouth	Squamous cell carcinoma, sarcoma, fibroma	Mader (1996)
<i>Alligator mississippiensis</i>	American alligator	Papilloma, seminoma, fibrosarcoma	Mader (1996); Elsey et al. (2013)
<i>Anolis carolinensis</i>	Carolina anole	Reticulum sarcoma	Hernandez-Divers and Garner (2003)
<i>Apalone ferox</i>	Florida softshell turtle	Lymphoreticular neoplasia	Hernandez-Divers and Garner (2003)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (cont.)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Arizona elegans occidentalis</i>	California glossy snake	Pheochromocytoma	Mader (1996)
<i>Aspidites melanocephalus</i>	Black-headed python	Gastric adenocarcinoma, angioliipoma	Ladds (2009); Dietz et al. (2016)
<i>Aspidites ramsayi</i>	Woma	Lymphoma, colonic adenocarcinoma	Ladds (2009)
<i>Basiliscus plumifrons</i>	Green basilisk	Fibrosarcoma	Hernandez-Divers and Garner (2003)
<i>Bitis arietans</i>	Puff adder	Leukemic lymphoma, adenoma	Mader (1996)
<i>Bitis gabonica</i>	Gaboon viper	Transitional cell carcinoma, carcinoma, adenocarcinoma, fibrosarcoma, lymphoma, squamous cell carcinoma	Mader (1996) Catão-Dias and Nichols (1999)
<i>Bitis nasicornis</i>	Rhinoceros viper	Lymphoma, leukemic lymphoma, leukemia	Mader (1996)
<i>Boa constrictor</i>	Boa constrictor	Fibrosarcoma, malignant peripheral nerve sheath tumor, malignant perivascular wall tumor, squamous cell carcinoma, fibrosarcoma, melanoma, hemangiosarcoma, lipoma, leukemia, adenocarcinoma, carcinoma, rhabdomyosarcoma	Mader (1996); Dietz et al. (2016)
<i>Boa cookii</i>	Cook's tree boa	Hemangiosarcoma	Mader (1996)
<i>Boiga dendrophila</i>	Mangrove snake	Fibrosarcoma	Mader (1996)
<i>Bothrops atrox</i>	Common lancehead	Adenocarcinoma	Mader (1996)
<i>Caretta caretta</i>	Loggerhead	Fibropapilloma, lymphoblastic lymphoma	Ladds (2009)
<i>Chalcides ocellatus</i>	Ocellated skink	Lymphoma	Chu et al. (2012)
<i>Chamaeleo dilepis</i>	Flap-necked chameleon	Hepatoma	Hernandez-Divers and Garner (2003)
<i>Chelonia mydas</i>	Green sea turtle	Papillomas, fibromas, fibropapillomas, fibroadenoma, carcinoma, myxofibroma, leiomyoma, papilloma of the gall bladder	Reichenbach-Klinke (1963); Brill et al. (1995); Mader (1996); Ladds (2009)
<i>Chilabothrus inornatus</i>	Yellow tree boa	Squamous cell carcinoma, hepatoma, leiomyosarcoma	Mader (1996)
<i>Chondropython viridis</i>	Green tree python	Lymphoid leukemia, fibrosarcoma, chromatophoroma (small intestine), thymoma, myeloid leukemia, lymphoma	Catão-Dias and Nichols (1999)
<i>Clelia clelia</i>	Mussurana	Hepatoma	Mader (1996)
<i>Cnemidophorus uniparens</i>	Desert grassland whiptail lizard	Teratoma	Hernandez-Divers and Garner (2003)
<i>Coleonyx mitratus</i>	Central American banded gecko	Coelom	Hernandez-Divers and Garner (2003)
<i>Corallus caninus</i>	Emerald tree boa	Leiomyosarcoma, lymphoma, adenocarcinoma, malignant peripheral nerve sheath tumor	Catão-Dias and Nichols (1999); Dietz et al. (2016)
<i>Cordylus polyzonus</i>	Karoo girdled lizard	Adenoma	Hernandez-Divers and Garner (2003)
<i>Crocodylus acutus</i>	American crocodile	Lipoma	Mader (1996)
<i>Crocodylus porosus</i>	Saltwater crocodile	Lymphoma, papilloma, cancer of the cerebellum, squamous cell carcinoma	Reichenbach-Klinke (1963); Hill et al. (2016)

(Continued)



TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (*cont.*)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Crocodylus siamensis</i>	Siamese crocodile	Fibrosarcoma	Hernandez-Divers and Garner (2003)
<i>Crotalus atrox</i>	Western diamondback rattlesnake	Fibrosarcoma	Mader (1996)
<i>Crotalus horridus</i>	Timber rattlesnake	Adenoma, adenocarcinoma, fibrosarcoma, leukemia, mesothelioma, hemangioma	Mader (1996)
<i>Crotalus mitchellii pyrrhus</i>	Southwestern speckled rattlesnake	Adenocarcinoma	Mader (1996)
<i>Crotalus ruber</i>	Red diamond rattlesnake	Sarcoma	Mader (1996)
<i>Crotalus viridis helleri</i>	Prairie rattlesnake	Hemangioma	Mader (1996)
<i>Crotalus viridis viridis</i>	Prairie rattlesnake	Fibrosarcoma	Mader (1996)
<i>Cyclura cornuta</i>	Rhinoceros iguana	Chondro-osteofibroma	Hernandez-Divers and Garner (2003)
<i>Cyclura ricordii</i>	Hispaniolan ground iguana	Biliary adenoma	Hernandez-Divers and Garner (2003)
<i>Dipsosaurus dorsalis</i>	Desert iguana	Adenoma, adenocarcinoma	Hernandez-Divers and Garner (2003)
<i>Dispholidus typus</i>	Boomslang	Adenoma	Mader (1996)
<i>Drymarchon corais</i>	Eastern indigo snake	Melanophoroma	Mader (1996)
<i>Drymarchon couperi</i>	Eastern indigo snake	Adenocarcinoma	Mader (1996)
<i>Drymarchon melanurus erebennus</i>	Texas indigo snake	Leiomyosarcoma	Mader (1996)
<i>Echis carinatus</i>	Saw-scaled viper	Hepatocarcinoma	Catão-Dias and Nichols (1999)
<i>Elaphe guttata guttata</i>	Corn snake	Lymphoma, carcinoma, chondrosarcoma, renal cell carcinoma, adenocarcinoma, myeloid leukemia, leiomyosarcoma, lipoma, fibrosarcoma, malignant peripheral nerve sheath tumor, rhabdomyosarcoma	Mader (1996); Catão-Dias and Nichols (1999); Dietz et al. (2016)
<i>Elaphe obsoleta</i>	Western rat snake	Adenocarcinoma, adenoma, fibrosarcoma, rhabdomyosarcoma	Mader (1996); Catão-Dias and Nichols (1999)
<i>Elaphe obsoleta rossalleni</i>	Everglades rat snake	Melanoma	Mader (1996)
<i>Elaphe obsoleta quadrivittata</i>	Yellow rat snake	Transitional cell carcinoma	Mader (1996)
<i>Elaphe taeniura</i>	Beauty snake	Hepatocarcinoma	Catão-Dias and Nichols (1999)
<i>Elaphe taeniura friesei</i>	Taiwan beauty rat snake	Malignant chromatophoroma	Chu et al. (2012)
<i>Elaphe vulpina</i>	Fox snake	Adenocarcinoma	Mader (1996)
<i>Emys orbicularis</i>	European pond turtle	Squamous cell carcinoma, fibroadenoma	Mader (1996)
<i>Epicrates cenchria</i>	Rainbow boa	Histiocytoma, lymphoma, adenoma, myelomonocytic leukemia, squamous cell carcinoma	Catão-Dias and Nichols (1999)
<i>Epicrates subflavus</i>	Jamaican boa	Malignant peripheral nerve sheath tumor, malignant perivascular wall tumor	Dietz et al. (2016)
<i>Eryx conicus</i>	Common sand boa	Squamous cell carcinoma, mixed cell tumor	Mader (1996)
<i>Eublepharis macularis</i>	Leopard gecko	Cholangiocarcinoma	Hernandez-Divers and Garner (2003)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (cont.)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Eumeces fasciatus</i>	Five-lined skink	Hepatocarcinoma	Hernandez-Divers and Garner (2003)
<i>Eunectes murinus</i>	Green anaconda	Lymphoma, fibrosarcoma, granulosa cell tumor	Mader (1996)
<i>Eunectes notaeus</i>	Yellow anaconda	Cystadenoma	Catão-Dias and Nichols (1999)
<i>Geochelone carbonaria</i>	Redfoot tortoise	Adenoma	Mader (1996)
<i>Gopherus agassizii</i>	Mojave desert tortoise	Adenoma, interstitial tumor	Mader (1996)
<i>Gopherus trijuga</i>	Ceylon terrapin	Carcinoma, squamous cell carcinoma	Mader (1996)
<i>Heloderma suspectum</i>	Gila monster	Squamous cell carcinoma, melanoma	Hernandez-Divers and Garner (2003)
<i>Heterodon nasicus</i>	Western hognose snake	Sarcoma, lymphoma	Mader (1996)
<i>Hydrosaurus amboinensis</i>	Amboina sailfin lizard	Lymphoma, plasma cell tumor	Hernandez-Divers and Garner (2003)
<i>Iguana iguana</i>	Green iguana	Lymphoma, hepatoma, cholangioma, adenocarcinoma, ovarian teratoma, adenoma	Hernandez-Divers and Garner (2003)
<i>Indotestudo elongata</i>	Yellow-headed tortoise	Leukemia	Chu et al. (2012)
<i>Lacerta agilis</i>	Sand lizard	Papilloma, squamous cell carcinoma	Reichenbach-Klinke (1963); Hernandez-Divers and Garner (2003)
<i>Lacerta lepida</i>	Ocellated lizard	Papilloma	Reichenbach-Klinke (1963)
<i>Lacerta viridis</i>	Green lizard	Papilloma, osteosarcoma	Reichenbach-Klinke (1963); Hernandez-Divers and Garner (2003)
<i>Lamprophis fuliginosus</i>	African house snake	Malignant peripheral nerve sheath tumor	Dietz et al. (2016)
<i>Lampropeltis getula californiae</i>	Eastern kingsnake	Adenoma, carcinoma, lymphoma, squamous cell carcinoma, cholangiocarcinoma, melanoma, malignant peripheral nerve sheath tumor	Mader (1996); Dietz et al. (2016)
<i>Lampropeltis getula getula</i>	Eastern kingsnake	Tubular adenoma	Catão-Dias and Nichols (1999)
<i>Lampropeltis getula holbrooki</i>	Speckled kingsnake	Adenoma	Mader (1996)
<i>Lampropeltis triangulum annulata</i>	Mexican milk snake	Sarcoma	Mader (1996)
<i>Lampropeltis triangulum sinaloae</i>	Sinaloan milk snake	Myxosarcoma, sarcoma, hepatoma	Mader (1996); Catão-Dias and Nichols (1999)
<i>Lampropeltis triangulum triangulum</i>	Eastern milk snake	Adenocarcinoma, adenoma	Catão-Dias and Nichols (1999)
<i>Morelia spilota</i>	Carpet python	Multicentric lymphoma, soft tissue sarcoma, fibrosarcoma, cholangiocarcinoma, coelomic carcinoma	Ladds (2009)
<i>Morelia spilota spilota</i>	Diamond python	Myxosarcoma, monocytic leukemia of azurophilic type, lymphoid leukemia	Ladds (2009)
<i>Morelia spilota variegata</i>	Darwin carpet python	Cholangiocarcinoma	Mader (1996)
<i>Morelia viridis</i>	Green tree python	Ossifying fibrosarcoma	Mader (1996); Ladds (2009)
<i>Naja naja</i>	Indian cobra	Leiomyosarcoma, adenocarcinoma, adenoma, lymphoma, hepatocarcinoma	Mader (1996); Catão-Dias and Nichols (1999)

(Continued)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (*cont.*)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Naja nigricollis</i>	Black-necked spitting cobra	Adenoma, lymphoma	Mader (1996)
<i>Naja nivea</i>	Cape cobra	Adenocarcinoma	Mader (1996)
<i>Natrix natrix</i>	Grass snake	Pancreatic adenocarcinoma, malignant peripheral nerve sheath tumor	Reichenbach-Klinke (1963); Dietz et al. (2016)
<i>Ophiophagus hannah</i>	King cobra	Tubular adenoma	Catão-Dias and Nichols (1999)
<i>Pantherophis alleghaniensis</i>	Black rat snake	Ameloblastoma	Comolli et al. (2015)
<i>Pelomedusa subrufa</i>	African helmeted turtle	Leukemia	Mader (1996)
<i>Pelusios subniger</i>	East African black mud turtle	Carcinoma	Mader (1996)
<i>Pituophis melanoleucus</i>	Pine snake	Adenocarcinoma, malignant chromatophoroma, carcinoma, adenoma	Mader (1996)
<i>Pituophis melanoleucus mugitus</i>	Florida pine snake	Rhabdomyosarcoma, adenoma, adenocarcinoma, melanoma	Mader (1996)
<i>Pituophis melanoleucus sayi</i>	Bullsnake	Papilloma, adenocarcinoma, malignant melanoma	Reichenbach-Klinke (1963); Mader (1996)
<i>Podarcis muralis</i>	Common wall lizard	Papilloma	Hernandez-Divers and Garner (2003)
<i>Pogona vitticeps</i>	Bearded dragon	Adenocarcinoma of the liver, disseminated myelogenous leukemia, monocytic leukemia, malignant nerve sheath tumor	Hernandez-Divers and Garner (2003); Ladds (2009)
<i>Podarcis sicula</i>	Italian wall lizard	Lymphoma, fibrosarcoma, undifferentiated mesenchymal tumor	Hernandez-Divers and Garner (2003)
<i>Pseudechis porphyriacus</i>	Red-bellied black snake	Cutaneous papillomas, adenomatous proliferation, adenoma of the bile duct	Mader (1996); Ladds (2009)
<i>Pseudonaja affinis</i>	Dugite	Melanoma	Ladds (2009)
<i>Pseudonaja nuchalis</i>	Western brown snake	Leukemic lymphoma	Ladds (2009)
<i>Python molurus</i>	Indian rock python	Ameloblastoma, fibroma	Mader (1996)
<i>Python molurus bivittatus</i>	Burmese python	Carcinoma, adenocarcinoma, interstitial cell tumor, osteosarcoma	Mader (1996)
<i>Python molurus molurus</i>	Indian python	Sarcoma, lymphoma, leukemia	Mader (1996)
<i>Python regius</i>	Ball python	Fibrosarcoma	Mader (1996)
<i>Python reticulatus</i>	Reticulated python	Carcinoma, melanoma, lymphoma	Mader (1996)
<i>Python sebae</i>	African rock python	Adenoma	Mader (1996)
<i>Rhamphiophis oxyrhynchus</i>	Rufous beaked snake	Hemangiosarcoma, lymphoma, fibrosarcoma	Catão-Dias and Nichols (1999)
<i>Sistrurus catenatus</i>	Massasauga	Adenoma, hemangioma, carcinoma	Mader (1996)
<i>Spilotes pullatus</i>	Yellow rat snake	Adenocarcinoma	Mader (1996)
<i>Strophurus spinigerus</i>	Spiny-tailed gecko	Neuroblastoma	Ladds (2009)
<i>Terrapene carolina</i>	Common box turtle	Adenocarcinoma	Mader (1996)
<i>Testudo graeca</i>	Spur-thighed tortoise	Adenoma	Mader (1996)
<i>Testudo hermanni</i>	Hermann's tortoise	Lymphoma, neurilemmoma	Mader (1996)
<i>Testudo horsfieldii</i>	Afghan tortoise	Fibroma, fibroadenoma	Mader (1996)
<i>Thamnophis sauritus</i>	Ribbon snake	Lipoma	Dietz et al. (2016)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (cont.)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Thamnophis sirtalis</i>	Common garter snake	Squamous cell carcinoma, cholangioma, granulosa cell tumor, Sertoli cell tumor, malignant perivascular wall tumor, malignant peripheral nerve sheath tumor	Mader (1996); Dietz et al. (2016)
<i>Thamnophis elegans terrestris</i>	Coast garter snake	Malignant chromatophoroma	Mader (1996)
<i>Tiliqua rugosa</i>	Shingle-back lizard	Subcutaneous osteoma, liposarcoma	Ladds (2009), Hernandez-Divers and Garner (2003)
<i>Trachemys scripta elegans</i>	Red-eared slider	Carcinoma, leukemia	Mader (1996)
<i>Tupinambis nigropunctatus</i>	Tegu	Squamous cell carcinoma	Hernandez-Divers and Garner (2003)
<i>Tupinambis rufescens</i>	Argentine red tegu	Hepatoma	Hernandez-Divers and Garner (2003)
<i>Tupinambis teguixin</i>	Golden tegu	Squamous cell carcinoma	Hernandez-Divers and Garner (2003)
<i>Uromastyx acanthimura</i>	Bell's dabb lizard	Lymphoma	Hernandez-Divers and Garner (2003)
<i>Uromastyx aegyptia</i>	Egyptian mastigure	Lymphoid neoplasia	Gyimesi et al. (2005)
<i>Varanus bengalensis</i>	Bengal monitor	Leukemia, osteochondroma, enchondroma	Hernandez-Divers and Garner (2003)
<i>Varanus exanthematicus</i>	Savannah monitor	Lymphoma	Hernandez-Divers and Garner (2003)
<i>Varanus komodoensis</i>	Komodo dragon	Carcinoma, adenoma, islet cell tumor, pheochromocytoma, interstitial cell tumor	Hernandez-Divers and Garner (2003)
<i>Varanus niloticus</i>	Nile monitor	Plasma cell tumor	Hernandez-Divers and Garner (2003)
<i>Varanus salvator</i>	Water monitor	Lymphoma	Hernandez-Divers and Garner (2003)
<i>Vipera ammodytes</i>	Horned viper	Adenocarcinoma	Mader (1996)
<i>Vipera palestine</i>	Palestine viper	Adenocarcinoma	Mader (1996)
<i>Vipera russelli</i>	Russell's viper	Fibrosarcoma, leukemia, myofibroma	Mader (1996)
<i>Walterinnesia aegyptia</i>	Desert cobra	Pheochromocytoma	Mader (1996)
<b>Birds</b>			
<i>Acanthagenys rufogularis</i>	Spiny-cheeked honeyeater	Nephroblastoma	Ladds (2009)
<i>Agapornis lilianae</i>	Nyasa lovebird	Fibromas and fibrosarcomas of integument and/or skeletal muscle, Sertoli cell tumors	Reece (1992); Ladds (2009)
<i>Agapornis roseicollis</i>	Peach-faced lovebird	Fibromas and fibrosarcomas of the integument and/or skeletal muscle, visceral fibromas and fibrosarcomas, subcutaneous lipomas, intraabdominal lipomas, lymphoblastic lymphomas, lymphocytic lymphomas, and mixed-cell lymphomas, hepatocarcinomas, neurilemmoma	Reece (1992); Ladds (2009)
<i>Ailuroedus crassirostris</i>	Green catbird	Myelocytomas	Reece (1992); Ladds (2009)
<i>Aix sponsa</i>	North American wood duck	Malignant melanoma	Chu et al. (2012)

(Continued)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (*cont.*)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Alectoris graeca</i>	Chukar partridge	Liposarcomas, cholangiomas	Reece (1992); Ladds (2009)
<i>Alisterus scapularis</i>	Australian king parrot	Plasma cell tumors	Reece (1992); Ladds (2009)
<i>Anas castanea</i>	Chestnut teal	Lymphocytic lymphomas and mixed-cell lymphomas, metastatic abdominal adenocarcinomas	Reece (1992); Ladds (2009)
<i>Anas cyanoptera</i>	Cinnamon teal	Adenocarcinoma	Snyder and Ratcliffe (1966)
<i>Anas novaehollandiae</i>	New Zealand scaup	Dermal squamous cell carcinomas	Reece (1992); Ladds (2009)
<i>Anas platyrhynchos</i>	Mallard, domestic duck	Intraabdominal lipomas, chondromas, osteomas, lymphoblastic lymphomas, seminomas, metastatic abdominal adenocarcinomas, astrocytoma	Reece (1992); Ladds (2009); Chu et al. (2012)
<i>Anas superciliosa</i>	Pacific black duck	Myxomas and myxofibromas, malignant melanomas	Reece (1992); Ladds (2009)
<i>Anhinga novaehollandiae</i>	Darter	Hemangiomas	Reece (1992); Ladds (2009)
<i>Anser anser</i>	Graylag goose	Chondromas	Reece (1992); Ladds (2009)
<i>Anser domesticus</i>	Domestic goose	Fibrosarcoma	Ratcliffe (1933)
<i>Aprosmictus scapularis</i>	King parrot	Fibrosarcoma	Ratcliffe (1933)
<i>Ara militaris</i>	Military macaw	Squamous cell carcinoma	Ratcliffe (1933)
<i>Barnardius barnardii</i>	Mallee ring-neck	Lymphoblastic lymphomas	Reece (1992); Ladds (2009)
<i>Barnardius zonarius</i>	Port Lincoln parrot	Plasma cell tumors	Reece (1992); Ladds (2009)
<i>Barnardius zonarius semitorquatus</i>	Twenty eight parrot	Plasma cell tumors	Ladds (2009)
<i>Brotogeris tirica</i>	Plain parakeet	Fibrosarcoma	Ratcliffe (1933)
<i>Bubo virginianus</i>	Great horned owl	Myelogenous leukemia	Wiley et al. (2009)
<i>Buteo jamaicensis</i>	Red-tailed hawk	Cholangiocarcinoma	Hartup et al. (1995)
<i>Cacatua galerita</i>	Sulfur-crested cockatoo	Visceral fibromas and fibrosarcomas, subcutaneous lipomas, intraabdominal lipomas, osteosarcomas, lymphoblastic lymphomas, lymphocytic lymphomas, and mixed-cell lymphomas, granulosa cell tumors, squamous cell carcinoma, adenocarcinoma	Reece (1992); Ladds (2009); Ratcliffe (1933)
<i>Cacatua leadbeateri</i>	Pink cockatoo	Dermal squamous cell carcinomas	Reece (1992); Ladds (2009)
<i>Cacatua moluccensis</i>	Gang-gang cockatoo	Lymphomas	Ratcliffe (1933)
<i>Cacatua roseicapilla</i>	Galah	Subcutaneous lipomas, intraabdominal lipomas, granulosa cell tumors	Reece (1992); Ladds (2009)
<i>Cacatua sanguinea</i>	Little corella	Intraabdominal lipomas, lymphoblastic lymphomas	Reece (1992); Ladds (2009)
<i>Callocephalon fimbriatum</i>	Gang-gang cockatoo	Visceral fibromas and fibrosarcomas, osteosarcomas, plasma cell tumors	Reece (1992); Ladds (2009)
<i>Calyptorhynchus baudinii</i>	White-tailed black cockatoo	Myeloblastomas	Reece (1992); Ladds (2009)
<i>Casuaris casarius johnsonii</i>	Southern cassowary	Papilliform mesotheliomas, gastrointestinal adenocarcinomas	Reece (1992); Ladds (2009)
<i>Centropus phasianinus</i>	Pheasant coucal	Hepatoma, hepatocarcinoma, cholangioma	Ladds (2009)
<i>Cereopsis novaehollandiae</i>	Cape Barren goose	Plasma cell tumors	Reece (1992); Ladds (2009)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (cont.)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Chalcophaps indica</i>	Emerald dove	Pinealoma	Reece (1992); Ladds (2009)
<i>Chloephaga leucoptera</i>	Upland goose	Adenocarcinoma	Snyder and Ratcliffe (1966)
<i>Chrysolophus pictus</i>	Golden pheasant	Adenocarcinoma, adenoma	Ratcliffe (1933)
<i>Columba livia</i>	Domestic pigeon	Fibromas and fibrosarcomas of integument and/or skeletal muscle, visceral fibromas and fibrosarcomas, subcutaneous lipomas, intraabdominal lipomas, liposarcomas, rhabdomyoma, leiomyomas and leiomyofibromas, myelocytomas, lymphoblastic lymphomas, lymphocytic lymphomas and mixed-cell lymphomas, plasma cell tumors, basal cell tumors, crop carcinoma, cholangiomas, renal adenocarcinomas, metastatic abdominal adenocarcinomas, seminomas, thyroid adenomas	Reece (1992); Ladds (2009); Shimonohara et al. (2013)
<i>Columba pulchricollis</i>	Ashy wood pigeon	Cholangioma	Chu et al. (2012)
<i>Conurus holochlorus</i>	Green parakeet	Carcinomatoid embryoma	Ratcliffe (1933)
<i>Coscoroba coscoroba</i>	Coscoroba swan	Cholangiocarcinoma, renal cell carcinoma	Chu et al. (2012)
<i>Coturnix australis</i>	Brown quail	Subcutaneous lipomas	Reece (1992); Ladds (2009)
<i>Coturnix chinensis</i>	King quail	Fibromas and fibrosarcomas of integument and/or skeletal muscle, hepatocarcinomas, seminomas, metastatic abdominal adenocarcinomas	Reece (1992); Ladds (2009)
<i>Coturnix coturnix japonica</i>	Japanese quail	Fibromas and fibrosarcomas of integument and/or skeletal muscle, visceral fibromas and fibrosarcomas, osteosarcomas, hemangiomas, lymphocytic lymphomas and mixed-cell lymphomas, cholangiomas	Reece (1992); Ladds (2009)
<i>Cyanoramphus novaezelandia</i>	Red-fronted parakeet	Intraabdominal lipomas	Reece (1992); Ladds (2009)
<i>Cygnus atratus</i>	Black swan	Myxomas and myxofibromas, osteosarcoma	Reece (1992); Ladds (2009); Chu et al. (2012)
<i>Cygnus olor</i>	Mute swan	Myxomas and myxofibromas	Reece (1992); Ladds (2009)
<i>Dacelo novaeguineae</i>	Laughing kookaburra	Intraabdominal lipomas, cholangiomas	Reece (1992); Ladds (2009)
<i>Dendrocygna autumnalis</i>	Black-bellied whistling duck	Adenocarcinoma	Snyder and Ratcliffe (1966)
<i>Dromaius novaehollandiae</i>	Emu	Pancreatic adenocarcinomas	Reece (1992); Ladds (2009)
<i>Dryonastes berthemyi</i>	Buffy laughingthrush	Fibrosarcoma	Ratcliffe (1933)
<i>Egretta novaehollandiae</i>	White-faced heron	Lymphoma	Ladds (2009)
<i>Emberiza icterica</i>	Red-headed bunting	Lipoma	Ratcliffe (1933)
<i>Emblema temporalis</i>	Red-browed firetail	Esophageal papilloma	Reece (1992); Ladds (2009)
<i>Eolophus roseicapilla</i>	Galah	Lipomas	Ratcliffe (1933)
<i>Erythrura gouldiae</i>	Gouldian finch	Adrenocortical adenomas	Reece (1992); Ladds (2009)
<i>Erythrura trichroa</i>	Blue-faced parrot finch	Renal adenoma, adenocarcinoma	Ladds (2009)
<i>Eudyptula minor</i>	Little penguin	Lymphocytic lymphomas and mixed-cell lymphomas, fibroma, fibrosarcoma, cutaneous papillomas	Reece (1992); Ladds (2009)

(Continued)



TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (*cont.*)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Falco naumanni</i>	Lesser kestrel	Malignant intracranial teratoma	Lopez and Murcia (2008)
<i>Gennaues nycthemerus</i>	Silver pheasant	Adenocarcinoma	Ratcliffe (1933); Snyder and Ratcliffe (1966)
<i>Geopelia cuneata</i>	Diamond dove	Leiomyomas and leiomyofibromas	Reece (1992); Ladds (2009)
<i>Geopelia humeralis</i>	Bar-shouldered dove	Osteosarcomas	Reece (1992); Ladds (2009)
<i>Geopelia placida</i>	Peaceful dove	Leiomyomas and leiomyofibromas	Reece (1992); Ladds (2009)
<i>Ginnaeus swinhoii</i>	Swinhoe's pheasant	Visceral fibromas and fibrosarcomas	Reece (1992); Ladds (2009)
<i>Gracula religiosa</i>	Greater hill mynah	Chondrosarcoma	Chu et al. (2012)
<i>Gymnorhina tibicen</i>	Australian magpie	Fibromas and fibrosarcomas of the integument and/or skeletal muscle, myeloblastomas, lymphocytic lymphomas, and mixed-cell lymphomas	Reece (1992); Ladds (2009)
<i>Larus novaehollandiae</i>	Silver gull	Lymphocytic lymphomas and mixed-cell lymphomas	Reece (1992); Ladds (2009)
<i>Larus pacificus</i>	Pacific gull	Chondromas, myelocytomas	Reece (1992); Ladds (2009)
<i>Leipoa ocellata</i>	Malleefowl	Lymphomas	Ladds (2009)
<i>Leptolophus hollandicus</i>	Cockatiel	Lipomas	Ratcliffe (1933)
<i>Lonchura castaneothorax</i>	Chestnut-breasted mannikin	Lymphocytic lymphomas and mixed-cell lymphomas	Reece (1992); Ladds (2009)
<i>Lopholaimus antarcticus</i>	Topknot pigeon	Lymphomas	Ladds (2009)
<i>Macropygia amboinensis</i>	Cuckoo-dove	Gastrointestinal adenocarcinomas	Ladds (2009)
<i>Malurus cyaneus</i>	Superb fairy-wren	Lymphocytic lymphomas and mixed-cell lymphomas	Reece (1992); Ladds (2009)
<i>Mareca sibilatrix</i>	Chiloe wigeon	Adenocarcinoma	Snyder and Ratcliffe (1966)
<i>Megaquiscalus major</i>	Boat-tailed grackle	Adenocarcinoma	Ratcliffe (1933)
<i>Meleagris gallopavo</i>	Wild turkey	Adenocarcinoma	Ratcliffe (1933)
<i>Melopsittacus undulatus</i>	Budgerigar	Adenoma, adenocarcinoma, carcinomas, fibromas and fibrosarcomas of integument and/or skeletal muscle, visceral fibromas and fibrosarcomas, myxomas and myxofibromas, subcutaneous lipomas, intraabdominal lipomas, osteomas, leiomyomas and leiomyofibromas, hemangiomas, myelocytomas, reticulum cell sarcoma, lymphoblastic lymphomas, lymphocytic lymphomas and mixed-cell lymphomas, plasma cell tumors, dermal squamous cell carcinomas, feather folliculomas, uropygial adenomas, proventricular adenocarcinomas, cholangiomas, renal adenocarcinomas, seminomas, Sertoli cell tumors, Leydig cell tumor, ovarian adenocarcinoma, granulosa cell tumors, oviduct adenomas, metastatic abdominal adenocarcinomas, adrenocortical adenomas, thyroid adenomas, thyroid mixed-cell tumor, neurofibroma, nephroblastoma, lipomas, glioma, lymphoma, teratoma	Ratcliffe (1933); Reece (1992); Ladds (2009)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (cont.)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Neochmia ruficauda</i>	Star finch	Myxomas and myxofibromas	Reece (1992); Ladds (2009)
<i>Neophema pulchella</i>	Turquoise parrot	Lymphocytic lymphomas and mixed-cell lymphomas	Reece (1992); Ladds (2009)
<i>Neopsephotus bourkii</i>	Bourke's parrot	Plasma cell tumors	Reece (1992); Ladds (2009)
<i>Northiella haematogaster</i>	Blue bonnet	Plasma cell tumors	Reece (1992); Ladds (2009)
<i>Nycticorax caledonicus</i>	Rufous night heron	Myelocytomas	Reece (1992); Ladds (2009)
<i>Nymphicus hollandicus</i>	Cockatiel	Liposarcomas, renal adenocarcinomas, fibroma, fibrosarcoma	Reece (1992); Ladds (2009)
<i>Nyroca americana</i>	Redhead duck	Adenocarcinoma	Snyder and Ratcliffe (1966)
<i>Oxyura australis</i>	Blue-billed duck	Cholangiomas, hepatoma, hepatocarcinoma	Reece (1992); Ladds (2009)
<i>Padda oryzivora</i>	Java sparrow	Lymphocytic lymphomas and mixed-cell lymphomas, metastatic abdominal adenocarcinomas	Reece (1992); Ladds (2009)
<i>Palaeornis cyanocephala</i>	Burmese parrakeet	Adenoma	Ratcliffe (1933)
<i>Palaeornis eupatrius</i>	Alexandrine parrakeet	Teratoma	Ratcliffe (1933)
<i>Paroaria cucullata</i>	Red crested cardinal	Myxosarcoma	Ratcliffe (1933)
<i>Passer domesticus</i>	House sparrow	Lymphocytic lymphomas and mixed-cell lymphomas	Reece (1992); Ladds (2009)
<i>Pavo cristatus</i>	Common peafowl	Esophageal papilloma	Chu et al. (2012)
<i>Plegadis falcinellus</i>	Glossy ibis	Intracutaneous keratoacanthomas	Reece (1992); Ladds (2009)
<i>Phalacrocorax carbo</i>	Great cormorant	Melanoma	Kusewitt and Ley (1996)
<i>Phaps chalcoptera</i>	Common bronze-wing	Dermal squamous cell carcinomas	Reece (1992); Ladds (2009)
<i>Phasianus colchicus</i>	Ring-necked pheasant	Lymphoblastic lymphomas, lymphocytic lymphomas and mixed-cell lymphomas, renal adenocarcinomas, cholangioma, pulmonary carcinoma, renal cell carcinoma, thyroid adenoma, fibroma	Reece (1992); Ladds (2009); Chu et al. (2012)
<i>Phasianus versicolor</i>	Green pheasant	Fibrosarcoma, lymphomas	Ratcliffe (1933)
<i>Phylidonyris novaehollandiae</i>	New Holland honeyeater	Cutaneous papillomas	Ladds (2009)
<i>Planesticus m. migratorius</i>	Three-legged robin	Nephroblastoma or renal carcinoma	Ratcliffe (1933)
<i>Platycercus elegans</i>	Crimson rosella	Lymphocytic lymphomas and mixed-cell lymphomas, plasma cell tumors	Reece (1992); Ladds (2009)
<i>Platycercus eximius</i>	Eastern rosella	Lymphocytic lymphomas and mixed-cell lymphomas	Reece (1992); Ladds (2009)
<i>Plectorhyncha lanceolata</i>	Striped honeyeater	Nephroblastoma	Ladds (2009)
<i>Plectropterus gambensis</i>	Spur-winged goose	Fibrosarcoma	Ratcliffe (1933)
<i>Podargus strigoides</i>	Tawny frogmouth	Intraabdominal lipomas	Reece (1992); Ladds (2009)
<i>Polytelis swainsonii</i>	Superb parrot	Lymphoma, plasma cell tumors	Reece (1992); Ladds (2009)
<i>Prunella collaris</i>	Alpine accentor	Hepatoma	Chu et al. (2012)
<i>Psephotus dissimilis</i>	Hooded parrot	Fibroma, fibrosarcoma	Ladds (2009)
<i>Psephotus varius</i>	Mulga parrot	Fibromas and fibrosarcomas of integument and/or skeletal muscle	Reece (1992); Ladds (2009)

(Continued)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (*cont.*)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Quelea quelea</i>	Red-billed quelea	Teratoma	Ratcliffe (1933)
<i>Serinus canaria</i>	Canary	Fibromas and fibrosarcomas of integument and/or skeletal muscle, visceral fibromas and fibrosarcomas, myxomas and myxofibromas, chondromas, leiomyomas and leiomyofibromas, lymphoblastic lymphomas, lymphocytic lymphomas and mixed-cell lymphomas, plasma cell tumors, dermal squamous cell carcinomas, intracutaneous keratoacanthomas, feather folliculomas, uropygial adenomas, proventricular adenocarcinomas, hepatocarcinomas, adrenocortical adenomas, pituitary adenoma	Ratcliffe (1933); Reece (1992); Ladds (2009)
<i>Sicalis flaveola</i>	Saffron finch	Adenocarcinoma	Ratcliffe (1933)
<i>Spatula clypeata</i>	Shoveler duck	Adenocarcinoma	Snyder and Ratcliffe (1966)
<i>Strepera</i> spp.	Currawong	Lymphocytic lymphomas and mixed-cell lymphomas	Reece (1992); Ladds (2009)
<i>Struthidea cinerea</i>	Apostlebird	Plasma cell tumors	Reece (1992); Ladds (2009)
<i>Struthio camelus</i>	Ostrich	Papilliform mesotheliomas	Reece (1992); Ladds (2009)
<i>Tadoma radjah</i>	Radjah shelduck	Oviduct adenomas, nephroblastoma	Reece (1992); Ladds (2009)
<i>Tadoma variegata</i>	Paradise shelduck	Plasma cell tumors	Reece (1992); Ladds (2009)
<i>Taeniopygia bichenovii</i>	Double-barred finch	Fibroma, fibrosarcoma	Ladds (2009)
<i>Taeniopygia castanotis</i>	Zebra finch	Adenocarcinoma, teratoma	Ratcliffe (1933)
<i>Thraupis palmarum</i>	Palm tanager	Lipoma	Ratcliffe (1933)
<i>Torgos tracheliotus</i>	African eared vulture	Adenocarcinoma	Snyder and Ratcliffe (1966)
<i>Trichoglossus chloroepidotus</i>	Scaly-breasted lorikeet	Pancreatic adenocarcinomas	Reece (1992); Ladds (2009)
<i>Trichoglossus rubritorquis</i>	Red-collared lorikeet	Intraabdominal lipomas, hepatocarcinomas, metastatic abdominal adenocarcinomas	Reece (1992); Ladds (2009)
<i>Turdoides terricolor</i>	Jungle babbler	Adenoma	Ratcliffe (1933)
<i>Turdus merula</i>	Blakbird	Nephroblastoma or renal carcinoma (hypernephroma)	Ratcliffe (1933)
<i>Turnix melanogaster</i>	Black-breasted button-quail	Metastatic abdominal adenocarcinomas	Reece (1992); Ladds (2009)
<i>Vanellus miles</i>	Masked lapwing	Lymphoma	Ladds (2009)
<b>Mammals</b>			
<i>Acinonyx jubatus</i>	Cheetah	Myometrial leiomyomas, uterine fibroleiomyoma	Munson et al. (1999); Walzer et al. (2003)
<i>Acrobates pygmaeus</i>	Feathertail glider	Biliary adenocarcinoma	Ladds (2009)
<i>Addax nasomaculatus</i>	Addax	Intestinal tubulopapillary carcinoma	Chu et al. (2012)
<i>Aepyprymnus rufescens</i>	Rufous rat-kangaroo	Thyroid adenoma, lymphoma, hemangiomas, carcinoma	Ladds (2009)
<i>Ammotragus lervia</i>	Barbary sheep	Lymphoma	Chu et al. (2012)
<i>Antechinus stuartii</i>	Brown antechinus	Squamous cell carcinoma, trichoepithelioma	Canfield et al. (1990)
<i>Antechinomys laniger spenceri</i>	Kultarr	Pulmonary adenomatosis	Attwood and Woolley (1973)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (cont.)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Antechinus minimus</i>	Swamp antechinus	Renal pelvic transitional cell proliferation	Canfield et al. (1990)
<i>Arctictis binturong</i>	Binturong	Hepatocarcinoma	Chu et al. (2012)
<i>Arctocephalus forsteri</i>	New Zealand fur seal	Renal adenocarcinoma, papilloma, basal cell carcinoma, osteosarcoma, anaplastic renal adenocarcinoma, neuroblastoma	Ladds (2009)
<i>Arctocephalus pusillus</i>	Afro-Australian Fur Seal	Hepatoma, hepatocarcinoma, uterine and intestinal leiomyomas, thyroid adenoma, lymphoma, ovarian granulosa cell tumor, adenocarcinoma, malignant melanoma	Newman and Smith (2006); Ladds (2009)
<i>Atelerix albiventris</i>	Four-toed hedgehog	Epithelial tumors, round cell tumors, mesenchymal or spindle cell tumors, endometrial stromal sarcomas, leiomyosarcoma, adenoleiomyoma, adenocarcinoma, lymphoma, oral squamous cell carcinoma, schwannoma or neurofibrosarcoma, plasma cell tumor, hemangiosarcoma, fibrosarcoma, osteosarcoma, undifferentiated or poorly differentiated sarcomas, mammary gland tumors, mast cell tumors, sebaceous carcinoma, lipoma	Mikaelian et al. (2004); Heatley et al. (2005)
<i>Atherurus macrourus</i>	Brush-tailed porcupine	Inflammatory myofibroblastic tumor	Chu et al. (2012)
<i>Balaena mysticetus</i>	Bowhead whale	Lipoma	Newman and Smith (2006)
<i>Balaenoptera borealis</i>	Sei whale	Melanocytoma (possibly hamartoma)	Newman and Smith (2006)
<i>Balaenoptera musculus</i>	Blue whale	Mediastinal ganglioneuroma, mucinous cystadenoma, granulosa cell tumor, gastric lipoma, fibroma of the pleura	Newman and Smith (2006); Ladds (2009)
<i>Balaenoptera physalus</i>	Fin whale	Neurofibroma of the cerebellum, Hodgkin's-like lymphoma, fibromas of the tongue, of the pleura, of the subcutis and skin, granulosa cell tumor, ovarian carcinoma, osteoma, lipoma	Newman and Smith (2006); Ladds (2009)
<i>Bassariscus astutus</i>	Ringtail cat	Basal cell carcinoma	Ratcliffe (1933)
<i>Bison bison</i>	Bison	Adenocarcinoma	Ratcliffe (1933)
<i>Bos bubalis</i>	Buffalo	Adenoma	Ratcliffe (1933)
<i>Bos taurus</i>	Domestic cattle	Esophageal papilloma, cutaneous squamous cell carcinoma	Chu et al. (2012)
<i>Boselaphus tragocamelus</i>	Nilgai	Fibroma	Ratcliffe (1933)
<i>Callimico goeldii</i>	Goeldi's marmoset	Myelolipoma	Porter et al. (2004)
<i>Callithrix jacchus</i>	Common marmoset	Myelolipoma	Porter et al. (2004)
<i>Callorhinus ursinus</i>	Northern fur seal	Granulosa cell tumor, lymphoma, lipoma, fibrosarcoma, squamous cell carcinoma, ganglioneuroblastoma, rhabdomyosarcoma	Newman and Smith (2006)
<i>Camelus bactrianus</i>	Bactrian camel	Hemangioma	Ratcliffe (1933)
<i>Canis anthus</i>	Senegalese wolf	Medullary carcinoma	Ratcliffe (1933)
<i>Canis latrans</i>	Coyote	Chondrosarcoma	Ratcliffe (1933)
<i>Canis lupus baileyi</i>	Mexican wolf	Basal cell carcinoma, squamous cell carcinoma, nephroblastoma, adenocarcinoma	Ratcliffe (1933)

(Continued)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (*cont.*)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Canis lupus dingo</i>	Dingo	Lymphoma, thymoma, lipoma of subcutis, fibromatous epulis, perianal adenoma, sebaceous adenoma, squamous cell carcinoma, bronchial adenoma	Ladds (2009)
<i>Canis mesomelas</i>	Black-backed jackal	Osteoma, hemangiosarcoma	Chu et al. (2012)
<i>Canis rufus</i>	Red wolf	Adenocarcinoma, carcinomas	Snyder and Ratcliffe (1966); Seeley et al. (2016)
<i>Capra hircus</i>	Domestic goat	Lymphoma	Ratcliffe (1933)
<i>Caracal caracal</i>	Caracal	Osteochondroma	Ratcliffe (1933)
<i>Cebus albifrons</i>	White-fronted capuchin	Cholangiocarcinoma	Porter et al. (2004)
<i>Cebus apella fatuellus</i>	Tufted capuchin	Adenoma	Ratcliffe (1933)
<i>Cercocebus atys</i>	Sooty mangabey	Hepatocarcinoma	Porter et al. (2004)
<i>Cercocebus atys lunulatus</i>	White-naped mangabey	Hepatocarcinoma	Porter et al. (2004)
<i>Cercopithecus aethiops</i>	African green monkey	Hepatoma, mixed hepatocellular and cholangiocellular carcinoma, uterine leiomyoma	Porter et al. (2004); Chu et al. (2012)
<i>Cercopithecus diana</i>	Diana monkey	Cholangiocarcinoma	Porter et al. (2004)
<i>Cercopithecus mitis</i>	Blue monkey	Biliary adenoma/cystadenoma	Porter et al. (2004)
<i>Cercopithecus mitis ssp. albogularis</i>	White-throated guenon	Biliary adenoma/cystadenoma	Porter et al. (2004)
<i>Cercopithecus mona</i>	Mona monkey	Biliary adenoma/cystadenoma	Porter et al. (2004)
<i>Chalinolobus gouldii</i>	Gould's wattled bat	Cutaneous papilloma of the wing	Ladds (2009)
<i>Chlorocebus sabaeus</i>	Green monkey	Adenocarcinoma	Ratcliffe (1933)
<i>Connochaetes gnou</i>	Black wildebeest	Squamous cell carcinoma	Ratcliffe (1933)
<i>Cuniculus paca</i>	Lowland paca	Lymphoma	Ratcliffe (1933)
<i>Cynomys ludovicianus</i>	Black-tailed prairie dogs	Hepatocarcinoma, hepatoma, biliary cystadenoma, cholangiocarcinoma, odontoma (elodontoma), lingual squamous cell carcinoma, salivary gland adenocarcinoma, gingival squamous cell carcinoma, intestinal leiomyoma, multicentric lymphoma, malignant round cell tumor, high grade lymphoma of liver and gall bladder, cutaneous lymphoma, malignant thymoma, atrial hemangiosarcoma, splenic hemangioma, thoracic lipoma, thyroid adenocarcinoma, pancreatic adenocarcinoma, cystadenocarcinoma, adenocarcinoma, probably mammary, basal cell tumor, squamous cell carcinoma, bronchioloalveolar carcinoma	Thas and Garner (2012)
<i>Dasycercus cristicauda</i>	Mulgara	Prostatic carcinoma	Canfield et al. (1990)
<i>Dasyskaluta rosamondae</i>	Little red kaluta	Splenic myeloid hyperplasia	Canfield et al. (1990)
<i>Dasypsecta albida</i>	Agouti	Uterine fibroleiomyoma	Chu et al. (2012)
<i>Dasypsecta azarae</i>	Azara's agouti	Squamous cell carcinoma	Ratcliffe (1933)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (cont.)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Dasyuroides byrnei</i>	Kowari	Pulmonary adenoma, splenic hematopoietic hyperplasia, trichoepithelioma, dermal mastocytoma metastatic to spleen, squamous cell carcinoma, metastatic adenocarcinoma of unknown origin, spindle cell tumor of scapula, multiple hepatomas, schwannoma, apocrine gland cystadenoma, splenic and thoracic fibrosarcoma, squamous cell carcinoma, cerebellar medulloblastoma, schwannoma	Attwood and Woolley (1973); Canfield et al. (1990); Ladds (2009)
<i>Dasyurus geoffroyi</i>	Western quoll	Metastatic facial fibrosarcoma	Canfield et al. (1990)
<i>Dasyurus hallucatus</i>	Northern quoll	Lymphoma, squamous cell carcinoma of teat, lymphocytic leukemia, histiocytoma	Canfield et al. (1990); Ladds (2009)
<i>Dasyurus maculatus</i>	Tiger quoll	Pulmonary carcinoma, mesothelioma of peritoneum, squamous cell carcinoma, renal adenoma, abdominal lipoma, splenic hemangiosarcoma, adrenal adenocarcinoma, adenocarcinoma of the small gut, ovarian hemangioma, cutaneous lipoma	Attwood and Woolley (1973); Canfield et al. (1990); Ratcliffe (1933); Ladds (2009); Chu et al. (2012)
<i>Dasyurus viverrinus</i>	Eastern quoll	Adrenal cortical nodular hyperplasia, multiple hepatomas, papillomas, metastatic squamous cell carcinoma to lung, trichoepithelioma, splenic leiomyosarcoma, mammary adenocarcinoma, ganglioneuroma of liver, metastatic mammary adenocarcinoma, splenic hemangioma, ovarian adenocarcinoma, dermal spindle cell tumor, sebaceous hyperplasia, papillomas of head and feet, carcinoma of the rectum, medullary carcinoma	Ratcliffe (1933); Attwood and Woolley (1973); Canfield et al. (1990); Ladds (2009)
<i>Delphinus delphis ponticus</i>	Short-beaked common dolphin	Fibroma of the epididymis, Leydig cell tumor, testicular neoplasia	Newman and Smith (2006); Ladds (2009); Diaz-Delgado et al. (2012)
<i>Dendrolagus bennettianus</i>	Bennett's tree kangaroo	Generalized sarcoma	Ladds (2009)
<i>Didelphis marsupialis</i>	Common opossum	Adenocarcinoma, squamous cell carcinoma	Ratcliffe (1933); Snyder and Ratcliffe (1966)
<i>Didelphis virginiana</i>	Virginia opossum	Transitional cell carcinoma of the bladder, pulmonary adenomatosis, lymphoma	Attwood and Woolley (1973); Canfield et al. (1990); Marrow et al. (2010); Higbie et al. (2015)
<i>Dorcopsis muelleri</i>	Brown forest wallaby	Pulmonary metastasis of carcinoma	Ladds (2009)
<i>Elaphurus davidianus</i>	Père David's deer	Cutaneous squamous cell carcinoma	Chu et al. (2012)
<i>Elephas maximus</i>	Asian elephant	Cutaneous fibrosarcoma, uterine leiomyoma	Chu et al. (2012)
<i>Enhydra lutris nereis</i>	Southern sea otter	Osteosarcoma, osteoma	Rodriguez-Ramos Fernandez et al. (2012)
<i>Equus asinus</i>	Donkey	Renal hemangiosarcoma	Chu et al. (2012)
<i>Equus ferus przewalski</i>	Przewalski's wild horse	Uterine adenocarcinoma	Thompson et al. (2014)
<i>Equus quagga</i>	Common zebra	Fibrosarcoma	Ratcliffe (1933)
<i>Equus zebra zebra</i>	Mountain zebra	Sarcoid tumors	Sasidharan (2006); Sasidharan et al. (2011)

(Continued)



TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (*cont.*)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Erethizon dorsatum</i>	North American porcupine	Chorion epithelioma	Ratcliffe (1933)
<i>Erinaceus europaeus</i>	Hedgehog	Adenocarcinoma, uterine leiomyoma	Chu et al. (2012)
<i>Eulemur fulvus</i>	Common brown lemur	Hepatocarcinoma	Porter et al. (2004)
<i>Eulemur macaco</i>	Black lemur	Biliary adenoma/cystadenoma, hepatocarcinoma	Porter et al. (2004)
<i>Eulemur mongoz</i>	Mongoose lemur	Adenoma	Ratcliffe (1933)
<i>Eumetopias jubatus</i>	Steller's sea lion	Fibroleiomyoma, adenocarcinoma	Newman and Smith (2006)
<i>Galago crassicaudatus</i>	Greater galago	Hepatocarcinoma, uterine leiomyoma	Chu et al. (2012)
<i>Galagoides demidoff</i>	Demidoff's dwarf galago	Cholangiocarcinoma	Porter et al. (2004)
<i>Gazella dorcas</i>	Dorcas gazella	Osteoma	Ratcliffe (1933)
<i>Gazella thomsonii</i>	Thomson's gazelle	Hepatocarcinoma	Chu et al. (2012)
<i>Genetta genetta</i>	Common genet	Basal cell carcinoma	Ratcliffe (1933)
<i>Gerbilliscus robustus</i>	Fringe-tailed gerbil	Fibrosarcoma, squamous cell carcinoma	Ratcliffe (1933)
<i>Globicephala macrorhynchus</i>	Short-finned pilot whale	Granulosa cell tumor	Newman and Smith (2006)
<i>Globicephala melaena</i>	Long-finned pilot whale	Fibroleiomyomas, leiomyoma	Newman and Smith (2006)
<i>Gorilla gorilla gorilla</i>	Lowland gorilla	Uterine adenocarcinoma, squamous cell carcinoma of vulva, cervix, and uterus	Stringer et al. (2010)
<i>Herpestes urva</i>	Carb-eating mongoose	Uterine leiomyoma	Chu et al. (2012)
<i>Heterocephalus glaber</i>	Naked mole-rat	Adenocarcinoma possibly of mammary or salivary origin, neuroendocrine carcinoma	Delaney et al. (2016)
<i>Hyaena brunnea</i>	Brown hyena	Mammary gland adenocarcinoma	Chu et al. (2012)
<i>Hyaena hyaena</i>	Striped hyena	Lymphoma, bronchioalveolar carcinoma	Chu et al. (2012)
<i>Hydromys chrysogaster</i>	Water-rat	Mediastinal lymphoma, adenoma, pheochromocytoma	Ladds (2009)
<i>Hydrurga leptonyx</i>	Leopard seal	Fibromatous epulis	Ladds (2009)
<i>Hystrix brachyura longicauda</i>	Malayan porcupine	Scirrhus carcinoma	Ratcliffe (1933)
<i>Hystrix cristata</i>	Crested porcupine	Uterine leiomyosarcoma	Chu et al. (2012)
<i>Inia geoffrensis</i>	Amazon river dolphin	Squamous cell carcinoma	Newman and Smith (2006)
<i>Isoodon auratus</i>	Golden bandicoot	Unidentified cloacal neoplasia	Canfield et al. (1990); Marrow et al. (2010)
<i>Jaculus jaculus</i>	Lesser Egyptian jerboa	Angiolipoma	Ratcliffe (1933)
<i>Lagenorhynchus obliquidens</i>	Pacific white-sided dolphin	Squamous cell carcinoma, eosinophilic leukemia, lymphoma, teratoma, fibroma	Newman and Smith (2006)
<i>Lagenorhynchus obscurus</i>	Dusky dolphin	Dysgerminoma, uterine leiomyomas, fibroleiomyomas	Newman and Smith (2006); Ladds (2009)
<i>Lagenorhynchus acutus</i>	Atlantic white-sided dolphin	Fibropapilloma, adenoma, leiomyoma	Newman and Smith (2006)
<i>Lama glama</i>	Llama	Gastric squamous cell carcinoma	Chu et al. (2012)
<i>Lemur catta</i>	Ring-tailed lemur	Cholangiocarcinoma, biliary adenoma/cystadenoma, mammary gland Adenoma	Porter et al. (2004); Chu et al. (2012)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (cont.)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Leopardus pardalis</i>	Ocelot	Hepatocarcinoma	Miranda et al. (2015)
<i>Leopardus wiedii</i>	Margay	Cholangiocarcinoma, vaginal leiomyoma	McClure et al. (1977)
<i>Leporillus conditor</i>	Greater stick-nest rat	Sarcoma, mediastinal thymoma, adenocarcinoma	Ladds (2009)
<i>Lutra canadensis</i>	North American otter	Squamous cell carcinoma	Snyder and Ratcliffe (1966)
<i>Lycaon pictus</i>	African wild dog	Hemangioma	Ratcliffe (1933)
<i>Macaca fascicularis</i>	Crab-eating macaque	Hepatocarcinoma, mixed hepatocellular and cholangiocellular carcinoma	Porter et al. (2004)
<i>Macaca fuscata</i>	Japanese macaque	Biliary adenoma/cystadenoma, hepatocarcinoma, squamous cell carcinoma, adenoma	Ratcliffe (1933); Porter et al. (2004)
<i>Macaca sinica</i>	Toque macaque	Papilloma	Ratcliffe (1933)
<i>Macropus agilis</i>	Agile wallaby	Focal hepatobiliary proliferation, biliary adenoma	Ladds (2009)
<i>Macropus giganteus</i>	Eastern gray kangaroo	Dermal lymphoma, metastatic hemangiosarcoma, hepatoma, trichoepithelioma, bronchioloalveolar carcinoma, bronchial carcinoma	Ladds (2009); Chu et al. (2012)
<i>Macropus parma</i>	Parma wallaby	Osteochondromatous proliferation, squamous cell carcinoma of the cervix and vagina	Canfield et al. (1990); Ladds (2009); Marrow et al. (2010)
<i>Macropus parryi</i>	Whiptail wallaby	Lymphoblastic lymphoma	Ladds (2009)
<i>Macropus robustus</i>	Common wallaroo	Hepatic vascular proliferation, hamartoma, biliary adenoma	Ladds (2009)
<i>Macropus rufogriseus</i>	Bennett's wallaby	Oral melanoma, oral adenocarcinoma, lymphoma, bile duct proliferation	Brust (2013); Ladds (2009)
<i>Macropus rufus</i>	Red kangaroo	Adenocarcinoma, lymphoma, squamous cell carcinoma, basal cell carcinoma of the pouch, squamous cell carcinoma of the oral cavity, gastric carcinoma, pulmonary carcinoma	Brust (2013); Ratcliffe (1933); Ladds (2009)
<i>Macrotis lagotis</i>	Greater bilby	Fibrosarcoma of skin and lung, osteosarcoma, hemangioma of pancreas, hemangiosarcoma, histiocytoma, basal cell carcinoma, pulmonary sclerosing squamous cell carcinoma and adenocarcinoma, pulmonary adenomatosis, lymphoma	Ratcliffe (1933); Ladds (2009)
<i>Manis pentadactyla</i>	Pangolin	Hepatocarcinoma, hepatoma	Chu et al. (2012)
<i>Marmota monax</i>	Groundhog	Adenoma	Ratcliffe (1933)
<i>Megaptera novaeangliae</i>	Humpback whale	Lipoma, fibroma	Newman and Smith (2006)
<i>Melomys burtoni</i>	Grassland mosaic-tailed rat	Fibrosarcoma, hepatoma, adenocarcinoma, carcinoma	Ladds (2009)
<i>Mephitis mephitis</i>	Striped skunk	Biliary cystadenoma, renal cell carcinoma, adenocarcinoma	Snyder and Ratcliffe (1966); Chu et al. (2012)
<i>Mesembriomys gouldii</i>	Black-footed tree-rat	Thymic lymphoma, hepatoma	Ladds (2009)
<i>Mesoplodon densirostris</i>	Blainville's beaked whale	Vaginal fibromas	Newman and Smith (2006); Ladds (2009)

(Continued)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (*cont.*)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Microcebus murinus</i>	Gray mouse lemur	Hepatocarcinoma	Porter et al. (2004)
<i>Mirounga leonina</i>	Southern elephant seals	Adrenocortical adenoma, malignant granulosa cell tumor	Ladds (2009)
<i>Mus musculus molossinus</i>	Japanese waltzing mice	Adenocarcinoma, fibroadenoma	Ratcliffe (1933)
<i>Mustela putorius furo</i>	Ferret	Sebaceous carcinoma, adrenocortical carcinoma	Chu et al. (2012)
<i>Mustela vison</i>	American mink	Cutaneous squamous cell carcinoma, hepatocarcinoma, adrenocortical carcinoma, lymphoma, hemangiosarcoma, hepatoma	Chu et al. (2012)
<i>Myocastor coypus</i>	Nutria	Adenocarcinoma, fibroma	Ratcliffe (1933)
<i>Myrmecophaga tridactyla</i>	Giant anteater	Multicentric lymphoma	Sanches et al. (2013)
<i>Nasua nasua</i>	South American coati	Squamous cell carcinoma	Ratcliffe (1933)
<i>Neofelis nebulosa</i>	Clouded leopard	Pheochromocytoma, uterine leiomyoma, mesothelioma, hemangioma	Snyder and Ratcliffe (1966); Chu et al. (2012)
<i>Neophocaena phocaenoides</i>	Indo-Pacific finless porpoise	Fibroma	Newman and Smith (2006)
<i>Notomys alexis</i>	Spinifex hopping mouse	Fibroma, lipoma, rhabdomyosarcoma, cavernous hemangioma, thymic lymphoma, multicentric lymphoma, melanoma	Ladds (2009); Old and Price (2016)
<i>Nyctereutes procyonoides</i>	Raccoon dog	Adenocarcinoma	Ratcliffe (1933)
<i>Nycticebus coucang</i>	Slow loris	Cholangioma, adrenocortical adenoma, myeloid leukemia	Chu et al. (2012)
<i>Nyctophilus geoffroyi</i>	Lesser long-eared bat	Fibrosarcoma of the abdomen	Ladds (2009)
<i>Odocoileus hemionus</i>	Mule deer	Intracerebral malignant plasma cell tumor	Clancy et al. (2016)
<i>Odocoileus virginianus</i>	White-tailed deer	Fibroadenoma, oligodendrogliomas	Ratcliffe (1933); Gottdenker et al. (2012)
<i>Orcinus orca</i>	Killer whale	Hodgkins-like lymphoma, papilloma	Newman and Smith (2006); Ladds (2009)
<i>Ornithorhynchus anatinus</i>	Duck-billed platypus	Papilloma, hepatoma, adrenocortical adenoma	Ladds (2009)
<i>Oryx gazella gazelle</i>	Gemsbok	Adrenocortical adenoma	Chu et al. (2012)
<i>Otolemur crassicaudatus</i>	Brown greater galago	Cholangiocarcinoma, hepatoma	Porter et al. (2004)
<i>Otospermophilus beecheyi</i>	California ground squirrel	Osteoma	Ratcliffe (1933)
<i>Pan troglodytes</i>	Chimpanzee	Hepatocarcinoma, hepatoma, reproductive neoplasia, uterine leiomyomas	Stringer et al. (2010)
<i>Panthera leo</i>	Lion	Gallbladder adenocarcinomas, mammary gland adenocarcinoma, uterine leiomyoma, hepatocarcinoma, biliary cystadenoma, malignant histiocytosis, scirrhous carcinoma	Ratcliffe (1933); Sakai et al. (2003); Chu et al. (2012)
<i>Panthera onca</i>	Jaguar	Adrenocortical carcinoma, pancreatic islet cell carcinoma, metastatic leiomyosarcoma, leiomyoma, mammary fibroadenoma, lymphangioma	Port et al. (1981); Chu et al. (2012); Ratcliffe (1933)
<i>Panthera pardus</i>	Leopard	Hepatoma, parathyroid carcinoma, mammary gland adenocarcinoma, cholangiocarcinoma, lymphangioma	Sakai et al. (2003); Chu et al. (2012); Ratcliffe (1933)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (cont.)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Panthera tigris</i>	Tiger	Mammary gland adenocarcinoma, adenomatous polyps, squamous cell carcinoma	Chu et al. (2012); Ratcliffe (1933)
<i>Panthera tigris bengalensis</i>	Bengal tiger	Endometrial adenocarcinoma	Linnehan and Edwards (1991)
<i>Papio cynocephalus</i>	Yellow baboon	Adenocarcinoma, fibroadenoma	Ratcliffe (1933)
<i>Papio cynocephalus anubis</i>	Anubis baboon	Cutaneous squamous cell carcinoma, trichofolliculoma	Chu et al. (2012)
<i>Papio hamadryas</i>	Hamadryas baboon	Gall bladder adenocarcinoma, biliary adenoma/cystadenoma	Ratcliffe (1933); Porter et al. (2004)
<i>Papio papio</i>	Guinea baboon	Gall bladder adenocarcinoma	Porter et al. (2004)
<i>Papio sphinx</i>	Mandrill	Uterine leiomyosarcoma, cutaneous lipoma	Chu et al. (2012)
<i>Papio ursinus</i>	Chacma baboon	Gall bladder cystadenocarcinoma, fibrosarcoma	Ratcliffe (1933); Porter et al. (2004)
<i>Paradoxurus hermaphroditus</i>	Asian palm civet	Adenocarcinoma	Ratcliffe (1933)
<i>Parantechinus apicalis</i>	Dibbler	Lymphoma (leukemic)	Canfield et al. (1990)
<i>Perameles bougainville</i>	Western barred bandicoot	Pulmonary carcinoma, prostatic carcinoma, cutaneous papillomatosis, and carcinomatosis	Ladds (2009)
<i>Perameles gunnii</i>	Eastern barred bandicoot	Colonic leiomyosarcoma and leiomyoma, leiomyosarcoma of skin and lymph nodes, fibriohistiocytoma, cutaneous histiocytoma, mast cell tumor, basal cell tumor of the larynx	Canfield et al. (1990); Ladds (2009); Marrow et al. (2010)
<i>Perodicticus potto</i>	Potto	Cholangiocarcinoma	Porter et al. (2004)
<i>Perodipus richardsoni</i>	Kangaroo rat	Fibrosarcoma, lymphoma	Ratcliffe (1933)
<i>Peromyscus leucopus</i>	White-footed mouse	Fibrosarcoma, adenocarcinoma	Ratcliffe (1933)
<i>Petaurus breviceps</i>	Sugar glider	Subcutaneous fibroma, histiocytoma, sebaceous carcinoma, lymphoma, leukemia, fibrosarcoma, myxosarcoma, adenocarcinomas and carcinomas of the adrenals, intestines, liver, and mammary glands, transitional cell carcinoma of the urinary bladder	Brust (2013); Ladds (2009); Marrow et al. (2010)
<i>Phalanger gymnotis</i>	Ground cuscus	Cutaneous lymphoma	Goodnight et al. (2008)
<i>Phascogale tapoatafa</i>	Brush-tailed phascogale	Hemangiopericytoma, trichoepithelioma, fibrosarcoma, lymphoma, hemangioma, hemangiosarcoma, basal cell tumor, squamous cell carcinoma, hepatocarcinoma, melanoma	Canfield et al. (1990); Ladds (2009)
<i>Phascolarctos cinereus</i>	Koala	Lymphoma, meothelioma, tumors of the cartilaginous or osseous tissues of the craniofacial region, testicular teratoma, myeloid leukemia, rhabdomyosarcoma, myxofibroma of the subcutis, leiomyoma of the intestine, oral fibrosarcoma, biliary adenoma, hepatoma, ovarian tumor, adenoma of fimbria, mammary adenocarcinoma, cutaneous papilloma and squamous cell carcinoma, pilomatixoma, chromophobe adenoma, adenoma of the frontal sinus, serosal adenocarcinoma	Ladds (2009)

(Continued)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (*cont.*)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Phocoena phocoena</i>	Harbor porpoise	Papilloma, adenocarcinoma	Newman and Smith (2006)
<i>Physeter macrocephalus</i>	Sperm whale	Uterine leiomyoma, fibroleiomyoma, fibroleiomyosarcoma, hemangioma, fibromas of the jaw and skin, penil papillomatosis	Newman and Smith (2006); Ladds (2009)
<i>Planigale maculata</i>	Common planigale	Dermal spindle cell tumor, uterine adenocarcinoma, squamous cell carcinoma	Canfield et al. (1990)
<i>Pongo pygmaeus</i>	Bornean orangutan	Malignant granulosa cell tumor	Stringer et al. (2010)
<i>Presbytis entellus</i>	Gray langur	Hepatoma	Porter et al. (2004)
<i>Procyon cancrivorus</i>	Crab-eating raccoon	Adenocarcinoma	Ratcliffe (1933)
<i>Procyon lotor</i>	Raccoon	Adenoma, adenocarcinoma, pancreatic exocrine adenocarcinoma, hepatocarcinoma, mammary gland adenocarcinoma, sweat gland adenocarcinoma	Ratcliffe (1933); Chu et al. (2012)
<i>Proteles cristatus</i>	Aardwolf	Peritoneal mesothelioma	Chu et al. (2012)
<i>Pseudantechinus bilarni</i>	Sandstone antechinus	Lymphoma or splenic erythroid hyperplasia, sebaceous adenoma	Canfield et al. (1990)
<i>Pseudantechinus macdonellensis</i>	False antechinus	Lymphoma (leukemic)	Canfield et al. (1990)
<i>Pseudocheirus peregrinus</i>	Common ringtail possum	Lymphoma, metastatic adenocarcinoma	Ladds (2009)
<i>Pseudomys albocinereus</i>	Ash-gray mouse	Liposarcoma, lymphoma	Ladds (2009)
<i>Pseudomys australis</i>	Plains rat	Hemangiosarcoma, adenocarcinoma, carcinoma	Ladds (2009)
<i>Pteropus d. dasymallus</i>	Flying fox	Hepatocarcinoma, chondrosarcoma, uterine adenocarcinoma	Chu et al. (2012)
<i>Pteropus poliocephalus</i>	Gray-headed flying fox	Metastatic carcinoma, fibropapilloma, subcutaneous fibrosarcoma, rhabdomyoma	Ladds (2009)
<i>Puma concolor</i>	Mountain lion	Fibrosarcoma, thyroid carcinoma	Chu et al. (2012)
<i>Rangifer tarandus tarandus</i>	Reindeer	Lymphoma	Jarplid and Reh binder (1995)
<i>Rattus norvegicus</i>	Rat	Mammary gland fibroadenoma	Chu et al. (2012)
<i>Rattus tunneyi</i>	Pale field rat	Adenocarcinoma	Ladds (2009)
<i>Saguinus oedipus</i>	Cotton-top tamarin	Intestinal adenocarcinoma	Chu et al. (2012)
<i>Saimiri boliviensis</i>	Black-headed squirrel monkey	Hepatocarcinoma	Porter et al. (2004)
<i>Saimiri sciureus</i>	Squirrel monkey	Cutaneous lipoma, adenocarcinoma of vaginal wall, hepatocarcinoma	Porter et al. (2004); Chu et al. (2012)
<i>Sarcophilus harrisii</i>	Tasmanian devil	Papillomas, splenic erythroid hyperplasia, adrenocortical nodular hyperplasia, keratoacanthoma, mammary cystadenoma, metastatic squamous cell carcinoma of lung, trichoepithelioma, fibrosarcoma of lung, squamous cell carcinoma, sebaceous, and apocrine hyperplasia; adrenal dermal lymphosarcoma, hemangioma, smooth muscle hyperplasia of esophagus, sebaceous hyperplasia or adenoma of pouch, apocrine and mammary gland hyperplasia, pyloric leiomyoma, hepatoma, Tasmanian devil facial tumor disease	Ratcliffe (1933); Attwood and Woolley (1973); Canfield et al. (1990); Ladds (2009)

TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (cont.)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Sciurus niger</i>	Fox squirrel	Adenocarcinoma and adenoma of the kidney	Ratcliffe (1933)
<i>Sciurus carolinensis pennsylvanicus</i>	Northern gray squirrel	Hypernephroma	Ratcliffe (1933)
<i>Setonix brachyurus</i>	Quokka	Liposarcoma, papilloma	Ladds (2009)
<i>Sminthopsis crassicaudata</i>	Fat-tailed dunnart	Dermal spindle cell tumor, splenic lymphoma, squamous cell carcinoma, round cell sarcoma of the upper forelimb	Canfield et al. (1990)
<i>Stenella coeruleoalba</i>	Striped dolphin	Myelogenous leukemia, squamous cell carcinoma	Newman and Smith (2006)
<i>Suricata suricatta</i>	Meerkat	Rhabdomyosarcoma	Chu et al. (2012)
<i>Sus barbatus</i>	Black small-eared pig	Uterine adenocarcinoma, uterine leiomyoma	Chu et al. (2012)
<i>Sus scrofa</i>	Pig	Adenocarcinoma	Ratcliffe (1933)
<i>Tachyglossus aculeatus</i>	Short-beaked echidna	Lymphoma of spleen, fibroma of subcutis, leiomyoma of the cloaca, pericloacal leiomyosarcoma, fibroma of the beak, myocardial lymphoma, lymphoma with leukemia, cystic adenoma of the thyroid	Ladds (2009)
<i>Taurotragus oryx</i>	Common eland	Cutaneous lymphoma	Chu et al. (2012)
<i>Taxidea taxus</i>	American badger	Peritoneal epithelioid leiomyosarcoma, undetermined adenocarcinomas	Chu et al. (2012)
<i>Thylacomys lagotis</i>	Rabbit-eared bandicoot	Squamous cell carcinoma	Snyder and Ratcliffe (1966)
<i>Thylogale billardieri</i>	Tasmanian pademelon	Squamous tumor of the stomach, melanoma	Kusewitt and Ley (1996); Ladds (2009)
<i>Tragelaphus eurycerus isaaci</i>	Bongo	Uterine leiomyomas	Napier et al. (2005)
<i>Tragelaphus strepsiceros</i>	Greater kudu	Renal cell carcinoma	Chu et al. (2012)
<i>Trichosurus vulpecula</i>	Common brushtail possum	Thoracic chondrosarcoma	Ladds (2009)
<i>Tupaia belangeri</i>	Northern treeshrew	Hepatocarcinoma	Porter et al. (2004)
<i>Tursiops truncatus</i>	Common bottlenose dolphin	Lymphoma, myeloma, malignant seminoma, hepatic and thyroid adenoma, pancreatic carcinoma, reticuloendotheliosis of lung, liver, lymphoma of spleen, myelogenous leukemia, immunoblastic lymphoma, lymphadenopathy, splenomegaly, plasmacytoid neoplastic cells, sublingual squamous cell carcinoma, uterine adenocarcinoma, renal adenoma, teratoma	Newman and Smith (2006); Ladds (2009)
<i>Urocyon cinereoargenteus</i>	Gray fox	Adenoma, splenic myelolipoma, cutaneous squamous cell carcinoma, sweat gland adenoma of eyelid, lymphoma	Ratcliffe (1933); Chu et al. (2012)
<i>Ursus americanus</i>	American black bear	Medullary carcinoma, basal cell carcinoma	Ratcliffe (1933)
<i>Ursus arctos</i>	Brown bear	Bronchial adenoma, cholangiocarcinoma, hypernephroma	Ratcliffe (1933); Chu et al. (2012)
<i>Ursus maritimus</i>	Polar bear	Cutaneous lymphoma, adenocarcinoma	Ratcliffe (1933); Chu et al. (2012)
<i>Ursus thibetanus</i>	Asiatic black bear	Biliary cystadenoma	Chu et al. (2012)

(Continued)



TABLE 2.1 Examples of Neoplasia Across the Animal Kingdom (*cont.*)

Latin name	Common name	Neoplasia (including benign and malignant abnormal cell growths)	References
<i>Ursus thibetanus formosanus</i>	Formosan black bear	Bronchioloalveolar carcinoma	Chu et al. (2012)
<i>Varecia variegata</i>	Black-and-white ruffed lemur	Hepatocarcinoma, biliary adenoma/cystadenoma	Porter et al. (2004)
<i>Vicugna pacos</i>	Alpaca	Medullary carcinoma	Ratcliffe (1933)
<i>Viverra zibetha</i>	Malayan civet	Adenocarcinoma, squamous cell carcinoma	Ratcliffe (1933); Snyder and Ratcliffe (1966)
<i>Viverra zibetha</i>	Large Indian civet	Adenocarcinoma	Ratcliffe (1933)
<i>Vombatus ursinus</i>	Coarse-haired wombat	Fibropapilloma, lymphoma, leukemia, adenocarcinoma	Ladds (2009)
<i>Vulpes corsac</i>	Corsac fox	Adenoma	Ratcliffe (1933)
<i>Vulpes v. pennsylvanicus</i>	American red fox	Adenoma	Ratcliffe (1933)
<i>Zalophus californianus</i>	California sea lion	Adenocarcinoma, hypernephroma, squamous-cell carcinoma, leiomyoma, fibroma, carcinoma, adenoma, ovarian granulosa cell tumor, lymphoma, islet cell adenoma or carcinoma, transitional cell carcinoma, adenoma, duct adenoma, hepatocarcinoma, lipoma, nephroblastoma, sarcoma, neuroendocrine tumor, fibrosarcoma, myosarcoma, melanoma, mesenchymoma, multicentric neurofibromatosis	Newman and Smith (2006); Rush et al. (2012)

<sup>a</sup>We tried to provide a comprehensive list of examples of neoplasia in wild and captive animals, but understandably the list cannot be complete due to limited space. Review articles were used primarily due to restricted space for citations. We are well aware of that several taxonomic revisions have been undertaken since many of the listed references were published. We, however in virtually all cases followed the taxonomy used in the studies referred to in the table.

TABLE 2.2 Cancer Prevalence in Wild Animals

Species	Neoplasia	Prevalence (%)	References
<b>Fish</b>			
Atlantic salmon ( <i>Salmo salar</i> )	Leiomyosarcoma	4.60	Coffee et al. (2013)
Bicolor damselfish ( <i>Stegastes partitus</i> )	Neurofibromatosis-like disease	23	Coffee et al. (2013)
Brown bullhead ( <i>Ameiurus nebulosus</i> )	Liver neoplasms	5–15	Baumann et al. (2008)
Chinook salmon ( <i>Oncorhynchus tshawytscha</i> )	Plasmacytoid leukemia	6	Eaton et al. (1994)
Dab ( <i>Limanda limanda</i> )	Epidermal papilloma	1–7	Dethlefsen et al. (2000)
English sole ( <i>Parophrys vetulus</i> )	Carcinomas, adenomas, hepatic mesenchymal neoplasms	up to 24	Malins et al. (1987)
European smelt ( <i>Osmerus eperlanus</i> )	Spawning papillomatosis	5.50	Coffee et al. (2013)
Gizzard shad ( <i>Dorosoma cepedianum</i> )	Spindle cell neoplasms	20	Geter et al. (1998)
Northern pike ( <i>Esox lucius</i> )	Lymphosarcoma	21	Papas et al. (1976)
Roach ( <i>Rutilus rutilus</i> )	Epidermal papillomatosis	3–31	Korkea-aho et al. (2006)
Walleye ( <i>Sander vitreus</i> )	Dermal sarcoma	20–30	Coffee et al. (2013)
Walleye ( <i>Sander vitreus</i> )	Epidermal hyperplasia	up to 20	Coffee et al. (2013)
White sucker ( <i>Catostomus commersoni</i> )	Epidermal papilloma	59	Coffee et al. (2013)

TABLE 2.2 Cancer Prevalence in Wild Animals (cont.)

Species	Neoplasia	Prevalence (%)	References
<b>Amphibians</b>			
Japanese fire belly newt ( <i>Cynops pyrrhogaster</i> )	Skin papilloma	5.50	Asashima et al. (1982)
Leopard frog ( <i>Rana pipiens</i> )	Renal adenocarcinoma	9	McKinnel (1965)
Montseny brook newt ( <i>Calotriton arnoldi</i> )	Chromatophoroma melanocytoma	27	Martinez-Silvestre et al. (2011)
<b>Reptiles</b>			
Green turtle ( <i>Chelonia mydas</i> )	FP	23	Foley et al. (2005)
Green turtle ( <i>Chelonia mydas</i> )	FP	22	Adnyana et al. (1997)
Green turtle ( <i>Chelonia mydas</i> )	FP	<sup>a</sup>	Chaloupka et al. (2009)
Green turtle ( <i>Chelonia mydas</i> )	FP	58	dos Santos et al. (2010)
Green turtle ( <i>Chelonia mydas</i> )	FP	16	Aguirre et al. (1999b)
Loggerhead turtle ( <i>Caretta caretta</i> )	FP	6	Aguirre et al. (1999b)
<b>Birds</b>			
Canada geese ( <i>Branta canadensis</i> )	Spindle cell sarcomas	0.2	Gates et al. (1992)
White-fronted geese ( <i>Anser albifrons</i> )	Multicentric intramuscular lipomatosis/fibromatosis	23	Daoust et al. (1991)
<b>Mammals</b>			
Baltic gray seal ( <i>Halichoerus grypus</i> )	Uterine leiomyomas	64	Bäcklin et al. (2003)
Beluga ( <i>Delphinapterus leucas</i> )	Adenocarcinoma, squamous cell carcinoma, dysgerminoma, lymphosarcoma	18	Martineau et al. (2002)
Brown hare ( <i>Lepus europaeus occidentalis</i> )	Ovarian tumors	5.60	Flux (1965)
California sea lion ( <i>Zalophus californianus</i> )	Metastatic carcinoma, spindle cell sarcoma, adenocarcinoma, adrenocortical adenoma	18–26	Gulland et al. (1996)
Cape mountain zebra ( <i>Equus zebra zebra</i> )	Equine sarcoid	53	Marais et al. (2007)
Gray squirrel ( <i>Sciurus carolinensis</i> )	Fibromatosis	<sup>b</sup>	Terrell et al. (2002)
Northern sea otter ( <i>Enhydra lutris</i> )	Uterine leiomyomas	2	Williams and Pulley (1981)
Pacific walrus ( <i>Odobenus rosmarus divergens</i> )	Uterine leiomyomas, ovarian leiomyoma, mesenteric leiomyoma, gastric gastrointestinal stromal tumors, ovarian dysgerminomas, intestinal hemangioma, hepatic hemangioma, mammary adenoma	17	Fleetwood et al. (2005)
Roe deer ( <i>Capreolus capreolus</i> )	Fibropapillomas	33	Erdélyi et al. (2009)
Roe deer ( <i>Capreolus capreolus</i> )	Adenoma, brain tumors, bile duct carcinoma, hemangiosarcoma, lymphoma, osteosarcoma, rhabdomyosarcoma	2	Aguirre et al. (1999a)
Santa Catalina Island fox ( <i>Urocyon littoralis catalinae</i> )	Ceruminous gland tumors	52	Vickers et al. (2015)
Sea otter ( <i>Enhydra lutris</i> )	Leiomyoma	1.80	Williams and Pulley (1981)
Western barred bandicoot ( <i>Perameles bougainville</i> )	Cutaneous papillomatosis and carcinomatosis	<sup>c</sup>	Woolford et al. (2008)

FP, Fibropapillomatosis.

<sup>a</sup>Significant temporal decrease in prevalence.

<sup>b</sup>Epizootic, no data provided on exact prevalence.

<sup>c</sup>High, no data provided on exact prevalence.

up to 9% of the frogs were diagnosed with renal adenocarcinoma in 1965. However, no information about tumor etiology or its possible effects on the frogs was provided. Interestingly, in a later study [McKinnell and Martin \(1979\)](#) observed a gradual temporal decline in tumor prevalence and in 1978 no tumors were observed in 1216 dissected frogs. [McKinnell and Martin \(1979\)](#) suggested that the decline in cancer prevalence was caused by a significant reduction in frog numbers and a concomitant reduction in the release of oncogenic viruses into the breeding ponds. However, the authors could not rule out that a gradual reduction of carcinogenic pollutants into the breeding ponds could have caused the decline in tumor prevalence.

[Asashima et al. \(1982\)](#) studied the occurrence of spontaneous skin papillomas in Japanese newts (*Cynops pyrrhogaster*) in northern Japan. The prevalence of papillomas showed a seasonal variation, being highest in autumn, ranging from 1.93% to 5.45%, whereas during the rest of the year the prevalence ranged between 0.16% and 0.50%. A spatial difference in cancer prevalence was also recorded with newts collected from the northern, seaside prefectures having higher papilloma rates (1.00–5.45%) than newts from the southern, Pacific Ocean prefectures (0–0.27%). No intersexual differences in tumor prevalence were recorded. Virus-like bodies, resembling herpes-type virus, were found in the cytoplasm of the epithelias, suggesting that tumor may have been caused by a viral agent. Unfortunately the study does not provide any information of the underpinning(s) of the temporal and spatial variation in tumor prevalence or whether the tumors affected newt mortality.

In a recent study skin tumor prevalence was investigated in the Montseny brook newt (*Calotriton arnoldi*) in Spain ([Martinez-Silvestre et al., 2011](#)). The range of this taxon is restricted to a small geographic area <40 km<sup>2</sup> of the North Eastern Iberian Peninsula. Similar to the Japanese newt a profound spatial population difference in tumor prevalence was observed ranging from 0%, 2% to 29%. The tumors were only observed in adult newts, which led the authors to suggest that the tumors may be caused by increased UV-B exposure. Yet again no data are provided on whether the tumors may affect newt mortality.

Although our sample is small, it shows that cancer prevalence may affect a substantial proportion of wild amphibians. Considering the dramatic decline in amphibians caused by the chytrid fungus, *Batrachochytrium dendrobatidis* ([Daszak et al., 1999](#)) makes it even more important to further investigate the possible negative effects of cancer in this group of vertebrates.

## Reptiles

The only reptile taxa for which we have been able to retrieve data on cancer prevalence in the wild are

restricted to marine turtles. Although fibropapillomatosis (FP) mainly affects green turtles (*Chelonia mydas*) it has also been documented in loggerheads (*Caretta caretta*; [Aguirre et al., 1999b](#)). Green turtles have been subjected to numerous and extensive research projects and here we summarize the major findings from some of these studies. FP in green turtles results in tumor growth on eyes, oral cavity, skin, carapace, plastron, and/or internal organs ([Santos et al., 2010](#)). Consequently the disease may significantly reduce turtle foraging efficiency. FP shows significant geographic variation not only in prevalence (ranging from 0% to 92%) but also in severity ([Santos et al., 2010](#)). Moreover, in Brazil the disease is absent in juvenile green turtles but increases in prevalence in older turtles ([Santos et al., 2010](#)). In contrast in Hawaii, FP affects mainly juvenile turtles ([Balazs and Pooley, 1990](#); [Work and Balazs, 1999](#)). However, the reason(s) for the age-specific increase in FP prevalence in Brazil and the age-specific difference in cancer development in Brazil and Hawaii is unknown. Interestingly, [Chaloupka et al. \(2009\)](#) reported on cases where FP had regressed and even completely disappeared in some individual green turtles in Hawaii, and that the diseases since the mid-1990s has showed a significant decline in prevalence.

Although we have not been able to find data on how FP affects green turtle mortality rates, the disease results in high parasite load, immune suppression, increased physiological cost ([Work and Balazs, 1999](#); [Work et al., 2001, 2005](#)) and is the most common cause of green turtle stranding on Hawaii ([Chaloupka et al., 2008, 2009](#)). Consequently, we find it highly likely that FP may impose considerable mortality cost on green turtles in the wild. In spite of FP's high prevalence in some areas and its possible severe effects on green turtle fitness the etiology of FP is still not known. Some studies have found an association between herpesviruses and FP ([Greenblatt et al., 2005](#)), whereas others have implicated that pollution and habitat quality may be major factors explaining the presence of FP ([Herbst and Klein, 1995](#)).

The detrimental impact of cancer on marine turtles and the emergence of a novel fungal disease in squamate reptiles ([Guthrie et al., 2015](#)) warrant increased research efforts to investigate how cancer might affect the demography of reptiles in the wild.

## Birds

We find it remarkable that although birds are often abundant in both urban and rural habitats we have only been able to find a handful of studies that have recorded cancer prevalence in wild birds. [Jennings \(1968\)](#) estimated the prevalence of neoplasia in wild birds in Great Britain to be between 0.1% and 1.0%. Similar low cancer prevalence was recorded by [Gates et al. \(1992\)](#) in

Canada geese (*Branta canadensis interior*; 2 out of 1272 birds, 0.2%). Both birds were young and emaciated and microscopical analyses suggested that the tumors “had the typical appearance of spindle cell sarcomas” (Gates et al., 1992). Similar results on low cancer prevalence in wild birds were published by Siegfried (1983) who found tumors in only 9 out of more than 18,000 birds examined (0.05%). Although based on a significantly smaller sample size, 3 out of 13 (23%) ruffed grouse (*Bonasa umbellus*) were diagnosed having tumors (Howerth et al., 1986). One bird was diagnosed with a lipoma, the second bird a fibroma, while the third bird had developed a renal carcinoma metastatic to the liver (Howerth et al., 1986). The high prevalence recorded in ruffed grouse should, however, be interpreted with caution as all three birds were delivered for examination because they all suffered from obvious lesions. Reece (1992) reported 383 cases of cancer from a collection of more than 10,000 birds (3.8%) submitted for necropsy in Victoria, Australia from 1977 to 1987. As the birds examined included both wild and captive birds and no data are provided on the number of birds in each of the two groups, again the data on cancer prevalence should be interpreted with caution.

The only publication we have found showing that cancer prevalence in birds may reach similar levels as that found among other vertebrates is a study by Daoust et al. (1991) who reported that out of 30 wild white-fronted goose (*Anser albifrons*) killed by hunters 7 (23%) were diagnosed as having developed multicentric mesenchymal tumors. Daoust et al. (1991) suggested that the high prevalence could have been caused by “a genetically influenced susceptibility to the disease.” Unfortunately, however, no data are provided to support this statement.

In their review of wildlife cancer McAloose and Newton (2009) listed the endangered North American Attwater’s prairie chicken (*Tympanicus cupido attwateri*) as an example of a species being further threatened by extinction due to cancer. Although reticuloendotheliosis virus may infect up to 50% of the captive birds, we have not been able to find any publication that relate this high infection level to mortality in the wild.

The few publications that we have been able to retrieve suggest that cancer prevalence in birds in general appears to be low. Although the sample size in some of the studies were very high, they were often restricted to large-bodied and long-lived species, such as geese. In order to make any robust generalization of cancer prevalence among wild birds, future research should incorporate birds representing a significantly more diverse taxonomic range.

## Mammals

Cancer prevalence and its effect on some wild mammal population, such as California sea lions (*Zalophus*

*californianus*) and belugas (*Delphinapterus leucas*) have been subjected to intensive research (Gulland et al., 1996; Martineau et al., 2002). Between 1979 and 1994 the prevalence of a metastatic carcinoma of urogenital origin in stranded California sea lions was reported to be 18% (Gulland et al., 1996). However, between 1998 and 2012 the prevalence of this cancer increased to 26% (Browning et al., 2015). This metastatic carcinoma appears to result in 100% mortality as all animals died during rehabilitation (Gulland et al., 1996). The actual prevalence of this cancer is most likely lower as only sick animals are likely to strand, but despite this the cancer represents a significant cause of death (Browning et al., 2015). Recent studies have found that the etiology of the cancer is associated with individual genotype, persistent organic pollutants, and/or a herpesvirus (Browning et al., 2015). Similar high cancer prevalence has been recorded in an isolated beluga population living in the St. Lawrence estuary (Martineau et al., 2002). Although the primary causes of death were respiratory and gastrointestinal infections with metazoan parasites, observed in 22% of the belugas, cancer was the second most common cause of death across all age groups and observed in 18% of the stranded belugas (Martineau et al., 2002). Cancer prevalence in adults was even higher (27%) and Martineau et al. (2002) estimated the annual rate of all cancer types in belugas to 163 out of 100,000 animals, a rate significantly higher than that reported for any other cetacean populations and similar to that of recorded in humans. Beluga habitat in the St. Lawrence estuary is highly contaminated by polycyclic aromatic hydrocarbons produced by the local aluminum smelters, strongly suggesting that polycyclic aromatic hydrocarbons are a major cause of the high cancer prevalence recorded in this population (Martineau et al., 2002).

High cancer prevalence has also been recorded in other marine mammals, such as Pacific walrus (*Odobenus rosmarus divergens*) and Baltic gray seal (*Halichoerus grypus*). In the former, 18 neoplasms were found during examination of tissues collected from 107 carcasses (17%) from Alaskan subsistence hunting over a 10-year period (Fleetwood et al., 2005). However, no data regarding cancer etiology or pathogenesis of the walrus examined are presented. Between 1975 and 1997, 53 female Baltic gray seals aged between 15 and 40 years were found dead along the Baltic coast of Sweden, of which 34 (64%) were diagnosed having developed uterine leiomyomas (Bäcklin et al., 2003). Although little is known about the etiology and pathogenesis of leiomyoma in Baltic gray seals, Bäcklin et al. (2003) tentatively suggested an association between cancer prevalence and pollutants, such as organochlorines. However, as mentioned earlier, the actual prevalence of uterine leiomyomas in female Baltic gray seals is most likely lower as only sick animals are likely to strand. Regardless, similar to the California sea



lion, this cancer may constitute a significant cause of mortality in this species.

In contrast to the four marine species mentioned previously, neoplasia in northern sea otters (*Enhydra lutris*) appears to be rare and Williams and Pulley (1981) only found tumors in 2 females out of 112 otters examined (1.8%). Similar to the female Baltic gray seals, tumors of the female otters were diagnosed as uterine leiomyomas (Williams and Pulley, 1981).

Our review of the literature also revealed significant geographical species-specific difference in cancer prevalence. For example, of 42 roe deer (*Capreolus capreolus*) carcasses examined in Hungary, 14 (33%) showed macroscopic lesions consistent with skin FP (Erdélyi et al., 2009), whereas out of 985 carcasses examined in Sweden only 19 were diagnosed having neoplasia (2%) and only 1 of the 19 having developed FP (Aguirre et al., 1999a). Moreover, within the Hungarian study neoplasia was confined to certain geographical areas (Erdélyi et al. 2009). As FP is caused by the infection of papillomavirus (CpPV1) this led Erdélyi et al. (2009) to suggest that genetic factors may underpin roe deer susceptibility to FP.

In humans increased cancer prevalence has shown to be associated with reduced genetic diversity (Assié et al., 2008; Rudan et al., 2003). It is therefore interesting to note that some of the highest cancer prevalence's observed in wild mammals (>50%) have been recorded in species/populations with low genetic diversity, such as the Santa Catalina Island foxes (*Urocyon littoralis catalinae*; Funk et al., 2016; Vickers et al., 2015) and the South African Cape mountain zebra (*Equus zebra zebra*; Marais and Page, 2011; Marais et al., 2007; Sasidharan et al., 2011). Vickers et al. (2015) suggested that the high prevalence of ceruminous gland tumors (carcinomas and adenomas) observed in the Santa Catalina Island foxes may have a genetic basis. Similarly, the high cancer prevalence observed in one of the South African Cape mountain zebra populations has also been suggested to be associated with concomitant low genetic diversity (Marais et al., 2007; Sasidharan et al., 2011). Interestingly, as mentioned earlier, the high prevalence of cancer in California sea lions may also, at least partly, have a genetic basis (Browning et al., 2015). The possible association between reduced genetic diversity and cancer prevalence is further supported by the high prevalence of cancer observed in both captive and wild western barred bandicoot (*Perameles bougainville*), a highly endangered Australian marsupial once widespread across western and southern Australia but now restricted to two small islands off the Western Australian coast (Woolford et al., 2008, 2009). Captive breeding of this species has been severely hampered by debilitating cutaneous and mucocutaneous papillomatosis and carcinomatosis, associated with infection

of papillomatosis carcinomatosis virus type 1 (BPCV1) (Woolford et al., 2008, 2009).

Low genetic diversity in the wild has been found to result in increased risk of inbreeding depression and concomitant increased risk of extinctions (Madsen et al., 1996, 1999, 2004). If low genetic diversity results in an increased risk of cancer, as suggested by the examples mentioned previously, this may further imperil the long-term survival of the numerous wild organisms presently suffering from low genetic diversity.

## CANCER ETIOLOGY AND PREVALENCE IN FRENCH ZOOLOGICAL PARKS

Although conditions (and hence associated cancer risks) in zoological parks are often significantly different from those experienced in nature (e.g., altered levels of activity and food and abnormal breeding frequency; Vittecoq et al., 2013), cancer studies in captive animals are facilitated by the absence of masking variables, such as predation. In addition, because of curative and preventive improvements in veterinary medicine, diseases of captive animals are closely monitored and routine necropsies are performed using microscopy analysis (Hubbard et al., 1983; Lombard and Witte, 1959).

### Materials and Methods

The study was conducted from September 2013 to February 2015. Thirty zoological parks were contacted through a partnership with two French animal histopathology laboratories (ONIRIS in Nantes, VetDiagnostic in Lyon) and the French Association of Zoological Park Veterinarians (AFVPZ). Data collection consisted of (1) consultation of veterinarian archives in the zoological parks and (2) analysis of centralized data by veterinarian histopathology laboratories.

As accurate cancer diagnosis relies on histopathological examination of samples from biopsies, resection, or autopsy/necropsy (Martineau et al., 2002), we therefore only entered tumor type (benign or malignant) into our database when they had been confirmed by histological analyses. We also recorded the organs affected, and, if any, the presence and the location of metastases. In order to facilitate data presentation, we classified the tumors into 12 anatomical systems.

### Results

The database consisted of 343 tumor references, including 271 cases of cancer in mammals, 46 in birds, and 26 in reptiles representing 27 different orders (Table 2.3).

**TABLE 2.3** Number of Tumors Recorded Among 27 Vertebrate Orders in French Zoological Parks

<b>Birds (<i>n</i> = 46)</b>		<b>Mammals (<i>n</i> = 271)</b>	
<b>Order</b>	<b><i>n</i></b>	<b>Order</b>	<b><i>n</i></b>
Accipitriformes (e.g., birds of prey)	2	Afrosoricida (e.g., tenrecs and golden moles)	2
Anseriformes (e.g., ducks and geese)	5	Carnivora (e.g., cats and wolves)	114
Bucerotiformes (e.g., hornbills and hoopoes)	3	Cetartiodactyla (e.g., pigs and deer)	49
Ciconiiformes (e.g., storks)	1	Chiroptera (e.g., bats and flying foxes)	4
Columbiformes (e.g., pigeons and doves)	3	Cingulata (e.g., armadillos)	2
Galliformes (e.g., turkeys and chickens)	2	Diprotodontia (e.g., kangaroos and koalas)	7
Gruiformes (e.g., cranes, coots, and rails)	1	Lagomorpha (e.g., hares and rabbits)	1
Pelecaniformes (e.g., pelicans and cormorants)	8	Perissodactyla (e.g., zebras and rhinoceros)	14
Phoenicopteriformes (e.g., flamingos)	2	Pilosa (e.g., anteaters)	2
Psittaciformes (e.g., parrots and parakeets)	10	Primates (e.g., monkeys and apes)	70
Rheiformes (e.g., rhea)	2	Rodentia (e.g., rats and capybaras)	6
Sphenisciformes (e.g., penguins)	3		
Strigiformes (e.g., owls)	4		
<b>Reptiles (<i>n</i> = 26)</b>			
<b>Order</b>	<b><i>n</i></b>		
Crocodylia (e.g., crocodiles and alligators)	1		
Squamata (e.g., snakes and lizards)	23		
Testudines (e.g., turtles and tortoises)	2		

### Anatomical Distribution by Class

The tumor frequencies observed in the three vertebrate classes revealed remarkable similarities. High

**TABLE 2.4** Anatomical Percentage Distribution of Tumors in Three Vertebrate Classes in French Zoological Parks

	<b>Birds (<i>n</i> = 46)</b>	<b>Mammals (<i>n</i> = 271)</b>	<b>Reptiles (<i>n</i> = 26)</b>
Mammary	N/A	4.9	N/A
Cardiovascular	4.6	5.6	4.4
Digestive	20.9	18.4	34.8
Endocrine	2.3	7.9	4.4
Genital	4.6	7.1	4.4
Hematopoietic	27.9	17.6	21.7
Musculoskeletal	7.0	6.7	4.4
Neural	0.0	1.9	0.0
Oral cavity	0.0	3.4	4.4
Pulmonary	4.6	6.4	0.0
Skin	18.6	14.2	17.4
Urinary tract	9.3	6.0	4.4

frequencies of digestive (18.4–34.8%), hematopoietic (17.6–27.9%), and skin tumors (14.2–18.6%) were observed in mammals, birds, and reptiles whereas tumors in the remaining 9 anatomical systems occurred in similar low frequencies (0–9.5%; Table 2.4).

### Benign and Malignant Tumors Recorded in Mammals, Birds, and Reptiles

The prevalence of malignant tumors differed among taxa ( $\chi^2 = 8.68$ ,  $df = 2$ ,  $P = 0.01$ ; Table 2.5) and posthoc tests revealed that reptiles had a higher prevalence of malignant tumors than mammals ( $P = 0.018$ ), while no significant difference in prevalence of malignant tumors were observed between mammals and birds and reptiles and birds ( $P > 0.17$ ).

**TABLE 2.5** Number of Benign and Malignant Tumors in Three Vertebrate Classes in French Zoological Parks

<b>Class</b>	<b>Number of benign tumors</b>	<b>Number of malignant tumors</b>
Aves	10	25
Mammalia	94	142
Reptilia	4	20



## DISCUSSION

### Comparison to Other Studies

#### Mammals

The results from the present study show that the highest tumor prevalence was observed in the carnivores (42.1%, 114 of 271). Similar high cancer prevalence in this group of mammals was observed by Lombard and Witte (1959) and Effron et al. (1977). Carnivores include both domestic cats and domestic dogs, of which both have been shown to be subjected to high prevalence of tumors (Merlo et al., 2008; Zambelli, 2015). However, we have not been able to find any information explaining the high prevalence in these two groups of mammals. Our results also revealed similar levels of cancer prevalence in mammal digestive system (18.4%) to that recorded by Lombard and Witte (1959) (20%). Moreover, the second most common tumors observed in mammals by Effron et al. (1977) was hematopoietic/lymphosarcoma (8.9%) followed by skin tumors (8.7%). Our results thus again show a remarkable similarity with the results obtained by Effron et al. (1977) as we also found hematopoietic and skin tumors being the second and third most common tumors recorded (17.6 and 14.2%, respectively).

In contrast Lombard and Witte (1959) found that the second most prevalent tumors were confined to the endocrine system (18.4%) whereas in our study endocrine tumors were only found in 7.9% of mammals. Both Effron et al. (1977) and Lombard and Witte (1959) found that pulmonary tumors were the most prevalent cancer recorded (14 and 16%, respectively) whereas in our study pulmonary tumors were only found in 6.4% of the animal investigated that is, the 7th of the 12 anatomical systems.

#### Birds

Comparing our results of tumor prevalence in birds with those obtained by Effron et al. (1977) again revealed some striking similarities. In both studies hematopoietic/lymphosarcoma were the most prevalent tumors recorded (27.9 and 32.4%, respectively). In the studies by both Effron et al. (1977) and Lombard and Witte (1959), as well as in our study the second most prevalent cancers were confined to the gastric/digestive system (20.9, 22.2, and 12.6%, respectively). In all three studies the third most prevalent tumors were fibrosarcoma/skin tumors (18.6, 11.1, and 9.9%, respectively). In contrast the second most common tumors recorded by Lombard and Witte (1959) were confined to genital system (20.2%) whereas these tumors were the fourth most common tumors recorded by Effron et al. (1977) (9.9%) and the sixth most common tumors in our study (4.6%).

#### Reptiles

The most common cancers recorded by Effron et al. (1977) in reptiles were lymphosarcoma (25%) followed by tumors in the intrahepatic biliary/digestive system (21%). Again our results are quite similar to that recorded by Effron et al. (1977) although the order of the two cancer types was reversed, that is, our results showed a highest prevalence in the digestive system (34.8%) followed by the hematopoietic system (21.7%).

## CONCLUDING REMARKS

The high prevalence of cancers observed in our study affecting the digestive, hematopoietic, and skin systems recorded across the three vertebrate classes is remarkable and certainly warrants further studies to investigate whether these high prevalences also occur at other zoological parks. As these animals are kept under quite different conditions, that is, most mammals and birds are kept in outdoor cages whereas reptiles are mostly kept indoors we presently have no explanation for the similarities in tumor prevalences among these three groups of vertebrates.

The results from the present study suggest that malignant tumors in reptiles were more prevalent than that observed in mammals. However, this is not supported by the study of Effron et al. (1977) who did not find any significant difference in malignant tumors among the three vertebrate classes. As our data on tumor prevalence in reptiles are based on fairly small number of individuals we therefore suggest that our results should be interpreted with caution.

Although many of the results from the present study are similar to that observed by Effron et al. (1977) and Lombard and Witte (1959) we do emphasize that the cancer etiology and prevalence were all obtained from animals kept in captivity. Cancer in captive animals has been shown to develop predominantly in older age cohorts. For example, although cancer prevalence in captive black-footed ferrets (*Mustela nigripes*) has been shown to affect 55% of the ferrets, the cancer almost exclusively affected postreproductive animals (Lair et al., 2002). The age-specific increase in cancer prevalence recorded in captive animals suggests that the significance of cancers recorded, similar to that recorded in black-footed ferrets, may therefore have limited or in some cases even no fitness effect in the wild. Regardless, cancer statistics recorded in captive animals remain an important source of information for studies in comparative oncology, as well as providing data on cancer etiology.

### Acknowledgments

We acknowledge the French zoological parks who welcomed us into their premises and provided data on their animals: Safari de Peaugres, Réserve

Africaine de Sigean, Zoo de la Barben, Zoo La Palmyre, Montpellier Parc Zoologique, Réserve de la Haute-Touche, ZooParc de Beauval, Zoo de La Boissière-du-Doré, Planète sauvage, Bioparc Zoo de Doué, Zoo de Lyon, La Ménagerie, le zoo du Jardin des Plantes, Zoo/Fauverie du Mont Faron.

This work was supported by the ANR (Blanc project EVOCAN), the CNRS (INEE), the Australian Academy of Science's French–Australian Science Innovation Collaboration Program Early Career Fellowship, and an International Associated Laboratory Project France/Australia.

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